Solid-state relays fight for sales with winning punches. But load specs are often feints, not true performance. And transients and heat can deliver knock-out blows. However, SSRs can be winners with silent operation, long life and zero-voltage turn-on. Make sure you're in the right corner. Get a ringside view on p. 48.
FEEL the pot ...

CLICK the switch ...

GANGL the modules ...

and add "feel appeal" to your product.

FEEL THE POT ... a smooth, quality feel, only from Bourns® 81/82 Model Potentiometers. Rotational torque range, only .3 to 2.0 oz. inch, is consistent for one, two, three or four cup assemblies.

Independent linearity of ±5% and low 1% CRV provide exceptional setability in both cermet and conductive plastic element types.

CLICK THE SWITCH* ... one that really clicks, with positive action detent at either CW or CCW end. The Bourns Model 85/86 potentiometer/switch combination is rated at 2 amps in DPST style and 1 amp in DPDT. Contacts are constructed of fine silver with gold overlay. This provides exceptionally low contact resistance, for reliable operation at low level analog or logic signal levels — or any application requiring an "on-off" function.

GANGL THE MODULES ... potentiometers and switches. Up to 4 modules can be ganged on the same single or dual concentric shaft, without sacrifice to the satin-smooth feel or the sure-fire click. Other options include a wide choice of bushing and shaft styles, P.C. pins or solder lugs. Think of the possibilities! Now you can specify custom pots and switches assembled from "off-the-shelf" modules — at standard cost and leadtime.

Add "feel appeal" to your equipment with BOURNS Model 80 Family of Modular Potentiometers and Switches. Write or call today for complete technical information, direct or through your Bourns distributor.

FEEL, CLICK, GANGL ... BEAUTIFUL!

TRIMPOT PRODUCTS DIVISION, BOURNS, INC., 1200 Columbia Avenue, Riverside, California 92507, Telephone (714) 781-5122 — TWX 910 332-1252.

*Patent pending
You probably remember our Model 3000 (shown at left)—the AM/FM phase-locked signal generator that covers the 1 to 520 MHz frequency range? Well, now we’ve got a companion model that’s even better. The new Model 3001 is identical to the 3000 except: (1) FM accuracy is now 0.001%; (2) A ±5 kHz frequency vernier is provided in all modes; (3) You can lock the 3001 to an external frequency standard (optional at $150); and (4) An internal reference frequency standard (with 5 x 10⁻⁹/day stability) is also an available option at just $500.

At just $2,600, the Model 3001 is a downright bargain when you consider its accuracy, stability, programmability, and ease of operation.

We’ll gladly send you detailed specifications on our competitive new signal generator. When we’re competing with ourselves, we know everything about the competition.

Model 3001 Specifications:
- Frequency Range: 1-520 MHz
- Frequency Accuracy: ±0.001% (all operating modes)
- Resolution: 1 kHz
- Stability: 0.2 ppm per hour
- Output Range: +13 dBm to −137 dBm
- Flatness: ±0.75 dB
- AM Modulation Range: 0-90%
- FM Deviation Ranges: 0-10 kHz and 0-100 kHz
- Internal Modulation Rates: 400 Hz and 1 kHz
- Dimensions: 12" wide x 5½" high x 13¾" deep
- P.O. Box 190, 66 North First Avenue, Beech Grove, Indiana 46107, Phone (317) 783-3221, TWX 810-341-3226.

The model 3000.
The New Model 3001.
The only Double-Balanced Mixers with a 2-YEAR GUARANTEE* featuring Hi-Rel tested diodes - still only $7.95 (100 pieces) $9.95 (1-49)

*including diodes!

Yes, a two-year guarantee for DBM's is now a reality . . . made possible by an accelerated-life diode screening program adopted at Mini-Circuits. Each Schottky diode used in Mini-Circuits' SRA-1 mixers is now preconditioned by the HTRB (High Temperature Reverse Bias) technique, previously reserved almost exclusively for semiconductors assigned to space applications. With HTRB testing, each diode is operated for 168 hours at 150°C with one volt reverse bias applied.

To screen out "infant mortality", the diodes are deliberately stressed to accelerate aging and to force time-related failure modes to take their toll. In conventional testing or "baking", the diode does not experience anywhere near the stress encountered with the HTRB program. Hence, the ability at Mini-Circuits' to locate the potentially-unreliable diodes before they are assembled into SRA-1 units and, with double-balanced mixers, the overall reliability hinges almost entirely on the diodes used.

Yes, the HTRB procedure costs us more and screens out more devices. But our goal is to improve reliability to a level unmatched for off-the-shelf DBM's at no increase in cost to our customers. You - our customers by your overwhelming confidence in our product line have made us the number one supplier of DBM's in the world.

To earn your continuing support, we are now employing HTRB Hi-Rel testing for every diode used in the SRA-1, at no increase in cost to you. So, for the same low price of $7.95, you can purchase our SRA-1, with a two-year guarantee, including diodes.

To ensure highest system reliability, demand highest quality diodes on your source-control drawings and purchase orders. Specify SRA-1 mixers, with HTRB tested diodes from Mini-Circuits... where low price now goes hand-in-hand with unmatched quality.

MODEL SRA-1
Freq. range (MHz) LO 0.5-500, RF 0.5-500, IF dc-500
Conversion loss (dB) Typ. Max.
One octave from band edge 5.5 7.5
Total range 6.5 8.5
Isolation (dB) Typ. Min.
Lower band edge to LD-RF 50 35
one decade higher LD-RF 45 30
Mid range LD-RF 45 30
Upper band edge to LO-IF 40 25
one octave lower LO-IF 35 25
Min. Electronic attenuation 120 mA 3 dB
Signal, 1 dB compression level 0 - 1 dBm
Impedance all ports 50 ohms

Mini-Circuits Laboratory
837-843 Utica Avenue: Brooklyn, NY 11203
Domestic Telex 125460
International Representatives:
AUSTRALIA General Electronics Services, 99 Alexander Street, New South Wales, Australia 2565. ENGLAND Data Electronics Data House, Wharf Road, Frienley Green, Cumberley, Surrey. FRANCE S. C. C. I. E. D. S. M. I. S, 31 Rue Gourge, Saint-Germain, France. GERMANY, AUSTRIA, SWITZERLAND Industrial Electronics GmbH, Kulbneckrass 14, 600 Frankfurt/Main, Germany. ISRAEL Electromics, Ltd., 69 Gordon Street, Tel Aviv, Israel. JAPAN Denko Kado, Ltd., Epworth Building, B. I. 1 Chome Hamamatsucho Minato-ku, Tokyo. EASTERN CANADA B. D. Hummel, 2274 Maynard Avenue, Utica, NY 13502. (315) 736-7921. NETHERLANDS, BELGIUM, LUXEMBOURG.
Coomer, Veldweg 11, Hattem, Holland. NORWAY Datamatik AS, Osletangen 62, Oslo 6, Norway
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Box 13803, Philadelphia, PA 19101.
The only microcomputer with the power of a PDP-11. The PDP-11/03.

If you've been looking for a microcomputer with minicomputer power at a micro price, join the hundreds of OEMs who've already found it with the Digital microcomputer. The PDP-11/03.

The 11/03 gives you everything you could ask for in a small computer. High performance. High reliability. And a low price—just $1,357 in quantities of 50.

And that micro price buys you mini features that quickly translate into benefits OEMs appreciate. Features like full PDP-11 instructions with eight general purpose registers for fast program development. RAM (MOS or Core) and PROM memories that let you match the memory with the application. Hardware vectored interrupts with stack processing for real computer power. And multiple-sourced components for sure delivery.

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Besides growing bigger in size, the 11/03 lets you grow bigger in scope. It's software compatible with every other PDP-11 we offer. From our LSI-11 all the way up to our medium scale PDP-11/70. That means you can take full advantage of Digital PDP-11 software and services.

You can also take advantage of Digital's OEM Referral program—your chance to take on an international marketing and support team without hiring them. The OEM Referral program can help you locate new custom-
ers and new markets around town and around the world. And it can all start with the PDP-11/03. So if you're looking for a proven microcomputer with proven power and performance, get the micro with all the power and performance of a PDP-11.

If you're looking for a and performance of a PDP-11, Digital Equipment Corporation, Maynard, Massachusetts

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digital

50,000 computers saving managers millions.
Thin-Trim. capacitors

Tucked in the corner of this Pulsar Watch is a miniature capacitor which is used to trim the crystal. This Thin-Trim capacitor is one of our 9410 series, has an adjustable range of 7 to 45 pf, and is .200" x .200" x .050" thick.

The Thin-Trim concept provides a variable device to replace fixed tuning techniques and cut-and-try methods of adjustment. Thin-Trim capacitors are available in a variety of lead configurations making them easy to mount.

A smaller version of the 9410 is the 9402 series with a maximum capacitance value of 25 pf. These are perfect for applications in sub-miniature circuits such as ladies' electronic wrist watches and phased array MIC's.

Johanson Manufacturing Corporation
Rockaway Valley Road
Boonton, New Jersey 07005
(201) 334-2676  TWX 710-987-8367
Guess what’s hiding in the calculator?

Anyone using Texas Instruments' SR-52 might be interested to know that up to 28 "software" data registers are "hidden" within the calculator. It doesn't mention these registers in its user's manual. Program memory can be automatically partitioned into these 28 additional registers, each of which has a length of eight storage locations.

Keyboard addresses of these registers range from 70 (location 000) to 97 (location 216), inclusive, and are accessed via STO and RCL operations. Even though these software registers are not cleared by the CMs key, they do prove useful in the storage of both program codes and data for transfer to magnetic cards.

The user must keep careful track of the program-address space; however, the remainder of memory can be used to store data in register locations lying above the program. Data are automatically formatted for either scientific or fixed and floating notation. A microprogram performs the address conversion and data formatting.

J. M. Davidson  
Research Engineer  
Applied Automation, Inc.  
Pawhuska Rd., RB2 106  
Bartlesville, OK 74004

Forget us not

Having read Stanley Runyon's "Focus on Network Analyzers" (ED No. 16, August 2, 1976, p. 50), I was quite surprised to find that EMR's Model 1172 Frequency Response Analyzer had been deleted from the article, particularly since our primary competitor, Bafco, was included, and EMR was included in the vendors' list at the end of the article.

Marshall Fram  
Product Line Manager  
Dynamic Analysis Instrumentation  
EMR Telemetry  
Weston Instruments, Inc.  
P.O. Box 3041  
Sarasota, FL 33578

What's in a name . . .

In our News Briefs section of the November 8, 1976 issue (Vol. 24, No. 23, p. 16), we accidentally referred to American Microsystems, Inc., as American Micro Devices. Our apologies. Moreover, the company doesn't make an all-solid-state telephone—just the circuits.

Loved the article, but . . .

Thank you for "FCC Swamped with Complaints as Sources of RFI/EMI Increase" (ED No. 20, September 27, 1976, p. 24). The article is well written, presents the problem in a readily understandable manner and is one of the best general articles on the subject of interference and its control that I have read.

There are a few minor inaccuracies. In the section, "Battle lines drawn," you refer to the Citizen's Radio Station of EIA. This should be Citizen's Radio Section. In the same paragraph, you refer to John Sadowsky as EIA staff vice president of communications. His name is John Sololski and his title is Staff Vice President, Communications Div. On page 34, paragraph 2, you say that the FCC proposes to discard its 1948 maximum-emission (continued on page 13)
Dance
It's the Tri-
And who could blame you for dancing?
It isn't every day a Bi-Polar PROM like this comes along.
It virtually eliminates fuses being blown incorrectly by out of calibration programmers, because 3 distinct and separate circuit conditions must be effected to blow the fuse.
So what?
So typical programming yields of 98%, that's what.
And we've got the reliability data to prove it.
As if that weren't enough, our titanium-tungsten fuse material provides greater reliability after programming.
Tri-Safe® PROMS come in 1K, 2K and 4K capacity, and are Schottky-clamped for high speed operation.
So get your pen out.
And your dancing shoes.

National Semiconductor
2900 Semiconductor Drive, Santa Clara, CA 95051

Gentlemen:
Please send me an invitation to the Tri-Safe PROM...data sheets, application note, reliability data, process info, the works.
Name
Company
Address
City State Zip
Specifying both resistors and trimmers? Here's a single solution from CTS.

CTS proudly presents a single solution to many of the problems you face in specifying resistors and trimmers... the Series 380 thru 384 Cermet Resistor/Trimmer combinations.

Have Board Space Problems? The Series 384 offers you up to eight fixed resistors plus a trimmer in a .46” square (.275” high) package.

Need Hefty Power Capability? All units in this Series can handle one watt at 70°C and ¾ watt at 85°C.

Need Cermet Stability? ±250 ppm/°C is the standard temperature coefficient in this Series with ±100 ppm available for your critical needs.

Want Rock Bottom Prices? The Series 383 (shown above) provides you combinations of three fixed resistors plus a trimmer for only 35¢ in production quantities. The Series 380 trimmer only is priced under 25¢. This economical space saving form factor is available as a trimmer only, resistor/trimmer networks, and as resistor networks only. Let the Application Engineer from CTS Microelectronics help you decide which Series is best for your design.

CTS MICROELECTRONICS, INC., 1201 Cumberland Avenue, West Lafayette, Indiana 47906. Phone (317) 463-2565.
Meet the cost cutter

New wire-wrap relay socket cuts costs up to 50% per connection

Here is the first wire-wrap socket in the industry for a standard industrial relay. It can cut your connection costs in half because now you can wire-wrap industrial relays, too! It's another new idea from Midtex.

Wrapped wire connections cut costs because they're faster. Less than half the time it takes to solder.

Wrapped wire connections cut costs because they're cleaner. No solder splatter or wire clippings to short.

Wrapped wire connections cut costs because they can be wire-wrapped . . . at once.

Designed for our Type 156 4PDT 3 amp relay, the Midtex wire-wrap socket provides 14 mating terminals, .031" x .062" x .75", and will accept solid wire wrapped or stranded Termi-point connections ranging in size from 20 AWG to 26 AWG. Terminals will provide for three separate connections. Socket dimensions: .75" x 1.55"; two .160" diameter mounting holes are 1.3" center-to-center. Socket body is U/L approved G.P. Phenolic.

Our job is to help you make your job more profitable through relays and relay assemblies. Midtex, The Total Relay Company, @ Trademark of Gardner-Denver Co.
You get variety, unique design, economy and more when you specify AMP's DIP sockets.

You get more performance.

And that’s what all the features of AMP’s DIP and microprocessor sockets add up to.

Take variety. You can choose from standard and low profile housings, a wide range of sizes, tin or gold plated contacts, in widths of .300", .400" or .600". And that’s only the beginning.

There’s design and economy. DIP socket contacts include a unique retention feature. It makes sure that every socket you insert into a pc board will stay there, even during the soldering process.

The design also prevents solder wicking problems. And with AMP automatic insertion equipment, the sockets can be installed at rates to meet your production needs.

And don’t forget AMP’s solid backup. You can count on it with the kind of personal attention your product line deserves.

So why not get AMP quality when you need DIP and microprocessor sockets. Just call Customer Service at (717) 564-0100. Or write AMP Incorporated, Harrisburg, PA 17105.
(continued from page 7)

standard of 15 $\mu$V/m at $\lambda/2\pi$. Actually, this standard was first adopted in 1938 and has been in effect under various rule numbers since that date.

Herman Garlan, Chief
RF Devices & Experimental Branch
Federal Communications Commission
Washington, DC 20554

Misplaced Caption Dept.

This new geiger counter runs for three years on a single D cell. Then you need a sword to cut through the corrosion when you change the battery.

ACROSS THE DESK

Sorry. That's Francisco Goya's "General Jose de Urrutia," which hangs in the Prado Museum in Madrid.

Don't start a trend we are trying to avoid

In your article on CRTs (ED No. 17, August 16, 1976, p. 26), you state:

"A widespread misconception about CRTs is that if you don't buy a standard item, you will pay more for the device. That may be true in some cases, but in most instances a tube design can be fit to an application with no engineering charge by putting together existing gun, screen and envelope designs."

For some time, we and some of our customers have been striving to achieve a higher degree of standardization of CRT types and CRT parts. Your comment encourages a counter trend.

Many manufacturers in our industry are plagued by short runs of a large variety of sophisticated tube types. This greatly reduces the effectiveness of our engineers, deteriorates the profit margins in our industry and reduces the effectiveness of our products.

Our customers are unable or unwilling to support the costs of retooling and preparing new processes for revised types. The changes, which often appear to be simple, embody subtle problems that result in schedule delays as well as excess cost to the user and the manufacturer.

Unless our industry can return to a higher degree of use of common tube types, the deterioration of the quality and potential of the industry will continue, and a very essential aspect of the U.S. display industry will be further compromised.

William N. Moody
President
Tubes & Devices Corp.
DuMont Electron
DuMont Div.
750 Bloomfield Ave.
Clifton, NJ 07015

Whose 2909, 2911?

You'd never know it from the article, "Bipolar Controllers—They're Fast, Cheap and Easy to Use" (ED No. 22, October 25, 1976, pp. 106-110), but two leading bipolar microprogram sequencers, the 2909 and 2911, were pioneered by Advanced Micro Devices of Sunnyvale, CA.

Interested now?

CIRCLE NO. 88

Second glance at naked model

In our June 7, 1976 Computer '76 Issue (ED Vol. 24, No. 12, p. 88) Computer Automation was incorrectly mentioned as offering the Naked Milli LSI-3/04. The correct model number is the Naked Milli LSI-3/05.
... Hammer up and lay an eyeball on this copy for a minute. We don’t want to overmodulate, but we’ve got four handbooks that, for not much lettuce, can have you doing your thing in the left lane in no time.

How to get your license from Uncle Charley. How to select and set up a rig. How it works. How to fix your set when something’s dusting your ears. Do you copy... it’s all here!

Whether you’re a green apple or a trucking guy, even if you drive a pregnant roller skate and want help the next time you get bubble trouble, here’s the information, tips and techniques you need.

Use the coupon and put down your handle (name) and 10-20 (address) to order the book(s) you want. They come with a 15-day money back guarantee. And keep the wheels spinning and the beavers grinning.
Two new 1300 series relays give you the most complete line of miniature enclosed relays to meet your most exacting specifications.

Your Guardian Angel calls these relays the 1300 series. You'll call them miraculous. Check these specs for proof:

- **1310 AC and 1315 DC relays, 4PDT, 5 amp** in your choice of .107" solder lug or .059" printed circuit termination.
- **1330AC and 1335DC relays, DPDT, 5 amp** with .098" solder lug or .059" printed circuit termination.

**NEW!** 1345DC relay, SPST-NO, SPST-NC, or SPDT, 10 amp. Termination is standard .055" x .030" printed circuit. Just over a cubic inch small, yet specifically designed for low cost, high reliability.

**NEW!** 1390AC and 1395DC relays, DPDT, 13 amp. Dual type .187" or solder lug termination. Space saving, compact. Give large control capacity in about half the size of competitive relays that do the same job. Small price, too.

- **1360AC and 1365DC relays, DPDT, 5 amp** with .060" diameter, 13/64" long terminal pins on .1" grid spacing for PC board. Also available in SPST and SPDT up to 50 amps.

Mounting sockets and hardware. A complete line of solder lug, PC and wire wrap sockets. Plus, side mounting/permanent stud hardware that allows you to mount these relays in any position.

Send for the free book that tells it all:

Guardian's 48 page relays catalog. Full of facts and specs to make selecting a relay a snap.
American Zettler takes genuine pride in offering to you its beautifully crafted relays. There's a very real heritage of technical competence and consistent quality behind the Zettler name. Although we are an American manufacturer, the design and fabrication of our relays reflect the 100-year-old tradition of Zettler ... now one of the world's largest makers of precision electromechanical products. American Zettler invites you to examine its relays carefully. You'll find elegant design, true precision construction, generous use of high-quality materials, and workmanship that meets tight specifications ... all at most attractive prices. Compare our products with those of our biggest competitors and you'll agree that Zettler relays are Masterworks.

The full American Zettler line includes hundreds of configurations in the most popular and important electromechanical relay styles.

MINIATURE GENERAL PURPOSE RELAYS
DPDT through 6PDT models • AC/DC coils • dry circuit to 5 amp contacts • UL and CSA approved • hermetically sealed versions also available

LOW-PROFILE THINPAK® RELAYS
Unsealed and sealed styles • Less than 0.5 inch high • SPDT through 4PDT models • DC coils • dry circuit to 5 amp contacts • UL approved • magnetic latching versions also available

GENERAL PURPOSE HEAVY DUTY RELAYS
SPDT through 4PDT models • AC/DC coils • 5 to 10 amp contacts • octal/11-pin or quick-connect versions • UL and CSA approved

Over 40 American Zettler representatives and distributors in the U.S. and Canada stand ready to help you with your applications or order. Contact us today for a full-line catalog, the location of your nearest representative, and evaluation samples.
A QUANTUM STEP
IN SIZE
AND PRICE
REDUCTION!

TWO NEW CRYDOM
CHALLENGER
SOLID-STATE RELAYS!

The new Crydom Series 2 and 3 SSRs combine small size and low price, challenging all comparably rated SSRs, hybrid relays, and in-house designs on a size/cost/performance basis. They provide photo isolation, zero voltage switching, high current rating and rugged packaging — first established by the original Crydom Series 1, now the world’s leading SSR design. Designed for UL/CSA approval, they offer the advantages of long life, RFI-free switching, logic level control, and excellent electrical and mechanical isolation of signal and power circuits.

The application of SSRs is no longer limited by size and cost. Crydom Challengers have knocked down these barriers. SSR control of motors, heaters, lamps, transformers, solenoids, valves and contactors now becomes practical in many new applications.

Think about it for your product... and join the Challengers!

INTERNATIONAL RECTIFIER
CRYDOM DIVISION
1521 Grand Avenue, El Segundo, CA 90245 (213) 322-4987
...the pacesetters!

CIRCLE NUMBER 121
DELCO'S NEW 25-AMPERE HIGH VOLTAGE DARLINGTONS WITH THE SPEED AND ENERGY CAPABILITY YOU ASKED FOR.

Good news for motor speed control designers who have expressed a need to upgrade horsepower ratings. The 25-ampere gain of these new Darlington permits increased horsepower ratings of existing AC motor speed control systems and a reduction in paralleling in new designs. However, grouping of t_{on} is available for current sharing in designs with parallel Darlington. A speed-up diode is built into the DTS-4074 and DTS-4075 permitting data sheet t_{on} typicals of 1.0μs. Drive circuit techniques involving 1 μs ≤ 2A and a Baker clamp produce t_{on} typicals in the 0.4-0.6μs range for the DTS-4066, DTS-4067, DTS-4074, and DTS-4075.

Our experience with tolerances, faults, transients, and start-stall conditions in most systems convinces us that these Darlington have the right trade-off between speed and peak power handling capability. Note the greater than 10kVA region of the reverse bias safe operating graph. All this, and you still get Delco's traditional solid copper TO-3 hermetic package that has a conservative 0.75°C/W thermal resistance.

These Darlington are already in high volume production and are available on distributor shelves. For prices, applications literature and data sheets, visit your nearest Delco sales office or Delco distributor, or mail in the coupon on the right.

<table>
<thead>
<tr>
<th>Type</th>
<th>hFE @ 25A</th>
<th>hFE @ 10A</th>
<th>VCEO (sat)</th>
<th>VCE (sat) @ 20A</th>
<th>ICEO @ 600V</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTS-4066</td>
<td>5</td>
<td>75</td>
<td>350V</td>
<td>3.5V</td>
<td>0.25mA</td>
</tr>
<tr>
<td>DTS-4067</td>
<td>10</td>
<td>150</td>
<td>350V</td>
<td>2.0V</td>
<td>0.25mA</td>
</tr>
<tr>
<td>DTS-4074</td>
<td>5</td>
<td>75</td>
<td>350V</td>
<td>3.5V</td>
<td>0.25mA</td>
</tr>
<tr>
<td>DTS-4075</td>
<td>10</td>
<td>150</td>
<td>350V</td>
<td>2.0V</td>
<td>0.25mA</td>
</tr>
</tbody>
</table>

**TYPICAL SWITCHING**

- **DTS-4066**
  - t_{on} = 0.5μs
  - t_{off} = 5.0μs
  - N = 4.5μs

NPN triple diffused silicon Darlington are packaged in solid copper cases conforming to JEDEC TO-3 outline dimensions.

**SAFE OPERATING CURVES**

For more information about Delco's new 25-Ampere High Voltage Darlington, mail this coupon to:

Delco Electronics Division
General Motors Corporation
Marketing Services MS A-213
700 E. Firmin Street
Kokomo, Indiana 46901

NAME: ____________________________
COMPANY: _________________________
ADDRESS: _________________________
CITY: _____________________________
STATE: ____________________________
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DELCO ELECTRONICS SALES OFFICES
Kokomo, Indiana (317) 459-2175
Charlotte, North Carolina (704) 527-4444
Van Nuys, California (213) 988-7550

16B

Electronic Design 26, December 20, 1976
48-pin IC Tester: Total programming flexibility and no program boards put the IT-200 in a class by itself.

Here is an extremely flexible integrated circuit tester that can handle virtually all digital devices.

Its 100 kHz functional capability, coupled with a powerful DC parametric capability, allows testing of CMOS, NMOS, PMOS, ECL, and TTL devices of any complexity. The particularly powerful DC parametric test capacity provides current ranges from ±200 na to ±200 ma, and voltage ranges up to ±20 V.

The versatile IT-200 operates under ROM or RAM program control (software load) and readily interfaces with handlers, probers and other instrumentation.

Check out the IT-200. You'll find the specs are truly in a class by themselves and the price is surprisingly low. For complete details, write or call: Siemens Corporation, Computest Products, 3 Computer Drive, Cherry Hill, New Jersey 08034 (609) 424-2400.

SIEMENS
Theodore Knudson, an American dedicated to assisting the European aerospace community at ESTEC, Noordwijk, Holland, states: "I usually read each issue of Electronic Design for its unique features. I also find E.D. useful in the form of a resource material depicting recent state-of-the-art advances that is not totally theoretical and therefore can be suggested for application in our real life designing and procurement processes."

If you read Electronic Design, you're in good company. Almost 90% of those firms who have taken the trouble to find out which magazines their customers read, rank Electronic Design in first position.

For example: ITT Cannon mailed 1,000 questionnaires to a portion of their prospect list (respondents to advertising and publicity releases in many publications).

The survey asked: "Designate in order of importance those publications which you are now receiving and read on a regular basis." Here are the top winners:

<table>
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<tr>
<th>PUBLICATION</th>
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<td>ELECTRONIC DESIGN</td>
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<td>EDN</td>
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<td>ELECTRONICS</td>
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PASS THE WORD

Maybe your advertising brass doesn't know as much about the power of Electronic Design as you do. If your company wants to reach engineers and engineering managers... pass the word. Tell your sales, marketing and advertising people which publication will bring highest readership among the engineers who make the wheels go round in this industry... Electronic Design.

Electronic Design

BEST READ ELECTRONICS PUBLICATION IN THE WORLD
Sharpen your competitive edge.

Use an HP computing calculator for design, analysis, control, and test.

In the highly competitive, high-technology electronics business, everything counts: keeping costs in line, exploring promising design alternatives, shortening lead times, product and prototype testing, increasing productivity. That's where HP computing calculators, software, peripherals, and interfacing capabilities come in. They can help you get and maintain a competitive edge.

Three computing calculators and plenty of peripherals: it's your choice. Three different models—the low-cost HP 9815, the powerful HP 9825 and the all-purpose HP 9830—offer a range of computing power. HP peripherals include paper tape punch and readers, printers, storage devices, a digitizer, a CRT, and an X-Y plotter. You choose the model and I/O options to configure a system just right for you.

Software, specialized and generalized, helps you look at more alternatives. HP engineers developed software to optimize designs and analyze engineering problems quickly. There's a State Variable package for control system analysis. There's CNAP for circuit design and analysis, BAMP for microwave design and analysis, and Digital Simulation for state and timing analysis. You can add other programs, too—commonly needed math routines and statistical programs to name but two. Programs are also available for accounting applications, report generation, and financial analysis.

Automate your instruments. We make the connection friendly. From simple data logging to complex integration, our programming commands and interface cards make instrument interfacing easy. Whether your instruments require BCD, bit-parallel, RS-232-C, or HP-IB (HP's implementation of IEEE Standard 488-1975), you plug the correct interface into the calculator and connect the cable to your instrument. It's the friendly connection.

HP computing calculators: from initial design to final test. Whether you're in research, design, production, or test—or all four—we can provide the computing power and programs to help you increase productivity and sharpen your competitive edge. Our new brochure for electronic engineers will show you how. Get a copy from your HP representative, or circle our reader service number in this magazine.

HP desktop computing systems put the power where the problems are.
SSR UPDATE

We’ve got 87 answers to your AC solid state relay needs.

Teledyne Relays can handle virtually any AC solid state relay switching application. The reason? A family of AC SSRs with 87 models — and more on the way. We offer a broad range of voltage ratings up to 600V peak, with current ratings from 0.5 to 40 Amps. Add to that a variety of packages for pc board, chassis, or heat sink mounting and you have the industry’s most complete line of AC SSRs.

But hardware isn’t the only answer. You need assurance of the best available applications engineering support.

And we’ve got it — backed by seven years as a pioneer and leader in SSR technology to enable you to use our SSRs to their maximum advantage.

That know-how, for example, is reflected in Teledyne’s new 970 Series MOV transient suppressors designed specifically to protect our AC solid state relays against high voltage transients.

Contact your local Teledyne Relays people. You’ll find we have the experience, technical support and products to meet your SSR needs.

A. 601 Series*
   5 and 10A (to 600V peak). Optically isolated, zero voltage turn-on. Screw terminals, quick disconnects, and pcb pin options.

B. 611 Series*
   10, 15, 25 and 40A (to 600V peak). Optically isolated, zero voltage turn-on. Dual purpose screw/quick disconnect terminals.

C. 675 Series*
   Low profile (0.5" max.) pc board SSRs. Output rating 3A, up to 600V peak. Optically isolated, zero voltage turn-on.

D. 671 Series
   I/O Converter Modules. Special purpose SSRs for use in programmable controllers, machine tool controls, etc. Mounting panel available.

E. SerenDIP® Series*
   TO-116 DIP package. Output rating 1A/300VRMS. Logic compatible 3.8 to 10VDC input.

F. 970 Series MOVs
   High voltage transient suppressors designed specifically for use with all Teledyne AC SSRs.

*UL recognized/CSA certified.

TELEDYNE RELAYS
3155 West El Segundo Boulevard, Hawthorne, California 90250
Telephone (213) 973-4545
Popular µP bit slice has an even better twin

A pin-compatible version of the 2901, the most widely used µP bit slice, is 20 to 30% faster, 30% cheaper, and 50% stiffer in Y-output drive currents, yet uses 25% less power. The 2901A will also be available next month from Advanced Micro Devices, Sunnyvale, CA.

Functionally, the 2901A chip is identical to the 2901. But plugging in the 2901A in place of the 2901 cuts the typical time for a read/modify/write cycle from 105 to 75 ns and the I_{OL} from 280 to 200 mA (at V_{max} and 125 C). The 2901A also boosts I_{OL} on the Y output from 16 to 24 mA and improves noise immunity by increasing V_{IL} from 0.7 to 0.8 V max.

Die size is cut from 33,000 to 20,000 square mils. Cost in 100s drops from $21 for the 2901 to $14.70 for the 2901A.

The 2901A's improvements are the result of two-layer metallization and internal logic simplifications.

The 2901A's improved speed will not affect the throughput in every application: Its impact depends on the microcode-sequence architecture used with the bit slice. AMD plans to offer other aids to improve throughput, including a 2930 program control chip that can relieve the 2901A of program counting.

Although several other manufacturers may soon announce similar devices, AMD's 2901 remains the leading bit-slice part and the fastest TTL slice available. The 74S481 from Texas Instruments is not yet out, although its introduction had been planned for the fall of 1976. (See "Bipolar bit slice µP's shrink the size and cost of minis and controllers," ED 10, May 10, 1976, p. 34.) Raytheon and Motorola are alternate sources for the 2901.

Since 2901 users have had to develop microcoding capability, Motorola, an alternate 2901 source, now offers training courses on the 2901 hardware and microprogramming. A 2901-2901A microprogram assembler will soon be available on Computer Sciences Corp.'s Infonet time-sharing service.

The availability of the microcoded 2901 has led several computer manufacturers to design universal device controllers, identical hardware units, for such peripheral devices as printers, tapes and discs. At system-generation time, the central processor specializes each controller by loading its RAM with a microcode-program design for the peripheral device it controls.

Solderless interconnect system shown by Augat

A new interconnection packaging method that allows components to be plugged directly into printed wiring boards without the need for soldering has been introduced by Augat Interconnection Products, Attleboro, MA.

Called Holtite, the interconnection system is based on precision-machined contacts that are press-fit into a printed wiring board, plated-through hole.

Until recently, plated-through holes for socket applications have been used as soldered receptacles to mount standard style sockets, according to Richard Holt, Augat product manager. These sockets are mounted above the top surface of the board with an average profile height of 0.16 in.

The Holtite system is the first solderless method to use the existing space within the board as the contact receptacle, says Holt. As a result, the socket offers a very low profile that permits card rack spacing as close as 0.4 in.—equal to that of boards with soldered components.

The tapered entry contact is recessed into the board to provide a large contact target area (0.044 in. diameter), which makes it ideal for automatic component insertion, Holt observes.

Holtite contacts can be installed in boards at a rate of 30,000 per hour by means of a specially designed, mass-loading machine that features a vibratory feed and vacuum system.

Undersea communicator sharpens speech clarity

An underwater voice communicator that uses enhanced speech-processing techniques to improve the intelligibility of subsurface communication has been developed by Sound Wave Systems, Costa Mesa, CA. Called the "WetPhone," the device also features specially developed transducer encapsulating material and a 31-kHz, amplitude-modulated carrier signal.

"Reverberations caused by speaking into a small face mask as well as breathing and gurgling noises have been the main problems with previous undersea voice systems," observes Dennis Johnson, president of Sound Wave Systems. The WetPhone filters out these noises along with those components of human speech below 650 Hz—including breathing sounds.

Because 65% of voice intelligibility is contained in speech components above 1000 Hz, the unit employs two high-pass filters and a very sensitive receiver. The receiver is equipped with an automatic gain control whose dynamic range covers 85 dB.

The WetPhone communicator delivers 1 W of acoustic power into the water and has a range of a quarter mile. Its operating cycle runs six to seven hours with replaceable alkaline batteries or an optional, rechargeable battery pack.

Two other options are available. One is an alarm, called AutoAlarm, that is activated automatically when the WetPhone detects that the diver isn't breathing. This alarm can alert any underwater companions as well as a surface rescue unit. It can also be...
used as a tracer signal for search and rescue operations. A separate acoustic direction finder is also available for use in such an emergency.

The other option, called VOX, is a voice detector that can be placed against the larynx to automatically switch the WetPhone from "receive" to "transmit" without manual intervention.

**Solar µ wave repeater saves power and money**

A solar-powered microwave communications repeater that uses only 4 W of power and can operate at temperatures as high as 140 °F has been developed by GTE Lenkurt Inc., San Carlos, CA. The repeater, called the 700F1, can be installed at about one-fourth the cost of existing repeater systems.

The first commercial installation of the solid-state repeater begins operation this month to provide telephone service to a remote Navajo Indian outpost near the community of Mexican Hat in southeastern Utah.

Currently, the 700F1 can transmit 36 simultaneous telephone conversations, but a system with "much greater capacity" is planned for next year, according to Herbert Krengel, GTE Lenkurt's president.

Power is supplied to the repeater as well as to a bank of four storage batteries by 36 silicon solar cells mounted on two panels. The batteries allow the system to operate for up to 10 days of total darkness.

Ability to operate at high temperatures (over a range nearly three times higher than repeaters currently in use) eliminates the need for costly, high-power air conditioning to cool the electronics.

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**Minicomputer system to be the first OEM for IBM**

A general-purpose computing system with both communications and sensor-based capabilities represents IBM’s first venture into the OEM minicomputer business.

Developed and being manufactured at IBM’s General Systems Div., Boca Raton, FL, the Series/1 will enable users to attach many different input and output devices, including custom-made equipment for special applications.

Formerly known by the code name “Peachtree,” the Series/1 is expected to replace some large computer systems in organizations that wish to decentralize their operations. IBM’s first two sales are to Citibank in New York and to an automobile parts distributor, Middletown, Delaware, which will use three units for inventory control, accounts receivable and automatic ordering.

Offered for sale—not for leasing—Series/1 models will range in price from $10,000 to $100,000. The 19-in., rack-mounted units are available in 16,384-byte increments of memory, from 16,384 to 65,536 bytes, in Model 3 and from 16,384 to 131,072 bytes in Model 5. Model 3 has a storage cycle-time of 800 ns, and Model 5 660 ns.

Not only are the IBM minicomputers competition for DEC, Data General and Hewlett-Packard, but for IBM itself. The firm’s 370 sales force is reportedly concerned.

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**News Briefs**

The first family of CMOS programmable ROMs requiring one hundredth the power of their bipolar counterparts has been introduced by Harris Semiconductor. The power cut will keep systems running cooler and make them more power efficient. However, since the PROMs are CMOS, they will not operate at bipolar speeds—access times will be about 200 ns instead of 60 to 100 ns. . . . Users of specialized digital communications circuits, called ASTRO (asynchronous transmitter/receiver), developed by financially-troubled Western Digital, will soon have a second source. A pin-compatible replacement is due from SMC Microsystems, Hauppauge, NY, in the first quarter of 1977. . . . A Motorola single-bit controller circuit, built with CMOS technology and scheduled for introduction early in 1977, will find its way into a number of control applications in industrial processes and in such appliances as blenders and washing machines. The circuit will reduce both manufacturing cost and the size of the finished product by eliminating large numbers of discrete components—transistors, small-scale integrated logic and (possibly) medium-scale ICs. . . . The Defense Dept.’s Autodin communications system in Europe will soon acquire a new switching system capable of handling both analog and digital transmissions. Specifications will be published in 1977. A full digital system won’t be installed before 1985, according to an EOD spokesman.
Introducing the amazing EECO

This machine uses a computer, and people, and hardware all under the same roof, and gives you a chance to correct or change your circuitry before we go to hardware. We deliver in as little as two weeks, including time for you to review. We've been doing this for more than five years, almost in secret. Now we're telling you and the world because it's about time.

Write or phone the keeper of the EECO machine, Dick Hunter.

An IC Location List, lists for IC Type and Socket Size, a Wire Loop List, a Pin Assignment List, an Unused Circuit Elements and Pins List, a Pin by Pin Wire List, and your diagram back, fully annotated.

Machine: in one end you put your raw, un-annotated logic diagram, and out of the other comes your fully wire wrapped socket board/frame/drawer/system—your choice. Together with a Final Exception Report, a Final String List.
ATTENTION ALL ENGINEERS!

Design yourself a free vacation for two!

Yes, you can win an all-expense-paid Caribbean vacation plus $1,000 cash — or one of 99 other valuable prizes!

There's nothing to buy, nothing to write, no slogans or gimmicks.

All you have to do is pick the ten advertisements that our readers will best recall having seen in the January 4 issue.

It's Electronic Design's popular TOP TEN CONTEST — the contest that can pay off handsomely for you and for your company.

Win a free vacation for yourself

Think of it! Clear sky... warm sun... expanses of blue water. The Caribbean is at its best when viewed from the deck of a sailing ship.

Top prize is a fabulous week's Windjammer Cruise for two. You can choose trips among the Bahama Out Islands, the U.S. and British Virgin Islands, or the exotic Windwards and Leewards.

Visit colorful ports with their old world charm and duty-free shops. Swim, fish, snorkel, relax, or lend a hand with the ship.

And it's all free! The prepaid cruise is worth many hundreds of dollars — not to mention the $1,000 cash for travel and incidentals.

Win for your company

More and more companies are urging their engineers to enter this contest. Why? Because a large sample of Electronic Design subscribers will determine the top-scoring ads. The ten best will be rerun free of charge. Your company can win one of these reruns, worth up to several thousand dollars! (To receive this prize, your company must have an ad in the contest issue.)

Separate contest for advertisers and their agencies

The TOP TEN CONTEST is actually two contests with separate sets of prizes (1) for engineers and engineering managers (readers) and (2) for company executives, marketing and advertising personnel and their advertising agencies.

Urge your top brass to enter. Xerox this page and pass it on to them. Maybe they can pick the top ten ads and walk off with one of the separate prizes.

Here's all you have to do to enter

First, read the rules contained in the January 4 issue. Then:

(1) Examine the contest issue with extra care.

(2) Pick the ten ads that you think Electronic Design subscribers will best recall having seen. List these ten ads by company name and reader service number on the entry card. Mail before February 15, 1977.

Your selections will be checked against Reader Recall, Electronic Design's method of measuring readership.

100 reader prizes in all

Watch for the January 4 Top Ten issue, then try your skill. This year, maybe you can sail away with the top prize.

PRIZES
READER CONTEST
1st PRIZE
A WINDJAMMER CRUISE (FOR TWO) IN THE CARIBBEAN
(Choice of itineraries and dates)
PLUS
$1,000 CASH FOR TRANSPORTATION AND INCIDENTALS

2nd PRIZE
GTE SYLVANIA PORTABLE COLOR TV SET ($325 value)

3rd, 4th & 5th PRIZES
DIGITAL WRISTWATCH ($100 value)

6th through 100th PRIZES
TECHNICAL BOOKS
(title to be announced)

PRIZES
ADVERTISER CONTEST
1st PRIZE
WINDJAMMER CRUISE (FOR TWO) IN THE CARIBBEAN
(Choice of itineraries and dates)
PLUS
$1,000 CASH FOR TRANSPORTATION AND INCIDENTALS

2nd PRIZE
GTE SYLVANIA PORTABLE COLOR TV SET ($325 value)

3rd PRIZE
DIGITAL WRISTWATCH ($100 value)
NOTE TO ENGINEERING MANAGERS
Urge your staff to enter.
The winning ads will receive free reruns worth $ thousands for your company.

WATCH FOR THE
TOP TEN CONTEST
(JAN. 4 ISSUE)
The switch to digital accelerates in radios, phones and satellites

Never before has the Army communicator or the design engineer who develops his equipment known in such detail what battlefield communications would be like 20 years hence and the steps their evolution would take.

Hybrid capability, both analog and digital, which has been part of the Army’s tactical communications since 1972, will accelerate.

By 1982, the balance will start leaning toward the digital side. By 1992, everything that can be digital will be—even telephones, if one can be built cheaply enough.

Electronic switching equipment will be found even in the forward combat areas.

Voice communications probably won’t go out of style, but more and more data will be transmitted: maps, handwritten messages and photographs shot back and forth by facsimile—even to the fronts. High-speed facsimile will be transmitted on a new vhf family of radios on a time-shared basis with voice users. The facsimile device will transmit an 8 × 10-in. page of 240 words in approximately 30 seconds. Today's teletypewriter takes four minutes.

Conventional hf-radio teletypewriter assemblages may be eliminated in favor of high-speed, automatic teletypewriter terminals that print out at 12 s/page. These machines will be smart and will enable the operator to type, store, edit and display before transmitting over satellite and uhf radios.

At the brigade and division levels, the conventional multichannel radio system will be replaced by a fully automatic radiotelephone switching system known as the Mobile Subscriber Equipment (MSE) subsystem.

Multichannel tactical satellite terminals and automatic voice and teletypewriter switching will improve the grade and speed of service even further.

High-frequency radio will retreat from the field as the satellite communications advance—even for short-haul links.

Equipment will be secure or securable. If it isn’t built secure, it will be designed to accommodate a secure module, or adapter, later.

And all systems will be as interoperable and standard throughout the Defense Dept. as possible. To ensure this conformity, a special Defense Dept. office called Tri-Tac (Joint Tactical Communications) has been established to pass on every tactical-communications development proposed by any service.

The future is known for the Army because of a study called Intacs (Integrated Tactical Communications Systems), carried out in its early stages by the Army Signal School at Fort Gordon, GA, and completed by the Aerospace Division of Martin Marietta Corp., Baltimore, MD. The input for the study includes some 46,000 communications-support requirements turned in by combat arms and other tactical Army users of communications equipment.

When Intacs is implemented, it is hoped that 30,000 less signal personnel and 5000 fewer vehicles will be needed to support the 24-division Army projected for 1980.

“This is the first time in the his-
tory of the Signal Corps that we have been able to cover the gamut of tactical communications in a single study,” says Colonel William E. Wilson, director of the U.S. Army Signal School Combat Development Directorate at Fort Gordon.

Much of the equipment required to implement the concept is either being developed or planned for development by such Defense agencies as Tri-Tac and the Army’s Tactical Satellite Communications and Single-Channel Ground and Airborne Radio Subsystem (Sincgars) programs.

A new family of radios

The Sincgars family of vhf/FM radios, which will probably go into the battalion level and below, will be smaller and lighter than the currently used VRC-12 family as well as secure and hardened against electromagnetic pulse.

All Sincgars radios—manpack, vehicular and airborne—will be essentially identical, with special modules for different applications.

The radios will be optimized for 16-kbs digital data: They will have to perform with the same functions and interoperate with the current Army inventory of vhf/FM equipment in both the secure and nonsecure modes, and they will have to provide at least 920—and preferably more—usable channels. At least four of these will be preset frequency/crypto-net channels.

A lightweight family of antennas is required that are simple to operate, need no physical tuning adjustment, and minimize the targeting of the operator.

The secure manpack radio will not exceed 20 lb, including batteries. The batteries, some of which will be lithium organic, will provide power for 24 hours of continuous operation for normal duty cycles.

The minimum acceptable MTBF will be 1250 hours, with the best operational capability set at 3300 hours for the manpack and 1500 for the vehicular and airborne units. The scheduled organizational maintenance time will be no more than 30 min/week.

Improved filter technology will be required—“more than likely in the active filters rather than in the passive,” says Theodore A. Pfeiffer, chief, Communications Electronics Systems Integration Office, Army Electronics Command at Fort Monmouth, NJ. “And we’re probably going to a higher level of microprocessor technology where practical. This will reduce power consumption, physical size and weight, as well as other phenomena such as transient problems.”

Switching for the future

Designed to tie the present to the future the AN/TTC-39 is an automatic communications central office switch—a telephone switchboard that accommodates both analog and digital transmissions. Actually, the TTC-39 has two switches: a circuit switch for voice and data, and a message switch for data exclusively. Both switches can operate with a wide range of transmission systems, such as satellite communications, tropospheric scatter and microwave, cable, data terminals and voice telephones.

The circuit switch can be equipped with a mix of both analog (space-division) and digital (time-division) matrices controlled by the same central processor. This combination provides a hybrid switch that can interface with both current and future analog and digital systems.

Both the circuit switch’s hardware and software are modular to provide a family of compatible switching combinations.

Circuit-switching modularity is provided by a basic switching mod-
The 82nd Airborne Div.'s AN/VSC-2 radio-teletypewriter terminal is air-droppable, lightweight and long-range. Mounted in a jeep, it uses an AN/GRC-106 single-channel, hf, SSB radio with a frequency-shift modem.

A continuously variable-slope-delta (CVSD) technique is used to convert the analog input into digital signals.

The message switch is a means for data-terminal equipment with dissimilar characteristics to communicate with each other. Its hardware and software permit it to understand, and be understood by, any military data terminal. The switch can process up to 81-million characters per day, with a one-second peak throughput up to 9000 characters. Single messages may be as long as 44,000 characters.

In the TTC-39, LSI is used as much as possible along with multilayer PC cards. CMOS is used primarily to keep power consumption down, but where necessary, low-power Schottky TTL mediascale integration is used.

The TTC-39 system is being built by GTE Sylvania's Electronic Systems Group's eastern division, Needham Heights, MA.

Telephone network on the move

Probably the most advanced equipment under development for Intacs is a mobile radio-telephone subscriber system, known as the Mobile Subscriber Equipment (MSE), which will provide secure automatic radio telephone service to subscribers who require access while in transit.

The Army wants to get away from the multichannel line-of-sight equipment now used. It takes too long to set up; and it requires large antennas, retransmission stations, and too much cable. And its limited mobility is no longer acceptable. "The multichannel equipment takes too long to wire up our command posts," Colonel Wilson says. "It's just not good enough for the future battlefield."

With the MSE, each subscriber has a unique address that can be reached at distances up to 45 km with the help of one or more relay centrals. Direct calls without a central should be possible up to 10 km.

Switching will be automatic. If a call doesn't get through by direct link, it switches over to a central. The concept is a significant emulation of the old, now defunct, Random Access Discrete Address system under development in the 1960s.

The MSE subsystem will be operational some time in 1987.

Tactical satellites step forward

The Tactical Satellite Communication System is being upgraded, says Colonel Fred M. Knipp, commanding officer of the Army Satellite Communications Agency, Fort Monmouth, NJ. "We're putting in new digital terminals and converting existing terminals. The first one went in earlier this year, and by 1980 we'll be all digital."

Satellite communications can be used over a wide range of point-to-point distances. "You can use them from one valley to the next or for distances up to 9000 miles," Col. Knipp says.

The satellite network has three satellites operating at shf that are shared by the Strategic Satellite system: one for the Atlantic, one for the Pacific, and one for NATO forces. A second NATO satellite is soon to be launched. The tactical system also uses several classified satellites operating in the uhf region plus two Marisat relay craft, also uhf.

Uhf is used for vehicular and manpack terminals. Shf is used with 8-foot antennas installed on trucks. Collins is manufacturing the uhf equipment, and RCA, the shf. The manpacks, which will use whip antennas, are being built by Cincinnati Electronics.

The satellite-communications system is moving to Time Division Multiple Access modulation, Col. Knipp says, because the spectrum is so tight. With TDMA, each channel is divided into a number of discrete time slots, with 30 ns the lowest practical limit.

Each terminal in the communication system will be assigned a time slot on a given channel and will transmit in a burst mode. With burst transmissions, each channel will be able to accommodate many more subscribers with no loss in communications capability per terminal.

Uninterrupted voice communica-
Belden has it: a total service capability. Extensive design and application know-how. What it takes to deliver complex cable configurations, special harnesses, cords, lead wires, and even special packages to fit your requirements.

Our specialists and engineers will meet with your people at your plant to discuss problems in processing, assembly, installation, ordering, human engineering, color coordination, physical and electrical parameters, opportunities for cost reduction. And when we can't help you using standard products, we'll innovate a solution to your problem.

Talk to a Belden specialist about your new applications, product ideas, processing problems—all your wire, cable and cord needs. He has thousands of standard items to draw from. And standard or special, he'll come through with the best wire buy around. For answers right now, phone:

317-966-6661 Electronic Div. or mark No. 400 on reader service card
312-986-1600 Electrical Div. or mark No. 401 on reader service card
312-887-1800 Transportation Div. or mark No. 402 on reader service card, or write Belden Corporation, 2000 S. Batavia Ave., Geneva, IL 60134.
tions can be expected in this mode, just as with a straight-through channel, since the time slots are so small and so frequent that no loss of communication can be perceived.

Millimeter waves are in the future, according to Col. Knipp: 30 GHz up to the satellite, and 20 GHz down.

Technology leads the way

The Army wants fundamental technology change in all future communications inventory. For example:

"We're trying to get away from punched paper tape as a recording medium," says Pfeiffer at Fort Monmouth. The goal is to cut what is considered the biggest time waster at the communications center, message handling.

To get away from the problems inherent in electromechanical devices keyboard technology will be as solid-state as possible. Fort Monmouth is looking at a number of possibilities including piezoelectric technology.

For video display, CRT is being considered, of course, because it's the most prevalent. But the field is open. Liquid crystals (LCD) and plasma are both possible.

Many battlefield transmitters that all send data may one day be combined: sensors, IF, wideband data links from aircraft to ground terminals and position beacon, says Pfeiffer "Maybe someday we'll be small enough to build modular transceivers that can do all these things."

For possible answers, Pfeiffer's group is looking at Time Division Multiple Access techniques, which have already been selected for the satellite program.

The Army currently uses PCM to multiplex, which, of course, is digital: "The Army is probably more digital today than any other service," Pfeiffer observes.

TDMA will eventually join the Army in the field via the Joint Tactical Information Distribution System, which the Air Force is handling for all the services. An outgrowth of the basic communication system proposed for the Air Force's airborne warning and command system aircraft, AWACS, the system can be applied to a communications network serving a large

High-Speed Data Buffer TD-1065 is being developed for digital access of high-speed data and wideband, secure voice traffic at rates of 32,000 and 16,000 bits/s into the Army's tactical trunking system.

The AN/PRC-77 manpack radio, which still uses some germanium transistors, will be used until Singers radios come into inventory.

many community of users who share the same general data interests and can share the same transmission, explains Grady Banister, Deputy Project Manager of Army Tactical Data Systems at Fort Monmouth.

For example, an air-defense sensor can send out a message describing an enemy position via the TDMA system to all system members. Also, each participant has a time slot for transmitting his own data, which can be received only by the addressees.

"I believe TDMA will dramatically change the way we communicate," says Banister. "It has a high bit rate and serves a large number of subscribers."

A digital multiplexer joining the Army's inventory will permit the digital access of high-speed data and wideband, secure voice traffic with rates of 32 k and 16 kbits/s to be fed into the Army's tactical communication transmission system. The 1065 will sense analog or digital signals and process them accordingly. Digital telephones are now under development. In such an instrument the a/d converter will be right in the telephone.

"Perhaps the continuously variable slope delta modulated (CVSDM) chips being used in the satellite program, the TTC-39 and in other Defense Dept. programs could be used in the digital telephone," Pfeiffer suggests.

A problem with digital telephones is that of loop length. "We're told now that the digital telephones are limited to 3.2 km over a pair of field wires," according to Col. Wilson at Fort Gordon. "And since we don't want repeaters that have to be powered by an outside source, we've got to have one that can operate on a couple of flashlight batteries for an extended period of time."

Fort Monmouth recognizes the benefits of multilayer printed-circuit boards. Some of the security equipment now being built contains cards 14 layers thick. "A 14-layer PC card has such high density that it can't be repaired easily, so they've got to be reliable," Pfeiffer observes.

For memory technology, the Army will use whatever is available—bubbles, if they are ready, because they save power; but definitely solid-state memories, cassette tapes and discs. • •

ELECTRONIC DESIGN 26, December 20, 1976
Who provides the industry's broadest line of electronic packaging hardware ... including Card Files?

SAE does! In either kit form or fully assembled, VARIFILE's® exclusive snap-together construction lets you assemble a card file in just minutes—without tedious component stringing.

Designed on a modular basis, SAE card files contain only five basic parts: end plates; support bars; card guides; nylon snap locking tabs; and connector mounting feet. Also available is a complete line of accessories including identification tabs, card pullers, circuit card ejectors, circuit card ejector/retainers, printed circuit board edge connectors, and cable connector hoods.

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* Stanford Applied Engineering, Inc.
Smart industrial robot sees whatever it’s supposed to do

The robot’s video camera, similar to the TN-2200, can inspect and measure piece parts, recognize printed material and collect data in real time.

Industrial robots are well known for grabbing small parts as they ease down an assembly line, whirling around and screwing them on to another part a few feet away—all without being able to see.

But now a robot from Auto-Place Inc., Troy, MI, has been given “eyes,” an automatic camera, and even a “brain,” a microprocessor. Opto-Sense, a small black box with an air-powered arm that can lift up to 30 lb, can watch products move down the line, much like a shepherd watching sheep file through a mountain pass. It can also pick up all the round ones—if that’s what it’s been told to do—and throw out the rest.

If, say, five different-sized products have to be grouped into one package, the brainy, sighted robot can be instructed to do so. For more complicated tasks, two robots can be used, each handling as many decisions as it can.

Opto-Sense’s possibilities are infinite, as demonstrated at the recent North American Industrial Robot Conference in Chicago. With a GE TN-2000, an automated standard TV camera modified for sequential scanning, Opto-Sense picked up playing cards, inspected them and sorted them according to suit.

The camera was developed by GE originally for the Air Force to guide “smart” bombs.

"Using conventional analytical circuitry, we gave the TN-2000 camera the ability to make a number of decisions," says Frederick A. Sachs, marketing manager for GE’s Optoelectronic Systems operation, Syracuse, NY. "If the robot presented the wrong side of the card to the camera, the circuitry told the robot arm, to turn it over."

The camera then focused on the small number and suit symbol in the corner of the card, determined the suit by area analysis and told the robot which pile to put it in.

“End of the game” was the final decision for which the camera was programmed. If there were no more cards, the camera waited until a new game began.

The GE camera’s charge-injection area sensor, which consists of 244 rows with 188 elements per row, produces 46,000 pixels (picture elements). The output signal conforms to the EIA RS 170 signal-structure standard—which means the camera can interface with any monitor built to U.S. standards.
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Mr. W. T. Noel is Senior Engineer at the Naval Air Systems Command, Arlington, Virginia. He is involved with infrared avionics development and procurement for the Navy Department. Mr. Noel states:

"I refer to the GOLD BOOK often and find it quite useful in my work. It’s very convenient and always on my desk. I don’t have to go somewhere else to use it.

"Navy avionics procurements are largely to specification. The performance sheets and vendor sources provided by the GOLD BOOK are quite useful in the preparation of these specifications."

This is the *Electronic Design* audience working for you. (The GOLD BOOK goes essentially to *Electronic Design*’s audience of engineer/specifiers.) Mr. Noel, like 78,000 electronics engineers and engineering managers, purchasing agents and distributors throughout the U.S. (plus 13,000 abroad) has his own personal copy of the GOLD BOOK.

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Produced by the original "little light" people.
Air Force, Canada seek new air-warning system

The Air Force, in a joint program with Canada, is asking for industry proposals by January 7 on a network of seven military air-traffic control centers to be known as the Joint Surveillance System (JSS). The system will replace the existing Semi-Automatic Ground Environment (SAGE) and Back Up Intercept Computer (BUIC) systems installed in the late 1950s and early 1960s, which have become too expensive to operate.

The JSS, which is expected to cost $300-million, will be managed by the Air Force's Electronic Systems Div., Bedford, MA. Canada is putting up about $45-million of the total cost, and Canadian subcontractors are expected to receive a comparable share of the business.

The Air Force expects to award parallel-development contracts to two firms in September and then choose a single prime contractor to produce the entire system around January, 1979.

Boeing, Hughes Aircraft and Burroughs are the likely contenders for the prime contract. Boeing has teamed with IBM (builder of the original SAGE system) to propose a land-based version of its Airborne Warning and Control System (AWACS). Hughes and Burroughs (builder of the BUIC) are bidding alone. Ford Aerospace & Communications (formerly Aeronutronic Ford) and GTE Sylvania, which had indicated an interest in the prime contract, are no longer expected to bid.

Navy seeks ion implantation, electron-beam ideas

The Navy is interested in pushing the state of the art of IC fabrication by seeking ideas from industry on new ion-implantation and electron-beam imaging systems to be operated in an IC process line.

The ion-implantation system should be capable of processing at least 100 wafers per hour. Other requirements include high beam currents of more than 1 milliamp for most encountered dopants, low-energy implants of 5 to 30 KEV and reproducibility to within 1% accuracy across a 3-in.-diameter silicon wafer.

The electron-beam imaging system should be fully automated and capable of producing at least 60 wafers per hour with sub-micron resolution and alignment accuracy. Current single-beam, pattern-generation systems that serially scan each pattern are too slow for production applications, according to the Navy.

Interest has not reached the request-for-proposals stage yet, but if the Navy sees something it likes it might award hardware contracts later. The project is being handled by the Naval Regional Procurement Office at Long Beach, CA.
DOD criticized for keeping R&D from industry

The Defense Dept. continues to keep development work within its own research establishment that should be contracted out to industry, according to a declassified study prepared for Congress by the General Accounting Office (GAO). The study focuses on Mitre Corp. of Bedford, MA, and its relationship with the Air Force’s Electronic Systems Division. Mitre is one of nine federal contract research centers, commonly called “think tanks.”

The GAO investigators reviewed three Air Force programs, managed by Mitre—the Pave Paws phased-array radar, the AN/GPN-XX air-traffic-control radar and the Tactical Loran C/D navigation system—and found that industry would have bid on the same technical management tasks if they’d had the opportunity. In the case of Pave Paws, for example, 10 radar producers were asked if they would have bid on the technical management contract even if it involved a hardware-exclusion clause. All 10 firms said they could have done all or part of the work, and five would have signed a hardware exclusion clause to get the job, according to GAO.

Defense Dept. regulations prohibit the federally sponsored centers from doing such work unless they can prove that private industry cannot do it. Mitre and the Air Force failed to provide such evidence for the three programs reviewed, according to the GAO study.

NBS to calibrate diagnostic X-ray units

A calibration service for high-voltage dividers used with diagnostic X-ray units has been established by the National Bureau of Standards as part of an effort to reduce unnecessary exposure to X-rays.

Diagnostic dividers, consisting of a number of resistors, are hooked into the high-voltage points of X-ray units to divide the voltage and reduce it to a point low enough to be measured. By ensuring that the peak voltage is consistent from one X-ray unit to another and from day to day within the same unit, a calibrated divider enables patient dosage to be reduced. Consistency also reduces the number of retakes required by cutting the number of nonuniform film exposures.

The calibration service, which has been tested for the past year by the Dept. of Health, Education and Welfare’s Bureau of Radiological Health, is now being made available to the X-ray industry on a cost-reimbursable basis.

Capital Capsules: The Federal Aviation Administration is considering making it mandatory for all commercial aircraft to carry FAA approved equipment for transmitting and receiving information about adverse weather. . . . The Defense Dept. plans to increase its funding to industry to apply new manufacturing-technology methods to increase productivity. This year’s funding level of $114-million is due to rise to $132-million in the new budget to be submitted to Congress in January. The eventual goal is $200-million a year to support more automation and other productivity-related investment. . . . The Army Mobility Equipment R&D Command, Fort Belvoir, VA, is seeking a new infrared aiming device with a laser diode for rifles to illuminate targets at night. The system should be effective at 100 meters and work with current Army night-vision goggles. Average power output of the diode should be 150 microwatts in the near-IR spectrum of about 850 nanometers.
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CIRCLE NUMBER 23
N-channel SC/MP-II doubles speed but cuts power by four times

By going to n-channel processing, designers at National Semiconductor have boosted performance, slashed power and cut costs to come up with a “super” version of the already popular SC/MP 8-bit microprocessor. The SC/MP-II requires only a +5-V power supply, not the +5 and -7 required by the original SC/MP.

With the power requirement cut to only 225 mW—one-quarter that of the p-channel version—the SC/MP-II can be housed in an inexpensive plastic package. And, being an NMOS device, the super µP can operate at clock frequencies as high as 4 MHz—double that of the PMOS version. Thus, low-cost, 3.58-MHz timing crystals can be used for the clock source.

The SC/MP-II can slip into the same socket as the SC/MP if the negative supply is eliminated and the pin is grounded. However, there are three minor software changes: The bus-request, enable-in and enable-out lines, which are active-high in the SC/MP, are (continued on page 40)

Satellite-borne µP system can repair itself

A powerful µP-based system designed to operate reliably in space for seven years is being developed by Hawker Siddeley Dynamics of Stevenage, England. A custom µP will be used in communication satellites from 1980 on and will have two unique features: direct, high-level language programming and sophisticated self-repair facilities.

Normal µP design procedure has been reversed to design the space microprocessor around its own real-time, high-level programming language, which provides a one-to-one compilation into assembly language instructions.

To improve reliability, two µPs, with specially developed firmware to detect failures, will be used in the satellite system. Although it will have seven types of NMOS LSI devices, the complete Siddeley system will contain about 20 chips, some of which will be doubly redundant.

The µP is currently in the chip-fabrication stage and, following successful simulation trials, is scheduled for flight trials in 1978. The device is being produced with a low-power NMOS process that features “semi-dynamic” techniques. For example, the memories will need no refresh cycle but will be powered up briefly during access and write cycles.
MICROPROCESSOR DESIGN

(continued from page 39)
active low in the SC/MP-II. And minor hardware adjustments must be made.
Like its predecessor, the super µP has a three-state data bus, separate serial-data input and output ports, full TTL compatibility on all lines and an addressing capability of 65 kwords. And, by use of their special delay instruction, either microprocessor can interface with memories or peripherals operating at any speed.
Available from stock, the SC/MP-II sells for less than $10 in quantities of 1000 or more. National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. H. Patel, (408) 737-5000.

CIRCLE NO. 508

Dual µPs simplify interactive terminal operation

The first interactive graphic display system to incorporate two programmable microprocessors—the Sanders Associates Graphic 7—can either independently operate or be interfaced with most 16-bit computers. The dual intelligence of the Nashua, NH, firm's system provides a "universal" interface and minimizes the cost of special interface hardware and programming.
The basic system has terminal control circuitry, a 21-in. CRT display, such input devices as a keyboard, and such optional features as a light pen and a trackball.
The terminal controller includes two "µPs," one a display processor the other a graphic controller. Both are actually built from 6700-series bipolar bit slices from Monolithic Memories. The display processor, a general-purpose unit, operates with 8 and 16-bit words. It has eight general-purpose registers and an 8-k read-write memory, expandable in 8-k increments.
The graphic controller is a 16-bit parallel µP with 40 display instructions, 13 display registers and four general registers, and provides the refresh functions. A 4-k × 16 ROM contains the graphic control program, which handles communications between the terminal and a host computer, controls and data-entry devices, manages the display-image refresh and performs other functions usually done in a host computer.
The CRT screen has 2048 × 2048 addressable locations with 1024 × 1024 reserved for viewing.
The standard character set is 96 ASCII elements. Up to 32 user-defined characters are optionally available, and each can be rotated 90 degrees counterclockwise and presented in four different sizes. However, 2.4 µs are required to present a typical character. Eight brightness levels are available.
The firmware-committed, graphic control program makes terminal operation transparent and minimizes host-computer involvement in display functions. It also frees the system programmer from having to support the graphics terminal and allows him to concentrate on the application software.

Software development package plugs into a microcomputer

By plugging four EPROMs, the RDP2 package, into Intel's SBC 80/10 single board computer, and adding power supplies and a teletypewriter, it is possible to give a system program editing, assembly, and debugging capabilities.
The programs are subsets of Intel's versions supplied for the MDS development system.
(continued on page 42)
The new Dale resistors are more efficient to use. Today, one out of every 10 Dale employees is directly involved with quality control. Tangible results include: More than 100 separate QPL listings for wirewound and metal film resistors and the world's most reliable wirewound resistor (proven failure rate .000021% per 1000 hours). As a result, we're certain the new Dale resistors will give you less trouble—before and after purchase—than any others you can buy—and that's efficiency! Call 402-564-3131 for wirewound and 402-371-0080 for metal film.

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MICROPROCESSOR DESIGN

(continued from page 40)

The assembler, for example, will not create macros—user generated subprograms—or use operand expressions.

The editor prepares assembly-language paper tapes for the assembler. In one pass the assembler generates up to 500 lines of code and puts it into the SBC 80/10 memory. Because source code only has to be read once, the RDP2 is two to three times faster than other multipass assemblers.

The monitor contains functions for software debugging, including tape dumping and loading, storage and register modifications, and selective program execution.

The package price of $995 includes complete documentation, periodic software updates, and a warranty. RDP2 is available for immediate delivery.

Extensys Corp., 592 Weddell Dr., Suite 3, Sunnyvale, CA 94086. (408) 734-1525.

CIRCLE NO. 509

Microprocessor development system has resident compiler

A combined resident-compiler and modular-programming system from Intel can support the 8080, the SBC80 single-board computers and other 8080-based products.

Residing in the Intellec microcomputer, the software system consists of an advanced version of the PLM-80 compiler for the 8080A, and a new diskette operating system, the ISIS-II. The compiler is supplied on diskettes and costs $975.

The PL/M compiler supports modular software designs and generates linkable and relocatable object code modules. These modules can be automatically connected not only to each other, but also to object-code modules produced by a new relocating micro-assembler contained in the ISIS-II package.

Since the Intellec resident compiler does away with having to access large, expensive computer or time-sharing systems, development costs come down.

ISIS-II includes all other subsystems required for modular programming: macro-assembler, linker, locater and library manager. A text editor with string search, substitution, insertion and deletion commands is also included.

Intel, 3065 Bowers Ave., Santa Clara, CA 95051. (408) 246-7501.

CIRCLE NO. 510

Micro Capsules

Both a commercial temperature-range series and a plastic-encased series of microprocessors have been added, with related support circuits, to the 6800 family by Motorola, Austin, TX. Identified by a “C” suffix, the commercial circuits have a temp range of -40 to +85 C and cost 60 to 80% more than standard 6800 parts. The plastic units are intended for operation over the 0-to-70-C range and will probably cost 15 to 20% less than the ceramic-cased models...

In a few years, one 300-mil-square chip should contain not only the CPU, but all the ROM, RAM and interface circuitry. Volume production of the large chips should be economically feasible by 1981, predicts National Semiconductor’s William Baker, Group Director for Microprocessors. ... MicroForth, a high-level language developed by Forth Inc. of Manhattan Beach, CA, permits the user to work on a resident or direct basis to develop programs on the RCA 1802 µP. The new language executes 10 to 100 times faster than Basic and requires only 8 kbytes of memory, including a 2-k work space ... A small, hand-held terminal will be introduced soon by the microprocessor-development group at RCA, Somerville, NJ. With a built-in keyboard and LED display, the terminal is expected to cost about $300.
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A new exclusive Sprague development, Series 2000 Transistor Arrays are high-voltage, high-current integrated circuits comprised of seven silicon NPN Darlington pairs on a common monolithic substrate. They feature open collector outputs and integral suppression diodes for inductive loads.

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For more information, write or call George Tully, Semiconductor Division, Sprague Electric Co., 115 Northeast Cutoff, Worcester, Mass. 01606. Tel. 617/853-5000.


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Electronic Design 26, December 20, 1976

CIRCLE NUMBER 25
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Electronic Design 26, December 20, 1976
The importance of being important

Joe's new X-21 was a winner. Every day he'd get a dozen calls about it from potential customers who seemed almost as excited about it as he was. Then one day the calls stopped coming. Abruptly.

Joe began to sweat. He had expected the calls to taper off eventually, after the novelty of the product wore off. But this was too sudden. So he spent lots of time worrying about the product. Had a competitor suddenly introduced a more exciting unit? Did customers see flaws that he had missed? Had marketing priced his product too high? He checked with the fellows in marketing, but they were stymied, too. Something very strange had happened.

Well, because the situation seemed hopeless anyway, Joe began to forget about it. Trying to help him forget, Charlie one day told Joe to size up Sally, the new switchboard operator—"a real knockout."

"Sally?" Joe gulped. "What happened to Mary?"

"Not to worry," Charlie calmed him. "Mary just has a mild case of pregnancy. She'll be all right in a few months. Before she left she broke in Sally thoroughly. Told her everything about the switchboard and the company."

Well, not quite everything, Joe discovered. Mary had prepared a chart listing everybody's extension number. And she'd told Sally that Joe was the chief engineer, Charlie the sales manager, Jack the president, and Ted the company wolf. But she had neglected to tell Sally that if a caller wanted information on the X-21 (or almost anything else), then Joe was to get the call. So, very courteously, Sally told such callers that she didn't know what they were talking about. She needed a person's name.

That was unfortunate because the X-21 was important. All the important people in the company knew about it. Had Sally been important, she would have known about it, too.

GEORGE ROSTKY
Editor-in-Chief
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CIRCLE NUMBER 28
Question a solid-state relay manufacturer about his specs, and he is likely to come back with several questions that you must answer first—a sure sign that the spec sheet shouldn't be taken simply at face value.

For example an SSR's output-current capability appears simple to specify. Not so! Although the "maximum" current is boldly flaunted, contingent conditions, such as temperature and the need for a heat sink hide in footnotes and derating curves.

Designers more accustomed to working with electromechanical relays (EMRs) tend to forget about temperature—the SSR's greatest enemy—because EMRs are hardly affected by heat.

Heat can sink an SSR

Up front, the spec list may simply say, "Maximum load current: 15 A rms." But buried at the bottom is a typical fine-print footnote: “Above 5 A rms, the relay must be mounted on a 6 × 6 × 1/8-in. aluminum plate held in a vertical position. Use silicone grease to seal the relay tightly to the plate.”

The relay itself may occupy a surface of only 1-3/4 × 2-1/4 in., so you may find yourself squeezing in a much larger heat sink after your layout has been completed. Worse, a burnout may be the first indication that you have forgotten the heat sink. And that's not all.

Not only will the SSR usually not handle the listed maximum current without a sizable heat sink, but many specs state (and some make you guess) that the ambient must be at room temperature—about 25 C. Sound reasonable? No, it isn't. Rarely do you find air at room temperature in the immediate vicinity of power-handling electronic components. Temperatures over the range of 40 to 80 C are more realistic.

Even with the recommended heat sink, that "15-A" relay can probably carry only 10 A safely, because the ambient is 60 C, not 25 C. But you find this out only after you carefully study the derating curves, which aren't always supplied with the spec sheet.

The typical 15-A relay's derating curve might be flat to 25 C, then rapidly slope to 10 A at 60 C. But be careful: When you operate on the slope, a slight increase in ambient temperature or load can often lead to regenerative behavior, and to the SSR's destruction.

Some derating curves can fool you even further, so examine them very closely. Are the curves plotted for ambient temperature? Often, manufacturers plot allowable load current against the SSR's case temperature, not the ambient, even though the curve's title boldly states, “Permissible Load Current vs Ambient Temperature.” Sometimes there's no label: You are left to guess. Case temperatures can run 20 to 40 C higher than the corresponding allowable ambient, and so make the spec look better than it is.

Another point: Thermal derating curves of SSRs designed for use without heat sinks can define the general derating conditions, but curves that call for a specific type of heat sink can't. Those for the rather frequently cited 6 × 6-in. aluminum plate are of limited value, because you can use such a plate only rarely. Moreover, even if a standard heat sink is specified, the specific unit listed may not fit your packaging concept. Then the heat-sink curves are at best useful only as guidelines.

Some manufacturers specify an allowed thermal resistance between the SSR's case and am-

Morris Grossman
Associate Editor
bient. With a thermal resistance, you can easily select a heat sink to fit your specific application. This is the preferred method.

**A case of high heat**

If thermal resistance is not provided, you can use a rough relationship to obtain the temperature rise of the SSR's case above the ambient under free convection conditions. The relation is

\[ T \approx 133 (W/A), \]

where \( W/A \) is the dissipated watts per square inch. So, for a 15-A load, an ON-state forward-voltage drop of 0.7 V and 6 × 6-in. heat sink, the case temperature of an SSR reaches almost 40°C above the ambient temperature.

With a PC-mounted SSR, only the sink's top side is exposed to the free flow of air. Thus, the value of 36 in.\(^2\) is used in the example—only one side of the plate.

Of course, a heat sink can't extend an SSR's rating beyond the maximum allowed ambient operating temperature. A typical spec might list an operating ambient range of -30 to 100°C. But take note: The relay is useless at or near 100°C because it is derated to carry zero current as 100°C is approached. Also, the -30°C end of the range limits operation, though not as severely as the high end. Minimum allowed load current rises sharply near the low limit.

At the low end of an SSR's "operating" temperature range, the relay can fail to turn on reliably, especially if the load current is low. At normal operating temperatures, SSRs with SCRs or triacs as output devices require a minimum load current—typically about 5% of the rating. Between -20 and 80°C, the minimum-current requirement rises only slightly as the temperature drops. But at temperatures colder than -20°C, the minimum-current requirement increases very rapidly; at -30°C, the current can rise to about 30% of rated.

**SSR leaks can sink a design**

Besides being temperature-dependent, SSRs can leak in the OFF state—seldom a problem with EMRs.

Although leakage in SSRs is not important in most power circuits, occasionally it can be troublesome, such as when a null is required in a servo-motor drive or when lightly loaded solenoids must drop out. And even when low, leakage does add substantially to the power the relay must dissipate, since in the OFF state, the full voltage is across the SSR.

The SSR's ON-to-leakage current ratio is

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**The four-screw terminal-block style of housing** has become a widely used package for solid-state power relays. The same sized package (about 1-3/4 W × 2-1/2 L × 1 H in.) serves loads from 2 to 40 A rms. But be very careful: Above about a 2-A load, the relays must be mounted on a sizable heat sink for safe operation. Many manufacturers such as Grigsby-Barton, MagneCraft, Electrol, Crydom and North American Philips (from lower left, clockwise) package their SSRs in these block-style plastic cases.
generally over 1000:1. A 10-A SSR typically exhibits a 5-to-10-mA leakage proportional to the load voltage—5 mA at 120 V and 10 mA at 240 V.

Not all the leakage comes from the SSR’s semiconductor output device: An RC snubber network—used to limit the rate of output voltage rise—as well as internal control and biasing circuits, can easily contribute at least half.

**Broad turn-on voltage range featured**

Interestingly, although specifying the load of an SSR leads to many complications, an SSR’s input presents few difficulties. EMRs generally operate over a relatively narrow input-voltage range with a single coil. Coil changes or even different relay styles may be needed to cover the same range handled by one SSR. Typical SSRs easily turn on positively and safely over a range as wide as 3 to 32 V dc, and in some cases as wide as 3 to 300 V dc—and even ac over the same voltage range. Furthermore, SSR inputs are no more temperature-sensitive than EMRs.

The more sophisticated SSR designs incorporate a current regulator to maintain a relatively constant input current over most of the rated ON input-voltage range.

Hybrid SSRs have reed-relay inputs and are probably the most limited in input-voltage range—determined by the reed’s pick-up and drop-out characteristics and the coil’s resistance. But a reed input is simple, low-cost, and effective in many applications. Most applications need only a narrow range of inputs, and the life of a reed that can run into hundreds of millions of operations is often more than adequate.

Opto-isolated-input and transformer/oscillator coupled SSRs, however, are preferable where the speed and mechanical life of a reed may be a limitation; they allow wide, versatile input conditions.

Pickup and dropout ratings for SSRs are handled very much like EMRs. The low end of an SSR’s input-control voltage range is analogous to an EMR’s pick-up voltage rating and often referred to confusingly as “maximum pick-up” voltage. A less ambiguous name is “must-operate” voltage. Of course, the high-end, must-operate voltage should not be exceeded, or the relay may be damaged.

Similarly, turn-off voltage—the highest input voltage at which the relay in the ON state can return dependably to the OFF state—is often called “minimum drop-out” voltage. The term, “must-release” voltage, is less confusing. Must-release voltage is generally less than half the must-operate voltage.

The difference between the must-operate and must-release voltages gives the SSR a control hysteresis—a desirable (usually) characteristic that promotes clean switching. Uncertain, or fuzzy, ON/OFF action can be caused by control-voltage fluctuations, noise pick-up in the control circuit and transients coupled from the power line, among other things.

**A relay is a four-terminal device**

Since a relay, by definition, is a four-terminal device, the degree of input/output isolation is important. The three specs that define input/output isolation—insulation resistance, dielectric strength, input-output capacitance—are usually unambiguous.

The insulation resistance between input and output (and to a metal case, if any), usually measured at 500 V dc, is typically in the neighborhood of 10⁸ Ω.
The dielectric strength, typically about 1500 V rms, can be as high as 5000 V rms in some special designs. And the input-to-output capacitance, though not always given, can range from 5 to 10 pF in small units, though 10 to 20 pF is usually low enough to ensure little noise coupling from load back to the input.

Hybrid SSRs have input/output isolation characteristics determined mostly by the properties of the input reed relay. Hybrids probably have the most rugged inputs—more tolerant of input transients than all-solid-state designs, because the input relays require a substantial amount of energy to operate.

The solid-state-input SSR needs little input energy. But when the SSR operates on short pulses, the pulses must contain a minimum amount of energy for reliable turn-on. The pulse height may exceed the SSR’s trigger level, but the width must last long enough to supply the needed energy.

Such a minimum-energy spec is hardly ever provided. You must ask for it.

Of course, maximum input-voltage specs (almost always provided) should never be exceeded. Solid-state input circuits can be damaged by high, narrow spikes even though they don’t last long enough to turn the SSR on.

Many SSR designs have built-in input protection circuits. Units for dc input are often protected against accidental reversal of the input polarity. Where necessary, external circuits—low-pass filters, clippers and special signal conditioners can remove most transients without materially affecting the desired performance.

Also, special input circuits can be provided to match impedances, shift levels and accept balanced signals with high, common-mode voltages. Naturally, inputs compatible with TTL, CMOS and other popular logic families are a common feature of SSRs.

Let the dynamic response fit the load

Between its input and output, the SSR allows a wide choice of dynamic responses, many not possible with EMRs. Compared with EMRs, the SSR can turn on almost instantaneously—1 µs in some fast units vs 1 to 50 ms for EMRs.

Random turn-on SSRs are generally recommended for resistive loads only, because there are no current surges or inductive kickbacks to worry about.

Of course, if you want fast turn-on, choose a transformer or optically coupled unit. The hybrid is slower, limited by the reed relay to about 1 ms, but still 10 times faster than any EMR of comparable load rating.

Zero-voltage turn-on—closure of the output circuit synchronized with a zero crossing of the ac line voltage—is highly desirable for high input-current surge loads like lamps and capacitors. In addition to protecting the SSR against huge current surges, zero-voltage turn-on keeps electromagnetic interference to a minimum. Note that zero turn-on response has an inherent delay, which may be as much as a half cycle, or 8.33 ms on 60-Hz power.

Be aware that an SSR doesn’t necessarily have zero turn-on, merely because the manufacturer claims “internal transient protection” for an SSR. He may be referring only to an internal snubber network that, though helpful (especially for inductive loads) can’t do the job of zero turn-on.

If you decide you need zero-crossover turn-on, ask about the worst-case, zero-switching voltage. Very few spec sheets include this information.
lower the worst-case voltage, the less the current surge.

Note: Zero turn-on SSRs work best at the relay’s nominal rated voltage; at reduced voltage, turn-on is delayed, and the output distorted.

SSRs turn off softly

The abrupt interruption of current in an inductive circuit can cause very high transient voltages (kickbacks) reaching several thousand volts. The attendant arcing and EMI can be very damaging. EMRs must be particularly rugged with inductive loads, since protection is limited to only partially effective snubbers and semiconductor suppressors.

With SSRs on ac systems, SCR or triac output devices inherently turn-off only when the circuit current falls close to zero, regardless of when the OFF command occurs. The result: no current, no kickback and no EMI. The inherent 2-to-5-µs delay that the SCR or triac introduces at turn-off has little effect compared with the maximum 8.33-ms (half-cycle) delay that may occur between the turn-off command and actual load turn-off in a 60-Hz system.

But another problem pops up. The output triac or SCR may turn off when the output current goes through zero; however, with reactive loads (capacitive or inductive), the supply voltage to the output device may be near its peak (close to 90 degrees out of phase with the current). The result: a steeply rising voltage across the SCR or triac as the device turns off. This voltage rise is termed dV/dt on the spec sheet.

Turned off by turn-off specs?

Here is where the output-to-input capacity spec becomes important. The dV/dt generated across the SSR uses the I/O capacitive path—along with any stray wiring capacitance—to find its way back to the triac’s or SCR’s input control gate. The result is a commutation failure—the circuit refires (false fires) repeatedly and hangs up the circuit in an ON condition.

Transients originating in remote sources can enter the load wiring to the SSR and also cause false firing, but last usually only half a cycle. Such random false triggering may not be detected when you switch lamps or heater loads, and usually can be tolerated with such loads. However, with inductive loads, fast and repetitive false triggering can degrade and eventually destroy the SSR.

Thus, an SSR’s dV/dt rating is an important output characteristic. Many manufacturers list a maximum dV/dt. Some don’t. Of course, it’s better to have a high maximum dV/dt.

But be careful: dV/dt ratings come in two categories, commutating and OFF-state, with the latter much higher in value than the former. An OFF-state dV/dt of 100 V/µs minimum is usually considered satisfactory for most applications. The corresponding commutating dV/dt value generally is only about 5 V/µs.

Sometimes a spec sheet lists only one value without identification: if the value is 100 V/µs or more, it’s the OFF-state value.

Another problem: dV/dt ratings should be determined under realistic test conditions. Both the load and source impedance must be defined. A 50-Ω resistance has been proposed as an industry standard to be included in the NARM (National Association of Relay Manufacturers) SSR specifications. Clearly, this resistance can be set arbitrarily high to produce a seemingly better (higher), but unrealistic, dV/dt rating. Spec sheets rarely mention the test conditions for the given values: It’s better to ask than be surprised.

Finally, if an SSR’s built-in transient tolerance and dV/dt rating are insufficient you can add an external snubber circuit across the load to help suppress the transients.

High on/off rates can hurt

When an SSR is fully ON, its load-switching element may carry a high current, but the voltage

What’s a solid-state relay?

A relay is defined as a four-terminal device whose input can control—but is de-isolated from—its output. A solid-state relay, in addition to passive components, contains mostly semiconductor active devices. Unlike electromagnetic relays, most solid-state units are specifically designed to carry either ac or dc loads; the same SSR usually can’t switch both.

Popular SSR load voltages include such ranges as 6 to 48 V and 90 to 150 V dc, or 80 to 140 V, 90 to 280 V and 200 to 480 V ac (rms). Higher voltages to the limits of modern semiconductors—about 1000-V peak—are also obtainable. The low limit is established by the minimum voltage needed for reliable turn-on of the load-switching semiconductor. Most manufacturers specify a range of 47 to 63 Hz for ac SSRs; 400-Hz units are available on special order.

Both SCRs and triacs are used for ac switching—SCRs tend to be more resistant to false turn-on than triacs. Power transistors are usually used for dc. However, some manufacturers make a back-to-back transistor bidirectional unit that can handle either dc or ac loads.

Isolation of the input from the output is usually done at the input circuit. Three methods are commonly used: optical, transformer/oscillator and reed relay.
drop across the element is low (typically 0.7 to 1.7 V). When the SSR is fully OFF, the current is low (milliamps of leakage), even though the voltage is high. In both cases, consequently, the power dissipated by the switching device is modest—between, say, 2 and 15 W for medium-sized SSRs. Generally, this power dissipation is included in published SSR specs, if not always adequately.

However, during the interval the SSR switches on or off (the breakover state), both high current and high voltage are present, and substantial power peaks are generated, peaks that must be dissipated.

Some SSR-design experts advise that the power-switching semiconductor should be built with glassivated junctions. Properly glassivated junctions produce devices with sharp breakover “knees.” The “softer” the knee the longer the high-leakage interval during switching and the greater the heating, especially at chip edges where surface impurities can cause hot spots.

Switching time is short (microseconds), so when switching rates of the SSR are low—or even moderately high—the heat generated during switching contributes little above that of the static ON/OFF states. However, when switching occurs very rapidly, the heat generated during switching can become substantial. A marginal

**Optical isolation is all solid state**

Some manufacturers, like C.P. Clare, use LEDs optically coupled to a phototransistor or photo-SCR. This approach is said to provide a fast or snap-action transfer characteristic desirable for triggering a triac or SCR. Other manufacturers, like Theta-J and Sigma, prefer a photocell or photoresistor sensor for greater light sensitivity, increased immunity to noise, higher voltage rating and lower cost.

However, the photocell is slow and produces a “soft” trigger for the output semiconductor, which may shorten the semiconductor’s life. Photocoupled SSRs have a high parts count when compared with reed-relay inputs, and especially with zero turn-on characteristics. Therefore photo SSRs are relatively high in cost.

**Transformer isolation is fast**

SSRs for dc often use a modulated-oscillator input and a small toroid transformer for isolation. This approach, used by Theta-J and Teledyne in some models, can have a very fast turn-on time—as fast as 1 µs—and low contact offsets—as low as 150 µV.

The transformer should have electrostatic shielding against capacitive coupling of transients from the load to the input, which can damage the input gate. Another caveat: Since the switched output current depends on the input current, any attempt to switch more load current than the input circuit can make available may damage the output semiconductor.

Also, the oscillator can produce rf noise in the load—from a few microvolts to as much as 200 mV at 3 to 9 MHz. This noise, of course, can be bypassed.

**Reed-relay isolation is low cost**

Many SSR users have balked at using a reed-relay-input hybrid SSR, because it’s a departure from the use of all-solid-state components. But low-cost, reliable performance and good trigger action, especially for triacs, have won over many users to reed-relay isolated types, such as Gordos’ Redac series. The over-100-million operation life is adequate for many applications.

Some disadvantages include sensitivity to shock, vibration and magnetic fields. Furthermore, a reed relay can stick when closed—not a fail-safe condition. Optocouplers generally fail in the open condition.
heat-sink design can then cause a unit to be short-lived. An SSR must be derated for such duty.

Then why are almost all SSR specs silent on this subject? For applications involving high switching rates (for which SSRs are superior to EMRs), you are practically forced to consult the SSR manufacturer.

Curb that surge

One series of specs that is almost never missing from even the most abbreviated spec sheet is the current-overload, or surge, maximums.

Exceeding those surge-current ratings can permanently damage an SSR. The rapid rise of the output semiconductor’s junction temperature on a current surge ultimately limits the current rating. Most semiconductor junction temperatures should not exceed about 100°C maximum.

Overload ratings often appear in two ways: peak current for one cycle and peak current for one second. (Note that steady-state current is rated in rms values, not peak). Generally, the one-cycle, peak-surge current rating is about 10 times the steady-state rms value. As the number of cycles increases, the allowed maximum current, understandably, decreases, until the steady-state rating is reached.

Careful: Though not often stated, most manufacturers assume an initial junction temperature of 25°C for peak surges—a value that’s not very realistic for either surge ratings or steady-state loads.

Some manufacturers supply a plot of allowable surge data in the form of a derating curve. Typically, a 10-A, steady-state-rated relay can have a one-cycle, 90-A rating. For one second (or for 60 cycles on 60 Hz), the allowed current can drop to 20 A. And at 120 cycles, the curve can approach the steady-state value.

A disturbing phenomenon frequently observed but seldom reported by manufacturers occurs when the overload exceeds certain levels of current and time. The SSR can lose its ON/OFF control for several seconds and lock into the ON state until the junction cools. Recommendation: Use slow blow fuses or circuit breakers, since this lock-ON condition can damage both controlled equipment and the SSR. At least one manufacturer describes the overload capabilities of its SSRs with a plot of amps vs duration of overload—showing the safe regions and regions of control loss after an overload condition.

Thermal fatigue shortens life

Despite such curves and other “safe” overload criteria, avoid operation near specified extremes and near overloads. Working at maximum load or repeated overload produces a cumulatively destructive effect on an SSR.

Thermal fatigue of SCRs and triacs is a subject dealt with gingerly by manufacturers of power semiconductors—and totally avoided by SSR makers.

Virtually all SSRs use SCRs and triacs made with soft-soldered chips. Solderable chips switched at maximum ratings undergo substantial temperature excursions that stress the solder interface.

Operating a semiconductor close to the limits of its specs produces thermal fatigue that can cause failure after only 5000 to 10,000 operations.

The life of a SSR’s input LED also is shortened by heat and operation near its maximum rating. A LED has a definite half-life—a fact well known to LED manufacturers, but not widely publicized. A LED’s brightness gradually diminishes to half its initial output in hundreds of thousands of hours, depending on how hard it’s driven. A well designed SSR with optocou-
SSR current ratings are based upon the maximum junction temperature of the output semiconductor device. Opto-22 recommends a safe value of 100°C for its units.

A choice of PC-mounting, quick-on or screw connectors is available for Heinemann's line of SSRs. The units feature fail-safe fusible links to prevent short-circuit damage.

Sampling operates the LED conservatively—say, at 20% of maximum brightness—to achieve long life in a generally hot (60 to 80°C) environment.

**Don't snub the snubber**

Many manufacturers build snubbers into their SSRs; some units don't have the room. Don't overlook the need for an external snubber when driving inductive loads.

While a snubber can ensure that an SSR's dV/dt ratings are not exceeded, it can have some undesirable side effects as well. Its capacitor can resonate with the load inductance and in some cases develop voltages that exceed the line voltage and the SSR's voltage rating.

A similar phenomenon occurs when switching load capacitors. For example, when switching the capacitor in a reversing motor, the voltage across the SSR can rise as much as 100 V above a 120-V line.

One way to protect the SSR against overvoltage is to install a metal-oxide varistor (MOV) across the output terminals. But be careful: The MOV should be not only in a fully conductive state at a voltage less than the peak voltage rating of the SSR, but also in a high-impedance state below the maximum line voltage.

Therefore, to allow "room" for the MOV to operate properly, the SSR's rating should be well above the maximum line voltage. If a 200-V-peak SSR is used for a 120-V rms line without an
MOV, choose the next highest rated SSR—possibly a 400-V unit—with an MOV.

SSRs for dc loads are as susceptible to overvoltage as ac types. But dv/dt is not a factor, because the output switching semiconductor (usually a power transistor) is a non-triggerable device; thus, dv/dt snubbers are not needed. But MOVs, diodes or zeners should be used to limit overvoltages. And the constraint of using an SSR rated well above the line voltage applies for both ac and dc units. In some cases, it may be necessary to use transient suppression across both SSR and load.

Another way to suppress transients in dc switching circuits is to employ a controlled-response circuit. Controlling the rise and fall rates of the switched load current can substantially reduce the kickback in inductive loads. But, of course, external transients must still be controlled by voltage-limiting devices.

**Need more information?**

For further information on solid-state relays, readers may consult the manufacturers listed here by circling the appropriate numbers on the reader service card. More vendors and information may be found in ELECTRONIC DESIGN’S GOLD BOOK.

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Ohio Manufacturing, 3601 Howard, Skokie, IL 60070. (312) 675-2680. Circle No. 471

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Gate-turn-off SCRs provide fast and efficient alternatives to power transistors. Pulse input signals can switch high dc currents and voltages both on and off.

Ordinary thyristors once fired, can be turned off only by removal of the anode voltage—not an easy task in dc high-voltage, high-power applications. Gate turn-off switches (GTS), however, have the advantage that they can be turned off with relatively little effort by a negative pulse to the gate.

GTS thyristors can be used where only transistors (and sometimes electromechanical devices) could do the job before—in solid-state relays for the control of high-voltage and high-current dc; in the control of dc traction motors, stepping motors and powerful dc solenoids; and in power inverters and many other applications.

Further, GTS thyristors can do a better job than transistors. They are more efficient (especially for high power), operate with low-control power (need only pulses to turn ON or OFF) and can act faster and provide higher blocking voltage (to 800 V) and higher current switching (to 30 A average) for a given size.

GTS construction similar to ordinary SCR

The GTS thyristor is a four-layer pnpn device constructed similarly to a conventional thyristor (Fig. 1a). However, a new factor, turn-off gain \( G_{\text{off}} \), is introduced, and defined as equal to the anode current, \( I_A \), divided by the amount of reverse gate current, \( I_g \), required to turn off the anode current,

\[
G_{\text{off}} = \frac{I_A}{I_g}.
\]

Fig. 1b shows an approximate equivalent circuit of a GTS. The device acts as if it contained two transistors and one zener diode and the gate (G) to cathode (K) path presents a voltage/current characteristic similar to a zener diode (Fig. 1c).

A positive pulse to gate, G, turns Q2 ON, which then turns Q1 ON. The regenerative feedback via paths \( I_1 \) and \( I_2 \) keeps the \( Q_1/Q_2 \) combination con-

K. P. Ohka, Vice President of Engineering, and E. D. Lucas Jr., Consultant, Sabor Corp., 12597 Crenshaw Blvd., Hawthorne, CA 90250.
ducting after removal of the pulse, provided the current gains $a_1$ and $a_2$ of $Q_1$ and $Q_2$, respectively, are adequate. This behavior is exactly as for ordinary SCRs. But because of design compromises to achieve a fast gate turn-off capability in GTS thyristors, the high regenerative gain inherent in conventional SCRs is reduced in GTS design.

GTSs are specially configured so that a negative current flow to $G$ can turn off the device by drawing off current from $I_a$ sufficiently to "break" the regenerative loop. Although a large $G_{off}$ would make turning off the GTS easier, a limit is reached for a $G_{off}$ between 15 and 20. Above this gain range, GTS fabrication requirements produce an increase in forward-voltage drop, $V_f$ (see Fig. 1d for typical values), and a decrease in reverse blocking voltage. Therefore, especially for high-power devices, $G_{off}$ must be traded at the expense of providing a higher turn-off current, $I_o$, from the external control circuit.

Dc can turn off a GTS, but a sharp pulse is best, especially in rapidly repeated on/off application. The reasons for this conclusion can be understood by referring to the equivalent circuit, Fig. 1b.

- If the reverse gate current is gradually increased, then near the turn-off point, transistors $Q_1$ and $Q_2$ only slowly release from saturated states, as $I_a$ decreases. During this interval, the voltage rises between the anode (A) and cathode (K) and the relatively high current and voltage will produce high power consumption, and hence, loss of efficiency.

- Further, with the negative voltage still applied to the gate after the gate has turned OFF, the zener can conduct, and the loss of power into the gate can also be very high.

Fig. 2 is the first of several successful circuits used for controlling a GTS thyristor. With only 20 mA, about 30-A-dc current can be turned on, but a sizable, 10-to-15-A, 5-µs pulse is needed to turn it off. Thyristor GTS1 is the main power-control unit and GTS2 acts as a turn-off trigger for GTS1.

A capacitor supplies the turn-off pulse

A positive pulse to terminal A turns GTS1 on. Capacitor C, is charged by an independent power supply, shown in the dotted box enclosing $R_1$, $D_2$, and a small transformer, XF.

To turn off GTS1, a positive pulse is applied to terminal B. GTS2 fires and discharges a current pulse from C2 through resistor $R_2$. This pulse applies a negative voltage to the gate of GTS1 for a period sufficiently long to turn off GTS1. GTS2 also turns off automatically when the current from C2 drops below GTS1's hold-on current—$R_1$ limits C, charging current below the hold-on current. With GTS2 OFF, C, recharges.

A similar control circuit (Fig. 3) uses transistor, $Q_3$, to turn on the GTS and another, $Q_2$, to discharge a capacitor, C, to turn off the device. Note that again, separate power sources are needed. They supply the transistor voltages and charge C.

Resistor $R_1$ controls the forward gate turn-on current of the GTS, and $R_2$ the charging current of C. And, acting in series, resistors $R_1$ and $R_2$ determine the amount of power drawn from the separate power supplies.
5. The peak current needed to turn off a GTS depends upon the forward anode current.

6. An inductor in the turn-off circuit allows the use of a reduced voltage source, \( V_{cc} \), to charge the turn-off capacitor, \( C \), sufficiently to extinguish the GTS.

7. Ignition signals from an automobile distributor control the on/off timing of a GTS thyristor. High-voltage developed in the ignition-coil secondary, when the GTS turns off, produces a spark across the gap of a spark plug. The GTS turns on within 100 \( \mu s \) and off in about 50 \( \mu s \) and needs about 1-A peak to extinguish.

Clearly, turning off the GTS requires a bit more ingenuity than turning it on. The turn-off pulse must be applied for several tens of microseconds, \( t_{off} \), but fortunately the amperes of peak current that may be required need persist for only a few microseconds, \( t_s \), of the interval, \( t_{off} \) (Fig. 4). A very rough rule of thumb calls for an instantaneous peak pulse current, \( I_{go} \), of about one-half the anode current at the time of turn off. Fig. 5 provides a more accurate range of peak-current values for a typical GTS, than this rule of thumb. New GTS developments may strongly reduce the peak-current requirement.

For example, for a GTS carrying 20 A, roughly 10-A peak turn-off current should be supplied to ensure reliable rapid turn off. However, this high current needs to be supplied for only a very short time—0.5 to 5 \( \mu s \), depending on the GTS—defined as \( t_s \) in Fig. 4. Thereafter, the current can drop to near zero during the fall time, \( t_f \), of the anode current.

The turn-off voltage specification, \( V_{go} \), of a GTS thyristor is assumed by most GTS manufacturers to be derived from a low-impedance constant-voltage source. The \( V_{go} \) for the device of Figs. 4 and 5 is specified as 14 V.

**Amp-\( \mu s \): A better way to spec turn off**

But this is not very helpful data when designing a capacitor turn-off circuit as shown in Figs. 2 and 3.

A more meaningful way of dealing with short current pulses, which also would provide a simple approach to the capacitor-circuit design, is to describe the pulses in terms of ampere-seconds (or rather \( A-\mu s \)) of charge needed to turn off a GTS.

Therefore, for the approximately triangular pulse, in Fig. 4, the “average” current can be taken as \( I_{go} / 3 \). And for a 5-\( \mu s \) pulse interval, \( t_s \), the charge is

\[
Q = \frac{10 \times 5}{3} \approx 17 \text{ A-\( \mu s \).}
\]

To assure the required high initial current and still retain some charge for the total \( t_{off} \) time, and also to overcome wiring and capacitor losses, the open-circuit voltage used to charge the capacitor may be two to three times the recommended low-impedance-sourced voltage, \( V_{go} \). Thus for a \( V_{go} \) specified at 14 V, a 35-V charging source for the capacitor is appropriate.

Now a capacitor, \( C \), can be chosen to provide the required charge:

\[
C = \frac{Q}{V} = \frac{17/35}{0.5} \approx 17 \text{ \( \mu F \).}
\]

A 100-\( \Omega \) series charging resistor for \( R_c \) (Fig. 3) would produce a 50-\( \mu s \) time constant for charging \( C \).

Note: With capacitor \( C \) sufficiently large, only part of its charge is drained off during the initial \( t_s \) surge, because the impedance of the GTS gate
8. In this dc-to-ac converter, input-control pulses turn the two GTS thyristors on alternately. When one GTS goes on, the other is automatically turned off by the charge stored in $C_1$ or $C_2$. Thus, alternate half-cycle pulses in the primary of the transformer become ac in the secondary. Low-loss and high-current capabilities of GTSs provide efficient power conversion.

9. For use as a dc-motor speed control, a dc tachometer turns transistor $Q_2$ on or off as the motor speed and tachometer voltage rises above or drops below a reference level set by resistor $R_v$ and the zener diode. At low speeds, $Q_2$ turns off and its collector voltage rises to turn the GTS on via a 20-V Shockley diode. When the speed, and thus, the tachometer's voltage rises above the reference level, $Q_2$ turns on and the GTS gate becomes negative with respect to its cathode, turning the GTS off. The Shockley diode produces a sharp turn-on point when it "breaks" into conduction, and also, it introduces some desirable hysteresis into the circuit. The circuit can also be used as a solid-state relay operating from a wide variety of input sources for driving motors, solenoids, mechanical counters and many other devices.

10. In this voltage regulator, a positive reference control level turns the GTS on. When the regulated voltage stabilizes, transistor $Q_1$ stays on, which keeps $Q_2$ off, to allow GTS to conduct and supply power to the regulated-voltage load. A rise in regulated voltage above the level established by the reference turns $Q_1$ on, which extinguishes the GTS temporarily, until the output voltage falls to the controlled level.

11. To switch high voltage and current between two loads under the control of low-voltage trigger pulses, two GTS devices serve as power switches in this flip-flop. A-µs approach is, admittedly, very "rough," but it gets practical results. As is so often the case with other solid-state nonlinear devices, design engineers can often best learn to use the GTS by studying the circuits of some representative application examples. A drive for an ignition circuit (Fig. 7), a dc-to-ac converter circuit (Fig. 8), a dc motor-speed control (Fig. 9), a dc voltage regulator (Fig. 10) and a high-voltage flip-flop (Fig. 11) show the diversity of possible uses for GTS. Each circuit is explained by its caption.
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Design flyback converters for best performance. Analyzing the two basic operating modes gives the relationships between the important parameters.

Knowing how the output parameters of a flyback converter vary with voltage and load, you can optimize the converter for various requirements, such as maximum current limits or minimum transformer volume.

To analyze what happens in the choke, assume an ideal switch and linear operation for the inductance. The power stage and the time variation of currents and voltages at the transformer input and output are shown in Fig. 1.

The principle behind flyback converters is based on the storage of energy in a choke during a time period, \( t_1 \), and the discharging of the energy to a load during a second period, \( t_2 \). If isolation is necessary between the battery—the primary source of power—and the load, the primary of a transformer can play the part of the storage choke in addition to its normal role.

Analysis boils down to two modes

Although there are many different flyback-converter designs, just two basic modes of operation exist. In one mode (A), the energy stored in the choke is yielded totally to the load before the next cycle begins. In the other mode (B), the choke begins to recharge before discharge is completed.

In mode A, during \( t_1 \), the input current increases linearly until it reaches a maximum value, \( I_{pM} \), given by:

\[
I_{pM} = \frac{E}{L_p} t_1,
\]

where \( E \) is the battery voltage, and \( L_p \) the primary inductance. During \( t_2 \), the current in the secondary decreases from a maximum of \( I_{sM} \) given by:

\[
I_{sM} = \frac{V_s (\text{off})}{L_s} t_2,
\]

where \( V_s \) is the voltage across the secondary, and \( L_s \) the secondary inductance.

The energy stored in the primary during \( t_1 \), expressed by \( 1/2 L_p I_{pM}^2 \), is transferred to the secondary with efficiency \( \eta_{1r} \), a number that indicates the quality of the transformer. From the relationship, \( 1/2 L_p I_{pM}^2 = \eta_{1r} I_{sM} I_{pM} \), comes:

\[
I_{sM} = \sqrt{\eta_{1r} \frac{n_p}{n_s}} I_{pM},
\]

where \( n_p \) is the primary turns and \( n_s \), the secondary turns. Find the load current by integrating the secondary current for the period \( T \) and getting this result:

\[
I_L = \frac{1}{2} I_{sM} \frac{t_2}{T}.
\]

Since the rectifier loses power, a rectifying efficiency, \( \eta_R \) (significant for low output voltages) must be introduced. Thus:

\[
\eta_R = \frac{V_L}{V_s (\text{off})}.
\]

Using the notation, \( \tau = t_1/T \), and introducing the over-all efficiency, \( \eta = \eta_{1r} \eta_R \), the power delivered to the load can be deduced from Equations 1 through 5:

\[
P_L = \left( \frac{1}{2} \eta \tau^2 \right) \frac{E^2}{f L_s}.
\]

The value of \( t_2 \) as a function of the load can also be found:

\[
t_2 = \sqrt{\frac{2 \eta_R I_{sM}}{f R_L}}.
\]

Expressions 4 and 5 can be reshaped for easier use in design. Thus:

\[
I_L = \frac{1}{2} \left( \frac{n_p}{n_s} \sqrt{\eta_{1r}} \right) \frac{\tau (1-\tau)}{f L_p} E; \quad \text{(8a)}
\]

\[
V_L = \eta_R \sqrt{\eta_{1r}} \left( \frac{n_s}{n_p} \right) \left( \frac{\tau}{1-\tau} \right) E. \quad \text{(8b)}
\]

What the equations show

Analyzing the equations reveals a number of things about converters working in mode A:

1. The maximum input current \( I_{pM} \) does not depend on load variations.
2. The power delivered to the load does not depend on the load value \( R_L \). The converter provides a constant power, and the battery is isolated from the load for any output conditions, including no-load. For the no-load condition, the output voltage increases until the dissipation of the leakage resistances equals the constant power of the converter. At that point, \( t_2 \) is very short.
3. The power delivered by the converter de-
PENDS ON THE PRODUCT, $fL_p$, FOR A GIVEN DUTY CYCLE AND BATTERY VOLTAGE, $E$. IN OTHER WORDS, FOR A GIVEN POWER, AN INCREASE IN THE FREQUENCY DECREASES THE INDUCTANCE, $L_p$, AND, HENCE, THE SIZE OF THE FERRITE CORE.

1. THE POWER STAGE OF A FLYBACK CONVERTER CAN BE IDEALIZED INTO AN IDEAL SWITCH AND A LINEAR TRANSFORMER FOR ANALYSIS (A). THE PRIMARY AND SECONDARY VOLTAGES AND CURRENTS OF THE IDEAL CONVERTER (IF ALL ENERGY IS DISCHARGED AT EACH CYCLE) ARE ShOWN IN (B).

2. IF ALL ENERGY ISN'T DISCHARGED BEFORE THE NEXT CYCLE BEGINS, THEN THE FLYBACK CURRENTS AND VOLTAGES ARE SOMewhat DIFFERENT FROM THOSE FOR COMPLETE DISCHARGE. ENERGY IS STORED DURING INTERVAL $t_1$.

4. THE VALUES OF $\tau$ OR $f$, OR BOTH, CAN BE MODIFIED THROUGH A FEEDBACK LOOP (USUALLY THE FREQUENCY IS KEPT CONSTANT AND ONLY $\tau$ IS THE VARIED) TO STABILIZE VALUES $I_p$ OR $V_L$ WITH LOAD VARIATIONS.

IN MODE B, THE PRIMARY AND SECONDARY CURRENTS AND VOLTAGES ARE SIMILAR TO MODE A (FIG. 2). DURING $t_1$, ENERGY IS STORED BY A LINEAR GROWTH OF THE CURRENT IN THE WINDING FROM A MINIMUM VALUE, $I_{pm}$ (RESIDUAL FROM THE PREVIOUS CYCLE), TO A MAXIMUM, $I_{pM}$, WHERE:

$$I_{pM} - I_{pm} = \frac{E}{L_p} t_1.$$

(DURING $t_2$, CURRENT APPEARS ONLY IN THE SECONDARY AND DECREASES LINEARLY FROM A MAXIMUM OF $I_{SM}$ TO A MINIMUM OF $I_{sm}$ AS FOLLOWS:

$$I_{sm} - I_{sm} = \frac{V_s (\text{off})}{L_s} t_2.$$

SINCE SWITCHING OCCURS BEFORE THE SECONDARY CURRENT DROPS TO ZERO, ENERGY REMAINS STORED IN THE CHOKE AND IS TRANSFERRED BACK TO THE PRIMARY THROUGH THE CURRENT $I_{pm}$. THE RELATIONSHIP BETWEEN THE CURRENTS—SIMILAR TO THE ONE IN MODE A—is GIVEN BY:

$$I_{sm} - I_{pm} = \eta_p \left( I_{pM} - I_{pm} \right),$$

AND THE LOAD CURRENT IS:

$$I_L = \frac{I_{sm} + I_{pm} \left( \frac{t_2}{T} \right)}{2}.$$

USING THE SAME NOTATIONS AS IN MODE A RESULTS IN THE FOLLOWING:

$$I_L = \frac{1}{2} \left( \sqrt{\eta_{1r} \frac{n_p}{n_s}} \right) \beta \left( 1 - \beta \right) \frac{E}{f L_p} + \sqrt{\eta_{1r} \frac{n_p}{n_s}} \beta \left( 1 - \beta \right) I_{pm}.$$

$$V_L = \frac{1}{2} \eta \tau^2 \frac{E^2}{f L_p} + \eta \tau E I_{pm}.$$

THE VALUES OF $I_{pm}$ AND $I_{pM}$ ARE GIVEN BY:

$$I_{pm} = I_{pM} - \frac{1}{2} \frac{E \tau}{f L_p};$$

$$I_{pM} = \frac{\eta_p}{\tau} \left( \frac{\tau}{1 - \tau} \right)^2 \left( \frac{n_p}{n_s} \right)^2 \frac{E}{R_L}.$$

IN MODE B, THEREFORE:


2. THE POWER DELIVERED BY THE CONVERTER IS A FUNCTION OF $R_L$, SO PROTECTION AGAINST OVERLOAD IS NECESSARY.

3. VOLTAGE $V_L$ CAN BE STABILIZED AGAINST VARIATIONS IN $E$ ONLY BY VARYING $\tau$.

4. EQ. 16 SHOWS THAT $I_{pm}$ VARIES WITH THE LOAD.
and, at a certain moment, can be zeroed. At that moment, a change in the working mode occurs since the increase of resistance $R_L$ leads to mode-A operation.

5. For the condition, $I_{pm} = 0$, the equations for mode B become the same as those for A, where $t_s = 0$, and $t_1 + t_2 = 1/f$. This case corresponds to a blocking-oscillator mode (self-oscillating fly-back). The limiting value for $R_L$ can be obtained from any of the cited conditions.

For $R_L$ in the blocking-oscillator mode, the frequency and the duty cycle vary according to:

$$R_L = \eta_\text{n} \frac{n_p^2}{n_\text{p}} \left[ \frac{2f L_p}{(1 - \tau)^2} \right]. \quad (18)$$

To illustrate the advantages and disadvantages of both modes, compare two converters with the same load, the same $R_L$, and the same power delivered from a battery $E$.

**How the modes stack up**

Begin by comparing the regulation of the output parameters (voltage or current). Notice that the load current is inversely proportional to $\sqrt{R_L}$ in mode A and inversely proportional to $R_L$ in mode B.

Consequently mode A is advisable for those converters with constant output current (for instance, remotely supplied amplifiers in cable-communication equipment), because the current variation to be stabilized for a given $R_L$ is small. On the other hand, mode B is better for a converter of constant output voltage, because $V_r$ is only mildly dependent on load variations (Eq. 14).

Comparing the maximum currents is important when the restricting element is the current limit of the semiconductor being used as the switch. From Equations 6 and 15, the output powers are:

$$P = \frac{1}{2} \tau E \eta I_{pm}, \text{ for mode A;} \quad (19)$$

$$P = \frac{1}{2} \tau E \eta (I_{pm} + I_{pm}), \text{ for mode B.} \quad (20)$$

Equating Eq. 19 to Eq. 20:

$$I_{pm} (\text{mode A}) = I_{pm} (\text{mode B}) \left[ 1 + k \right], \quad (21)$$

where $k = \frac{I_{pm} (\text{mode B})}{I_{pm} (\text{mode A})}$, and $0 < k < 1$.

So to obtain the same output power in mode B, the maximum current should be smaller and approach a limit that is half the value required in mode A. Specifically, $k$ ranges between $1/2$ and $2/3$.

The primary inductance for both cases follows from Equations 1, 9 and 21:

$$L_{pm} = L_{pm} \frac{1 + k}{1 - k}. \quad (22)$$

Hence, for the same core, the turns ratio is:

$$N_B = \sqrt{\frac{1 + k}{1 - k}}. \quad (23)$$

The greater number of turns in mode B depends on the factor, $k$, you choose. The number of ampere turns in the choke leads to the correct choice of the core's air gap. From Equations 21 and 22, it follows that:

$$N_B I_{pm} (\text{mode B}) = N_A I_{pm} (\text{mode A}) \left[ \frac{1}{\sqrt{1 - k^2}} \right]$$

Hence, for the same core in mode A, ferrite saturation occurs later and additional power can be supplied.

A continued comparison shows that diminishing the number of turns in mode A decreases copper losses and that the ripple induced in the supply is greater in mode A because of the greater variation in mode A's switching current.

**Designing the output transformer**

The major difference between a flyback transformer's design and a feedthrough converter's is a dc-current component in the flyback windings that requires a properly chosen air gap.

With the help of Equations 6 and 8 for mode A, and 13 to 15 for mode B, you can find the values of the primary inductance and the turns ratio for a given set of specs and a given switching frequency.

Knowing $L_p$ and $L_n$, you must then find the optimum core for the required power. That is, you can opt for either minimum volume or maximum efficiency (resulting in a lower temperature...
increase in the core). The conventional procedure uses the well known Hanna curves, a family of core curves using the air gap or the $A_L$ (inductance) factor as a parameter for each type of core.

Some data books provide a single Hanna diagram for all types of cores, but the values on the X or Y axis are normalized to volume or weight. In either case, using the diagrams is difficult when the starting point is the value of the output power. However, the curves can be redrawn.

Bear in mind that the Y axis on the Hanna curves represents the energy stored in the choke for a given ampere-turn product. In a flyback converter, this energy is transferred to the load at a rate of $f$ times a second. Knowing that the product, $1/2L_{i^2}f$, gives the output power of the converter (without the losses), and taking as a reference $f = 20$ kHz, you can compute the power values for each significant point on the Hanna curves.

Knowing that the saturation points for each $A_L$ lie along an approximately straight line, you can plot a new family of curves for each group of cores (for instance, pot cores). The new family represents the saturation points, with $A_L$ as a parameter and the output power and ampere turns, respectively, on the X and Y axes.

Replot the Hanna curves

A convenient diagram is shown in Fig. 3, in which $\sqrt{A_L}$ is plotted on the Y axis and $Pf/20$ is on the X axis ($f$ is in kHz).

The diagram in Fig. 3 stems from Hanna curves found in the 1975 MBLE ferrite catalog (available from Philips, Eindhoven, the Netherlands). The straight lines represent only the core’s nonsaturable mode. The relationships that govern the characteristics are as follows:

$$\frac{1}{2} Li^2 = k_1 NI + k_2,$$

which approximates linearly the nonsaturating portions of the Hanna curves, and

$$P = \frac{1}{2} Li^2f,$$

$$A_L = \frac{L}{N^2}.$$

To design a transformer, start with the value of the output power. Divide it by the estimated efficiency to get the power the transformer should handle. Then choose the switching frequency and locate that point on the X axis. A vertical line from the X point intersects the curves at the values of $A_L$ at which the cores will saturate. Since the inductance factor, $A_L$, has standard values, choose either the value below the intersecting point or a higher value on a larger pot core.

For the best transformer design, the copper and ferrite losses should be equal. This happens for $A_L$ values between 160 and 250.

The skin effect shouldn’t be overlooked in evaluating the transformer’s efficiency. At 20 kHz, efficiency can be increased with stranded wire. If you use solid wire, the diameter should not exceed double the penetration depth, or approximately 0.5 mm at 20 kHz.

Suppose you want a flyback, self-oscillating converter with the following values: $V_{in} = 200$ V; $V_{out} = 12$ V; $P_{out} = 60$ W; $f = 30$ kHz. With an assumed efficiency of 0.8, the input power equals 75 W.

From the diagram in Fig. 3, the 50-W point (for 20 kHz) corresponds to 75 W at $f = 30$ kHz. Following the vertical line from this point, you can see that this power can be handled by a couple of cores: $\phi 26 \times 16$, with $A_L = 100$; $\phi 30 \times 19$, with $A_L = 250$; and $\phi 36 \times 22$, with $A_L = 630$.

The optimum core is $\phi 30 \times 19$ since for the $\phi 26 \times 16$ core the copper losses exceed the core losses; for the $\phi 36 \times 22$ core, the core losses exceed the copper losses.

For a self-oscillating converter, the formulas for mode A are identical with those for mode B ($t_a + t_s = T$ for A, and $I_{pm} = 0$ for B). From Eq. 6 or Eq. 15, determine the value of $L_{p}$, assuming a maximum duty cycle (for $r = 1/2$, we obtain the value $L_{p} = 1.77$ mH). With $A_L = 250$, the number of primary turns is found from $N_p^2 = A_L/L_p = 84$. The number of secondary turns (six) is found from Eq. 8 or 14. To choose the switching transistor, calculate the maximum current for the inductance $L_{p}$. From Eq. 1 or Eq. 9, with $I_{pm} = 0$ and $t_s = T/2$, $I_{pm} = 1.88$ A.

The feedback windings are designed conventionally, with the feedback voltage double the $V_{BE}$ (Fig. 4). You can provide the converter with additional feedback control circuits for a regulated output.
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Stabilize optical-sensing systems with automatic light-intensity control. Negative feedback via the light path maintains the switching threshold accurately.

Anyone familiar with optical control and sensing systems knows how difficult it is to adjust and maintain light intensity and the alignment of the light path. And, adjusting multiple electro-optical channels is particularly difficult, especially when a system is called upon to sense less-than-perfect marks on colored or soiled documents.

If the documents are fully opaque and no dust accumulation occurs on the optical devices, choosing a safe, fixed switching level to differentiate “white” from “black” will not be a problem.

However, relatively thin documents may easily transmit 20% of the incident light, and a grease spot may let up to 30% of the light pass through. Even a small amount of dust on the light source or sensor window can cut the light transmission substantially. These problems, taken together with unavoidable tolerances, can make unattended reliable sensing for long periods almost impossible with the use of fixed switching levels.

Automatic light-intensity control (ALIC), however, has proven itself on both see-through and reflective systems, such as for sensing through translucent documents in a dusty environment and low-contrast marks on documents of varying reflectivity.

A servo-loop serves the system

A typical (but simplified) two-level ALIC system (Fig. 1), shows a closed-loop feedback system consisting of a differential control amplifier, A1, and driver circuit, D1 and QL. A LED light source, LD, and phototransistor, PS, close the loop via the sensing path. A second differential amplifier, A2, with its output driver, D2, provides a logic output. The logic switching point is determined by the internal reference voltage VR2, which—together with R2, R4, and the voltage swing at V5—establishes the reference voltage, VR, for the differential amplifier, A1.

Capacitor C2 (22 µF) provides heavy damping to prevent oscillations or overshoot and also slows the loop’s response. Therefore, only slowly changing light intensities are compensated. The C2 and R5 combination limits the LED-current rate of change to about 6 dB in 50 to 100 ms—much too slow to respond to small marks on a document. Rapid response to obtain the logic level outputs is provided by a separate path via A2 and D2.

If V5 rapidly drops to, or below, A2’s reference-voltage level of 1.5 V, when a black mark is sensed, V0 switches to the black level. At the same time, the A1 reference voltage, VR, drops from 1.82 V (WL) to 1.24 V, but the rapid change doesn’t affect the LED current.

However, note that for extended black periods Vn stabilizes at a level equal to 1.24 V (BL) and

Roland J. Braun, Advisory Engineer, IBM Corp., System Products Div., P.O. Box 6, Endicott, NY 13760.
Ip at 42 µA (Fig. 2). Thus the ALIC has a two-level threshold reference—BL after the input signal has been "black" for an extended period and WL after the signal has been at the "white" level. Also, note the fast compensation of overshoot in the white directions when compared with the slow response to a black excursion. Both the two-level threshold and a special discharge-path circuit for capacitor C₂ under "high" input-current conditions, which produces this black/white response discrimination, is discussed in detail for a single-chip implementation of the circuit (Fig. 3).

Threshold and hysteresis are adjustable

The circuit's built-in switching level and threshold values are determined by resistors R₁₀ and R₁₁ (equivalent to R₁ and R₄ in Fig. 1). These resistors can be chosen to provide almost any desired combination of values for the WL and BL thresholds. And for fast, reliable snap-action, a small switching hysteresis—about 3%—is built into the circuit of Fig. 3.

When transistors 17 and 23 turn off, current through diode chain 12 to 15 increases. Consequently, the switching reference voltage, V_R₂, rises from 1.46 V to about 1.50 V to produce the built-in hysteresis with terminals 5 and 6 open. As much as a 40% hysteresis can be achieved with a resistor (30 kΩ minimum) between terminals 3 and 5 (equivalent to R₁ in Fig. 1). However, because resistor R₁ provides positive feedback from the reference voltage V_R to the input V_n, not only the hysteresis, but also the switching thresholds are affected by a change in R₁. This interaction is normally desirable, because both hysteresis and switching levels increase together, providing higher noise immunity for lower sensitivity setting.

A single-chip implementation of the ALIC

Although the ALIC circuit can be built with discrete components and IC differential amplifiers and drivers, integrating most of the circuit into a single IC package (Fig. 3) provides money and space-saving ways to handle multiple-channel optical systems. Two such circuits have been built on an 82-mil-square silicon chip.

Transistors 1 through 8 and an external damping network (the equivalent of R₅ and C₂ in Fig. 1) form the automatic LED control circuit and provide a minimum open-loop gain of 126 dB. The reference voltage, V_n, is either 1.82 or 1.24 V, depending on the state of switching transistor 23. Transistors 9, 10, 11, 16 and 23 provide the output logic function equivalent to A₂ (Fig. 1), and transistors 17, 18, 19 and 20, equivalent to D₂, act as the output driver. Transistor-diodes 12 through 15 establish voltage-reference levels, with diode 15 serving in the constant-current circuits of transistors 4, 8, 11, 16 and 18.

As in Fig. 1, with the so-called full white condition (Ip = 62 µA and V₈ = 1.82 V), transistors 9 and 23 are fully ON and holding the output V_o at its down-level state and V_n at 1.82 V.

Switching occurs when a signal causes the input current to drop at least 20%—from 62 to 50 µA or less—which decreases the input voltage, V₈, below the switching reference voltage, V_R₂. Transistors 9 and 23 turn OFF, which switches the output to HIGH and the V_n to the black value—nominally 1.24 V. Current Iₚ is now regulated toward 42 µA for this new V_n of 1.24 V through control of the LED current.

The fast white-level restore function previously mentioned is provided by transistor-diode 3 in combination with transistor 1 and diode 15. As the input voltage rises above 2 V, diode 3 bypasses constant-current source transistor 4 and allows the collector current to transistor 1 to increase to 1.2 mA (limited by R₂ = 1 kΩ). This action produces a discharge rate for C₂ that is 50-times faster than the 241fLA, black-level charge current (limited by R₅ = 100 kΩ).
3. Two ALIC circuits can be integrated on an 82-mil-square IC chip. Only one of the two circuits per chip is shown. The circuits are connected together at the asterisk-marked points.

The ALIC circuit design allows loose component tolerances as well as a large range of input conditions. Even the black and white threshold levels, which are normally the only critical values, depend only on resistance ratios—$R_3/R_1$ in Fig. 1, and $R_{10}/R_{11}$ in Fig. 3—rather than absolute values. For different applications, these ratios and the components that determine the maximum LED current, input current, time-constant, high-frequency response and the adjustable portion of the switching threshold and switching hysteresis can all be changed over a wide range.

Both parts and temperature are uncritical

Temperature influences the threshold levels less than $\pm 5\%$ between 10 and 60°C, and a $\pm 10\%$ power-supply variation has negligible influence because of built-in voltage regulation (Fig. 3). A total threshold tolerance of $\pm 10\%$ can easily be achieved with ordinary IC-component tolerances and low-tolerance discrete components.

Exposure to high-frequency noise is not a serious problem, despite the low current and high impedance of the circuit's input, even with the
photosensor at a large distance from the amplifier. The signal frequency is low; thus, a filter capacitor, C₁, as large as 0.01 μF can be used across the amplifier input to suppress noise above 20 kHz without affecting signals with rise times of 0.1 ms or greater. For faster rise times, C₁ may be reduced; for extremely high-speed applications, photodiodes should be used with a pre-amplifier mounted near the sensor.

Dust indicator: a circuit feature

In many applications, an early warning of the system’s dust-accumulation status minimizes the need for frequent routine cleaning. Also, early warning can be a valuable diagnostic tool for identifying deteriorated or nonaligned components.

Normally, the LED current increases with dust accumulation and other degrading influences, which cause the collector voltage of the LED driver, Qᵣ (Fig. 1), to decrease proportionally. Once saturation of Qᵣ occurs, the circuit has reached its operational limit. To the point of saturation, the collector voltage of Qᵣ directly indicates the system’s remaining safety margin, and indirectly indicates the amount of dust accumulated in the optical path.

The ALIC’s ability to overcome the dust problem in optical sensing is of equal importance with the circuit’s insensitivity both to loose tolerances and a wide range of input conditions. Consequently, the ALIC principle can work with fluorescent, neon or incandescent lamps and almost any optical sensor, and, the principle can even extend to work with ultrasonic and magnetic sensing, among others.

The need for only low average light intensity is an important side benefit of the ALIC concept: Decreased power dissipation allows a long life for the light source.

Unfortunately, since each sensor in the ALIC system must have its own light source, sensor arrays with a common light source can use the ALIC principle only in a compromised form. But this problem should be readily solvable with the wide variety of available small LEDs that allow the use of closely spaced arrays of individual light sources to replace single sources. Also, the IC design of the ALIC circuit allows low-cost use of many circuits.

However, large arrays may suffer from optical crosstalk. Optical crosstalk between the LEDs and sensors in an array can become troublesome, especially where a common glass covers the LEDs and sensors. Internal reflections in the glass can mix the signals. Such reflections increase rapidly with even a thin layer of dust on the outside surface. But crosstalk is easily avoided with care in design of the optical paths.

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We're also introducing a new family of 7-segment High-voltage, High-current Darlington Drivers: The 9665 for general purpose use. The 9666 for PMOS inputs. The TTL and CMOS compatible 9667. And the
CMOS and PMOS compatible 9668. All four are available in a 16-pin plastic package with optional copper lead frame which increases power dissipation to 2 Watts.

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Following is a summary of the Fairchild Interface product line. Most devices are available in commercial and military temperature ranges, molded and hermetic packages and processing to Class B or MIL STD 883A. They’re also available right now at the right price.

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Transient-free pulsed acoustic sinusoids generated with phased-array speakers

When testing an acoustical-to-electrical transducer such as a microphone, it is often necessary to drive it with bursts of acoustic sinusoidal signals. But speakers are notorious for their poor transient responses. Thus, difficulties occur in deciding whether questionable characteristics of the test data result from the unit under test or from a poor acoustical-input signal.

The circuit (Fig. 1), with the use of principles known for years by rf-antenna designers, can provide a microphone with a distortion-free burst of acoustic sinusoids in free space. The circuit doesn't use the obvious approach of driving a speaker with a gated sinusoidal signal. Instead, two speakers in a phased-array configuration (Fig. 2) provide the bursts. Both are fed an identical, continuous sinusoidal signal. Almost any two speakers will do.

The microphone is placed, as shown, between the two speakers. The circuit sequentially changes the phase of the signal to one of the two speakers by 180 degrees (Fig. 3). The signal "seen" by the microphone is then either a sum or a cancellation of the two speakers' outputs. Moving the test microphone around allows you to obtain virtually any ratio of high-to-low amplitude for pulse testing.

The secret of the circuit lies in ensuring that the phase of the one speaker changes at the right time. Otherwise, the original transient-distortion problem will be still there. The phase should only change when the sinusoid is at a positive or negative peak, when the speaker diaphragm travels at zero velocity. At this point, a phase change merely causes the speaker to remain stationary a little longer.

In the circuit, the clock signal starts at twice the desired output frequency and is divided in half by ICsA. Then, after passage through a low-pass filter, it is amplified and drives one of the speakers, S1. The low-pass filter suppresses the higher harmonics of the digital signal, E. Of course, the better the filter, the more sinusoidal the signal out of speaker S1. For most applications, a simple two-pole active or passive filter is sufficient.

The TTL-level input labeled Gate controls the phase relationship between the two speakers. This signal can be provided by a switch, pulse generator or any TTL-logic source. Signal A (Fig. 3), a retimed version of the gate signal, is converted to pulses, C, which cause ICsB to "skip"
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The right idea at the right time.
IDEAS FOR DESIGN

(continued from page 78)
a clock pulse corresponding to the beginning and end of each gate signal.
Whenever IC<sub>n</sub> misses a clock pulse, signal D remains in its previous state until the next clock pulse. The result is a 180-degree phase change with respect to signal E.

Signal D is low-pass filtered and amplified, as in the case of signal E, and then fed to the speaker, S<sub>2</sub>. A reset switch ensures that both speakers start out in phase. The sum of signals from the two speakers (S<sub>1</sub> + S<sub>2</sub>) is “seen” by the microphone in the median plane between the two speakers.

Of course, an anechoic chamber is the ideal environment in which to use this system. However, good results are easy to get with two small speakers separated about a foot, with the test microphone only a few feet away between them. On-to-off amplitude ratios of 30 dB can be obtained in almost any room. The relative positions of the speakers and microphone are not critical. With reasonable care, experimental repeatability is no problem.

William F. Lawrence, Electronic Engineer, 707 Kingston Rd., Towson, MD 21212.

CIRCLE NO. 311

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When it's time to swit
Diodes act as temperature sensor in remote temperature-measuring circuit

A remote temperature probe can be built from ordinary diodes. The probe senses temperature by the change of voltage drop across several forward-biased silicon diodes. With such a probe outside temperature can be measured from inside a building. Even the water temperature at the bottom of a lake can be remotely measured with the sensor.

The circuit (Fig. 1) compares the voltage across the diode sensor with a voltage set with potentiometer $R_L$. As the temperature increases, the voltage across the sensor decreases at the rate of 2 mV/°C for each diode in the probe.

The circuit shown uses four diodes. Over a 25-C temperature range, the voltage change across the diodes is 200 mV. This voltage change causes a 50-µA current change into a 4-kΩ impedance.

With the probe exposed to the lowest temperature of interest, the meter is set to zero with the 5-kΩ potentiometer, $R_L$. The meter is adjusted to full scale with $R_H$, the series 2-kΩ resistance, when the probe is exposed to the highest temperature of interest. The zener diode and transistor regulate the voltage to the probe, so that readings are relatively independent of battery-voltage fluctuations.

Donald C. Elmore, Principal Engineer, Electronic Communications, Inc., P.O. Box 12248, M/S 22, St. Petersburg, FL 33733.

CIRCLE No. 312

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CIRCLE NUMBER 46
Heart-beat monitoring circuit provides steady output and a missed-beat alarm

A new technique called rate matching neatly circumvents the problems of pulse-averaging methods commonly used in frequency-meter circuits for applications like heart-rate monitoring. With pulse averaging, since the desired response time approaches the period of the measured waveform, the designer must either accept output ripple and a wavering ratemeter needle, or use more filtering to slow down the response.

Although rate matching is more complex than pulse-averaging, the new technique has four major advantages. Because the circuit’s output can change only at the beginning of each input cycle:

1. Rate matching has a ripple-free output for steady input rates;
2. It can track the base input rate, even in the presence of missed input cycles;
3. It can hold its output after the input has ceased;
4. It readily lends itself to providing a missed-cycle alarm.

The rate-matching circuit (Fig. 1) uses negative feedback to match a ramp rate to the input rate. The input signal passes through a pulse former that generates a short pulse at the beginning of each input cycle. The pulses then drive an analog switch labelled reference/reset.

An integrator, \( A_1 \), with no input resistor, presents a virtual ground that fully discharges capacitors \( C_1 \) and \( C_2 \) transferring the algebraic sum of their charges to \( C_3 \) each time an input cycle causes the analog switch to “operate.” Capacitor \( C_4 \) merely absorbs switching transients; its value is not critical.

After each discharge, a new ramp voltage starting from zero builds up across \( C_1 \) at a rate proportional to \( V_o \), the output of \( A_1 \).

If reference voltage \( V_r \) charges \( C_2 \) to be equal and opposite to the charge on \( C_1 \), then their combined discharge into the integrator has no effect on \( V_o \). However if the rate of ramp build-up across \( C_1 \) is slow, the \( C_1 \) charge doesn’t balance... (continued on page 84)

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1. A heart-beat monitoring circuit uses a CMOS quad 4066 analog switch to control transference of charge from \( C_1 \) and \( C_2 \) into the integrator-circuit’s storage capacitor, \( C_3 \).
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**Timesaver for spectroscopists: PMT circuit in a socket.**

No longer do you have to design circuitry to get the right voltages for photomultipliers. We've done it for you. Just plug the PMT into one of our compact solid state power supplies, apply 12 volts dc, and here's what you get:
- regulated — 500 to — 1250 V controlled by resistance or voltage programming (Model PF1042) or — 100 to — 1250 V that varies directly with input voltage (PF1043).
- Both power supplies work with most side-on PMTs in RCA's broad line, covering UV to near IR (165 to 1200 nm).

Some have broad range; others focus on the visible region. Ask for in-depth applications help from RCA.

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**RCA announces a new SI Imaging Device. Better performance, lower price.**

Using buried channel techniques, we've improved horizontal resolution in our new Silicon Imaging Device (SID). And we're subjecting units to more stringent blemish criteria. RCA's "Big SID" is a 512 x 320 array, 163,840 pixel, charge-coupled device that produces a standard interlaced 525-line TV picture with ultra low blooming and no lag or microphonics.

SID52501, priced under $1000 is available with 30-day delivery. Or get Big SID in our TC1160 camera for less than $2000.

---

**Hi-speed IR emitters for fiber-optic communications.**

The speeds are right: 100 MHz min, analog bandwidth (C30119) or 40 MHz min. (C30123). And so is the size: A 6-mil edge emitter in an OP-18 package with removable cap that assures good collection efficiency with single fibers or bundles. (Also available in hermetically sealed package.) These IR emitters are rated at up to 200 mA forward current for continuous operation and 1.5 A peak forward current for pulse operation. Competitively priced, they're available from stock.

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IDEAS FOR DESIGN

(continued from page 82)

the C₁ charge and the difference causes an increase in the output of Vᵯ. An increase in Vᵯ then increases the ramp rate. Conversely, Vᵯ is decreased if the ramp rate is too high to match C₂ at the time of the input signal causes the analog switch to operate.

Thus, the circuit’s negative feedback forces the ramp rate to match the rate of the input signal. And output Vᵯ is kept proportional to the input signal’s rate—a responsive measure of the input frequency. Vᵯ is ripple free once it has adjusted to reflect the input rate.

The ramp voltage at point X in Fig. 1 is used to trigger a missed-beat alarm. During normal operation, the signal at X is a sawtooth with a peak amplitude, Vₚk, equal to -2Vₚ/C₂/C₁ independent of input rate. However, if one beat is missing from the input stream, the ramp voltage continues to rise to approximately twice the normal peak voltage; two missed beats result in a triple-height peak, and so on. Thus, the comparator set to trigger at 1.5 times the nominal peak height will detect a single miss; another set to 2.5 times the nominal peak height will detect more serious interruptions.

Missed beats are reported without disturbing the base heart-rate measurement, Vᵯ, with the aid of an analog switch across C₁ to ground. When the missed-beat detector is ON, this switch then directly discharges C₁ to ground on the next input beat without connecting it to the summing circuit. Thus the circuit can carry over the Vᵯ output that prevailed before the emergency, even through several missed beats, and resume normal operation thereafter.

The response time of the circuit with the components shown in Fig. 2 is

\[ tᵢ = RCᵢ = 1.5 \text{ s.} \]

As the input frequency, f, approaches 1/tᵢ, the circuit’s response at first improves. When f exactly equals 1/tᵢ (40 pulses/min), the first correction fed back within the circuit is exact and the output is steady and correct thereafter; below frequencies of 1/tᵢ, corrections increasingly overshoot. Nevertheless, convergence to the correct output value eventually occurs as long as f remains greater than 1/2tᵢ. Below 1/2tᵢ, the error doesn’t converge; the circuit is unstable.

The CMOS pulse former and control logic may be powered by a ±5-V supply. The 4-V reference, Vᵱ, can be derived from the -5-V supply with a potentiometer. Adjustment of Vᵱ also provides calibration.

Note

1. A patent assigned to the University of Washington, Seattle 98195, has been granted for a circuit based on this technique, Patent 3,968,431.

Dr. Philip A. Ekstrom, Affiliate Assistant Professor, Dept. of Physics, University of Washington, Seattle, WA 98195.  

CIRCLE No. 313

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IFD Winner of August 16, 1976

Burt Sandberg, Engineer, Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, IL 60510. His idea “State Diagrams for a 555 Timer Aid Development of New Applications” has been voted the Most Valuable of Issue Award.

Vote for the Best Idea in this issue by circling the number for your selection on the Reader Service Card at the back of this issue.

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and then some.
Liquid crystals increase laser-beam deflection

An electrically controlled optical beam bender that uses liquid crystals to deflect a laser beam substantially has been developed at the Royal Radar Establishment in Malvern, England. Angular deflections to $\pm 20^\circ$ have been obtained with a liquid-crystal layer 1 mm thick. The Kerr cell, the Malvern device's potential major competitor, deflects laser beams only a fraction of a degree, and competing acousto-optic methods less than 1°.

The molecular orientation of liquid crystals is modified electrically to produce a spatially varying refractive index that causes light to follow a curved path through the liquid crystal. The Malvern device, which deflects light in a single plane, consists of a cell, 1 to 2 mm thick and 3 to 4 mm wide, that contains a positive nematic liquid crystal and electrodes at the top and bottom of the front and rear cell walls.

The crystal molecules are aligned parallel to the cell walls by applying equal and opposite voltages to the top and bottom electrodes (Fig. 1). In this state the device acts like a crystal with its straight optical axis parallel to the cell walls. A polarized beam, applied at right angles, passes through undeflected.

If the electrode-potential relationships are varied, the molecular alignment is modified to produce a curved optical axis. The light follows the curved path through the cell.

The angle through which the beam is deflected depends on the dimensions of the cell, the optical anisotropy of the liquid crystal, and the ratios of the electrode potentials. The absolute values of the electrode voltages determine the speed of deflection only. Since the optical-path length does not vary linearly across the cell, the angle of deflection varies with the location at which the beam is applied.

Although the device may be used for beam scanning, the region that produces maximum deflection is one in which switching produces turbulence in the crystals. Continuous scanning is not compatible with maximum deflection. Continuous scanning can be achieved, however, if the beam is focused outside the turbid region.

At 1 kV, the beam deflects full-scale and returns in less than 1 ms. At present, the transmission loss due to absorption and scattering is typically greater than 50%. Scattering is combated by specially treating the cell walls and by operating the device at high fields.

An eight-electrode device, capable of deflecting a beam in two dimensions, has also been constructed. With this device, x-y addressing, such as for use in holographic storage systems, becomes a possibility.

Japanese keyboard lowers mechanical parts

A thin, light-action electronic keyboard with a piezoelectric sheet has been produced at the Musashino Electrical Communication Laboratory in Tokyo. The 0.3-mm thick piezoelectric sheet lies on top of a PC board, which detects key depression and carries out the first stage of key encoding. This arrangement minimizes the number of mechanical parts and permits the use of low-profile keys. The sheet is formed by blending a base material of polyfluorocyclopentadiene resin with particles of zirconate-titanaite lead.

The keyboard also consists of a key mechanism, a MOSFET waveform circuit and final-encoding circuitry.

Thin-film matrix on glass will lead to flat TV

A low-cost, flat TV screen with either electroluminescent or liquid-crystal display elements may be commercially feasible in three years, says Dr. A. Fischer of the University of Dortmund, West Germany. He has developed an automated production system that allows thin-film transistor matrices to be deposited on glass.

Shift-register circuitry for the screen requires five components per stage. Depositing the register matrix on glass is a seven-mask process. The masks and their support frames are housed in a bell jar. Each mask can be drawn out or pushed back by means of magnetic drives that operate through the walls. The glass substrates can also be raised or lowered so that the masks can be properly mated with the substrates in the bell jar. Films are deposited from vapors generated by electron-beam heating. Film growth rate is monitored by preprogrammed controllers.
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CIRCLE NUMBER 37
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   Minimum operating power NF2E 190mw, NF4E 310mw.

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   With N2 gas enclosed.

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Arrow-M Flatpack NFE relays offer maximum reliability and sensitivity using half the power of ordinary relays. The Flatpack design, only .425 inches high, is ideal for high density PC board packaging. The unique automated modular assembly insures extra long life and total reliability. And the gas-filled plastic sealed construction allows for economical automatic wave soldering and ultrasonic cleaning.

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Member of Matsushita Group

CIRCLE NUMBER 43

88 ELECTRONIC DESIGN 26, December 20, 1976
Connector mass terminates flat-conductor, flat cable


Housing five to 33 contacts, a new connector, the Clincher, simultaneously terminates all conductors in a flat-conductor, flat cable. Crimping the connector to the cable is done faster and with less expensive tooling than is possible with the only other flat-conductor connector, one from AMP, Harrisburg, PA.

In production, Berg’s crimping machine simultaneously presses down on all the contacts, forces them to pierce the plastic surrounding each conductor, then squeezes around the copper to hold it securely. Additional ridges in the contacts pierce the copper to make a low-resistance connection, said to be a maximum of 10 mΩ.

The Clincher system cuts total assembly time for an 18-conductor connector to under 10 seconds—more than 20 seconds faster than the AMP system, whose crimping machine does one contact at a time at a rate of two per second. Then, the operator must snap the assembly into a separate housing. The AMP crimping machine must be rented for $300 a month, while Berg’s machine sells for $800.

However, AMP does make a variety of contact types and housings, while Berg makes only a single-row, 5-to-33 contact female connector series with 30 µin. of gold, or solder plating that mates with 0.023-in-square posts. AMP offers male, female, or solder-tab contacts and eight kinds of plating. Housings hold 9 to 33 contacts in single rows, or 18 to 70 in double rows.

Both connectors accept cable having conductor spacings of 0.1 in. The width of the conductor can measure from 0.04 to 0.062 in. The connectors can be installed on a cable end or in the middle to produce a daisy-chained connection. Both connectors carry about 3 A; the maximum for the copper conductors.

The Clincher’s housing comes with an opened lid so that the cable can be slipped into place between the contacts. The lid flips down after the contacts are crimped, which insulates the connection and provides strain relief for the cable.

The contacts are made of two different metals, one supplying spring retention and the other supplying high conductivity. The spring material is made of a beryllium-copper alloy, which provides high forces to the opposing contact. A copper-nickel alloy provides high conductivity. The housing material is made of polyester, rated up to 105 C.

The over-all height of the housing allows stacked connectors to be spaced in increments of 0.1 in.

Whether one method is cheaper than the other is unclear. The Clincher costs 7 to 9¢ per contact, with either 30 µin. of gold plating or solder-plated contacts 10-K quantities. AMP’s cost per contact—including housing and the same gold plating as the Clincher’s—is 4 to 10¢ in quantities of 5-K to 100-K.

Berg Electronics CIRCLE NO. 301
AMP, Inc. CIRCLE NO. 302

Operator station solders and desolders

Cooper Group Deutschland GmbH, 7122 Besigheim/Wurtt, West Germany. 07143 7063.

The Weller DS100P station solders and desolders components on PC boards. The unit consists of two solder pencils and stands, and a vacuum pump. The pencils are transformer-powered, low-voltage temperature-controlled types. One pencil has a standard soldering tip. The other pencil is fitted with a solder-suction nozzle and a transparent solder collector. Air vacuum or pressure is supplied from the built-in pump, a factory air line or a compressed air cylinder. When employed with air systems other than the vacuum pump, a transducer must be used to convert the compressed air into a vacuum. Solder is removed when a foot switch is depressed. The system will operate on air pressures between 30 and 120 lb/in².

CIRCLE NO. 303
Delays: 2 to 180 Sec.

Hermetically sealed - not affected by altitude, moisture, or climate changes...

SPST only - normally open or normally closed...

Compensated for ambient temperature changes from -55°C to +80°C...

Rugged, explosion-proof, long-lived...

Standard radio octal and 9-pin miniatures.

Price, standard or min., under $4.00 ea.

*Miniatures delays: 2 to 120 seconds.

**Problem? Send for Bulletin No. TR-81.

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**PACKAGING & MATERIALS**

Double-walled bushing insulates wires

Heyman Manufacturing Co., North Michigan Ave., Kenilworth, NJ 07033. (201) 376-7300. $3.05 (500-2000); stock.

A panel bushing, Model S-87, provides a double wall of insulation for wires going through its center. The bushing's outside surface is rounded to minimize sharp bends in the wire. The S-87 mounts using fingertip pressure, into a hole with a diameter of 0.875 in. It locks into panel thicknesses up to 0.062 in. The inside diameter is 0.5 in.

价格，标准或最小，每件4.00美元。

**New! LONG DELAYS**

240 & 300 Sec.

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**BALLAST REGULATORS**

Automatically keeps current and voltage at a definite value. For AC or DC... Hermetically sealed, rugged, vibration-resistant, compact, most inexpensive.

Price, under $3.00 ea.


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**Breadboard**

Breadboard has contacts of conductive elastomer

Lorraine Microelectronique, 53 Rue N.D. de Nazareth, 75003 Paris, France.

The Wonderboard solderless breadboard has electrical contacts made of conductive-elastomer slugs molded into an insulating substrate. The board measures 3.19 x 1.4 x 0.16 in. It has six rows of contacts, with spacings between row pairs of 0.3 in. On each row, contact-to-contact spacing is 0.1 in. The contacts accept wire diameters from 19 to 31 AWG and contact resistance is 1 mΩ. Insertion force is 750 grams.

CIRCLE NO. 306

**Silicone grease**

Silicone grease conducts heat well

Emerson & Cuming, Inc., Canton, MA 02021. (617) 828-3300. $6 (12 oz-up); stock.

A thermally conductive, electrically insulating, silicone grease, Eccotherm TC-5, is filled with inert metal oxides. The material features a thermal conductivity of 0.0062 (cal/cm)(s/cm)(C), a volume resistivity of 10^14 ohm-cm and a dielectric strength of 500 V/mil. Eccotherm TC-5 does not harden or run on prolonged exposure to temperatures up to 200°C.

CIRCLE NO. 307

**Conductive paints**

Conductive paints spray on, shield

Tecknit, 129 Dermody St., Cranford, NJ 07016. (201) 272-5500. 1 lb, 1-up prices: $55 (Acrylic 1), $44 (Acrylic 10).

Two acrylic conductive paints, Acrylic 1 and 10, have surface resistivities, after application, of 1 Ω·sq. and 10 Ω·sq. The paints provide a minimum of 25-dB insertion-loss shielding to electric and plane-wave fields. Both have the consistency of regular paint and can be applied in one operation with industrial sprayers. The paints stick to structural foam and molded plastics. They are colored silvered gray (Acrylic 1) or gray (Acrylic 10) and come in 1 and 7-lb containers. The operating temperature ranges from -65 F to +180 F.

CIRCLE NO. 308
INSTRUMENTATION

Generator delivers 3-kV pulses

Monroe Electronics, 100 House Ave., Lyndonville, NY 14098. (716) 765-2544, $995; stock.

Model 241 ±3-kV reference supply/pulse generator is designed as a calibration supply for high input-resistance instruments. It can be used as a high-voltage dc supply, 0.05% accuracy, or as a high-voltage pulse generator providing an output pulse of up to 3 kV with less than 1-msec rise time. Output pulse may be set for single-shot or repetitive operation at a 2-Hz rate. Pulse width and slope are variable by a front-panel control.

CIRCLE NO. 309

Unit takes test results and provides reports

Fairchild Systems Technology, 1725 Technology Dr., San Jose, CA 95110. (415) 962-3816. $125,000 to $250,000; 60 days.

A new concept in semiconductor test-system architecture correlates total test results into a meaningful management information system. The system, called the Integrator, is aimed at both manufacturers and volume users of complex LSI circuits. The system integrates raw data from on-line test systems to tell managers at every level what is happening in various process stages from silicon to finished product to the end system. The Integrator separates the data processing and software support functions from the product testing function. Essentially, the system consists of test locations, a communications network, and a centralized data storage and data processing system. Data are collected through the network into a disc file to create a central data base.

CIRCLE NO. 310

VICTOREEN WRAPS HIGH VOLTAGE PERFORMANCE IN SLIM-MOX PACKAGES.

Victoreen’s SLIM-MOX is the small, flat substrate, high voltage resistor that saves you space with no sacrifice in performance. That’s because small size is only one of many SLIM-MOX features. Designed into your high voltage circuits, SLIM-MOX will deliver better long term stability. You will appreciate its small temperature coefficients over a wide temperature range.

Switch to SLIM-MOX, the rugged and highly stable resistor now available in an expanded resistance range — 1 to 5,000 M. Tolerances to 1%.

Standard values are available from stock. And at any value, Victoreen quality is a built-in SLIM-MOX virtue. Find out for yourself by using SLIM-MOX wherever you need to save space in high voltage circuitry. Wherever stability and reliability are key performance characteristics.

Victoreen Instrument Division, Sheller-Globe Corporation, 10101 Woodland Avenue, Cleveland, Ohio 44104

CIRCLE NUMBER 45

RESISTOR SPECIFICATIONS

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Applicable above critical resistance

MAXIMUM DIMENSIONS (inches)

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1.3 IN. MIN.

LEADS 0.25 IN. TINNED COPPER
Standard interface bus boosts test speed


Two test systems owe their performance to the HPIB (HP's implementation of IEEE-488). The first, the 5390A frequency-stability analyzer, makes fast phase-noise measurements to within 0.01 Hz of a carrier. The second, the 8950A transceiver test system, needs just three minutes to check out a typical 2-channel mobile FM transceiver, CB radio, handi-talkie or AM transceiver. Both test systems are calculator controlled, and both are built up of mostly off-the-shelf instruments interconnected via the standard bus.

Transceiver tester
Stability analyzer

CB signal generator covers 50 channels

B&K Precision, 6460 W. Cortland Ave., Chicago, IL 60635. (312) 889-9087. $475; stock.

Model 2040 CB signal generator covers 50 channels, including all 40 authorized channels. Frequency calibration and stability are accurate to ±0.5 ppm (0.0005%) after a 15-min warmup. Phase-locked loop circuitry, referenced to a high-accuracy crystal, and powered by a well-regulated power supply, maintains performance standards under all normal operating conditions. A microvolt output meter and calibrated attenuators combine to provide accurate generator output measurements, down to 0.1 µV.

Distortion meter works automatically

Marconi Instruments, 100 Stonehurst Ct., Northvale, NJ 07647. (201) 767-7250. $850; 30 days.

Model 2337A automatic distortion meter enables rapid measurements to be made of both level and distortion of audio-frequency test signals. There's no need to set a reference level or to precisely tune a fundamental rejection filter. The only controls are pushbutton switches for selection of input voltage range, distortion range and fundamental frequency. Distortion down to 0.01% can be measured with an input signal of 100 mV.

Microwave counters measure pulsed carriers


A new 18-GHz pulsed microwave counter, Model 989G, and a similar 12.4-GHz instrument (Model 988G) measure carrier frequencies during pulse-modulation conditions. Frequency measurements to a resolution of 10 kHz (7 digits) are automatically provided, and rf pulses as narrow as 100 ns can be measured. Models 989G/988G also offer a CW mode providing resolution to 1 Hz (11 digits). Complete systems compatibility is available, including remote programming and data output in BCD or IEEE GPIB format.
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NEW!

These new power transducers compute instantaneous ac electrical power. Simple design and high quality yield excellent reliability at an unprecedented price. New capabilities meet the needs of hundreds of previously difficult or uneconomical applications. These include, ±0.50% accuracy, 50 Hz to 10 kHz frequency range, one and three-phase operation, accurate operation with non-sinusoidal waveforms, better than ±0.25% power factor influence and a 100µs response time.

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A reliable, accurate easy to install, "one shot" thermal limiter.
- temperature tolerance — ±1.7°C.
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Both devices are completely sealed against the atmosphere. Because of their unique design and construction, they won't derate. And they're unaffected by age or extended use. You can stack as close as ¼".

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Used where installation or space restrictions rule out MICROTEMP® thermal cutoffs.
- temperature tolerance — +0°C. — -3.3°C.
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- economical
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93
Relay Miss every 2-Billion Cycles

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Series E Relays offer:
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- Operation in all positions
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- Reliability at dry circuit or power loads
- Self-healing contacts
- Hermetically sealed contacts
- 1250V rms contact breakdown
- Low cost

Series E Relay uses a rugged LC2 welded capsule rather than a fragile glass reed switch. This patented design holds a film of mercury securely to the metal walls of the capsule. With every operation, the mercury film renews the switch contacts. You get the reliability of mercury relays, but with complete freedom of mounting orientation. LC2 welded capsule reliability is proven by hundreds-of-thousands of units in the field, as well as billions of cycles under stringent laboratory conditions.

Send for a FREE SAMPLE of the LC2 welded capsule on your letterhead. Circle the reader service card number for Series E Relay information.

—Relay Miss every 2-Billion Cycles—

COMPONENTS

DIP combines LED with TTL circuit

Data Display Products, Box 91072, Los Angeles, CA 90009. (213) 641-1232. $1.50 (100 up); 3 to 5 wks.

A new concept in PC-board indicator lights combines a visual indicator, using super or standard brightness LEDs and a TTL IC in a standard DIP package, thus saving the unnecessary cost and space of connecting separate components. This T² Lite is available with most 74-series ICs and either a super-bright or standard-bright LED in four colors. Current limiting resistors are built-in for 10, 20 or 30-mA LED current. LEDs are available either with tinted or clear encapsulation for narrow-beam, high-intensity units, or tinted or diffused encapsulation for wide-angle units.

New piezoceramic builds into stable filters

Channel Products Inc., 16722 Park Circle Drive W., Chagrin Falls, OH 44022. (216) 543-8137.

A new piezoceramic filter material, FGH, is said to have time and temperature stability that is greatly improved over currently available materials. The material has a frequency stability with time of +0.1% for 5 yr. Temperature stability is better than 0.1% from 0 to 50 C and 0.2% from -40 to 85 C. Present uses of the new material include filter resonators for AM radios and transceivers. For example, an FGH-01 filter resonator built with the material can be used for emitter bypass applications to improve selectivity and markedly simplify i-f alignment. The FGH-01 can also be used as a basic building-block resonator for complex bandpass-filter designs at 455 kHz.

Power transformers suppress line noise

Topaz Electronics, 3855 Ruffin Rd., San Diego, CA 92123. (714) 279-0831. From $95 (unit qty).

A line of noise-suppression transformers protects data-processing and other sensitive equipment from power-line transients. Some models are available with line cords and receptacles built-in for ease of installation. The transformers use a triple-box shielding technique to attain an extremely low primary-to-secondary winding coupling of less than 0.0005 pF. A low-impedance path for line noise to ground results in noise attenuation of more than 146 dB. Single-phase models are available in power ratings from 125 VA to 20 kVA. Three-phase models are rated from 3 kVA to 130 kVA.

Rotary switch provides coded outputs

AMP Inc., Harrisburg, PA 17110. (717) 564-0100.

AMP 3500 Series rotary switches use bidirectional rotating coded PC boards with fixed cantilever brush contacts to provide a variety of output codes that include BCD, a direct seven-segment numerical code and a number of special synthesizing codes. Switch modules have 18-to-50 detent positions. As many as seven modules can be ganged for multilayer operation from a single shaft without increasing mounting surface dimensions. Rated for 2.5-A nonswitching and 125-mA switching, the units have a dielectric withstanding voltage of 250 V dc min. Life expectancy is over 25,000 bidirectional rotations at rated load.
21-column head prints in two colors

Master Digital Corp., 1308-F Logan Ave., Costa Mesa, CA 92626. (714) 751-8271. $102 (100 up); stock.

Two-color printing is achieved in Model 308-21, a 21-column numeric print head, by using an ink-ribbon cassette that features no-mess ribbon replacement. The print head can be operated with a 100% duty cycle at a print rate of 3 lines/s. Life is 5-million printed lines. The print head can be mounted so the paper exits from either the top or front to allow flexibility in packaging. Dimensions of the head are 3.5 H x 5 W x 4.1 D in. and the unit weighs 3 lb.

CIRCLE NO. 331

EM transducer replaces precision potentiometers

Astrosystems Inc., 6 Nevada Dr., Lake Success, NY 11040. (516) 328-1600. $295 (1-9); stock to 2 wks.

A wiperless high-accuracy electromagnetic position transducer provides a replacement for precision potentiometers. Proven rotational life is in excess of 100,000,000 rotations. An electromagnetic rotary transducer with solid-state excitation and conditioning electronics provides a smooth continuous dc-voltage output proportional to shaft rotation. The shaft is capable of continuous rotation. The transducer has infinite resolution with a dead band of less than 0.02°, a starting torque of less than 0.1 oz-in, and an accuracy and linearity of 0.05%. Available output voltages are 0 to +10 V dc, −5 to +5 V dc or 0 to +10 V dc from an internal or external reference. Ripple voltage is less than 3 mV rms. The unit is approximately 1.5 in. in diameter by 1.3 in. long.

CIRCLE NO. 332

Polyester-film caps offer high cap/volume

Cornell-Dubilier, 150 Avenue L, Newark, NJ 07101. (201) 589-7500.

Type DMT polyester-film dipped capacitors provide very high volumetric efficiency and moisture resistance (95 to 100% relative humidity at 40°C for 240 h). A combination plastic coating with a firm bonding of epoxy around the leads prevent the entrance of moisture. The capacitors operate to 125°C without derating and with good stability, and at up to twice the rated voltage at 85°C.

CIRCLE NO. 362

Anatomy of Value in a Voltage-Tuned Oscillator

Avantek’s VTO Series

Power Output as High as 20 mW ± 13 dBm

Eight Models Cover 600 to 6600 MHz

Costs less Than $100*

Shown Actual Size

Hermetically Sealed

Weighs Less Than Two Grams

* in breadboard quantities

If you're designing a synthesizer or other instrument, why worry about designing voltage-tuned oscillators? Avantek VTO’s represent an outstanding value as a cost-effective alternative to in-house discrete designs. Contact Avantek for an applications brochure describing the VTO Series in detail.

Avantek
3175 Bowers Ave., Santa Clara CA 95051 Phone (408) 249-0700

CIRCLE NUMBER 48
Telonic wrote the book on filters

For 15 years Telonic's been considered an authority on filter design. Look at the prime, successful customers who use them. So why shouldn't they produce the most authentic, comprehensive catalog in the business? This 40-page volume covers specifications on several hundred designs (standard and special) with graphic data on attenuation, insertion loss, connectors and more. You'll find a broad range of tubulars in low and band pass types, cavities, combline, miniature, and tunable—all backed by a 5-year warranty. It's No. 1 on our best-seller list—since it's free. Write or call our Product Manager for your autographed copy.

DATA PROCESSING

Memory system adds 1 Mbyte to IBM's 370

Intel Memory Systems, 1302 N. Mathilda Ave., Sunnyvale, CA 94086. (408) 734-8102. $4567/mo.

An add-on memory system, Model 7125, expands the 96 kbytes of IBM's standard memory size for the 370/125 to 1 Mbyte. The Model 7125 semiconductor memory system uses 16 kbit RAMs for data storage. When parts of the memory fail, backup memory is automatically switched in. System access time runs 280 ns, and the cycle period is 480 ns.

CIRCLE NO. 333

Color-TV display accepts computer data

Comtal Corp., 169 N. Halstead St., Pasadena, CA 91107. (213) 793-2134. See text: 90 days.

The Model 2000 computer-output memory and buffer produces a full-color continuously refreshed, flicker-free display. The unit operates on-line with a host processor such as a 16-bit minicomputer ($17,950 with interface controller). Or the 2000 takes data from a magnetic-tape drive ($19,950 including 9-track drive). The unit displays 480 lines with 512 picture elements per line. The display is refreshed 30 times per second.

CIRCLE NO. 334

16-k x 20 RAM board accesses in 280 ns

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 737-5000. $1050 (large qty).

The Model NS3000-1 RAM board holds 16-k x 16, 18 or 20 bits, according to user requirements. The timing specifications are: access, 280 ns; read or write cycle, 430 ns; and read-modify-write cycle, 610 ns. Options include parity generation and check and data-available reset. The latter option permits the NS3000-1 to control a shared-data bus. The card measures 11.75 x 15.40 in. The NS3000-1 is rated for operation between 0 and 50 C.

CIRCLE NO. 335
Keyboard terminal drives a video monitor

Keyboard terminal drives a video monitor


The Conversor-8000 terminal has a keyboard and generates composite-video output for an 80-character by 24-line TV display. The terminal talks to a computer over RS232 lines at a 110 or 300 baud rate. The 8000 has automatic display scrolling. It weighs 6.5 lb, and measures $6 \times 11 \times 14$ in. Options include an integral acoustic coupler ($110$), video monitor ($120$) and software-controlled beeper ($30$).

CIRCLE NO. 336

Printer includes control electronics

Printer includes control electronics


A 40-column printer comes with control electronics. Designated the Model 140, it uses a dot-matrix printer. The system contains a MOS chip that has a 48-character buffer, a character generator, and control logic. Software commands alter character width, height and density. Extra-cost options include RS-232C or current-loop lines, a pin-feed platen, a high-speed paper feed, label printing and front-feed document printing.

CIRCLE NO. 337

Floppy-disc terminal searches for data

Floppy-disc terminal searches for data

Techtran Industries, 530 Jefferson Rd., Rochester, NY 14623. (716) 271-7953. $2595 (single qty); 60 days.

The 9512 floppy-disc drive and terminal can search its disc for a 14-character sequence and alter or read out the associated data. Other disc-based terminals require the track and sector location of the data be entered to alter it; the 9512 will also do that. The unit stores data on the disc in an IBM-compatible format. The 9512 has two 110-9600 baud serial lines. One line could connect to a keyboard, the other to a computer.

CIRCLE NO. 338

ICOM’s PROM Programmer

ICOM’s PROM Programmer

MAKES IT EASY FOR YOUR 2708’s AND 2704’s TO CHANGE THEIR MINDS.

Now you can program 2708’s & 2704’s in just 100 seconds including automatic verify using iCOM’s PROM Programmer/Memory Expander which occupies a single card slot in either Intel’s* SBC 80/10 or Intellic* MOS-800. The PP80 card also provides sockets for 8 additional 2708/2704 type devices for memory expansion.

Just $395 including 1K ROM resident programming firmware.

* Intel and Intellic are trademarks of Intel Corp.

6741 Variel Ave., Canoga Park, CA 91303 (213) 348-1391 TWX 910-494-2788

CIRCLE NUMBER 52
INTEGRATED CIRCUITS

Bipolar PROMs hold 8 k and access in 100 ns

Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. (408) 739-7700. $31 (100-up); stock.

Developed with either open collector or three-state outputs, the 82S184 and 82S185 field-programmable bipolar ROMs are available in a $2048 \times 4$ organization. The ROMs have an address access time of 100 ns maximum and a typical power dissipation of 50 $\mu$W/bit. Both devices are available in 18-pin ceramic DIPs with performance guaranteed over the commercial temperature range. Military temperature range devices will be available in the near future.

CIRCLE NO. 339

JFET-input amplifiers come in many models

Texas Instruments, P.O. Box 5012, Dallas, TX 75222. (214) 238-2011. From $1.60 (100-up); stock.

The LF155 series of JFET input op amps offers input-bias currents of under 50 pA (LF156A). There are three basic model groupings available: the LF155, 155A, 255, 355 and 355A are intended for low current drain applications; the LF156, 156A, 256, 356 and 356A are designed for wideband uses; the last group, the LF157, 157A, 257, 357, 357A are intended for wideband decompensated uses. The 155 series units are rated over the full military temperature range, the 255 series over a $-25$ to $+85$-$^\circ$C range and the 355 series over the 0 to $-70$-$^\circ$C range. The op amps are available in 8-pin ceramic or plastic DIPs and in TO-99, 8-pin metal cans. All units are pin-compatible with the LF155 series of op amps from National Semiconductor.

CIRCLE NO. 340

HiNIL counters deliver decimal or hexadecimal

Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94043. (415) 968-9241. From $3.06 (1000-up); stock.

Two up-down (reversible) counters, the HiNIL 373 and 374, offer a choice of decimal or hexadecimal outputs. Each unit has two clock inputs; pulsing one clock input causes the device to count up; pulsing the other causes it to count down. Other features include a noise immunity of 3.5 V, minimum, carry and borrow outputs for N-bit cascading, a clear input independent of count and load, individual presets to each flip-flop, and synchronous operation. The circuits operate at maximum counting frequencies of 1 MHz.

CIRCLE NO. 341

Speedy shift register handles ECL and TTL

TRW Defense and Space Systems, One Space Park, Redondo Beach, CA 90278. (213) 536-1500. $80 (1 to 99); 30 days.

A 128-bit bipolar shift register, the SR128, has both ECL and TTL compatible inputs and outputs. Its 60-MHz operating speed is guaranteed when the ECL connections are used. ECL outputs are complementary open-emitter, thus permitting hard-wire OR connections. In the 60-MHz ECL configuration, the SR128 can source 20 mA. The TTL mode operates at a guaranteed 40 MHz, and its output is single-ended with a 6-mA sink capability. TTL and ECL inputs are either single ended or differential and can be multiplexed with an ECL level control. The inputs and outputs can be interfaced with single-ended inputs by connecting the complementary input to one of the two on-chip reference voltages. In the differential mode, inputs can be used as analog comparators with the ECL inputs for high level signals and the TTL for lower level signals. The SR128 operates from a single power supply of 5 V for TTL or $-5.2$ V for ECL. Open-emitter ECL outputs may terminate in 50 $\Omega$ by connecting load resistors to a $-2.2$-V supply.

CIRCLE NO. 342
µP support circuits do control or bus driving

AMD, 901 Thompson Pl., Sunnyvale, CA 94086. (408) 732-2400. From $8.50 (100-up); stock.

A pair of system controllers and bus drivers, the Am8228 and Am8238, are designed for operation with 9080A/8080A microprocessor systems. They provide eight-bit, bidirectional bus drive and are controlled by signals from a gating array. These circuits, pin-compatible with like-numbered devices from Intel, provide multibyte instruction interrupt acknowledge and a selectable single level vectorized interrupt. The Am8238 has an extended memory write pulse width enhancing its application in large system timing controls. Both devices are available in molded and hermetic DIPs and are specified for operation over the commercial or military temperature ranges.

CIRCLE NO. 343

Telephone-tone decoder uses digital filtering

Collins Commercial Telecommunications, Division of Rockwell International, Newport Beach, CA 92663. (714) 833-4638. See text; stock.

Using a unique digital filtering technique, the CRC-8030 provides a low-cost solution for DTMF decoding. The circuit, which costs only $29 in hundreds, when used in conjunction with a front-end bandpass filter/limiter, forms a complete telephone-tone receiver. Valid tones are detected and converted to binary or 2-of-8 coded outputs within 22 to 39 ms, depending upon the front-end filter. The CRC-8030 is an ion-implanted depletion-mode, p-channel MOS/LSI device. It can operate from a +5-V supply and requires only a standard external 3.579545-MHz crystal for clock generation. It is housed in a 28-pin ceramic DIP.

CIRCLE NO. 344

8080 programming problems?

IF you need to know how to:

• service interrupts
• do multi-precision arithmetic
• convert number bases
• handle arrays and tables
• control complex peripherals
• use the stack pointer
• debug your programs

THEN... Practical Microcomputer Programming:
The Intel 8080 is the book you’ve been waiting for. Written by application programming people for application programmers, this is not a book of theory, but a book of step by step solutions to real problems. In eighteen chapters and more than 100 example programs it shows you exactly how to do all of the things listed above and many, many more with 8080 assembly language. A complete programmer’s guide to using the 8080, it also contains the full source text of a minicomputer cross assembler and a debug program for 8080 based systems. This could be the best programming information bargain you will ever see.

Northern Technology Books
Box 62, Evanston, Illinois 60204

Please send my copy of Practical Microcomputer Programming: The Intel 8080 at $21.95.

☐ check enclosed ☐ money order enclosed

Illinois residents add $1.10 state sales tax. No C.O.D. please.

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Address________________________________________________________________________
City________________State_________Zip________________________

CIRCLE NUMBER 54
A better selection of standard ‘specs’ to easily fit particular applications. We developed our complete line of strip chart recorder modules — with OEM needs in mind. Needs like reliability, accuracy, compactness, flexibility and, of course, low cost.

Chances are General Scanning has a standard off-the-shelf recorder module just right for your application. If we don’t, our modular construction method makes it simple to fill the most unique requirements. A sample of ‘specs’ to choose from:

- **Number of Channels**
  - single through eight

- **Channel Widths**
  - 20, 40, 50, 80 & 100 mm

- **Paper Feed**
  - roll
  - fan fold

- **Chart Speeds**
  - multi-speed, electrically selectable

- **Pen Motor Operation**
  - open loop
  - velocity feedback
  - closed loop

- **Inkless Thermal Writing**

We offer packaged recorders for your lab, portable DC recorders and precision pen motors, too. Make "the designer’s choice", call or write for full details. The general awaits your orders.

**Cutler-Hammer**, 4201 N. 27th St., Milwaukee, WI 53216. (414) 442-7800. From $6000; 20 wk.

Directrol is a multiplex system that permits industrial control devices to communicate over a two-wire loop. The manufacturer estimates that multiplexing can save up to 50% in wiring costs when compared with conventional point-to-point wiring networks. A system can handle up to 4096 input and/or output devices. Up to 4096 individual digital or 2048 analog signals, or a combination of the two, can be transmitted from as many as 128 separate locations via time-division-multiplexing at a throughput rate of 3 ms. The system transmits analog measurements between terminal stations and to the communications station, where they can be displayed on an optional monitoring panel or made available for a computer. This stand-alone system does not need a computer. However, it is compatible with many computers. A standard feature automatically bypasses a malfunctioning station without disturbing continuous-flow processes. A redundancy option, using two pairs of wires, reconfigures a new communications loop when wires break. Bipolar 12-V, non-return-to-zero pulses at a 500 kHz rate, bi-phase modulated (Manchester code) give the system a data rate of 190 k bits per s. Each 8-bit data word is redundant and undergoes a geometric parity-check. The systems meets or exceeds NEMA ICS 2-230 for noise.

**Stable ladders resolve 15 bits**

**Intech Inc.**, 282 Brokaw Rd., Santa Clara, CA 95050. (408) 244-0500. $199 (1-24); stock to 4 wks.

The A-857A-8 features an 800-ns conversion time, and can be short-cycled for 2-to-7-bit operation with proportionately shorter conversion times. At its input, the A-857A-8 accommodates ±10 V, ±5 V, and 0 to +10 V; digital outputs are provided in both parallel and serial formats. A low temperature coefficient guarantees no missing codes over the rated 0-to-70-C temperature range.
At Vanguard, when it comes to high Q hybrid chip inductors, we definitely don't monkey around. From field-proven fixed chip inductors like the Magna Q Mini or Micro to the world's smallest variable chip inductor to complete tuned circuits, we've got all your inductive needs covered.

With every VE chip inductor, you get high Q, low DCR and high...

**FEATURES**

1. SRF in an all-welded, transfer-molded microminiature device that's compatible with automatic insertion equipment, and meets and exceeds MIL-C-15305.
2. For specs, application assistance or to place an order, call (213) 678-7161, TWX 910-328-6126 or write 930 Hyde Park Blvd., Inglewood, CA 90302.

**SPECIFICATIONS**

1. Chart width: 250mm
2. Pen speed: 0.8 secs full scale
3. Measurement voltage: 0.5, 1, 5, 10, 50, 100, 500mV, 1.5, 10, 50, 100V full scale
4. Chart speed: 10, 20, 50, 100, 300, 600mm/hr, 20, 50, 100, 300, 600mm/min
5. Digital output (A or B): A...10-bit binary full scale at 1000 digit. 1 digit 0.1%. B...3-digits BCD 10^3 10^4 10^5 full scale 999

*Please write us on your letterhead for detailed information.

**CALL OR WRITE TODAY FOR CATALOGS, PRICES AND APPLICATIONS ASSISTANCE.**

**CIRCLE NUMBER 56**

**CIRCLE NUMBER 57**

**CIRCLE NUMBER 58**

**CIRCLE NUMBER 59**

Electronic Design 26, December 20, 1976
CIRCLE NUMBER 60

TAKE YOUR PICK!!

NLS' DPMs fill every need and the prices are pleasing.

NLS' Silver Jubilee Year

PM SERIES DC OR AC VOLTS

Features Include:
• Operates from a +5-volt separate power supply.
• MOS/LSI construction.
• Smallest package available anywhere - 1" H x 2.5" W x 3.25" D.
• Automatic zeroing.
• Programmable decimal.
• Overload indication.
• Protected input.
• Low power consumption.

PM-4 PANEL METER

<table>
<thead>
<tr>
<th>MODEL</th>
<th>RANGES</th>
<th>ACCURACY</th>
<th>AUTO POLARITY</th>
<th>MUX BCD OUTPUT</th>
<th>RATIO OPERATION</th>
<th>DIGITS</th>
<th>PRICE</th>
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<td>3-1/2</td>
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<td>Standard</td>
<td>3-1/2</td>
<td>$156</td>
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</tr>
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</table>

D/a converters get MIL-883 testing

Micro Networks Corp., 324 Clark St., Worcester, MA 10606. (617) 852-5400. From $89 (1-24).

DAC-85 series 12-bit d/a converters are routinely tested to MIL-883 Class C specs, at no extra cost. In quantities of 1 to 24, the Model DAC-85-C (0 to 70 C) starts at $69, while the DAC-85-CBI and CCD (−25 to +85 C) are priced at $89. These, as well as BCD and binary versions, come in sealed 24-pin DIPs, and offer guaranteed monotonicity within the −25 to +85 C range. Both voltage and current output models provide programmable ranges, TTL-compatible inputs, and work from standard +5 and ±15-V supplies.

CIRCLE NO. 348

Low-cost oscillators span 20-MHz range

Dale Electronics, 930 W. 23 St., Tempe, AZ 85282. (602) 967-7874. See text.

For $5.50 (1000 qty.) the XO-2000 series of crystal-controlled oscillators gives you an output frequency in the 3.7-to-25-MHz range. The frequency's stability is ±1000 ppm from 0 to 60 C. Stabilities of ±50, ±100 and ±500 ppm are available at higher costs. Fan-out is ten TTL inputs from the 14-pin DIP-type, 0.8 × 0.5 × 0.4 in., encapsulated unit. As an option, the height can be shrunk from 0.4 to 0.3 in.

CIRCLE NO. 349

Electronic Design 26, December 20, 1976
Programmer ties supplies to HP-IB


With this power-supply programmer you can control more than 80 models of HP unipolar and bipolar power supplies via the Hewlett-Packard Interface Bus (HP-IB). The Model 59501A controls a wide range of dc voltages and currents at power levels up to 10 kW. Output voltage (or current) of HP remotely programmable power-supplies is controlled by voltage programming from the unit, with gain provided by the power-supply control circuits. The programmer contains an adjustable resistance network that matches its output to various HP power-supply programming coefficients and full-scale output ratings. The device offers isolation rated at 600 V dc between bus input lines and the output terminals. The instrument also can be used as a low-level dc voltage source with two manually selected output modes. One mode is unipolar, from 0 to 9.99 V in 10-mV steps with an accuracy of 0.1% of output plus 5 mV. The other mode is bipolar, from -10 to +9.98 V in 20 mV steps with an accuracy of 0.1% of output plus 10 mV. Resolution for both modes is 0.1%. A bus-programmable 0.1-times range provides increased resolution and accuracy over the lower 10% of both output modes. Output current up to 10 mA is available. Internal conversion circuitry enables the 59501A to produce a full-scale d/a voltage change in less than 150 µs from the time the digital data are received until the programmed analog voltage is reached.

CIRCLE NO. 350

New Solid-State relays for PCB mounting offer designers the field-proven circuitry of the 7521 chassis mounted units. You get the same opto-coupled, zero-voltage synchronous switching, 1500 Vac isolation, 120 or 240 Vac switching capability. And they occupy only 1/5 the space.

For technical and pricing information call your Hamlin distributor or representative. Hamlin, Inc., 614 Lake St., Lake Mills, WI 53551 • 414/648-2361 • TWX 910/260-3740.

<table>
<thead>
<tr>
<th>VOLTAGE (47-63 Hz)</th>
<th>120 Vac</th>
<th>240 Vac</th>
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<tbody>
<tr>
<td>2.5</td>
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<td>7562</td>
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<td>7553</td>
</tr>
</tbody>
</table>

| INPUT | 3-32 Vdc | 3-32 Vdc, 80-140 Vdc, 90-280 Vac |

CIRCLE NO. 62

New "MM" Series Switchers pack up to 2.26 watts per cubic inch; cost less than 60¢ per watt!

• 21 models — one, two, three, four, five and six outputs.
• Most watts/in.² — more than 2 times denser than competitive switchers.
• Up to 80% efficient.
• Smallest sizes — 750 watt model measures only 5" x 5" x 12.75".
• Lightest weight — up to 62 watts/lb.
• Most reliable — all models carry 2-year guarantee.
• All models designed to meet UL 478.
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• Almost 20,000 LH high power switchers now in use.

Write for 8-page catalog.

CIRCLE NO. 63

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For a limited time you can buy the pictured evaluation package at the 1000 piece price, nine (9) enclosures for $89.11. This offer expires February 14, 1977.

Tracewell enclosures are opening many previously uneconomical product areas with high quality enclosures at low prices. Two exciting new series have just been added to the successful line. These are all included in the evaluation package.

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phone: (614) 263-3702

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Circuit Savers...
- AC POWER LINE PROTECTOR

Protects 110, 220, 380, 440 VAC line
1φ, 3φ - 50/60/400 Hz

The Series P operates rapidly to prevent damage to equipment operating on the AC power lines, by switching rapidly to a clamping state whenever a transient exceeds the clamping threshold. The units operate on overvoltages of either polarity, on 1φ or 3φ lines and recover automatically when the transient expires. Severe transient conditions cause the protector to switch to a crowbar mode and cause an external fuse or circuit breaker to operate.

CATALOG 801
Full line of protection modules for every hi-lo voltage/current requirement. Write or call for data.
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Electronic Design 26, December 20, 1976
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really saves
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CIRCLE NO. 359

Miniature switches

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Display devices

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Circle No.
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**Electronic Design** 26, December 20, 1976
Dialight
Switches
A switch for all reasons.

Reason 1: Dialight offers three switch configurations to meet all your needs—snap-action switches with silver contacts for moderate-level applications, snap-action switches with gold contacts for intermediate-level applications, and wiping-action switches with gold contacts for low-level applications. Each of these ranges is served by two switching actions—momentary (life: 750,000 operations) and alternate (life: 250,000 operations).

Reason 2: Dialight's snap-action and wiping-action switches come in a new modular design concept...a common switch body for either high or low current operation. All 554 series switches and matching indicators have the same rear-panel projection dimensions. The snap-action switching mechanism guarantees a fast closing and opening rate. This insures that contact force and contact resistance are independent of the switch's actuation speed. In the wiping-action switch, the contacts are under constant pressure (A unique Dialight design). This insures long life with a minimum build-up of contact resistance.

Both switch types are tease-proof.

Reason 3: Dialight offers a wide variety of panel and snap-in bezel mounting switches with momentary and alternate action configurations in SPDT and DPDT types. There are over 240 switch variations to choose from.

The 554 illuminated switch, designed for front of panel lamp replacement, gives you a choice of five different bezel sizes...¾” x 1”, ¾” x ¾”, ⅞” square, ⅜” square, and ½” square. The first four sizes are also available with barriers. You also get a choice of six cap colors...white, blue, amber, red, green, and light yellow...four different underlying filter colors...red, green, amber, and blue and a variety of engraved or hot-stamped legends...over 300 cap styles...over 100,000 combinations.

There is also a variety of terminal connections...solder blade, quick connect, and for PC board insertions.

Reason 4: Dialight's 554 series is designed as a low cost switch with computer-grade quality.

The 554 switch offers a wide variety of panel and snap-in bezel mounting switches with momentary and alternate action configurations in SPDT and DPDT types. There are over 240 switch variations to choose from.

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**Op amp category** | **What BiMOS contributes** | **RCA device**
--- | --- | ---
General Purpose | Wide applicability. Low cost. | CA3140, CA3130
FET Input | Lower device cost. Reduced circuit cost. Large input voltage range: capability of swinging to 0.5 V below rail. | CA3140, CA3130
Wideband | High slew rate with low ringing. | CA3140, CA3130, CA3100
Micropower down to 1.5 mW | Strobability. | CA3130
High Current up to 22mA | Eliminates driver stage. Low device cost. Rail-to-rail output swing. | CA3130

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**CA 3100**

**CA 3130**

**CA 3140**