Linear-IC amplifiers have limits. They drift, clip, overshoot, ring and add delay and noise. Some use more power than you can spare. But often data sheets don’t tell it all. “Typicals” abound while full ranges are absent for temp, input and supply-related data. Specs are quiet on noise. For amplification, turn to p. 72.

Note 5: The input offset voltage $V_{os}$.

Note 6: Due to limited temperature rise from junction to case, $T_j = 25 \degree C$.

Note 7: For voltage gain, use $\frac{V_{out}}{V_{in}}$. Common values: $R_{L} \geq 2k\Omega$, $V_{OUT} = \pm 10V$, $50,000$ to $300,000$. Common values: $10^6$ to $10^9$. Common values: $20$ to $180$. Common values: $50,000$ to $300,000$. Common values: $0.5$ to $5.0$.
Swage-Bond™...a revolution in trimmer reliability!

...here today at no extra cost in every Trimpot® Potentiometer

Historically, pin-to-element termination problems have been one of the primary causes of trimmer failure...especially during handling and P.C. board process operations. Bourns exclusive Swage-Bond™ process virtually eliminates pin termination failure...truly a revolution in trimmer reliability. Furthermore, Swage-Bonding results in a marked improvement in temperature coefficient consistency.

Other trimmer manufacturers utilize a simple clip-on termination. Some solder this connection, some rely on tension pressure alone. In the Swage-Bond process, the P.C. pins are secured through the substrate, with a high-pressure compression swage on both top and bottom sides. The pressure of the swage locks the pin solidly into the element, and thoroughly bonds it to the thick-film termination material.

The seal that seals...without springback
Bourns trimmers stay sealed when others fail. We know. We've tested them all. Bourns uses a chevron-type sealing technique, that seals without O-rings...eliminating the windup and springback that frequently occurs with such seals. The result is faster and more precise adjustability...with a seal that really works.

Wrap-around wiper for better setting stability
Bourns multi-fingered, wrap-around wiper delivers more consistent, more reliable performance. The unique design significantly reduces CRV fluctuations and open circuit problems due to thermal and mechanical shock...by maintaining a constant wiper pressure on the element. Compare the ruggedness of Bourns design with the common "heat-staked" wiper designs. Compare performance. Specify Bourns.

HERE'S PROOF:
Send for a copy of our new engineering report on TRIMMER PERFORMANCE. Tell us about your application, and we'll provide qualification samples that best suit your needs.

Bourns reliability is available at ordinary prices...off-the-shelf from nearly 100 local distributor inventories...plus our largest-ever factory stock. TRIMMER PRODUCTS, TRIMPOT PRODUCTS DIVISION, BOURNS, INC., 1200 Columbia Avenue, Riverside, California 92507. Telephone 714 781-5320 — TWX 910 332-1252.

International: HQ, Switzerland, 041/233 23 42 • Belgium 02/218 2005 • France 01/0393633 • Germany 0711/24 26 36 • Italy 02/52 56 88 • Netherlands 070/88 92 18 • United Kingdom 01/672 6531 • Japan 075 92 1121 • Australia 86 9410 • Brazil 257-3535 • India 373 544

CIRCLE NUMBER 252
The Model 186

art gallery.

Sine, square, triangle and dc
Pulse and ramp.
Trigger and gate
Amplitude Modulation
Frequency Modulation
Phase lock.

There's a whole lot more to the Model 186 than just pretty pictures. Like its calibrated phase lock and built-in oscillator for 1 kHz AM/FM capabilities. It also has 30 V p-p output plus continuous, triggered and gated modes. And it's the only generator that gives you the combination of AM and phase lock.

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*US domestic price only

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P.O. BOX 651, SAN DIEGO, CALIFORNIA 92112
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200 KHz-1000 MHz
Power Splitter/Combiner in a single unit... $44.95

Yes... it's no longer necessary to order several different models of power splitters/combiners if your designs are within the 200 KHz to 1000 MHz region. If your design is relatively narrow band, you can expect tighter specs.

Order Mini Circuits new, versatile model ZFSC-2-4 offering these benefits:

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- tighter specs over narrower band range
- lower cost with single-model, high volume purchasing
- fast delivery, one week maximum

For narrower bandwidth applications models in the ZFSC series are available at low prices starting from $31.95 (see chart)
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94 Use equations to parallel transistors. To get through the graphical morass, balance your currents with simple arithmetic and straight-line approximations.
100 Float your input amplifier and you can almost laugh at ground loops or high common mode-voltages. A new design gives low drift, too.
106 Measure phase noise in one of three ways, each of which has some advantages. Quadrature phase detection, for one, lets you avoid dynamic-range limits.
112 Measure SAW-device characteristics, and pin down the performance of acoustic-wave filters and delay lines. Frequency response and impedance are key specs.
120 Build a high-frequency synthesizer with a digital mixer in a phase-locked loop and use fewer and slower divider/counters in conventional loops.
126 Dick Lee of Siliconix speaks on making your engineers bigger.

Idea for Design:
Convert seven-segment numerical code to decimal with simple gates. Optical couplers isolate, control and monitor to allow 6-kv supply to float. Approximate the tangent function with a multifunction converter and op amp. Trace symbols on CRT screen with access to the Z axis.

International Technology

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Cover: Designed by Art Director Bill Kelly, photo courtesy of National Semiconductor, Santa Clara, CA.
Microprocessing becomes a buyer's market.
If you're a MOS microprocessor customer, the last few years haven't been a whole lot of laughs. One supplier had all the good stuff, made all the rules, told you what you could buy. And when. And for how much.

But something happened to change all that:

Advanced Micro Devices.

We make the best microprocessor in the world, the Am9080A, and we make all the support circuits you need. They're yours now, off the shelf, at competitive prices. That's right. Competitive.

But we make more than microprocessor products. We make you a promise:

We make the best microprocessor in the world, the Am9080A, and we make all the support circuits you need. They're yours now, off the shelf, at competitive prices. That's right. Competitive.

Write or phone Advanced Micro Devices, The Buyer's Market.

But something happened to change all that:

Advanced Micro Devices.

We make the best microprocessor in the world, the Am9080A, and we make all the support circuits you need. They're yours now, off the shelf, at competitive prices. That's right. Competitive.

So, if you suddenly find yourself having an easier time buying microprocessors, just remember why. And who.

**Ours and Theirs.**

(The 9080A & 8080A)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Intel</th>
<th>AMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Instruction Cycle Time</td>
<td>1.3 microseconds</td>
<td>1 microsecond</td>
</tr>
<tr>
<td>Maximum Power Dissipation (at 1.3 microsec)</td>
<td>1307 milliwatts</td>
<td>829 milliwatts</td>
</tr>
<tr>
<td>Output Drive</td>
<td>1.9mA @ 45V</td>
<td>3.2mA @ 4V</td>
</tr>
<tr>
<td>Minimum Input High Voltage</td>
<td>3.3V</td>
<td>3.0V</td>
</tr>
<tr>
<td>MIL-STD-883</td>
<td>Special</td>
<td>Standard</td>
</tr>
</tbody>
</table>

**AMD Part Number Description Availability**

**CPU**

<table>
<thead>
<tr>
<th>AMD Part Number</th>
<th>Description</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am9080A/2/-1/-4</td>
<td>0 to +70°C</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9080A/2/-1</td>
<td>25 to +85°C</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9080A/2</td>
<td>55 to +125°C</td>
<td>Stock</td>
</tr>
</tbody>
</table>

**STATIC READ/WRITE RANDOM ACCESS MEMORIES**

<table>
<thead>
<tr>
<th>AMD Part Number</th>
<th>Description</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am9101A/B/C/D</td>
<td>256 x 22 Pin</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9101L04B/C</td>
<td>256 x 22 Pin</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9102A/B/C/D</td>
<td>1K x 16 Pin</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9111A/B/C/D</td>
<td>256 x 18 Pin</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9111L04B/C</td>
<td>256 x 18 Pin</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9112A/B/C/D</td>
<td>256 x 16 Pin</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9113A/B/C/D/E</td>
<td>4K x 12 Pin</td>
<td>Stock</td>
</tr>
</tbody>
</table>

**DYNAMIC READ/WRITE RANDOM ACCESS MEMORIES**

<table>
<thead>
<tr>
<th>AMD Part Number</th>
<th>Description</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am9050C/D/E</td>
<td>4K x 18 Pin</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9050C/D/E</td>
<td>4K x 22 Pin</td>
<td>Stock</td>
</tr>
</tbody>
</table>

**MASK PROGRAMMABLE READ-ONLY MEMORIES**

<table>
<thead>
<tr>
<th>AMD Part Number</th>
<th>Description</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am9208B/C/D</td>
<td>1K x 8, 250 nsec max</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9216B/C</td>
<td>2K x 8, 300 nsec max</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8316A</td>
<td>2K x 8, 550 nsec max</td>
<td>Stock</td>
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</tbody>
</table>

**ERASABLE READ-ONLY MEMORIES**

<table>
<thead>
<tr>
<th>AMD Part Number</th>
<th>Description</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am1702A</td>
<td>256 x 8 1.0 nsec</td>
<td>Stock</td>
</tr>
<tr>
<td>Am2708</td>
<td>1K x 8, 450 nsec</td>
<td>1st Q. 1977</td>
</tr>
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**CPU:**

<table>
<thead>
<tr>
<th>AMD Part Number</th>
<th>Description</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am8212</td>
<td>8-bit I/O Port</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8216</td>
<td>Non-Inverting Bus Transceiver</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8224</td>
<td>Clock Generator</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8226</td>
<td>Inverting Bus Transceiver</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8228</td>
<td>System Controler</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8238</td>
<td>Extended Write System Controler</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8251</td>
<td>Prog. Communications Interface</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8255</td>
<td>Prog. Peripheral Interface</td>
<td>Stock</td>
</tr>
<tr>
<td>Am8257</td>
<td>Direct Memory Access Controler</td>
<td>2nd Q. 1977</td>
</tr>
<tr>
<td>Am8259</td>
<td>Priority Interrupt Controler</td>
<td>2nd Q. 1977</td>
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</tbody>
</table>

**SECOND SOURCE SUPPORT**

<table>
<thead>
<tr>
<th>AMD Part Number</th>
<th>Description</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am8236-4</td>
<td>High Speed System Controller</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9511</td>
<td>Arithmetic Processing Unit</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9517</td>
<td>Multi-mode DMA Controller</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9519</td>
<td>Universal Interrupt Controler</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9551/-4</td>
<td>Prog. Communications Interface</td>
<td>Stock</td>
</tr>
<tr>
<td>Am9555/-4</td>
<td>Prog. Peripheral Interface</td>
<td>Stock</td>
</tr>
<tr>
<td>Am25LS138</td>
<td>1-of-4 Decoder</td>
<td>Stock</td>
</tr>
<tr>
<td>Am25LS139</td>
<td>Dual 1-of-4 Decoder</td>
<td>Stock</td>
</tr>
<tr>
<td>*Am25LS273</td>
<td>8-bit Common Clear Register</td>
<td>Stock</td>
</tr>
<tr>
<td>*Am25LS374</td>
<td>8-bit 3-State Register</td>
<td>Stock</td>
</tr>
<tr>
<td>*Am25LS377</td>
<td>8-bit Common Enable Register</td>
<td>Stock</td>
</tr>
<tr>
<td>*Am25LS2513</td>
<td>Priority Encoder</td>
<td>Stock</td>
</tr>
<tr>
<td>*Am25LS2537</td>
<td>1-of-10 3-State Decoder</td>
<td>Stock</td>
</tr>
<tr>
<td>*Am25LS2538</td>
<td>1-of-8 3-State Decoder</td>
<td>Stock</td>
</tr>
<tr>
<td>*Am25LS2539</td>
<td>Dual 1-of-4 3-State Decoder</td>
<td>Stock</td>
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</table>

**IMPROVED SUPPORT**

<table>
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<th>AMD Part Number</th>
<th>Description</th>
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<tr>
<td>Am8238</td>
<td>High Speed System Controller</td>
<td>N/A</td>
</tr>
<tr>
<td>Am9511</td>
<td>Arithmetic Processing Unit</td>
<td>N/A</td>
</tr>
<tr>
<td>Am9517</td>
<td>Multi-mode DMA Controller</td>
<td>N/A</td>
</tr>
<tr>
<td>Am9519</td>
<td>Universal Interrupt Controler</td>
<td>N/A</td>
</tr>
<tr>
<td>Am9551/-4</td>
<td>Prog. Communications Interface</td>
<td>N/A</td>
</tr>
<tr>
<td>Am9555/-4</td>
<td>Prog. Peripheral Interface</td>
<td>N/A</td>
</tr>
<tr>
<td>Am25LS138</td>
<td>1-of-4 Decoder</td>
<td>N/A</td>
</tr>
<tr>
<td>Am25LS139</td>
<td>Dual 1-of-4 Decoder</td>
<td>N/A</td>
</tr>
<tr>
<td>*Am25LS273</td>
<td>8-bit Common Clear Register</td>
<td>N/A</td>
</tr>
<tr>
<td>*Am25LS374</td>
<td>8-bit 3-State Register</td>
<td>N/A</td>
</tr>
<tr>
<td>*Am25LS377</td>
<td>8-bit Common Enable Register</td>
<td>N/A</td>
</tr>
<tr>
<td>*Am25LS2513</td>
<td>Priority Encoder</td>
<td>N/A</td>
</tr>
<tr>
<td>*Am25LS2537</td>
<td>1-of-10 3-State Decoder</td>
<td>N/A</td>
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<tr>
<td>*Am25LS2538</td>
<td>1-of-8 3-State Decoder</td>
<td>N/A</td>
</tr>
<tr>
<td>*Am25LS2539</td>
<td>Dual 1-of-4 3-State Decoder</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*All combine high performance and low power in space saving 20-pin package.*
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.
Another HP-25 variation

I have received many letters from other ELECTRONIC DESIGN readers in response to my letter, and I have exchanged calculator programs with many of them. I was interested in Mr. Lewart's letter (ED No. 15, July 19, 1976, p. 11) in which the HP-25 program given for the binomial coefficient evidently has several misprints.

A program can be written in 17 steps with the same general procedure apparently used by Mr. Lewart, but with one less storage register. (This may be important because in general program use, the HP-25 has a couple of storage registers less than could be effectively used by the sizes of programs possible.) Here is a variation of that program, which is suitable for stand-alone use, but which is even shorter.

\[
\begin{align*}
\Sigma + \\
\uparrow \\
RCL \ 4 \\
RCL \ 7 \\
gx = 0 \\
GTO \ 14 \\
\div \\
x \\
1 \\
STO - 4 \\
STO - 7 \\
CLx \\
GTO \ 03 \\
\downarrow \\
n
\end{align*}
\]

To compute \( k:nk \), \#PGRAM, \#REG, R/S. It is preferable to use the smaller of \( k \) and \((n-k)\) for \( k \). (The other program version is obtained by replacing the first two steps with \( STO \ 7; \): \( STO \ 4 ; 1 \); and increasing the addresses in the GTO statements by 2. Then the \#REG is not needed.)

The programmable pocket calculator quickly seems to be reaching a calculation capability that makes it competitive with computer use in many situations. The readers of ELECTRONIC DESIGN seem determined to stay in the forefront of such developments.

Henry E. Schaffer
Professor of Genetics
North Carolina State University
School of Agriculture
and Life Sciences
Box 5487
Raleigh, NC 27607

Ed. Note: A corrected version of Mr. Lewart’s program appeared in the October 25 issue.

Get your Optical Industry Directory


Real world can be a rough place

Leland Langston's circuit for detecting asynchronous data edges (ED No. 22, Oct. 25, 1976, p. 192) is beautifully simple. In the real world, however, things often aren't so simple.

If the data input is truly sync-
(continued on page 8)
ACROSS THE DESK

(continued from page 7)
chronous, its transition may violate the set-up/hold requirements of flip-flop FF,. Behavior of the flop under such conditions is not specified. FF, may be unable to resolve the input; it may glitch—enter an unstable state that, in the case of TTL, may last much longer than the specified propagation time of the circuit. The resultant output of gate G, may very well look like this:

<table>
<thead>
<tr>
<th>DATA IN</th>
<th>CLOCK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Either or both glitches, X and Y, may be present, giving a variable total of from two to four output pulses.

Therefore, the data input to FF, must be synchronized with the clock in order for the given circuit to function reliably as intended.

Richard F. Binder
Engineer
Modular Computer Systems, Inc.
1650 W. McNab Rd.
Fort Lauderdale, FL 33309

A 'petite' protest

In "Compact High Voltage Supply Stands Tall in Performance" (ED No. 17, Aug. 2, 1976, p. 100), you make an apples and oranges comparison of three high-voltage power supplies. No mention is made that two of the three are designed to meet MIL specs, operate over a temperature range of \(-55\) to \(+71\) C, and be able to survive the MIL environments. The featured supply is commercial grade.

The article also implies that you get more for your dollar if you buy a large rather than a "petite" HV power supply. We can state from our experience that to squeeze 12 AVDC into a 6.4 in.\(^3\) case, provide comparable stability and regulation as power supplies three times the volume and meet all the MIL requirements at the same time are far more difficult and expensive. LectroLogic not only did this but we built our LP power supply with only hermetically sealed semiconductors, and used established reliability components.

Irwin B. Galter
President
LectroLogic Inc.
9406 N. 107th St.
Milwaukee, WI 53224

Misplaced Caption Dept.

Welcome to Thomson CSF. Our chief engineer will be right with you.

Sorry. That's the Boucher Room in the Frick Collection, New York City.

Of layoffs and leadership

Layoffs, layoffs, and more layoffs—is that what today's young engineer has to look forward to? As a young engineer new to the ranks of electrical engineering, I have already witnessed the deleterious effects upon both my colleagues and classmates: Graduates can't get jobs, and engineers—often the older, over-40 crowd—are laid off much too frequently, often having to support a wife and family on unemployment.

Yet I constantly read in our newspapers that engineers are in such great demand. Who is originating these stories? Could the IEEE be behind this dastardly deed?

Now I hear the IEEE leadership is dominated by academics and company executives, men who earn their livelihood by graduating more engineers, paying them less, and making them work uncompensated overtime. And when the interests of these men conflict with those of the working EE—as they often do—history shows who gets served first.

No other trade or professional association, union or federation would allow a member of management to be a union or association member, let alone a leader or officer! It is time we stood up to demand of the IEEE a stop to conflict-of-interest leadership. Then, and only then, will the IEEE become an organization that truly represents the engineer.

Robert Clare
Well Corp.
54 Cottage St.
Taunton, MA

Leadership

A corollary to your editorial, "COMPANY POLICY," in the December 6th issue, could relate to the willingness of managers to be led by the computer. "It is a 'sophisticated' tool; we are sophisticated; ergo we will work with it. It is faster (hence better) than we are; so we will follow it."

Martyn Hodes
Spectral Dynamics Corp.
of San Diego
San Diego, CA 92112

FCC 'interference' beats equipment interference

The article on EMI/RFI (ED No. 20, Sept. 27, 1976, p. 24) is definitely not up to your usual standards. Even on the cover of the magazine, you point out that EMI/RFI is "racing out of control," but then you go on to complain about the actions of the FCC to reduce these problems.

I, for one, applaud the FCC for finally getting in gear to update its regulations, and I think your magazine and our profession should offer help and solutions that provide jobs rather than allow selfish interests to whine about "interference." Better a little government interference than a lot of rf interference!

Wilson Lamb
Research Associate
Ocean Engineering Department
University of Rhode Island
College of Engineering
Kingston, RI 02881
Direct connection is made to the microprocessor with the "clothespin" clip. The EXTERNAL connections are through separate leads. These may plug directly onto test pins, or they may be inserted in pincher-type miniature probes as shown. The display on the CRT is a probe test verifying internal operations of the logic analyzer.

As new applications for microprocessor-based systems proliferate, Hewlett-Packard recognized the need for an instrument that could handle the vast quantity and complexity of data during system debugging. This measurement need resulted in the development of the new HP 1611A logic state analyzer with powerful triggering capabilities, mnemonic display and time interval measurements, saving you a significant amount of time in debugging microprocessor-based systems.

An extremely important feature of (continued on third page)
Economical counters

The 80 MHz 5381A and 1.3 GHz 5300B/5305B are two of the choices HP gives you in economical counters. Two of the eleven 5300B modules are at the right; the D/A converter and battery pack.

Many counter problems only require a simple, economical and dependable instrument. It is for this reason that the frequency-only 5380 family and the modular 5300 system were developed.

The 5381A, 5382A, and 5383A represent an inexpensive solution to a frequency only measurement problem up to the frequency ranges of 80 MHz, 225 MHz, and 520 MHz, respectively. All these counters feature direct counting capability (a resolution of 1 Hz in 1 second), as well as an optional TCXO for improved measurement accuracy.

For applications involving counter measurements other than just frequency, the modular 5300 system is an excellent and economical solution. Configurations can be changed to meet different needs by simply snapping on an appropriate module. For example, frequency extensions to 1.3 GHz, time interval measurements to 1 ns, battery operation, digital multimeter, and even “talk” capability on the H-P Interface Bus are just some of the possibilities with the expandable and economical 5300 system.

For the whole story, check K on the HP Reply Card.

HP-IB programmable word generator with pulse parameter control for thorough digital testing

Hewlett-Packard’s 8016A word generator is a versatile 50 MHz data source ideal for digital testing applications. Using it, you first set up your test pattern in the generator’s 9-channel by 32-bit memory. By adjusting clock and inter-channel delays, pulse widths and amplitudes, you can easily simulate worst case or other conditions.

Multi-channel parametric tests such as set-up times, hold times, propagation delay, critical timing, sensitivity and noise immunity tests, are now easy with the total capability of the 8016A.

Now, you can use the 8016’s multi-channel capabilities in CMOS applications as well. A new accessory, the HP 15451A TTL to CMOS translator, amplifies 4 channels of TTL information to CMOS levels with pulse amplitudes determined by the CMOS power supply.

In combination with HP’s 1600A logic analyzer, you have a practical stimulus-response combination for observing your logic circuits in action. Functional tests of your logic circuits, memories, microprocessors, etc. can be performed quickly with the 8016A/1600A combination.

A remote programming capability, (Option 001) allows fast loading of data to the instrument’s memory with an HP Interface Bus compatible card reader, calculator, or minicomputer—a valuable option for on-line testing where speed and accuracy are important.

For details on this powerful word generator, check M on the HP Reply Card.
Microwave synthesizer application note now available

A new HP Application Note 218-1, Applications and Performance of the HP 8671A/8672A, details applications ranging from satellite communications testing to electronic warfare and component test. The 8672A (Microwave News, May 1976) has AM/FM modulation and calibrated output usually associated only with signal generators but also resolution, spectral purity, stability and programmability of a high quality synthesizer.

A typical section of the note describes a technique to obtain finer frequency resolution of 1, 2, or 3 Hz at microwave frequencies from 2 to 18 GHz. Another section covers considerations and additional equipment required for microwave coverage to 36 GHz by use of external doublers.

Other sections provide detailed information on the actual operational performance of the 8672A, giving the user considerable help in getting the synthesizer applied to his job quickly. For example, specific synthesizer programming sub routines are listed and annotated to assist in writing application programs.

For your free copy, check R on the HP Reply Card.

Dedicated logic analyzer (continued from first page)

the 1611A is its ability to display the mnemonic set used by the microprocessor in the system. If cycle-by-cycle analysis is desired, the data can be displayed in the absolute mode where the display is in hex or octal machine language. Eight additional uncommitted probes allow you to relate activity elsewhere in the system.

With new highly sophisticated triggering capabilities, the 1611A permits the framing of a real-time data window around virtually any event, or set of related events or desired sequence of system operations. The 1611A also accurately measures execution time or counts selected events between two keyboard-selected events.

Mnemonic display has been made possible by the use of "personality" modules—consisting of special circuits and microprocessor probe—to monitor specific microprocessors. Presently, two options are available: Option 080 for the 8080 and Option 068 for the 6800. Additional optional modules will be available shortly. To reconfigure your analyzer, parts can be ordered as a kit and easily exchanged in about 15 minutes.

An internal 8-bit MOS microprocessor is used as a controller in this new keyboard controlled logic state analyzer. The CRT displays both the measurement conditions and results.

For detailed information, check B on the HP Reply Card.

Conversonally interactive programmable data logger also operates in unattended mode

A programmable data logger is a system to collect and analyze data, make decisions based on the data and interact with the test, process, experiment, instrument, or the system which generates the data.

The 3051A system can measure dc from 1 microvolt to 200 V with 1 µvolt resolution, ac from 10 µvolts to 200 V with 10 µvolt resolution, and ohms from 1 milliohm to 10 Megohms with 1 milliohm resolution. The system measures dc at five channels per second, ohms and ac at 4 channels per second.

System configuration includes the HP 3455A high accuracy/resolution 6½-digit DVM, a 3495A input multiplexer, a 9815A computing controller, and a 9815A HP-IB I/O card.

The user communicates with the system via an alphanumeric keyboard; the system communicates with the user by a numeric display and an alphanumeric thermal strip printer. This conversational interaction capability allows the system to be operated by personnel with no formal knowledge of programming or data logging. Auto start capability allows the system to operate unattended.

For more information, check D on the HP Reply Card.

The Hewlett-Packard 3051A data logging system scans from 1 to 80 channels of analog data. A ten channel relay actuator card provides alarm and multiple switching functions.
Easy tape duplication with expandable storage up to 1 Mbyte using new external memory unit

The HP 9877A External Tape Memory is a self-contained peripheral that can hold up to four cartridge drives to expand the capabilities of the HP 9825A desktop programmable calculator. Using the same cartridge unit, storage capacity from 250,000 to 1 Million bytes is now provided in increments of 250,000 bytes.

Each tape cartridge unit has a built-in two-track drive which provides rapid access to data and programs with automatic verification of all stored information. A 2,750 byte/second data transfer rate and a 228.6 cm/second search speed makes it a very fast and inexpensive method of storing, retrieving or duplicating data. An HP 9877A, fitted with four tape units, takes about six seconds to locate any file from any tape in the unit.

Using the duplicator program supplied with the 9877A, a full master cartridge can be copied and verified in about 16 minutes. Two copies, from the same master data tape, are sequentially copied and verified in 26 minutes and four copies in 50 minutes.

For more information on expanding tape storage capability, check P on the HP Reply Card.

Now, interface your 9825A desktop to a teletype or a remote computer

Data can now be gathered from a remote terminal or computer, reduced and analyzed by the high speed processing of the 9825A desktop, and results returned to the remote location.

The HP 98036A bit serial interface opens new areas of application for the HP 9825A desktop computer. In addition to bit parallel, binary coded decimal, and HP-IB (Hewlett-Packard's implementation of IEEE Standard 488-1975) interface capability, the advent of the 98036A allows connection to such devices as teletypes, CRT terminals, and telephone modems.

Because of the flexibility of the 9825A desktop computer, the 98036A can be used to configure the 9825A as a timeshare terminal. This allows the keyboard of the 9825A to be used to send information to a remote computer. The 9825A display or an attached printer can be used for output information received from the remote computer eliminating the need for another terminal in a distributed system.

The vectored interrupt capability of the 9825A further enhances the usefulness of the 98036A. The desktop computer's buffered input/output scheme will allow multiple interfaces to communicate simultaneously with different remote devices while locally executing another program. Priority interrupts ensure that more important information can be dealt with quickly to maximize system throughput.

Configuration of the 98036A is accomplished via internal switches and by programming the 9825A. The number of bits per character, parity, internal/external data clocking, and bit rate are configured by the user. The 98036A operates in an asynchronous mode with data rates from 75 bits per second to 9600 bits per second.

For complete information, check E on the HP Reply Card.

Three more spectrum analyzer application notes

Three new application notes relating to spectrum analyzers have just been published. Subjects of these brief, informative notes are:

AN 150-9: Noise Figure Measurement
AN 150-10: Field Strength Measurement
AN 150-11: Distortion Measurement

In each case, the theory is reviewed, measurement procedures described, and examples of measurements presented. Advantages and tradeoffs that apply to using the spectrum analyzer are discussed.

For free copies of these new notes, just check Q on the HP Reply Card.
New display station handles both APL and ASCII data

Use the power of APL on a small general purpose computer

Hewlett-Packard designed the 2641A Display Station to complement the power and elegance of the APL language. Key to the secret of APL’s capability is a distinctive set of characters, each one symbolizing a powerful operation.

The 2641A is a member of the 2640 family of HP terminals that pioneered internal mini-cartridge mass storage and offers features such as self-test and “soft keys”. The 2641A has these family features, plus a versatile keyboard labeled with both the APL and standard ASCII characters.

The 2641A supports a full 128 APL character set, a 64 character overstrike set and a 64 character Roman set. These sets represent the special symbols used on IBM and Burroughs systems, and most symbols used by timeshare bureaus that support APL.

Overstruck characters, an APL innovation, are a combination of two existing characters and are produced by striking one key, backspacing, and striking a second key. Without the high resolution display of the 2640 family, overstrike characters would be difficult to read. The 2641A assures crisp, clear characters.

After a user inputs an overstrike character, a search and compare with the existing set in memory assures that the character is valid.

The full complement of display enhancements (inverse video, blinking, half-bright, etc.) are standard, and the optional line drawing set allows the creation of readable forms with visual prompts.

For more information on the 2641A, or other family members, check C on the HP Reply Card.

With the advent of APL\3000 in conjunction with the HP 3000 Series II computer and a new interactive terminal, the 2641A, designed especially for the language, APL is now more readily available as a new dimension in computational capability.

APL\3000 is the first APL software available on a low-cost general purpose computer. Patterned after APLSV, this enriched version from Hewlett-Packard is particularly useful for business, education, scientific and engineering applications involving the manipulation of large data arrays.

Use of microcode. The most time consuming aspects of the subsystem have been microcoded to speed operation. The 3000 Series II computer treats APL\3000 as a standard language subsystem. When APL is executing, up to 16 terminals may be operating either in batch or interactive mode, with any of the 3000’s other languages: FORTRAN, COBOL, RPG, BASIC and SPL.

Powerful easy-to-use editor. The APL\3000 editor is a full text editor as well as a function editor. Commands are given in English-like words. Anyone who has made a mistake in editing will appreciate “UNDO” which allows quick recovery from an editing error avoiding long, complex recovery edits typical of most editors today.

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APL, A Programming Language, has a large following of users, who embrace its use for its capacity to express complex mathematical applications in a concise manner; numerous computer operations can be compressed into just a few lines of code.

Because of its mathematical power, APL is of growing interest to those in the fields of statistics, finance, forecasting and modeling.

Hewlett-Packard’s APL\3000 has the following enhancements:

Large workspaces. Since work spaces are virtual, they are effectively limited only by the on-line disk storage available. As code is needed and used, it is brought from disk into main memory. APL\3000 is infinitely more useable with this close-to-infinite workspace. Microcoding the “virtual workspace” scheme results in faster execution.

Dynamic compiler. APL is implemented as a dynamic, incremental compiler and not a simple interpreter; compiled code is preserved and when possible, used repeatably without recompiling. The result is faster execution of repetitive programs.

For additional details, check A on the HP Reply Card.

A new interactive terminal designed especially for APL, provides a clear, sharp display. APL is a terse and concise language for describing processes and algorithms.
Multiprogrammer expands your testing capabilities

Test engineers can now plug off-the-shelf units together and assemble their own automatic test and measurement system quickly and economically. A calculator-based HP Interface Bus (HP-IB) multiprogrammer system is designed for ease in communicating bi-directionally with your device under test.

A basic system includes the controller, (a desktop programmable calculator HP 9825 or 9830) connected via the HP-IB to a multiprogrammer interface unit, a 6940B multiprogrammer, and from 1 to 15 randomly-addressable I/O cards that plug into the 6940B mainframe.

Up to 15 extender mainframes, each holding 15 plug-in cards, can be combined permitting system expansion up to 240 I/O channels controlled by a single calculator.

Input card functions include current or voltage monitoring, digital input, counting, and event sensing. Output functions cover stimulus and control including voltage, current, resistance, relay contacts, digital bit patterns, stepping motor control, time and frequency references.

For more details, check L on the HP Reply Card.

Step attenuators now operate dc to 26.5 GHz

The APC-3.5 connectors used on these HP 8495D/K 70 dB step attenuators are fully compatible with the industry-standard SMA.

Considerable microwave activity is now focusing on coaxial designs above 18 GHz. Such diverse areas as satellite communications and electronic warfare require measurement components operating to 26.5 GHz and beyond.

The new HP-developed APC-3.5 coaxial connector provides a mode-free, beaded, air line for operation to 34 GHz (Microwave Journal, July '76). By use of this new connector, a step attenuator from the HP 8495 series is able to operate dc to 26.5 GHz.

HP 8495D manual step attenuator offers 70 dB range in 10 dB steps. HP 8495K is the programmable version with the same specifications. Solenoids operate from 20-30 volts at 110 mA. These attenuators are composed of four attenuator sections (one 10 dB card, and three 20 dB cards) connected in cascade. Each section consists of a precision thin-film attenuator card, a lossless thru line, and a ganged pair of gold plated center conductor contacts that switch the attenuation card in and out. This combination results in high accuracy and excellent repeatability (typically 0.03 dB).

For details, check N on the HP Reply Card.

Take your instrumentation tape recorder with you

Now HP instrumentation tape recording quality is available to you in the field, where and when you need it. A dc to ac inverter, capable of operating your HP 3964A or 3968A instrumentation tape recorder, from either a 12 or 28 dc voltage source is now available as Option 021.

This new inverter option is included as part of the recorder itself and is specified as part of the original purchase. Total weight of the recorder with inverter is 31.3 kg (69 lbs).

If you have need for a rugged, portable tape recorder to be used in a variety of applications, send for data on the HP 3964A and 3968A recorders.

Please check F on the HP Reply Card.

A 66-page catalog describing consumables available for HP plotters, x-y recorders, strip chart recorders, oscillographic recorders, and instrumentation tape recorders is available.

Check G on the HP Reply Card.

Analysis of vibration is possible when you transport your instrumentation tape recorder with you. Shown above is a Hewlett-Packard ITR recording data "live" on a speedway.
Two new low-noise microwave transistors

No dc bias needed with new Schottky detector diodes

New isolator rejects 100X more common mode noise

For details, check J on the HP Reply Card.

Two new technical notes

AN 967 describes the design of a single-stage state-of-the-art low noise amplifier at 4 GHz using the HXTR-6101 silicon bipolar transistor. Both the input and output matching networks are described. For a copy of AN 967, check T on the HP Reply Card.

AN 968 discusses IMPATT amplifier design. A waveguide amplifier produced 2 watts of power with 10 dB gain at 11.2 GHz. Using a coaxial structure, similar performance was obtained at 8.4 GHz. For a copy of AN 968, check U on the HP Reply Card.

For a technical data sheet, check I on the HP Reply Card.

The HSCH-3000 series zero bias Schottky diodes are available in either ceramic or glass axial lead packages.

Application Note 951-2 describes how isolators can be useful in applications where analog or DC signals need to be transferred from one module to another in the presence of large potential differences or induced noise between the ground or common points of these modules.

Applications are those in which large transformers, expensive instrumentation amplifiers or complicated A/D conversion schemes are used.

The note covers the basics of optoisolator operation. Specific HP devices are recommended. For your free copy, check S on the HP Reply Card.

MEASUREMENT/COMPUTATION NEWS
High performance and precision PLUS wideband coverage—all in one RF sweeper

Hewlett-Packard's 10 MHz-2.4 GHz RF plug in (models 86222A and B) for the 8620C sweeper mainframe offers performance capabilities that make it a truly multi-purpose test signal source. It can cover the 10-2400 MHz range in one continuous sweep and deliver calibrated RF output from 0 to +13 dBm with full range flatness of ±0.25 dB. For each of its key performance characteristics—e.g., frequency accuracy, linearity, stability, residual FM, harmonics, spurious content—the 86222 matches or exceeds other wide-range RF sweepers.

For overall performance specifications, the 86222 stands alone. This excellence of performance also commends the 86222 for narrow-band sweep testing as well. In fact, many CW test requirements can be filled with this sweeper.

The 86222B version adds precision crystal-controlled 'birdie' markers (1, 10, 50 MHz) for additional precision and convenience in setting or identifying frequencies. These digitally-processed markers are uniquely compatible with such analysis systems as the HP 8410B (vector) Network Analyzer and the HP 8755 (scalar) Frequency Response Test Set. An applications-oriented data sheet presents many ideas on how this sweeper contributes to better RF testing.

For all the details, check O on the HP Reply Card.
Mas/Ter INTERCONNECT SYSTEM INSULATION DISPLACEMENT CONNECTORS

High-speed mass termination that lowers your total installed cost! Here's the most exciting advancement in connector technology since Cannon introduced D Subminiatures—our new Mas/Ter-D Subminiature rectangular series of connectors and Mas/Ter-UND header series.

Designed to lower your total installed cost with a new level of reliability in mass terminating up to 50 conductors... quickly... error-free!

Look at these advantages:

- 25% more conductor surface contacted.
- Integral strain relief on the conductor insulator.
- Uniform contact force under extreme temperature, shock and vibration.
- Mas/Ter-UND accommodates 26 thru 28 AWG, while Mas/Ter-D offers two ranges of 22/24 and 26/28 AWG.

With the Mas/Ter Interconnect System, the entire connector is terminated at one time with no insulation stripping, no complex tooling... using standard round conductor flat cable or individual wires, solid or stranded. The contact penetrates and displaces the insulation without severing the conductor and still provides insulation support to the wire. Integral contact spring action wipes the conductor during termination to produce a high-force, low-resistance interface.

Mas/Ter-UND connectors and pin headers are intermateable and intermountable with other similar connectors, and Mas/Ter-D pin-and-socket connectors are fully intermateable and intermountable with Cannon's D Subminiature series.

These are only the first of a growing family of insulation displacement connectors coming your way from Cannon.

Write or call today for new detailed literature! ITT Cannon Electric, 666 East Dyer Road, Santa Ana, California 92702. Call toll-free, 24 hr. (800) 854-3573. In California (800) 432-7063.

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CIRCLE NUMBER 8

Electronic Design 4, February 15, 1977
Chess and chance games win at electronics show

The microprocessor invasion of the home entertainment field is creating new generations of interactive video and other electronic games. Among such games highlighted at the Consumer Electronics show in Chicago were "man-against-computer" games, such as a chess game from Fidelity Electronics, and games that feature lifelike figures and objects, like General Instrument's new Black Jack and Slot Machine chip sets.

The standout of the interactive games at the show was the Chess Challenger (see photo), which can play against a Nippon Electric 8080 µP with a 2.5-k memory. The current Challenger is programmed, according to Michael Samole, executive vice president of Fidelity Electronics, Ltd., Chicago, so that an average player can beat it from 20 to 70% of the time.

As in regular chess, pieces are placed on a game board moved by the player. Whenever the player makes a move, he enters it on the keyboard. The computer responds with its best counter move, which is programmed in accordance with the standard rules of chess.

If the computer move checkmates the player, a LED indicator is energized. If the player beats the game, another indicator says, "I lose."

Any time during the game the position of all pieces on the board can be verified by stepping the game through its moves with an Enter button through which the game moves are placed in it.

While some of the top chess experts may beat this version consistently, Samole says that the program ROM can be expanded to 5-k or 7-k for more sophisticated moves.

The trend to complex, interactive video games that feature lifelike objects and figures was heralded at the Chicago show by an announcement from General Instrument's Microelectronics Div. of a series of chip sets for new games and chip-set combinations. The largest manufacturer of videogame chips demonstrated such interactive games as Black Jack, Slot Machine and Tic Tac Toe.

With GI's AY-3-8888 chip, both the Black Jack and Slot Machine games can be played against the resident microcomputer.

The Black Jack game is a single-player Las Vegas-style game that uses the equivalent of four-card decks (208 cards). The Las Vegas rules built into the game include doubling and insurance betting. The "cards," which appear on the screen with the suit symbol and a number are dealt from a virtual four-deck "shoe" stored in the µC memory.

The game starts after the player enters the amount in his bankroll. The game requests the player to enter a bet in $10 increments with a $90 limit. After a player places his bet, his hand and the computer's hand are dealt.

With GI's Slot Machine, the well-known bell, orange, cherry, dollar-sign, star and bar symbols appear on the screen in a three-box area that simulates the reels of an actual slot machine. Play begins after the game requests the player to either place a bet of $1 to $9 or in a continuous mode that automatically places a $1 bet. The mode runs repeatedly with the depression of a "0" key each time a bet is requested.

Lifelike figures and objects were also featured in Magnavox's Odyssey 500 game. Other highlights of the show included a variety of interactive third-generation video games, an interactive hand-held-calculator-sized football game from Mattel Electronics, and the demonstration of the first µP-controlled home pin-ball machine from Bally. Dubbed the Fireball, the machine contains diagnostic programs to enable the owner to pinpoint trouble right down to the µP circuit board.

Soviet process control will go the µP route

The Soviet Union is beginning to put microprocessors into its process-control systems, and this year will begin production of a new line of microprocessor-based controllers.

Microprocessors are being produced at five integrated-circuit facilities in Moscow, Leningrad and Siberia, according to Professor Boris Timofeev, a leading Soviet expert on process control in the metallurgy industry and a speaker at a series of process-control seminars sponsored by Control Data Corp. (CDC). Addressing newsmen at a Washington, DC, press conference prior to the seminars, Timofeev noted that for process-control applications, the microprocessors will use an 18-bit format—two 8-bit words plus two parity bits—and operate at 200,000 arithmetical functions per second. More complex functions call for microprocessors with word lengths of 30 bits or more.

The new controllers will be interchangeable with the current M6000 and M7000-series controllers, added Timofeev.

Small PBX system has 'large' capabilities

A small (24 to 120 lines) electronic PBX with features formerly available only with much larger PBX systems is now being marketed in the United States by Nippon
Electric Co. Ltd. (NEC) of Japan.

Besides more than 50 built-in service features, including a μP with stored-program control and all solid-state switches, the NEAX 12 offers several options: a station-message detail system, outgoing trunk queuing, flexible routing, call back and call waiting.

"Trunk queuing" occurs when a user finds all trunks busy. He dials a special code and hangs up. The processor remembers the call being placed and, when a trunk is free, calls back to let the caller dial his call.

The "call-back" feature provides a similar service for internal calls.

With "call waiting," when an outside call comes in and the line of the intended recipient is busy, the recipient may be alerted by a beep tone audible only to him. Then, if he wishes, he can take the new call while interrupting and holding the original party.

Unlike ordinary systems of its size, NEC officials say, the NEAX 12 need not be reprogrammed after a power failure. The generic program is nonvolatile and a memory package with built-in, rechargeable batteries assures protection of station data in the event of a power outage.

Other major features include plug-in modular construction that is fully connectORIZED, easy expandability that can increase the number of lines in 4-line steps up to a total of 120 lines, a console that indicates call progress with lighted letters rather than blinking lights.

The company plans to start manufacturing electronic products in the United States—the NEAX 12 to be one of them—by the end of this year.

**NDRO core memory protects data from noise**

A memory system for microcomputers, designed for use in heavily industrial environments, uses ferrite beads to achieve nonvolatility of its stored data. Once written, the data remain undisturbed through power outages and noise spikes and even during read operations. This feature can eliminate tape drives, floppy discs, firmware ROMs and other devices used to "bootstrap" the system into operation after a power outage or severe noise conditions.

Controlex's CM-203 Electrically Alterable ROM doesn't actually switch its ferrite cores, but only "tickles" them to read data out. "This results in a true nondestructive readout (NDRO), and the usual 'destroy-restore' cycle common to most memory schemes is bypassed," explains Bruce Kaufman, President of the Van Nuys, CA, firm. "This is important in a severe industrial environment because noise from welders and other sources could alter the data in the critical period of time between destructive read and replication of the original data."

Eliminating the "restore" phase of the Read cycle provides the CM-203 with an access time of 350 ns and a Read or Write cycle time of 1 ms. The unit also has a switch-operated Write Enable/Disable function that allows portions of the 4-k x 8 memory to be treated as a firmware ROM, while other sections can be used as nonvolatile Read/Write Memory for real time data.

A number of NDRO core memories produced in the early 1960s soon fell into disfavor because of the critical circuitry needed to access the stored data without actually switching the ferrite cores.

"Today, however, a wide selection of integrated circuits is available with which the task of NDRO can be accomplished reliably," notes Kaufman.

Packaged on an 8.5-in. x 12-in. circuit board that needs 0.75-in. spacing along the backplane, the CM-203 takes a +5-V supply and ±12-V supplies and consumes about 25 W. It is mechanized to be compatible with Intel's SBC-8010 Single Board Computer. The memory is priced at $500 each in OEM quantities.

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**16-bit bipolar μP chip suits tough environment**

The first 16-bit bipolar μP on a single chip operates over a temperature range of -55 C to 125 C and a speed/power range of several decades. The new SBP9900 I-L (Integrated Injection Logic) μP from Texas Instruments of Houston, TX, uses the same memory-to-memory architecture, the same instruction set, and the same software as the NMOS TMS9900 μP introduced by TI in 1975. Programs for the 9900 μPs also run on the TI 990/10 minicomputer.

The block diagrams for the two 9900 chips are identical, but the new I-L unit needs only one power supply instead of three and uses static logic that its single-phase clock to be stopped without losing data.

The variable speed-power feature, typical of I-L devices, offers savings in supply power in return for proportional cuts in speed and output current-sinking ability. At full power, 700 mW, the SBP9900 has a nominal clock speed of 3 MHz—2.5 MHz is guaranteed over the whole temperature range—and sinks 20 mA on each output, which is equivalent to 10 TTL loads. If the user chooses a lower injector-node current, operating the chip at 1/n of the 700 mW, the speed and output current are also reduced by a factor of n.

The bipolar SBP9900 has no speed advantage over the 3-MHz TMS9900. "But we see considerable potential for speeding up the SBP9900 later, perhaps in a -1 version," says Robert Bergeler, TI's Product Manager, I-L logic.

In a 64-pin Cedrip package, the TI SBP9900 sells for $386 in quantities of 100.

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**News Briefs**

Shortwave broadcasts on 2.5 MHz by the National Bureau of Standards' standard time and frequency station WWV will not be discontinued after all. The bureau has discontinued, as it announced it would, broadcasts on 20 and 20 MHz from WWV and 20 MHz from WWWH.

Sperry Univac has introduced its first small-business computer, the BC-7, priced for purchase in a range of $28,286 to more than $60,000. Principle competitors, Sperry says, are IBM's System 32, Burrough's B-80 and NCR's Century 8200.
TI introduces the Face Gripper.

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*Patent Pending

Texas Instruments Incorporated

Circle Number 9
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Rockwell’s instruction sets provide ROM efficiencies of typically 2 to 1 over other microcomputers. For example, some one-byte multi-function Rockwell instructions perform operations requiring five instructions in other systems.

More than 80% of Rockwell’s instruction types can be executed in one byte and in a single cycle. Special ROM instructions allow many subroutine calls to be handled in one byte. Table look-up instructions for MM77 and MM78 chips provide easy look up of stored data and easy keyboard decoding with minimal programming.

The PPS 4/1 family of one-chip computers.

<table>
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<tr>
<th>Model</th>
<th>MM76</th>
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<td>Availability</td>
<td>Now</td>
<td>Now</td>
<td>Now</td>
<td>2Q 77</td>
<td>2Q/77</td>
<td>3Q 77</td>
<td>16 wk ARO</td>
</tr>
</tbody>
</table>

Power supply is 15v except low voltage version of Basic 76 available 3Q 77. Typical power dissipation is 70mw.

Two 8-bit or one 16-bit presetable up/down counter with 8 control lines.

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Wage busting plagues engineers, but help may be on the way

It was 1971, and "John Smith," an electronics design engineer with Pan American World Airways at the Kennedy Space Center in Florida, was approaching his 50th birthday. He was making $17,000 a year, which wasn't a great deal. But there were compensations: The cost of living in the Cape Canaveral area wasn't as high as it was in other places; his wife liked her secretarial job with a real estate firm; they were buying a house to which they would eventually retire; his parents who had moved down from Michigan were now installed in a small apartment three blocks away. And the weather was superb.

Within a few weeks John Smith's salary was slashed to $9600—a cut of more than 40%.

The reason for this personal disaster? Pan Am's contract had been "recompeted"—a nasty word to some 25,000 employees of companies holding service contracts with the National Aeronautics and Space Administration, and to approximately 141,000 in a similar situation at military installations.

Recompetition is a common practice. When a service contract expires, or when the Government agency involved decides to renegotiate its terms, the contractor is often asked to submit a new bid along with proposals from other potential contractors that want to take over the job.

Competition is fierce, and the low bidder usually wins. The trick, naturally, is to cut costs to the bone, which in a service contract begins and ends with personnel. Whoever can be eliminated is laid off. And those who are kept on, stay for less pay—if such an arrangement can be made.

His salary is 'adjusted'

In 1971, Smith was reclassified from Systems Engineer to Electrical Design Engineer and given an "adjusted" salary—$17,000 became $9600. He couldn't tell his employers what they could do with the new salary—the space agency's budget had depressed the whole area. And it was hard to pick up and try someplace else: He was 50 years old, he had a mortgage—the list of restraints went on and on. So he stayed.

Over the next 18 months he was able to move up to $11,700, and finally, with another company, to $12,480. But in 1974 his contractor had to recompete, and suddenly he was working for RCA for $11,648.

"John Smith" was not an isolated case. Pan Am, with RCA Service Co. as a subcontractor, recompeted its contract with the Air Force at the Kennedy Space Center in 1972—for the first time in 22 years. Hundreds of people were fired and the engineers RCA kept on took a 15% pay cut. Some Pan Am engineers lost up to 30%.

Meanwhile, the military and civil-service employees at the center and those who worked at the island stations on the Air Force Eastern Test Range received cost-of-living increases.

Salary cutting, better known as "wage busting," is handled in one of two ways—always, however, with the same goal:

- The no-frills approach—management tells the engineer that if he wants to keep his job under the new contract he'll have to work for less pay.
- The subtle approach—management informs the engineer that his regular job has been phased out but that there is an opening with a

John F. Mason
Associate Editor
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These techniques can be used by the old contractor that has rebid and won, or by the new contractor that has squeezed the old one out. It's all the same to the engineer, except that with a new employer he loses his retirement plan, accrued sick leave and vacation time.

Not all service-contract employees are subject to wage busting, however. Blue and white-collar workers are protected by the Service Contract Act of 1965 ("... if a contract succeeds a contract, under which substantially the same services are being furnished, the employee cannot be paid less in wages or fringe benefits, or equivalent, than he was formerly paid.")

Salary of a typical Kennedy Space Center engineer, used to annual increases, dropped steadily from 1967 on—15% in 1972 alone.

But engineers, who are "professionals," have always been trimmable fat. They are not covered by the Service Contract Act, and they are not unionized.

Other professionals, such as mathematicians, physicists, scientists and computer programmers, are also without protection but since there are more engineers than other professionals, the engineers get hit the hardest.

The problem remains

The results of wage busting are still evident, said John L. Alexander, president of the Coalition of Aerospace Professional Employees at the Kennedy Space Center, at hearings conducted in Washington last July by the House Subcommittee on Labor-Management Relations of the Committee on Education and Labor.

Quoting a report by the Institute of Electrical and Electronics Engineers, Alexander told the Subcommittee that a survey last spring of RCA analysts (with engineering or physics backgrounds, and an average age of 44) revealed that they would have to receive a salary increase of 24% to reach the average salary for EEs in the Southwestern part of the United States.

To reach the 1975 national mean salary would require a 33% increase, Alexander added.

The engineers who suffer the worst losses of all are those who move over to a new contractor to keep their jobs. Depending on the fringe benefits provided by the former employer, the loss can be anywhere from $1000 to as high as $5000 a year.

In 1971, a PhD, who urges, "For God's sake don't reveal my name!" was surplused by a company that had lost its contract. A few days later he got this letter:

"The Boeing Company is pleased to offer you employment as Industrial Engineer at a starting salary of $135 per week based on a 40-hour week."

The engineer declined the offer and was out of work for two years. "Engineers whose wives didn't have jobs were in bad shape," he recalls.

There are innumerable engineers in a similar situation—none of whom wants to be identified.

One EE, age 42, went from a $20,000 job with Electrone in Huntsville in early 1972 to Teltronics for $18,000. In 1975, he went to work for Planning Research Corp. (PRC) at $14,500.

A senior engineer for Siemens, earning $20,000, went with PRC in 1975 for $16,000.

A senior EE for Martin Marietta, making $17,000, switched to PRC in 1974 for $8700. He couldn't live on this amount, so in 1976 he became a technical writer for another company at $12,480.

A senior staff engineer for Martin Marietta, making $23,000, went to PRC in 1974 for $12,500.

An electronic design specialist was making $18,500 with Boeing, then, in 1972, $13,000 as a design engineer for Pan American.

Salaries don't fit

"Engineers who are engaged in design-support service contracts range in the lower 30% of the national average," Charles O'Neal, a PRC employee, told the Committee on Government Operations' Subcommittee on Federal Spending Practices, Efficiency, and Open Government last May at Merritt Island, FL.

O'Neal described some of the effects of wage busting:

- Fringe benefits go down by $1000 to $2000—hospitalization coverage is reduced and sick time paid for by working overtime.
- Payment in money for overtime is discontinued.
- Accrued vacation time is lost when contractors are changed.
- Retirement benefits are cancelled.
- Special savings plans are eliminated.

Typical of a large number of engineers who eventually leave both the Cape Canaveral and Huntsville areas—many of them giving up engineering and going into totally unrelated businesses—is "Bill Jones"—an EE, a mechanical engineer and a professional with 20 years' experience.

Bill is an engineering supervisor when his company's contract with the Marshall Space Flight Center at Huntsville expires. Luckily, he is transferred to another contract within the company, so he isn't out of a job. But he is demoted to a "senior level engineer" and given a $1000 salary cut.

Within a year this contract is

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CIRCLE NUMBER 12
lost, and Bill is offered a job by
the new contractor—for $3000 less.
(“How do you think the new con-
tactor won the contract from my
old contractor to begin with?” Bill
asks.)

Bill refuses and goes 10 months
without work. Finally, he has to do
something. He asks the contractor
if the offer of 10 months before
still stands. Yes, says the contrac-
tor, but for $5000 less, not $3000.
Bill accepts.

Later that year, a new contractor
comes to town and notifies Bill and
several colleagues that their con-
tactor is on the way out. “Would
you like to sign with us?” the
newcomer asks. “The salary won’t
be quite as good, of course. After
all...” This time the cut is $3000.

“It was flattering to be in such
demand,” Bill recalls, “but that
would have made a $9000 pay loss
in a very short period of time. I
realized that if I didn’t restrain
myself and start turning down of-
fers I’d be working free.”

Bill is now in the process of leav-
ing Huntsville. He’s found a job
elsewhere in another field.

Age hurts, too

Wage busting is harder on peo-
ple in their 40s and 50s than on
younger men, everyone agrees. Age
discrimination exists. It’s hard for
middle-aged engineers to find work.
And after 20 or 25 years with a
company, they have built up equity
they don’t want to leave. Also, they
are usually more firmly entrenched
in the community, economically and
otherwise—their house is almost
paid for, they have bought interest
in a fishing lodge nearby or they’re
making plans to retire.

Many engineers who have hung
on through thick and thin with
RCA—they accepted the 15% cut
in 1972 and survived—are worried
again. This time the Air Force
will contract directly with Pan Am
and RCA, ostensibly to prevent
Pan Am from making a profit on
a subcontract with RCA. “But
that’s not the frightening part,”
an RCA engineer says. “Although
Pan Am’s and RCA’s contracts
have been recompeted several times,
they have always been Cost Plus
awards. The new contracts will be
Fixed Price.

“A fixed-price contract is far
too restrictive for work as com-
plex as this—taking care of the
instrumentation, including radars,
here at the Cape and on the range.
A lot of people are going to be
hurt, as well as the calibre of the
work that we, or anyone who’d
come in and take our place, will be
able to do.”

What’s the solution? “You can’t
really blame the contractors too
much,” another RCA engineer says.
“They’re forced to bid low to get
the award. You can blame the Air
Force and NASA a little more, but
they, too, follow the law—if a
company is technically competent,
the award must go to the lowest
bidder.”

Air Force busts less

“The Air Force has been some-
what fairer than NASA,” a former

Engineers working on the Eastern
Test Range for RCA and Pan Am
under Air Force contract have suf-
fered salary cuts while civil service
personnel working alongside have
enjoyed steady increases.

Kennedy Space Center engineer
says. “Since 1969, contractor engi-
neers with the Air Force have
taken a $2500 cut while those on
contract with NASA have taken a
$5600 cut.”

Contract companies say they
don’t like wage busting, but refuse
to discuss it. When asked for its
official position, RCA’s execu-
tive group at Cherry Hill, NJ,
held a meeting and came back with
a firm, straightforward “no com-
ment.” “It’s like when did you stop
beating your wife,” an RCA repre-
sentative says. “We’d just pre-
fer not to get involved.”

Pan American at Patrick Air
Force Base, FL, returned no calls.
Personnel at PRC headquarters in
Virginia said “the company is so
departmentalized that no one would
be able to speak for the different
support-contract operations.”

NASA stated at the Merritt Is-
land hearings that it’s aware that
“it’s not in the best interest of the
government to select a contractor
purely on a low-cost basis when
there’s a likelihood that he can’t
employ the needed talent at the
wages proposed.” But as of that
time, “NASA management has not
decided on the best way to ap-
proach recompetitions.”

NASA and the Air Force are
held back by the Government
Accounting Office. “Specifically,”
says a NASA spokesman, “the
GAO has ruled that a contract may
not prescribe a minimum rate of
wages to be paid by a contractor,
in the absence of a specific statu-
tory authority.”

Engineers aren’t covered

The Service Contract Act of
1965 is such an authority. But it
doesn’t cover “professional” em-
ployees.

NASA’s only option, according
to the spokesman, is to use lan-
guage in its proposal instructions
that would discourage “so-called
wage busting.”

But so far NASA’s efforts to
toughen the language of its pro-
sposal instructions have disappoint-
ed Cape Kennedy engineers. The
new language states, in part:
“...Proposals which are unrealis-
tically low or do not reflect a rea-
sonable relationship of compensa-
tion to the job categories so as to
impair the contractor’s ability to
recruit and retain competent per-
sonnel may be deemed reflective of
failure to comprehend the complex-
ity of the contract requirement.”

“I can’t believe NASA couldn’t
come up with stronger language
than that,” says an engineer who
has worked on NASA contracts for
20 years.

At this point, NASA has very
little way of knowing how its con-
tractors match salary with respon-
sibility except for a few key per-
sonnel. The agency’s proposal
instructions state: “Resumes for
other than key personnel will not
be considered, and therefore, should
not be submitted.”

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tent, one statement in the agency's proposal instructions actually seems to encourage wage busting: "The Kennedy Space Center area, where the bulk of the effort will be performed, is an area of high unemployment. Although workforce selection is the prerogative of each proposer, recognition should be given to this high unemployment. Therefore, each offeror's recruitment plan and labor relations policies should demonstrate how they relate to the local labor situation."

"It sounds as though NASA's saying 'there are a lot of guys down there who'll work cheap—go get 'em,'" one engineer says.

"The blame belongs to the legislators who—perhaps innocently—push for fixed-price contracts and lowest-bidder-wins procedures, and who neglect to include protection for all kinds of employees in the Service Contract Act," says one long-suffering engineer at the Kennedy Space Center.

Legislation that would amend the Service Contract Act to include professionals was introduced last year by Representative Frank Thompson, Jr. (D-NJ) and Rep. James C. Corman (D-CA). The Congressmen knew it was introduced too late to get through last session, but they wanted to establish a basis for early entry in the new session.

On January 4, the first day of the new session, the bill was reintroduced, this time carrying the designation HR 314 (for π).

With 314 incorporated into it, the Act would protect professionals from wage busting as it now does blue and white collar workers. An engineer's salary could not be cut when a new contract goes into effect, if he is doing essentially the same work.

Opposition is lined up

Strongly opposed to the bill is the National Council of Technical Service Industries (NCTSI), which consists of 16 contractor members, including Avco, Boeing, Control Data, Federal Electric, Hughes Aircraft, Lockheed, Northrup, PRC, Raytheon, RCA and Systems Development Corp.

"It is our considered opinion that Congress need take no immediate action to either amend or extend the Service Contract act beyond its present scope as interpreted by the decisions of two U.S. district courts," said Edward C. Leeson, NCTSI executive director, at the House Subcommittee hearings in Washington last July.

"We're getting a little tired of this wage busting horseshit," Leeson recently told ELECTRONIC DESIGN.

"These people represent an iso-

Professional engineers opposed

Though far less vehement than the NCTSI, the National Society of Professional Engineers, headed by Paul H. Robbins, also opposes the bill.

"The problem with the Service Contract Act is that it applies to all Federal contracts, and there are many aspects of the payment in which professional people are involved which are quite different from the situation at the Cape and Huntsville. We'd like to zero in and solve the problems at the Cape and Huntsville without encompassing all the other contracts with the government that involve professional people.

"There are 350,000 engineers and scientists involved in the nation's R& D effort. We don't like the idea of setting the Labor Department or any other government agency up to establish their salaries."

The solution? "Do it by strong wording in the procurement regulations."

Both organizations are adamantly opposed to "falling into the clutches" of the Labor Department—delegating it any control of the problem. They prefer the executive branch to be in charge, which means putting clout into the procurement regulations, an approach that most engineers and many Congressmen believe is unrealistic. Both groups also fear "loss of professionalism" if salaries become fixed.

IEEE's John Guarerra believes a bill can be written so that "professionalism" will not be endangered and that all parties concerned can be appeased.

"Everyone is going to have to be willing to compromise," Guarerra says. "Everyone has got to contribute to writing the law."
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So for custom IC's, write Jim Meyer or call him at (714) 979-0941.
A digital-to-analog converter unveiled at this week's International Solid State Circuits Conference is not only the first monolithic 12-bit DAC, but also the first to avoid laser trimming. Instead, it makes use of a zener trim technique that permits precision adjustment after the DAC is hermetically sealed.

Under development by Precision Monolithics, Santa Clara, CA—and expected to be in production by mid-1977—the single-chip DAC-12, reportedly will be not only the smallest (24,000 mil² total chip area), but also the lowest-powered and fastest 12-bit DAC available.

The part is pin-compatible with Analog Devices' Model AD-562, a two-chip laser-trimmed hybrid that has led the 12-bit spec/cost race since its introduction in 1975.

The DAC-12 will have a faster settling time than the AD-562 (300 to 500 ns vs 3.5 µs), use half the power, be compatible with more digital logic families and use inexpensive plastic and Cerdip packages. Most hybrids use side-brazed metal cases with ceramic substrates.

Although details have been sketchy, a 12-bit single-chip d/a converter, also pin-compatible with the AD-562 but 35 times faster, is under development by Harris Semiconductor, Melbourne, FL. But what makes PMI's DAC-12 doubly unique, according to its developer Don Comer, is that its design eliminates the need for time-consuming laser trimming. Instead, precision trims can be done by computer after the DAC is hermetically sealed, and burned in.

**DACs within DACs**

On the production line, a computer will sense the DAC's slight bit-current errors and negate them.

Dave Barnes  
Western Editor
Our new low-cost industrial converter products are standard, too.

Standards, like that plug, make life less complicated. That's why we're leading the campaign to standardize converter products. And the group you see here is just part of a growing family that starts as low as $19.50 in the 100-piece quantity. They're on-the-shelf, for quick delivery. A new line of DAC's and ADC's for designers who can use standard functions. Plus thin-film ladder networks and a precision voltage reference to give exceptional design flexibility.

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For data, write or call Helipot Division, Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. Phone: (714) 871-4848, Ext. 1776.

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CIRCLE NUMBER 15
by selectively and permanently shorting (zapping) the appropriate zener diodes on the chip. Each time a zener is shorted, one of 31 pre-trimmed selectable polarity current sources on the chip can be taken out of the circuit. The computer trims each of the six most significant bits as well as the full-scale current.

The trim circuit for each bit is itself a DAC. Fig. 2 shows that the trim circuit for the most significant bit is simply a 4-bit bipolar DAC using the zeners as hard-wired inputs.

The need for trimming makes a 12-bit DAC a formidable design problem. The state of the art in photomasking and processing, whether by diffusion, ion implant or thin film, is 9 to 10 bits without trimming, says PMI. Since a 12-bit DAC must be 10 times better, it must be trimmed. And, if it is to maintain 12-bit accuracy, the errors must remain below 0.0125%.

Conventional DAC trimming uses a laser at the wafer-sort production step to trim the ladder resistors. This laser compensates for both resistor and current-source mismatches.

There are six problems in laser trimming for 12-bit devices, PMI points out. The laser attachment to the wafer probe is expensive. The trimming takes a lot of time, about 10 times as long as zener zapping. Laser-beam resolution is limited, so large-area resistors are needed to trim to 0.01%. And because the laser actually burns away parts of the resistors, the trimmed chip's appearance is questionable for high-reliability products. But, appearance counts under MIL-STD-883.

Most important, the intense concentrated heat from the laser creates thermal stresses in the chip that may cause resistor values to change. Over the long run, these stresses may cause long-term drifts or instabilities in the DAC's accuracy, linearity or scale factor.

The chips are down

All known laser trim methods were extensively evaluated by PMI before the decision to use zener-zap trimming, recalls Earl Rogers, PMI president.

The PMI design adds no extra pins for zeners but cleverly uses the 12-bit input pins for zapping and bit control. A thresholding circuit recognizes the zap circuit and a \(6 \times 6\) matrix decoder steers it to the right zeners.

This pin-usage technique also lets us make the DAC-12 zappable either to binary or BCD coding,” Rogers points out. “A three-digit BCD DAC requires only about 0.1% matching. Therefore, if the zapping doesn’t bring in the DAC-12 to true 12-bit accuracy, it automatically zaps itself over to a three-digit BCD unit, the DAC-30, and in either case, after all trims are done, a ‘fail-safe’ zener is shorted to prevent any further code alterations.”

The DAC-12 will be priced from $20 to $30 in 100 quantities.

"Eat your heart out, B.G." is the message carried by the chewed heart and initials beneath. It’s PMI’s answer to an industry spokesman who said last year: “There are no monolithic 12-bit DACs on the market at present, and there never will be.”
Now, analog output is just this simple.

You no longer need to assemble D/A converters, address decoders and interface logic to obtain analog output from your microprocessor-based systems. Burr-Brown has solved the problem completely—for most of today’s popular microprocessors—with 32-pin DIP’s that provide two analog output channels each and look like memory to your CPU.

For 8080A and 8008 type µPs you need our new MP10. And for 6800, 650X and 9002 types, our MP11. Both of these bus-compatible Analog Output Microperipherals are self-contained, requiring no external components for most systems. And since they’re treated as memory by the CPU, just one 8-bit memory location is required per channel, and a single instruction is all you need to output data to both channels.

For analog input applications, you can combine one channel of an MP10 or MP11 with a few external components and use the microprocessor to perform the logic of a successive approximation A/D converter. The second channel continues to function as an analog output.

Both the MP10 and MP11 provide ±10V outputs with 8-bit resolution and throughput accuracy better than ±0.4% of full scale range. With a price of just $99 (100’s), it just doesn’t make sense to design your own analog I/O solutions. Send for details today. Write or call Burr-Brown, International Airport Industrial Park, Tucson, Arizona 85734. Phone (602) 294-1431.

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CIRCLE NUMBER 16
Before you laugh, you better read.

Taken it for granted all these years, haven’t you — that old, established glass zener that’s everybody’s commodity and nobody’s state-of-the-art? After all, one supplier’s is pretty much like another’s. And it’s really funny how some of them knock themselves out with special deals and reduced prices just to get your biz, right?

Get serious. It’s not all over in 400 mW at Motorola. Never.

Our word is our bond

Metallurgical. Only Motorola 1N746/957 units have it down to 1.8 V.

Not a solder, but a homogeneous intermix of metal molecules between die and lead ensuring true metal continuity all the way through.

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Motorola DO-35’s withstand in excess of 30 pounds lateral lead pull. Try that with a TI, Siemens, ITT, etc.

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Not your average zener

There’s more in it. Computerized diffusion and testing. Oxide passivation. Laser scribing. Automatic inspections. MOS-inspired processes. 100% contact tests. And the largest active area with the biggest surge current rating of any DO-35.

As usual, the only thing we offer is everything. Unique.

Price. The secret word.

Pennies buys it all. At 25,000 pieces, unit cost is just 9¢.

Look at the quality. Look at the technology. Look at the reputation. Unique.

Maybe it’s time to take a look at the leading-edge quality of Motorola DO-35 glass zeners. Even though your present source soberly tells you his are just as good.

What a laugh.
Technology Breakthrough!

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This breakthrough in high voltage — high temperature ceramic capacitors provides the equipment designer ways to achieve new goals in design and reliability. Semtech high voltage capacitors were initially developed to meet stringent in-house requirements utilized in the manufacture of our industrial and military type solid state high voltage assemblies and multipliers. The resulting products have exceeded our most optimistic expectations. We have now set a new standard of excellence for high voltage ceramic capacitors. As a result of the many inquiries for these devices from our rectifier customers, we have established a production capability and we are now able to offer these new “state-of-the-art” capacitors for sale to the industry. These devices are now available in quantity from stock at pricing low enough for use in commercial applications.

"MONO" Chips

Construction: Monolithic with end terminations
Voltage: 1, 2, 3, 4 & 5KV
Capacitance: 18pF to .39 µFd
Dimensions: (Body) from .23” L x .19” W x .15” to .65” L x .60” W x .25” T

“GOLD CAP” Radials

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Capacitance: 18pF to .39 µFd
Dimensions: From (Body) .38” L x .29” H x .25” T to .80” L x .70” H x .35” T

Two Dielectric Types Available!

<table>
<thead>
<tr>
<th>X7R</th>
<th>NPO</th>
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<tbody>
<tr>
<td>Temperature Coefficient (T.C.)</td>
<td>0 ± 15% to +125°C</td>
</tr>
<tr>
<td>Dissipation Factor (D.F.)</td>
<td>2.5% max 1 KHZ, 1 VAC, 25°C</td>
</tr>
<tr>
<td>Insulation Resistance (I.R.)</td>
<td>100 K megΩ or 1000 megΩ microfarads, whichever is less (25°C, 500 VDC)</td>
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<tr>
<td>Aging</td>
<td>1% per decade</td>
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<tr>
<td>Dielectric Withstanding Voltage</td>
<td>1.2 Times Rated Voltage*, at 25°C</td>
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<tr>
<td>Voltage Coefficient (V.C.)</td>
<td>Less than 7% at 50 V per mil.</td>
</tr>
<tr>
<td>Dimensional Tolerance</td>
<td>± 0.010 or 5%, whichever is greater</td>
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</table>

*Dielectric Withstanding Voltage Test on Monolithic Chips and Gold-Caps is conducted with charging current limited to 10 mA and the discharge current limited to 5A.

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CUSTOM ENGINEERED PLASTIC MOLDINGS
Speedy arithmetic circuit unburdens busy microprocessor systems

Taking much of the calculation load off a µP-based system can accelerate processor speed. Up to now, however, all of the available calculator circuits haven’t been fast enough to unburden the µP. Advanced Micro Devices plans to change that with its Am9511 arithmetic-processor unit.

The 9511 connects either to a µP bus or via a DMA interface to the µP's memory and can do floating or fixed-point arithmetic, trig functions, inverse trig functions, square roots, logarithms and exponentials. An 11-kbit ROM on the chip does calculations by using Chebyshev polynomials.

The NMOS circuit can perform 32-bit floating-point additions in 8 µs, subtraction in 12 µs, multiplications in 38 µs, divisions in 41 µs, rooting in 184 µs, trig operations in a minimum 550 µs and inverse trig operations in a minimum 900 µs—all based on a 4-MHz clock rate.

Two versions of the 9511 are available: a 2-MHz unit called the 9511 and a 4-MHz model, the 9511-4. Thus, typical execution time for an 8-bit floating-point multiply operation is either 76 or 38 µs—both much faster than an

High-reliability control system uses three microprocessors

Redundant processing for high-reliability applications isn’t new, but off-the-shelf systems still aren’t commonly available. To solve this problem, Digital Dynamics of Sunnyvale, CA, has developed the System Q3—a triple-redundant microprocessor system for industrial-control applications that cannot be halted.

The triple system is built around three of the company’s 4004-based Q-series processors. Each processor simultaneously handles the input data and compares its results with the results of the other two processors. A software “voting” procedure determines which output will be selected—if one unit disagrees with the other two, it is voted down and alarm and diagnostic signals are generated to indicate a possible failure.

Dual-redundant power supplies with optional battery backup are diode-isolated and monitored by the processors.

The System Q3 hardware-software package has a base price of $16,500.
8080 software subroutine, which requires 3 to 4 ms to perform a similar function.

All transfers, including operand, result, status and command information, take place over an 8-bit bidirectional data bus. Transfers to and from the 9511 can be handled by the associated processor using conventional programmed I/O, or by a direct-memory-access controller. Upon completion of each command, the arithmetic chip generates an interrupt request to signal data are ready for the processor.

Two supplies, +5-V and +12-V, are required. A 24-pin DIP houses the circuit, and operation is specified for a 0-to-70-C range. Initial sample prices for the 9511 are expected to start at $100, and units will be available around July, 1977.


CIRCLE NO. 503

Video display board appears as a 4-k RAM to processor

Capable of storing and displaying a 24-line × 80-column field of ASCII characters, the MTX-2480 video RAM board can connect to almost any microcomputer bus. The unit generates a video signal that can directly drive any standard video monitor (10-MHz bandwidth, min.).

Outwardly, the MTX-2480 looks like a 4-k × 9 RAM that is TTL-compatible and has an access time of less than 500 ns. Characters are normally displayed as white on a black background, but can also appear as black on white, half-intensity, or blinking. Both American (60 Hz) and European (50 Hz) operation can be configured on the board.

The 7 × 7.5-in. board that holds the video RAM costs $290 in 100-unit quantities and is available from stock.

Matrox Electronic Systems, P.O. Box 56, Ahuntsic Stn., Montreal, Quebec, H3L 3N5, Canada. Lorne Trottier (514) 481-6838.

CIRCLE NO. 504

Two-board evaluation kit simplifies 6800-system prototyping

Prototyping and programming 6800-based systems can now be done with a combination hardware and software-development aid kit. Developed by Motorola, the MEK6800D2 kit has two printed-circuit boards with all the parts necessary to get a complete 6800 system up and running.

One board handles all the keyboard control, address and data display, and audio-cassette interfaces. The other board is the CPU, and even has a small breadboard area for custom interfacing. The cassette interface uses the "Kansas City Standard" for recording and playback levels. The transmitting rate is crystal controlled.

The CPU board contains the 6800, two PIAs, three 128 ×8 RAMs and one each of the

(continued on page 46)
Burroughs low-cost 40, 240 and 480 character SELF-SCAN® II panel displays can help you reduce the size and weight of your data terminals by more than 50%. You'll reduce costs as well. And, at the same time, obtain excellent display readability under all operating conditions — indoors or out, day or night. Characters are uniformly bright, free of jitter and flicker with no fuzziness, distortion or loss of linearity at the display's edges. Character-to-background contrast is better than ever. And, the SELF-SCAN II panel's 40-character line is compatible with popular software.

Other significant advantages include direct digital address, easy interface to microprocessors, thin cross-section and rugged construction for long service life under all operating conditions.

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MICROPROCESSOR DESIGN

(continued from page 44)

ACIA, clock generator and J-Bug ROM. The J-Bug ROM has a monitor program that allows the user to communicate with the 6800 via hexadecimal keyboard, trace instructions, set breakpoints and examine registers. Eight special-function keys simplify program writing and debugging.

The Evaluation kit costs $235, and delivery is from stock.

Motorola, 3501 Ed Bluestein Blvd., Austin TX 78721. (512) 928-2600.

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Analog I/O subsystem designed to mate with SBC-80/10 µC

An analog input/output subsystem functionally, electrically, and mechanically compatible with Intel's SBC-80/10 single-board computer has been introduced by Analog Devices. The RTI-1200 is the first product in a series of subsystems.

The data-acquisition section includes a CMOS multiplexer, a programmable-gain amplifier, a sample-and-hold amplifier, and a 12-bit analog-to-digital converter. The basic version offers either 16 single-ended or 8 differential analog inputs, and an on-board expander option permits the number of available input channels to be doubled. Two analog-output channels that can convert 12-bit digital data into analog command signals are available optionally.

The RTI-1200 appears to the microcomputer as a block of memory locations. Software written for the subsystem can therefore make use of all memory reference instructions; hence, programming is simple.

Features of the data-acquisition subsystem include two-level overvoltage-input protection, with which input signals of up to ±28 V can be tolerated; software-programmable amplifier, whose gain via software can be set to 1, 2, 4 or 8; a 4-to-20-mA current loop I/O, which can be set for eight of the input channels; a pacer clock system, in which two clocks are available to implement a system real-time clock or trigger evenly spaced a/d conversions; and an on-board PROM capability that allows for a 2708 1-kbyte PROM, or the equivalent.

The RTI-1200 requires +5 and ±15-V power. However, an optional on-board dc-to-dc power supply converts the +5 V to ±15 V. Prices for the RTI-1200 range from approximately $629 to $979 each.

Analog Devices, Inc., Route 1 Industrial Park, P.O. Box 280, Norwood, MA 02062.
Lowell Wickersham (617) 329-4700.

---

Dual 8-bit I/O buffer includes 16-bit programmable timer

Housed in a 40-pin DIP, the IOB1680 does all the data-management functions necessary to support the CP1600 microprocessor. The MOS circuit from General Instrument can replace more than a dozen TTL MSI packages—and operates from a single +5-V supply.

The IOB1680 buffers data transfer between the microprocessor and all external memory and peripheral devices connected to a 16-bit wide input/output bus.

Moreover, its ability to perform three levels of priority-interrupt logic enables parity-bit

(continued on page 48)
Intel delivers resident PL/M for the Intellec Microcomputer Development System.
Say goodbye to monthly computer bills.

Now Intel has a resident PL/M compiler available with the Intellec microcomputer development system. Resident PL/M can give you a competitive edge because it can drastically cut your software development time and help you get new products to market quicker.

Having PL/M resident on the Intellec system means the end of monthly computer time sharing bills too. And eliminates delays waiting for computer availability. It makes it easier than ever to take advantage of a high level programming language.

You can lease an Intellec system for $610* a month with ICE-80™ dual diskette drives, CRT terminal, line printer and resident PL/M compiler.

Or if you already own an Intellec system you can add resident PL/M for $975* Once. Not monthly.

That gives you everything you'll need for fast, reliable programming of Intel® 8080 or 8085 microcomputers or our SBC-80 Single Board Computers and System 80 packaged microcomputer systems.

Under the new Intellec ISIS-II diskette operating system, PL/M provides the capability for fully modular programming. This means that programs can be developed and debugged in small, manageable modules, and easily linked together, or linked with general purpose subroutines from a software library. And because the Intellec system supports your total development task, you save the cost and inconvenience of separate systems for hardware and software development and systems integration.

To arrange a demonstration of the Intellec system with resident PL/M contact your Intel sales office. For additional information use the reader service card or write Intel Corporation, 3065 Bowers Avenue, Santa Clara, California 95051.

intel delivers.

*CIRCLE NO. 161 FOR TECHNICAL INFORMATION
CIRCLE NO. 162 FOR TECHNICAL INFORMATION AND A DEMONSTRATION

*Domestic U.S.A. prices only.
errors in peripherals, data-transfer requests and event-timer operation to initiate microprocessor-interrupt requests.

The IOB1680's 16-bit programmable timer can be used to sequence peripheral events. On the chip are also two 8-bit bidirectional input/output ports, each with parity-check logic built in. All necessary automatic handshaking logic and signals, on-chip reset logic, and a control register are included on the chip.

Available for immediate delivery in small quantities, the IOB1680 costs $10 in 100-unit lots.


---

**Program-development aid for 6800 systems captures cycles**

Debugging can be shortened, production testing simplified and field microcomputers serviced—all with the 6800 Programmer's Panel, developed by Applied Microsystems. When connected to a 6800-based system, the unit offers such debugging features as reset, run, pause, single-step, examine/change memory and examine/change processor registers.

A memory-trace function can capture 100 processor cycles for troubleshooting, and a hardware-implemented breakpoint comparator can be set to stop program execution at any point. In addition the 16-key hexadecimal keyboard, 18 function keys permit simple operation. A six-digit hex LED display is built into the unit.

Interfacing between Panel and 6800 system is done via a 50 conductor flat cable. A separate, buffered bus interfaces to extra memory or peripheral circuits. The price is $1590, and delivery takes up to six weeks.

*Applied Microsystems, P.O. Box 245, Bothell, WA 98011. Robin Knoke, (206) 827-9111.*

---

**Hardware support for 2900 series includes 6 circuits**

Six circuits have been added to the 2900 family of bipolar microprocessor components from Raytheon. One of these circuits, the Am2902 high-speed look-ahead carry generator, is pin-compatible with the 16-pin AMD unit and provides look-ahead carries across a group of four 2901 ALUs with a typical propagation delay of 6 µs.

Three of the circuits are open-collector quad bus transceivers—the Am2905, 2906 and 2907. Each unit features a quad-D register on the driver side and a quad-output latch on the receiver side for pipeline operation. The driver outputs can sink up to 100 mA at 0.8 V, while the receiver outputs sink up to 12 mA. The 24-pin 2905 and 2906 feature dual driver inputs, while the 20-pin 2907 has only single-driver inputs. Also, the 2905 has three-state receiver capability while the 2906 has odd-parity outputs. The 2907 has both capabilities.

Another of the new units, the Am2911 microprogram sequencer, has essentially the same function as that of the 28-pin Am2909 microprogram sequencer, except that eight input
Multiple Output Power Systems

Built to user requirements, shipped in just nine days.

Avoid the complications of building power supply assemblies "in house" by having Acopian build them for you. The cost is very reasonable, even when only one is required. And, if no unusual construction or components are necessary, shipment is made within nine working days after your order is received.

Just list the dc output voltages and currents you require, determine what features and accessories (meters, controls, chassis slides, etc.) are to be included, and then call us collect at (215) 258-5441. Ask for the Power Systems Department.

During your call, we’ll review your requirements with you, assign a reference number to your power system, and quote a firm price. Then, within nine days after we receive your order, we'll ship your system, completely wired and fully tested.

Additional information about Acopian power systems is contained in a full color, 16-page brochure. It also describes our standard rack mounting supplies with outputs to 50 volts and to 60 amps, as well as redundant output power systems for use where extremely high reliability is paramount. Write for your copy.

Acopian Corp., Easton, Pa. 18042. Telephone: (215) 258-5441
lines are eliminated from the 2911 to accommodate the smaller 20-pin package. In the 2911, the four direct input and register inputs are internally connected, while the 2909 has eight separate pins for these signals. Four pins are saved by eliminating the four OR inputs of the 2909.

The sixth circuit, the 16-pin Am2918 quad-D register, has two sets of outputs: four standard totem pole types and four three-state types.

With these six circuits, Raytheon's 2900 family has grown to eight. The new circuits are available from stock in both commercial and military versions. They are currently provided in hermetic DIPs, but flatpacks and plastic packages will be available soon.

Prices for devices in 100-piece quantities of military/commercial quality are: $7.28/$3.31, $21.84/$7.80, $27.98/$9.31 and $9.26/$3.56 for the Am2902, 2905/6/7, 2911 and 2918, respectively.

Raytheon Semiconductor, 350 Ellis St., Mountain View, CA 94040. Dave Uimari (415) 968-9211.

CIRCLE NO. 509

Intelligent breadboard speeds up 8080 circuit design

Developed to accelerate the breadboarding of microprocessor and logic circuits, the Intelligent breadboard connects directly to the company's 8080-based microcomputer. Designed by Imsai, the breadboard communicates with the computer via the 8080 address and data bus and 48 TTL-level I/O lines.

Several thousand tie points are available for circuit connections; latched or unlatched LED indicators are available for status displays. Regulators are built onto the breadboard to regulate the ±18 and +8-V buses tapped from the computer.

Prices start at $435 for the breadboard in kit form and increase to $625 for the assembled version. Both units are available from stock.

IMSAl, 14860 Wicks Blvd., San Leandro, CA 94577. (415) 483-2093.

CIRCLE NO. 510

Micro Capsules

Prices for plastic-housed 6800 family components have finally been announced by Motorola, Austin, TX. The 6800 µP itself costs $19.95 in quantities of 25 to 99; the 6820 PIA costs $8; the 6850 ACIA, $9; the 6852 SSDA, $13; the 6826 modulator $14, and the 6860 modem, $12—all in quantities of 100 and up. And the price for the ceramic-cased 6800 µP has been dropped to $29.95 (for quantities of 25 to 99) . . . A complete personal computer system for under $500 is the goal of a Commodore, Palo Alto, CA, design team. Based on a 6502 µP the system will include a CRT display, full alphanumeric keyboard and resident Basic . . .

Two powerful support-circuits for µP systems, a DMA controller and a universal-interrupt controller, are on the drawing boards at Advanced Micro Devices, Sunnyvale, CA. Expected to be available by mid-1977, these circuits are aimed by AMD to offer more capability than anything currently available. . . . Entering the microprocessor design-aids market by signing an agreement with Millennium Information Systems, Tektronix, Beaverton, OR, will build and market Millennium's Universal One µP development system. Tektronix expects to make first deliveries of the system in mid-1977.
The Ultimate Instrument

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Now you can use two hands! Data Tech’s new low cost Portable Digital Multimeter with its unique contoured hand mount frees both hands for fast, two-handed test probing. The Model 22 measures AC and DC Volts, AC and DC Current and Resistance and features basic 0.1% accuracy. The perfect DMM for field service application, it provides over 200 hours battery life on standard size disposable AA batteries and has low battery indication. The large reflective Liquid Crystal Display gives clear concise information in average or high ambient light conditions.

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Data Tech Model 22 DMM

The Model 22 is the only low cost portable 3 1/2 Digit DMM that has all these features: Automatic polarity, complete overload protection, 200 hours minimum battery life on AA disposable cells, low battery indication, 60 hours per charge battery life on the optional Nickel Cadmium batteries, push-to-hold reading, 0.1% basic accuracy and large, crisp .5 inch high Liquid Crystal Display.

Measure DCVolts from 100µVolts to 1KV, ACVolts from 100µV to 750Vrms, DC and AC Current from 100nAmps to 20Amps, and Resistance from 0.1ohms to 20Megaohms.

User convenience features make the Data Tech Model 22 the ultimate DMM in versatility and applications. The test lead terminals are on the front, where they should be, all functions except 20A range are measured in the same two terminals, and no special battery packs are required to be replaced when changing batteries.

The Model 22 is engineered and built for rough environments. It’s rugged polycarbonate case and single board construction guarantee high reliability with over 35,000 hours calculated MTBF.

Ranges
Resolution 200mV 2V 20V 200V 1KV
Accuracy ±(0.1% Rdg + 1 digit)
Input Z 10MO
Max. Input 10KV
NMR 50-60 Hz 60dB
CMR 50-60Hz 120dB

Ranges
Resolution 200mV 2V 20V 200V 750V
Accuracy ±(% Rdg + 2 digit) 45Hz-1KHz
Input Z 10MO/<100pf
Max. Input 750Vrms

Ranges
Resolution 20Q 2KQ 2010 200kΩ 20MΩ
Accuracy ±(0.1% Rdg + 1 digit)
Test Current 1mA 1mA 100µA 10µA 1µA
Max. Voltage In 500 Vdc or Vac rms

Ranges
Resolution 200µA 2mA 20mA 200mA 2A
Accuracy ±(0.25% Rdg + 1 digit)
Voltage Drop 4V 4V 4V .4V .7V .4V
Max. Current 2A 2A 2A 2A 2A

Ranges
Resolution 200µA 2mA 20mA 200mA 2A
Accuracy ±(10% Rdg + 2 digit) 45Hz-5KHz
Voltage Drop 4V 4V 4V .4V .7V .4V
Max. Current 2A 2A 2A 2A 2A

General
Power 80mW
Display .5" Liquid Crystal Display
Operating Temperature 0°C to +55°C
Storage Temperature -5°C to +55°C
Operating Time Disposable Cells (AA) 200+ Hrs
NicAD (AA) 60 Hrs. Charge, 14 Hrs. Max. Charge Time
Hold Function Connecting Hold Jack to Low Terminal Holds Reading Indefinitely
Size 6.75" x 3.26" x 1.16" D (17.5 mm x 82.8 mm x 40.6 mm)
Weight 907 grams; 2 lbs with batteries
Power Options Disposable Cells ONLY (AA Size)
AC or Nickel Cadmium Cells (AA Size)

Ordering Guide
The Data Tech Model 22 is available with a choice of accessories and power options. Please order by the appropriate model numbers.

Model 22-100 DMM with disposable batteries
Model 22-101 DMM only (without batteries) disposable battery model
Model 22-120 DMM with rechargeable batteries and 115Vac battery eliminator/charger
Model 22-121 DMM with rechargeable batteries and 230Vac battery eliminator/charger
Model 22-122 DMM with rechargeable batteries and 100Vac battery eliminator/charger

Accessories
532176-001 115Vac Battery Eliminator/Charger
532176-002 230Vac Battery Eliminator/Charger
532176-003 100Vac Battery Eliminator/Charger
532317-100 Test Lead Set
532062-001 Deluxe Test Lead Set
532104-100 High Voltage Probe
532103-100 RF Probe
549121-101 Push to hold Probe
549734-100 Carrying Case
532312-100 Disposable Battery Set
532051-100 Rechargeable Battery Set
549735 Extra Operating Manual
Big 0.6" double and single digits.

Our new super bright orange double- and single-digit displays are available in both common cathode and common anode configurations. These 0.6" digits (with overflow) incorporate our latest rounded-corner solid segment font to give you a display that's easy to read and easy to like.

The package is new, too. It has a colored face for optimum ON/OFF contrast. It's just under an inch in length and packs densely to provide digits on .50" centers.

The light emitting material is our new GaAsP : N on GaP, so you get all the benefits of this new high brightness technology—including direct MOS drive—plus all the inherent shock resistance and long life of solid state. Not bad.

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Color</th>
<th>Luminous Intensity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAN6610</td>
<td>2 Digit; Common Anode, RHDP</td>
<td>Orange</td>
<td>510 µcd</td>
</tr>
<tr>
<td>MAN6630</td>
<td>1½ Digit; Common Anode, Overflow (±1.8), RHDP</td>
<td>Orange</td>
<td>510 µcd</td>
</tr>
<tr>
<td>MAN6640</td>
<td>2 Digit; Common Cathode, RHDP</td>
<td>Orange</td>
<td>510 µcd</td>
</tr>
<tr>
<td>MAN6650</td>
<td>1½ Digit; Common Cathode, Overflow (±1.8), RHDP</td>
<td>Orange</td>
<td>510 µcd</td>
</tr>
<tr>
<td>MAN6660</td>
<td>Single Digit; Common Anode, RHDP</td>
<td>Orange</td>
<td>510 µcd</td>
</tr>
<tr>
<td>MAN6680</td>
<td>Single Digit; Common Cathode, RHDP</td>
<td>Orange</td>
<td>510 µcd</td>
</tr>
<tr>
<td>MAN6710</td>
<td>2 Digit; Common Anode, RHDP</td>
<td>Red</td>
<td>125 µcd</td>
</tr>
<tr>
<td>MAN6730</td>
<td>1½ Digit; Common Anode, Overflow (±1.8), RHDP</td>
<td>Red</td>
<td>125 µcd</td>
</tr>
<tr>
<td>MAN6740</td>
<td>2 Digit; Common Cathode, RHDP</td>
<td>Red</td>
<td>125 µcd</td>
</tr>
<tr>
<td>MAN6750</td>
<td>1½ Digit; Common Cathode, Overflow (±1.8), RHDP</td>
<td>Red</td>
<td>125 µcd</td>
</tr>
</tbody>
</table>

Minimum digit average @ 10mA, DC per segment

So if it's bright you want, and your application calls for 0.6" displays, call your Monsanto man in and have a look at the MAN6600 and MAN6700 series. They're terrific.

Please send me a data sheet on your MAN6600 and MAN6700 series digits.

Name
Title
Company
Street
City
State
Zip
Mail to Monsanto Electronics Division, Dept. MCD, 3400 Hillview Ave., Palo Alto, CA 94304. Phone (415) 493-3300.
It’s easy to inspect, test and repair AMP Latch multi-conductor connectors.
Even after they’re in use.
We designed them that way. Because a mass termination connector should help you save time and effort before, during and after assembly.

Their unique folded contact design, with dual camming and latching ears, assures you of four-point electrical contact and mechanical grip for each conductor. And that means superior overall reliability and protection. In addition, these fork-type contacts make it especially easy to visually inspect each termination before the cover is applied.

And even after the cover is on, each contact can still be visually checked for proper locking and latching. Because every AMP Latch cover has a built-in inspection port over each termination. This also permits electrical testing without cover removal, saving additional production time. And if repair ever is necessary, we’ve made that easier, too, by designing special hand and pen tools.

There are more reasons why you should choose AMP Latch connectors such as quick, easy terminating with the AMP shuttle tool, and the broad variety of pin headers and connectors. You also get AMP backup . . . expert design and production help that’s yours for the asking from AMP connector engineers.

Why not contact Customer Service, at (717) 564-0100 for complete details on the AMP Latch connector line? Or write us direct. AMP Incorporated, Harrisburg, PA 17105.
One of ours outshines twenty-five of theirs.

We couldn’t think of a better way to demonstrate our brightness story on the printed page. And although it may seem a little unbelievable at first, it’s true. One of our Brite-Lite® LED lamps outshines twenty-five of most competitive LED lamps (50 mcd vs. 2 mcd). This comparison isn’t just a figment of our imagination. The facts have been tested time and time again. On the bench and on the job.

**Light before bright.** We know brightness is only part of the story, though. The lamps must turn on to begin with. No problem. We offer traditional incandescent-type brightness with proven solid-state reliability. Reliability that amounts to at least 100,000 hours per lamp. In most cases, that’s more than 10x the life of standard incandescent lamps.

**Brite-Lites® come through.** Our brightness story means that Brite-Lites® come shining through repeatedly in those panel and printed circuit board applications where lamp visibility is critical. In your choice of red, green or amber.

**The best combinations going.** In addition to outshining the competition lamps down, we offer the most complete selection of packages. From convenient snap-ins to space saving T² Lites, which enable you to design panel lamps right onto your PC boards. And, there are a number of current/voltage combinations you can specify. From 1.6 to 28 volts—10 to 35 milliamps. Complete with current-limiting resistors.

**We shine on delivery.** Feature for feature, Data Display Products outperform as well as outshine the competition. Best of all, we don’t keep you waiting. After all, delivery is as important as performance!

**The best and the brightest.** We don’t really expect any of you to use twenty-five lamps where one will do. We do hope you’ll let us shine up your project at the early design stages. Call or write, today. We’ll give you a lot more than twenty-five outstanding reasons to make you look our way. Because when it comes to LED lamps, the brightest also happens to be the best.

“The brightest LED lamps in the business.”

5428 W. 104TH ST., LOS ANGELES, CA. 90045
(213) 641-1232
Support looks good for Defense and Space budgets

The Carter Administration is expected to make some changes in the fiscal 1978 budget submitted by the outgoing Ford Administration. But, the final budget should reflect continued growth in both defense and space R&D and hardware.

Three areas in particular will have an impact on the electronics industry: accelerated development of strategic weapons to match recent Soviet missile deployments; a five-year, $48-billion shipbuilding program; and a series of new initiatives in space, led by the Space Shuttle program.

The Defense Department is due to receive $123.1-billion in total obligatory authority (TOA) of the total federal budget authority of $449.1-billion—up from $110-billion in fiscal 1977. The National Aeronautics and Space Administration TOA is projected at $4.02-billion—up from $3.7-billion.

Two categories in the Defense Department's budget that are extremely important to the defense-oriented electronics industry, procurement and research, development, test and evaluation (RDT&E), both exhibit strong growth in the department's proposed budget. Procurement is up from this year's level of $27.9-billion to $35.1-billion, and RDT&E is due to rise from $10.6-billion to $12.1-billion.

The B-1 isn't the only one

The most visible Defense program, the controversial B-1 bomber, will be scrutinized by the Carter administration. The outgoing administration ordered the aircraft into production last year and requested $2.16-billion in the fiscal 1978 budget to procure the first eight production models. The long-range plan calls for 19 more B-1s in fiscal 1979 at a cost of $2.9-billion. Total expenditure is estimated at $22.9-billion.

Lurking beneath the surface of the new budget figures, however, is an even more costly program: the M-X missile that outgoing Defense Secretary Donald Rumsfeld calls "the heart of the U.S. ICBM modernization plan." Designed to counter the new, heavier Soviet missiles, M-X will be more accurate and twice as heavy as the current Minuteman ICBM. The fiscal 1978 budget contains $294-million for M-X—$49-million for advanced development and $245-million to begin engineering—but the long-range plan calls for $1.5-billion in fiscal 1979. If retained by the Carter administration, M-X is expected to cost at least $30-billion to deploy.

A new shipbuilding program for the Navy calls for 157 new ships, of which only 18 will be nuclear-powered (16 submarines and two new nuclear-strike cruisers). The aim is to bring the Navy up to 600 ships by the 1990s. In response to the National Security Council recommendation against building more large nuclear-powered aircraft carriers, two smaller
carriers using conventional power and tailored for vertical-and-short-takeoff-and-landing (VSTOL) aircraft will be developed.

Another indication of the growth of the defense business is the increased procurement of aircraft. Of 548 obtained this year, 117 (mostly helicopters) went to the Army, 214 to the Navy and 217 to the Air Force. The fiscal 1978 budget calls for 697 aircraft: 139 for the Army, 181 for the Navy and 377 for the Air Force.

Tactical fighters are the major element. In fiscal 1978, 108 of the Air Force’s F-15 fighter will again be acquired while procurement of the new F-16 fighter is to begin with 105 and rise to 145 in fiscal 1979. Procurement of the A-10 attack aircraft is due to rise from 100 this year to 144 in the new budget and 180 in fiscal 1979. The Navy will take 44 F-14s in fiscal 1978—8 more than in the current fiscal year—and 60 in fiscal 1979. The F-18 goes on the block in fiscal 1979.

**Space programs will get a boost**

NASA’s major program, the Space Shuttle, is budgeted for $1.35-billion, up from this fiscal year’s $1.29-billion. The space agency’s total fiscal 1978 request includes $142-million to start acquiring three more orbiting vehicles to round out the planned fleet of five. An additional $491-million is projected for that purpose in fiscal 1979.

Orbiter-3 should be available in the first quarter of 1982. Orbiter-4 should follow in the first quarter of 1983 and Orbiter-5 a year later. The latter two spacecraft are earmarked for the Air Force. Total cost of production is estimated at $1.2-billion. NASA will keep Orbiter-1 and Orbiter-2, the first of which is to begin test flights in 1979.

Four new programs are slated in the NASA budget. The U.S. and Canada will put up $15-million each for a four-year search-and-rescue satellite demonstration, which will consist of piggybacking transponders on satellites launched for other purposes—probably weather satellites—in 1979 or 1980. The goal is to locate within two hours all distress beacons from aircraft, ships or ground users in the two countries.

The other innovations are a Space Telescope, budgeted at $36-million next year out of a total program estimated to cost upwards of $470-million over seven years; a Jupiter Orbiter/Probe, $20.7-million out of $280-million for five years; and a Landsat-D earth-resources observation satellite, $22-million out of $182-million over six years. The probe is to be launched from the Space Shuttle with the Interim Upper Stage in 1981, the Landsat-D by a Delta vehicle the same year. A Shuttle launch in 1982 is planned for the Space Telescope.

**Energy R&D will be a fast mover**

The Defense Dept. and NASA account for more than half of the total planned federal obligations for RDT&E in fiscal 1978, but energy R&D is the fastest growing budget sector. The federal total is projected at $27.96-billion next year, up 8% from the current-year level of $25.9-billion. Defense and NASA account for $14.9-billion this year and $16.1-billion in the new budget. Funding of the Energy Research and Development Administration (ERDA), meanwhile, is due to rise 13% from $3.6-billion to $4.06-billion in the new budget.

Nuclear research will lead the way: Fusion-work expenditures will rise 34%, from $322-million this year to $433-million in the new budget, and fission 23% from $717-million to $879-million. The biggest percentage gain will go to geothermal research—39%, from $49-million to $68-million.
Compare our SOA and $E_{S/b}$ to theirs and you'll understand why our high current/voltage transistors work.

High voltage and high current specs aren't enough.

If you've ever specified transistors above 50 amps, only to find they fail on the job, you know how high-current specs may actually be misleading.

The truth is, unless you see the SOA and $E_{S/b}$ specs, there's no way of knowing whether a high-current device has the guts to withstand a surge, and not blow out.

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We want you to see precisely the kind of super-ruggedness you can expect from PowerTech—and only PowerTech—high-current transistors. Compare our $E_{S/b}$ ratings, from 1.5 to 6 joules, against the millijoules or unpublished ratings of other high-voltage/current devices.

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We use extra-heavy copper-metalizing on our bigger beefier chip: thereby assuring maximum thermal and electrical conductivity and yielding the highest resistance to second breakdown with the lowest $V_{CE(sat)}$. Their smaller chips use thin aluminum-metalizing with fragile, current-limiting wires (ours have solid copper posts).

Which would you rather have your circuit depend on? And we don't stop there. To guarantee rapid delivery, we pre-mount our chip on an integral moly-copper heat sink so we can categorize and pre-test the module at high currents to insure maximum reliability prior to mounting in the package of your choice (again 100% tested to the most stringent MIL/AERO specs).

They, on the other hand, must first mount their chip on the package, then test to determine if it's shippable.

Delivery and prices.

Our catalogs come complete with prices...we don't believe in secrets.

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We rely on direct factory-to-customer contact to ensure 100% responsiveness, backed up by the flexibility of chips already built, pre-tested and ready for whatever electrical/packaging requirements you may have.

But see for yourself: call for further information and applications assistance: Sales Engineering, PowerTech, Inc., 0-02 Fair Lawn Avenue, Fair Lawn, New Jersey 07410; Tel. (201) 791-5050.

PowerTech, Inc.

"BIG IDEAS IN BIG POWER"

CIRCLE NUMBER 28

Electronic Design 4, February 15, 1977
The new Dale resistors are more efficient to buy. A network of computer terminals throughout our three resistor plants gives you more useful production information than you've ever been able to get—from anyone. Place an order and in seconds we can tell you whether it can be shipped from stock. Inquire about an existing order and we can tell you its exact production status equally as fast. Discover a need for earlier delivery and we can instantly mark your order for expediting. That's resistor efficiency you can use. It's part of an expansion program that has seen our floor space devoted to resistors grow from 300,000 square feet in 1970 to more than 400,000 square feet today. And much of this expansion has been devoted to automated facilities. Multi-station winders let you specify the stability and power of wirewounds at a lower cost than ever...and batteries of laser spiralling machines turn out RN-style metal film parts at machine-gun speed. We're making the most efficient resistors you can buy—and we're ready to prove it.
The new Dale resistors are made from more efficient materials than ever. Sophisticated equipment, like this scanning electron microscope, gives us state of the art capability for analyzing, identifying and specifying component materials. It’s part of an integrated materials improvement, performance testing and quality control program we initiated 15 years ago in the early days of the Minuteman High Reliability Development Program. 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; the world’s most reliable wirewound resistor (proven failure rate .000021%/1000 hours). 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.

Our complete product line can be found in Electronic Design's GOLD BOOK.
When you're designing microprocessors into your products... our 990 computer products can give you a head start.

Start with the TMS 9900 microprocessor.
It delivers surprising power, speed and flexibility in a low-cost, single-chip 16-bit package. Its repertoire of versatile instructions and high-speed interrupt capabilities provide computing power usually associated with a 16-bit TTL minicomputer.
Hardware multiply and divide is standard and the software you develop for the TMS 9900 is upward compatible with any other member of the 990 computer family.

When your application calls for a microcomputer—start with the 990/4 microcomputer on a board.
It offers all the advantages of the TMS 9900, plus flexible memory and CPU options ideally suited to manufacturers' applications; up to 8K bytes of dynamic RAM memory, up to 2K bytes of RAM and/or PROM, real-time clock input, eight vectored interrupts, expansion interface and optional ROM utilities. It's our off-the-shelf answer for many production needs.
The 990/4 microcomputer is also available in a low-cost three-slot OEM chassis... or housed in a 6- or 13-slot rack-mount chassis with programmer's panel... or in a 6-slot tabletop chassis. And, the 990/4 is available as a complete computer system supported by your choice of performance options and peripherals.

For applications requiring greater speed, we offer the most powerful member of the 990 computer family... the 990/10 minicomputer. It uses a TTL implementation of the 990 architecture and features TILINE®, an asynchronous, high-speed 16-bit parallel I/O data bus which links the CPU, memory, and high-speed peripheral devices.

In addition, the 990 family is well supported by a substantial library of software development packages.
Whatever your needs... the TMS 9900 microprocessor, the 990/4 microcomputer, or the 990/10 minicomputer... you'll be working with some of the most attractive computer component values on the OEM market. Price/performance leadership you expect from Texas Instruments.

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Datel's Digital Voltage Calibrator, DVC-8500 comes in a mini-benchtop package, at a mini-price ($295 in singles*), but provides very big performance. DVC-8500 offers 4½-digit resolution and a ±19.999 volt full scale output range with ±1 millivolt accuracy (±0.005% of full scale.)

Use your DVC-8500 to calibrate A/D and D/A converters, DPM's, DVM's, Op Amps, V/F converters, and Data Acquisition Systems. A short-proof, buffered output gives up to ±25mA output current with an LED overload warning signal. The ±1.5 millivolt front panel vernier allows fine tuning of A/D and D/A bit steps.

Included are rear PC sense terminals and a choice of 100, 115, or 230 VAC inputs. A panel mounting kit is optional.

Contact Datel, or your nearest Datel Representative listed in Gold Book or EEM.

* U.S.A. Domestic Price only.

Datel SYSTEMS, INC.
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Santa Ana (L.A. Exchange) (213) 933-7256
Sunnyvale, Calif. (408) 733-2424
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CIRCLE NUMBER 33

Electronic Design 4, February 15, 1977
The good word

I've always been madly in love with Lotte Lehmann. But I never told her. Though I've been to California dozens of times, I never went to Santa Barbara to give her a bunch of flowers and tell her how much she meant to me. For this glorious soprano could breathe more excitement, more passion, more fire and more sheer beauty into marvelous music than anybody I've ever heard. But I never told her.

Now it's too late. Back in September, Lotte Lehmann died in her sleep at the age of 88. I know that Lehmann, who was adored by millions, didn't need and never missed my words of esteem. But I feel smaller for not having given them. I missed my chance.

What's terrible is the fact that I'll probably miss countless future opportunities to tell people I like them or something they did. Most of us, I guess, are too shy to express our admiration openly. That's unfortunate because we all work better and are better with a word of praise now and then.

Recognizing this fact, several companies keep printed "You done good," "Attaboy" or other such awards to help shy people pat deserving colleagues on the back. That's a step in the right direction. But it would be a lot better if we could all train ourselves to lay praise where praise belongs, freely and without condescension.

Giving ourselves the excuse that we expect good things of our colleagues and are not surprised at their achievements, we too rarely can bring ourselves to say, "Joe, that was an elegant design," "Jack, that was a nifty idea," or "Sam, you're a fine human being." How sad. For praise enriches us all. And it costs nothing.

GEORGE ROSTKY
Editor-in-Chief
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Rocker Switches
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Cutler-Hammer, of course! The broadest line. Styled to meet today's and tomorrow's requirements. They're solid quality, look great, work long and hard. Carried in stock for local availability by Switch Distributors. Backed by Cutler-Hammer sales engineers who can deliver innovative design help for

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the exact switch or relay you need—when you need it.

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**Relays**
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CIRCLE NUMBER 35
Want mass terminations for I/O interconnecting?
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Now Scotchflex brand DELTA Connectors bring the proved labor-savings of 3M's mass termination system to subminiature connections. DELTA series components include pin and socket connectors, junction shells, 25-conductor flat cable and strain relief clips. These system assemblies interface directly with all other industry standard “D” series subminiature connectors. They're also compatible with all connectors in our complete Scotchflex line.

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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.

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Coming through...
with new ideas for moving electrical energy
You can design reliable, low-cost linear systems with IC amplifiers—if you can find out just how well the ICs perform. For a dependable design, you need dependable specs. But data sheets often lead off with shaky claims. Among the more blatant examples: the micropower op amp that actually draws milliwatts, the two-chip "monolithic," and the so-called premium 741 that is so "good," it doesn't have current or voltage noise specs. There is even a chopper-stabilized op amp with no published long-term, offset drift characteristic.

So-called "design" minimums and maximums are often untested claims that can be mistaken for guaranteed values. A particularly insidious practice is a declaration that a device operates over a broad range of either temperature, supply level or input level—but when you read further, you find only spot values for crucial parameters.

For example, you've got to look carefully at a data sheet to determine which parameters are specified over 0 to 70 or -55 to 125 C rather than merely at 25 C. Or temperature specs may be given relative to a 25-C junction temperature. Why? Because input currents, at least for FET devices, can look five times worse if stated at 25-C ambient.

You may rightly wonder—after going through the ambient-to-junction computation recommended in the footnote—if you indeed did arrive at the correct junction temperature. After all, it's not as if there is only one transistor on the chip or the chip didn't have thermal gradients.

Heavy reading ahead

Then there's the other kind of data "sheet" to contend with—one with so many pages as to rival Tolstoy's War and Peace. Such IC epics usually categorize several devices together to add to the confusion. By the time you dig useful information out of the abundance, your head is swimming. Yet the accompanying application notes somehow don't add to your knowledge of how the device behaves with, say, reduced power-supply voltages. You can sometimes get a clue about how good an IC is if it isn't second-sourced. In the main, there are three reasons that a device is available from only one company:

- There is an insufficient demand, so additional suppliers don't want to get on board.
- The process by which the device is made is unique to one manufacturer.
- The device exists only on a spec sheet that originates at the marketing end of the company. An example is the 108A, which some manufactur-
ers admit had to be redesigned to meet the published values for input offset-voltage temperature coefficient.

Not all bad specs are deliberate. A particularly bizarre example is the composite spec sheet for an op amp on which long columns of values are printed in an all but illegible gold on white.

Jelly beans can be unhealthful

One of the more popular of the general-purpose linear devices is the 741 op amp, a device sold in such large quantities, it's sometimes referred to as a "jelly bean." The operating temperature range of the device is stated as -55 to 125 C. But what does it do in this range? Don't expect to find out all from some 741 spec sheets. True, maximum values are listed over the full temperature range, at least for input offset voltage and current, bias current and power consumption. Also given are the minimum values for input voltage range, large-signal voltage gain, output-voltage swing, common-mode rejection ratio (but with only ±12 V, not the full ±15 V) and supply-voltage rejection ratio.

But if you want the drift for offset voltage or current, you may draw a blank. For the offset-voltage adjustment range you get a typical value at 25 C. All you can find for minimum input resistance is the 25 C value, and for output short-circuit current a "typical" at 25 C.

When it comes to the 741's ac characteristics, you're often really on your own. Typical unity-gain rise time is given at the spot value of 25 C. Overshoot and slew rate are also typical values at 25 C. Is bandwidth of interest to you? If so, don't be concerned about either the 3-dB or unity-gain points—neither one is even mentioned.

Listen' for silent popcorn specs

In other 741 spec sheets, there isn't even a blank to remind you that this device is often known for popcorn, or burst, noise—sporadic output spikes that blast their way from rail to rail. Like bursts, other noise characteristics are also conspicuously absent.

The consensus among IC manufacturers is that the popcorn effect results from imperfect semiconductor-surface conditions incurred during wafer processing. So popcorn is a function of the cleanliness and tightness of process control. Most also agree that burst-noise stems from a momentary change in input bias-current offset. The frequency of occurrence usually stays below 100 Hz. What is an acceptable value for burst noise? It depends on whom you talk to. Some vendors say 1.5-µV pk. Others go as far as 30-µV pk.

This kind of noise varies widely from lot to lot. Manufacturers, therefore, must accumulate sufficient data over long intervals before they can say with assurance that popcorn noise is no longer a problem with a particular IC amplifier.

Included in a noise spec should be the following:
- Input noise voltage from 0.1 to 10 Hz.
- Input noise voltage density at 10, 100 and 1000 Hz.
- Input noise current from 0.1 to 10 Hz.
- Input noise current density at the spot fre-
quencies of 10, 100 and 1000 Hz.

• Burst-noise peak voltage referred to the input for at least a 30-s sampling period.

Noise values must be given as maximums or minimums. Otherwise you can't adequately compute your amplifier's noise figure. Keep in mind that the input noise depends on the input resistor. Most vendors use 100 kΩ to specify the input noise—if you find a lower value, watch out.

Measurement of popcorn-noise levels requires

that the unit under test be retained in a test fixture for about one minute. Some manufacturers feel that such a long period imposes an unacceptable cost penalty on their products, so they either sample test on an acceptance-quality-level (AQL) basis—or they don't test at all. Other IC producers claim to test 100%, but the test data are nowhere to be found on the spec sheets. Still others use automatic test equipment to provide guaranteed values for popcorn noise.

One test set-up, developed by RCA, is dedicated to popcorn noise. The details are provided in an application note published by the company for those who would like to "roll their own."

Besides adding noise, amplifiers always distort the signals to be amplified. The specifications don't always say how much.

**Ac specs can be tricky**

At least half (and perhaps as many as 80 to 90%) of the linear amplifiers sold today are used in equipment for which ac characteristics are extremely important. For instance, audio equipment, telecommunications systems and data modems are filled with active filters designed with quad op amps.

Often the ac specs of quads are skimpy. Many manufacturers provide only typical values for such key parameters as slew rate, full-power response and gain bandwidth. You must be particularly careful to check the gain levels at which the guaranteed values are specified. Unity gain is the most meaningful, but the temptation to get better looking specs—like bandwidth—often leads to specifying at gains of 4, 5 or even 10.

Some quads are now partially decompensated. That is, the internal compensation capacitor has been reduced to the extent that the devices aren't stable at unity gain. Although these so-called "broadband" devices slew faster and exhibit higher bandwidths than the original 741 circuit from which they're derived, it's up to the user to make them stable.

Instability is by no means limited to quads. The 538 is a decompensated version of the 535, which itself is a 741 with an improved slew rate. Although the 538 is pin-compatible with the 741, before you drop it into an updated design, you had better check to see if external components are necessary. If you want to use the 538 as a follower, it's not quite clear how to relate its stated slew rate to its performance as a follower.

You can add a resistor from the 538's input to ground to get both unity-gain stability and the stated slew rate. The resistor, in effect, fools the amplifier by giving it a gain of —4—for stability—while to the external circuitry the gain is —1.

While data sheets don't usually tell you that you can do this, some application notes do. Since there's always a danger of oscillation even when you add components, be wary of this.

The slew rate itself is sometimes published in a less than candid manner. If you use an op amp whose slew rate is given for less than the full common-mode input voltage, you're in for an unpleasant surprise: the slew rate will be substantially slower over the full range.

There are two widespread ways to measure slew rates. In the first, a step much faster than the device can follow is applied to the input. The output response is the slew rate. In the second, a sine wave is impressed on the device's input, and the wave's frequency is increased until the output is a triangle. The slew rate is then measured on the triangle.

Opinions differ as to how closely related these tests are. Whatever the method, check the gain at which the device is operated, and that the output slew from the 10% to 90% points, not the 50% point. Be careful that the device slews
Look for internal frequency compensation plus better TC $I_{\text{in}}$ and gain in Precision Monolithics' next op amp. It will be an update of the low TC $V_{\text{ref}}$ OP-08.

New plastic packaging shares the honors with semiconductor advances in Fairchild's $\mu$A 759 op amp. The P5C plastic version delivers 1 A for $2.50 (in 100s).

Chip-to-package testing gives audio designers guaranteed ac performance and limits on input-noise voltage for Raytheon's RC 4156 quad op amp.

smoothly—not like a saw tooth, as some feed-forward amps do.

In general, you can associate slew rate with the more conservative specifications for full-power bandwidth. As a rule of thumb, then, 100 kHz of full-power bandwidth equals 6 V/\mu s of slew rate. But this isn't binding. For example, the HA2700 op amp doesn't follow this rule.

Tune in to audio

Aware of the increasing use of linear ICs in ac-coupled applications, manufacturers are beginning to test for previously ignored characteristics like hiss, distortion and 20-Hz-to-20-kHz noise.

An interesting specification is the one for total harmonic distortion (THD). It is generally accepted that the full clipping point corresponds to 10% THD. But various suppliers evaluate devices at the 1%, 2%, and 5% THD points as well.

A major problem with audio amplifiers is that they tend to oscillate. Some vendors address this problem by supplying low-parasitic PC-board layouts with their devices. Others leave you on your own. If you can use one of the recommended layouts, so much the better. But if you can't, be extremely careful with your layout.

With audio active filters, look for a guaranteed values for such important parameters as full-power response, distortion and input noise over the 20-Hz-to-20-kHz band. They are now available from some manufacturers at no extra charge. More suppliers are planning to broaden their ac specifications.

Two solutions to the muting problem in i-f amplifiers are currently available in commercial ICs. The 3089, for example, reduces its gain to mute the output when the signal amplitude gets too low. Thus, in the absence of an acceptable signal level, the ever-present noise isn't amplified. Other i-f strips use deviation muting, in which the output is reduced as the circuit goes off tune. You may whistle a rather different tune when you find out what other problems await.

And the list goes on

When you drive devices at the maximum common-mode input voltage, take care that there's enough driving-point impedance to keep input current below the maximum value. Remember,
input-current limits aren't always placed near the input-voltage values on data sheets.

Some devices are promoted for use with either single or dual-supply voltages. But when you look for the device's single-supply characteristics, you find nothing. Suspect the worst—that the operation of the circuit is degraded for all key parameters. Bear in mind that although devices can operate over a range of supply voltages, the data are usually given for only one or two fixed supply voltages.

For de-coupled applications, an important concern is output drive capability. Can the device sink, as well as source, current? Some output stages don't have equal bidirectional current capability. If you need a fast amplifier that can drive a capacitive load (say, over 100 pF), look carefully at the drive specs. Some amplifiers will drive 5 mA into a 2-kΩ load (10-V supply), but will not drive 5 mA into 200 Ω. (In some devices the output current is a function of supply voltage.)

For FET-input ICs, where bias current doubles for every 10°C increase, check that the values given are for a warmed-up device. In many amplifiers, both drift and gain specs degrade after the device is nulled. Gain and drifts should therefore be specified at null.

Everyone agrees that thermal feedback is an important and potentially serious effect in monolithic ICs. In audio work, excessive heat transfer from output to input can result in motorboating. Or because of temporary thermal imbalances, op amps drift excessively or microwave devices act up. Across the spectrum of linear applications, temperature-induced noise can degrade circuit performance.

All IC manufacturers have addressed the thermal feedback problem in the IC-die design stage. But it seems that no one wants to test for thermal feedback. Some claim that the effect is negligible in low-power devices, others insist that feedback effects will be uncovered by other tests. But almost no one runs direct tests. This lack can be a bit unsettling. But not as unsettling as some settling-time specs.

**Make sure it settles**

Whenever you expect to handle fast steps, look out for settling time. No matter how fast an amplifier is, if it keeps on ringing, it can be useless. Although some manufacturers specify a typical value for settling time, others decline to assign any value. And they may have a point. Settling time is determined by a combination of at least three effects:

- The bandwidth of the amplifier—a linear effect.
- The slew rate of the amplifier—a nonlinear effect.
- The recovery from limiting—both a nonlinear effect and a function of power-supply voltage.

Because settling time is made up of such linear and nonlinear effects, you often can't relate the settling time given by a test circuit to the settling time of your own circuit.

Moreover, settling time—for a nonringing amplifier—can be determined in many cases by components external to the amplifier. For example,
in one test circuit, the settling time of a 10-
MHz 118 op amp is 1 to 1.5 $\mu$s.

But in a d/a converter with a 20-kΩ feedback
resistor and a bunch of current switches on the
input, that same amplifier sees about 20 addi-
tional picofarads. This capacitance breaks with
the feedback resistor at a frequency lower than
1 MHz. The converter will then ring through five
cycles before it settles to within 0.1%—the
settling time of this “1-1/2-$\mu$s settler” is now
15 $\mu$s.

Since even the difference between a 25 and a
100-pF scope probe sometimes matters, you must
make sure that testing for settling time corre-
sponds to your application.

Some rf specs are vague

In rf devices, the ever-present problem of inter-
modulation distortion is quantified by intercept
points. For most rf and microwave amplifiers,
the second-order products are greater than the
third-order. The points for third-order intermod-
ulation products are also usually specified, since
these products can fall into an amplifier’s pass-
band. Some spec sheets, however, give the second-
order point only. What happens? The user finds
in practice that the third-order products are much
greater than he expected.

Another prime concern, at microwave frequen-
cies, is the power output in the linear-amplifica-
tion region. The usual specification gives the
power at a 1-dB gain compression. Some enter-
prising producers drive their devices farther into
saturation and so get inflated ratings for this
crucial parameter.

Still another bit of information seldom de-
tailed for rf devices is the power-supply require-
ment. Often the appropriate bias voltage can
come from the main system’s power bus through
a dropping resistor. This works out well only
when the amplifier acts as a constant-current
sink. But for amplifiers whose bias current
varies, the resistor spoils the effective power-
supply regulation. Then the amplifier usually
displays quirks.

Furthermore, while some IC manufacturers
still specify noise figures for rf devices at only
25 C, most vendors commendably now guarantee
noise values over 0 to 50, 0 to 75 and −55 to
+125 C ranges.

Finally, microwave-device parameters haven’t
kept pace with such sophisticated applications as
direction finding, wherein the designer wants
phase and gain-match data for several channels.
Superheterodyne receivers have progressed from
merely specifying an amplifier just to set the
noise figure at the system’s front end. Ampli-
fiers are becoming more crucial to total system
performance—they do much more than only over-
come the loss in a cable. Simply put, more param-
eters are needed. The need for new devices, on
the other hand, is being more than satisfied by
linear integrated circuit producers.

Devices keep coming

One reason that specifications for linear ICs
are so varied and confusing is the proliferation
of devices and producers. Various technologies,
processing methods and testing techniques pro-
vide the linear systems designer with a wide
choice of performance and pricing.

For example, National and RCA have cham-
pioned different approaches to mixing bipolar

With optical coupling, unique in IC-isolation amplifiers,
the hybrid 3650 and 3652 offer maximum gain non-
linearities of ±0.3% (H-grade) and ±1% (J-grade).

and FET technology on the same chip. Both pro-
ducers ion-implant their FETs, but RCA uses
PMOS transistors while National’s front-ends
are JFETs. Speeds are roughly the same for the
LF 155, 156, 157 family, National’s BI-FET de-
vices, and RCA’s BiMOS—the CA 3130 and CA
3140. Typical gain bandwidths are on the order
of 4.5 MHz, and typical slew rates fall in the
10-V/$\mu$s area, with a slight edge to the BiMOS.
Both BiMOS and BI-FET have ultrahigh input
resistances: in the neighborhood of $10^{12}$ $\Omega$.

Not surprisingly, the noise performance of the
BI-FET is superior to that of the BiMOS. The
CA 3140 series has a typical equivalent-input
noise of 40 nV/$\sqrt{\text{Hz}}$ at 1 kHz, while the LF
156 A has 15 nV/$\sqrt{\text{Hz}}$. Typically, the equivalent
input noise current is 0.01 pA/$\sqrt{\text{Hz}}$ at the usual
spot frequencies of 100 and 1000 Hz for the 155
family. But the parameter is unspecified for the
BiMOS operational amplifiers.

Because of the PMOS input transistors, you can drive BiMOS devices as much as 0.5 V below the negative-supply rail without losing the signal's phase sense. The inputs can be driven indefinitely past the negative supply voltage without harming the unit if you limit the input current to 1 mA (a resistor will do).

The BiMOS amplifiers use a COSMOS output pair, so that the output can swing to within 10 mV of either supply voltage, but only for very high values of load impedance. The soon to be announced CA 3160 BiMOS types will offer internal frequency compensation.

Another proprietary chip—the OP-08 from Precision Monolithics (PMI)—is a 108 redesigned with ion implantation and zener zapping. PMI still second-sources the 108/108A, and the yields are now reasonable. The problem has been a too high temperature coefficient of offset voltage ($5 \mu V/°C$) max. The new OP-08 boasts a TC of $3 \mu V/°C$ max as well as the ability to drive a 2-kΩ load. The 108A drives only a 10-kΩ load.

Still another proprietary device based on the OP-08 is on the way. It will provide the internal frequency compensation that chip users want as well as improved TC. Also, improved gain will result in a better common-mode and power-supply rejection ratio.

At Advanced Micro Devices (AMD), a three-level glassivation process produces extremely stable semiconductor surfaces. AMD's devices are marked by high radiation resistance and tend to be low on popcorn noise. All new linear IC products at AMD make heavy use of ion implantation, and several ion implants, not just one, are used to get both active and passive components in the same device.

In addition to second-sourcing the LF 155, 156 and 157, AMD has developed a PMOS front-end process—the company expects to market PMOS-bipolar devices later this year.

With dielectric-isolation separating semiconductors, Harris is constantly pushing monolithic ICs into performance usually found only in hybrid country. The HA 2530 op amp, which boasts a 330 V/µs slew rate and 5-MHz full power bandwidth, has just been joined by the HA 2660, a 100-MHz bipolar-FET device. At present, Harris doesn't offer an instrumentation amp, but the company is looking in that direction.

Data sheets at Harris are being expanded to show maximum values for slew rates and to give settling times for several gain values and configurations. In the wideband, high-slew-rate 2500 series, the updated specs will cover negative inputs as well as positive. In the audio area, Harris intends to specify distortion and other audio parameters for its 911 low-noise op amp and the 4741 and 4605 quad op amps.

In a few months you can expect improved noise performance from the HA-2900, 2904 and 2905 chopper-stabilized op amps. Designers at Harris are seriously looking into replacing MOSFET inputs with JFETs.

A standout in the Analog Devices line of monolithic amplifiers is the AD521—an instrumentation amplifier with programmable gains from 0.1 to 1000, floating differential inputs, a minimum common-mode rejection ratio of 110-dB and maximum noise from 0.1 to 10 Hz of 0.5-µV pk-pk. This internally compensated device also features complete input protection and a gain-bandwidth product of 40 MHz—all for $8.50 in quantities of 100 (for the 0 to 70 °C Model J).

Hybrids still shine

Like Analog Devices, Datel is another module house that has ventured into monolithics. Datel's monolithic AM-464-2 op amp boasts a ±35-V output swing. The unit also offers a 4-MHz gain bandwidth product and a 5-V/µs slew rate. The hybrid AM-500 blazes with a 1000-V/µs slew rate, 100-MHz gain-bandwidth product at only 100 ns of settling time.

The only optically coupled IC isolation amplifier on the market comes from Burr-Brown. The hybrid 3560/52 is tested at a stratospheric 4000-V peak. Leakage is held to 0.5 mA at 240 V and 60 Hz for 120 dB of isolation. With a rocket-like 2000 V/µs of slewing, Burr-Brown's 3553 buffer amplifier is yet another example of what hybrid technology can do.

At microwave frequencies up to 18 GHz, thin-film hybrid technology takes over. Monolithics haven't arrived at these frequencies yet. Watkins-Johnson offers a line of low-noise hybrids for every octave bandwidth from 1 to 18 GHz. With each unit, the customer gets a printout of gain, VSWR, power output and noise figure.

The company has ready a 6.5-dB noise-figure FET amplifier that can cover 12 to 18 GHz. Previously, the only solid-state amplifiers in this band were tunnel diode-based devices. The FET...
devices have one-fifth the weight of the tunnel-diode devices and 20% more dynamic range. Also, they don't require isolators. Tunnel-diode amplifiers in the 12-to-18-GHz region are noted for their erratic behavior.

At Avantek, 41 different units in the precision UTO series and the lower-cost GPD series of thin-film hybrid rf amplifiers have guaranteed frequency coverages ranging from 1 MHz to 2.3 GHz.

Monolithics are, however, moving to the higher frequencies. Plessey Semiconductors has the distinction of producing the highest-frequency monolithics available today. The company's wideband limiting amplifiers operate over 30 to 350 MHz. Plessey's shallow-diffusion processes yield devices with f_s up to 2.5 GHz. The SL 1521 limiting rf amplifiers offer minimum bandwidth of 315 MHz.

High frequencies aren't the only areas that monolithics are getting better at. Power—higher outputs and lower consumptions—are now monolithic features.

Monolithics are power conscious

Silicon General's SG 1250/2250/3250 op amps feature adjustable power consumption down to less than 20 µW. These internally compensated devices operate from supplies of ±0.75 to ±18 V, draw less than 15-nA bias current and are short-circuit protected.

Micropower linear devices are the specialty at Siliconix. The L144 is a triple op amp that draws a maximum source current of 350 µA at 25 °C when all its inputs are at zero. Another unit, the T100, is a micropower impedance buffer.

And, of course, there's the other side of the coin—higher power output. At Fairchild, new plastic-package technology shares the limelight with the company's semiconductor developments in power op amps. For example, the 1-A plastic µA 791-P5C is electrically identical to the tincup TO-3 µA 791-KC. But in quantities of 100, the former costs $2.50, the latter $12.50.

Company engineers look to the µA 759 as the next generation's workhorse op amp. Boasting internal frequency compensation the 759 delivers up to 350 mA and is almost indestructible. It features short-circuit, safe-area and thermal-overload protection (all of which are borrowed from the company's IC regulators). The plastic µA 759-UIC sells for $2 in quantities of 100.

Talking about power-output, an 8-W monolithic audio power amp aimed at automobiles is a feature product at volume-oriented SGS-AT-EES. Called the TDA-2002, the unit has a thermal resistance of only 4°C/W maximum. A recommended PC-card layout is included in the device's data sheets. Other features include thermal shutdown and load-dump voltage-surge protection. Motorola is preparing to second-source the TDA-2002.

Quality goes up

The big news at Motorola isn't any one device in its vast line of linear ICs. The horns now blow at its automotive division, where reliability has reached an all-time high. That production facility boasts an AQL of 0.25%. Plastic devices now have fewer than 0.2%/1000 hr catastrophic failures in rugged automotive use. And the division is looking toward 0.01%.

Special test fixtures and processes have been developed by Raytheon specifically for the company's RC 4156 quad op amp. With this device, you get the general characteristics of the 741, but with guaranteed ac performance and clearly specified limits on input-noise voltage. These internally compensated op amp feature a minimum unity-gain bandwidth of 2.8 MHz, a minimum slew rate of 1.3 V/µs and an input noise of 2.0 µV. In addition, active-filter designers will welcome the 4156's output stage because it produces no crossover distortion.

The Raytheon monolithic XR-2211 is a phase-locked system especially designed for data communications. Intended particularly for FSK modems, it operates over 0.01 Hz to 300 kHz as a...
demodulator and tone decoder.

Teledyne Semiconductor produces the 885/836 quad "741-type" op amps. These internally compensated devices have no crossover distortion and feature an input common-mode range that includes the negative supply voltage.

Three op amps from Sprague are unusually well specified: The 2139 has typical values only for input noise, output resistance and unity-gain bandwidth; all parameters for the 2151 have maximum or minimum values except for output resistance; and the 2171 shows typical values for only input noise and output resistance.

Looking primarily at the high-volume market, Texas Instruments intends its 084 to be the beginning of an extensive family of bipolar-FET op amps. In time, this family is expected to place all the company's linear bipolars.

Signetics is also producing the 538, a broadband version of the 555, with higher slew capability than its predecessor. The 538, however, isn't unity-gain stable. A low-noise op amp—the 5534—is imminent: input noise voltage is 4 nV/\sqrt{Hz}.

Exar is one of the sources for quad 741-type op amps that can keep your cost per op amp below 15 cents. In Exar's broad line of op amps, one standout is the XR-4202, a programmable quad. A control pin allows you to trade speed for power consumption in the 4202. Thus the IC can be operated either as a high-speed or a micropower op amp.

Need more information?

The products cited in this report don't represent the manufacturers' full lines. For additional details, circle the appropriate number on the Reader Service Card. For data sheets and more vendors, consult ELECTRONIC DESIGN'S GOLD BOOK.
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CIRCLE NUMBER 42
Driving inductive loads? Take advantage of collector-emitter diodes in monolithic power Darlington transistors. They can dissipate kickback as effectively as external diodes.

Most monolithic-power Darlington transistors have a built-in collector-emitter (C-E) diode that is usually ignored. But this diode is quite capable of serving as a surge suppressor for inductive loads to dissipate potentially destructive "kickback" voltages. However, the Darlington transistors must be used in such multiple transistor drive configurations as complementary push-pull, totem-pole, half-bridge and full-bridge circuits (Fig. 1).

Inductive loads presented by relays, solenoids, motors, transformers and even wiring cause special problems for switching transistors. If a transistor is suddenly switched off, and the circuit doesn't provide an alternate path for the load current, the kickback voltage can destroy the transistor.

Placing a suppressor diode to carry the load current when the transistor turns off dissipates, or snubs, this inductive kick. In multiple-transistor drive circuits, as one transistor turns off, the inductive current can travel through the Darlington C-E diode of the second transistor.

Of course, the diode must be able to handle the peak current and dissipate the resulting power loss. And to be an effective snubber, the diode should have a low forward-voltage drop for both transient and steady-state conditions, particularly when used in high-speed power-switching applications.

Because the C-E diode is usually ignored, its characteristics are seldom given in spec sheets. However, tests on a representative Darlington can fill this data gap. To properly evaluate the diode's snubbing capabilities, the following must be determined:
- Thermal properties.
- Static forward-conduction characteristics.
- Dynamic forward-conduction and switching characteristics.
- Reverse-recovery characteristics.
- Behavior with inductive loads.
- Ability to operate in parallel with other C-E diodes.

Compared to standard and fast-recovery rectifiers, C-E diodes in Darlington transistors such as the MJ10001 do a very effective job as suppressors.

Evaluating the thermal characteristics

The power-handling capability of a C-E diode is dictated by its thermal resistance, $R_\theta$, thermal response, $r(t)$, and thermal coupling, $K_\theta$. These thermal properties aren't found on a Darlington's spec sheet, so measurements are needed. The MJ10001's diode exhibits an $R_\theta$ value of 1.1 °C/W. With a conservative derating factor of about 60% $R_\theta$, becomes 1.75 °C/W. So, for an allowed junction temperature, $T_j$, of 200 °C, dis-
2. The thermal characteristics of C-E diodes in monolithic Darlington drivers are ample to allow dissipation of 100 W will produce a case temperature, $T_c$, of 25°C.

But this calculation is correct only if the transistors aren't powered. When the transistors, as well as the C-E diode, are powered, the thermal coupling of the junctions reduces the effective dissipation capability of each, as follows:

$$T_J - T_C = R_{eJ1} \cdot P_{o1} + R_{eJ2} \cdot K_e \cdot P_{o2}$$

where $P_{o1}$ is the diode power and $P_{o2}$ the transistor power.

The thermal coupling, $K_e$, between diode and transistor junctions in the MJ10001 is about 0.8 (at 25°C case temperature). Dynamic thermal-response curves for these Darlington units are shown in Fig. 2.

**Measuring the static and dynamic properties**

A plot of the static forward voltages ($V_F$) at currents to 90 A shows that C-E diodes compare favorably with several discrete diodes (Fig. 3). To generate these data, the diodes must be subjected to peak currents well above rated values. However, in actual applications allowed peak-current ratings shouldn't be exceeded. The MJ10001 limit is 30 A, determined by the unit's nominal bond-wire rating.

The circuits of Fig. 4a and 4b measure the C-E diode's dynamic forward and reverse characteristics to determine if the Darlington output transistor is adequately protected. The forward-switching properties of the C-E diode are characterized by a so-called modulation voltage, $V_{FM(DYN)}$, and forward-recovery time, $t_{tr}$, which determine the efficiency and effectiveness of a

(continued on page 88)

3. The forward-voltage characteristics of C-E diodes compare favorably with discrete diodes that are often used as load clamps.
4. Test circuits must be built to measure the C-E diode properties—forward switching (a) and reverse recovery (b)—because these properties are not usually published by Darlington manufacturers.

The forward-recovery time is the time interval, $t_{rr}$, between the 10% points defined in Fig. 4a, which characterizes the time taken for the diode voltage drop to stabilize after application of a current step.

Measurements on a C-E diode compare very favorably with several discrete rectifiers (Figs. 5a and 5b). In modulation voltage, only two discrete diodes are better—the large-die units 1N1202A and MR756. In forward-recovery time, at moderate current levels, the Darlington's C-E diode is nearly as good as even the fast-recovery rectifiers.

**Fast-recovery diodes erroneously specified**

Fast-recovery rectifiers are characterized by low reverse-recovery times: They aren't particularly fast on forward recovery. Nevertheless, fast-recovery units are often specified by circuit designers, when it's the forward-recovery characteristics that should be fast for snubbing applications. And although only the forward characteristics are important, reverse-recovery time, $t_{rr}$, and peak reverse-recovery current, $I_{R_{RM(REC)}}$, also should be measured to complete the comparison of C-E and discrete diodes (Fig. 6).

Reverse-recovery time is a measure of the commutation capability of a device to switch from an ON state to OFF: Charge stored in a forward-biased diode must be depleted when the diode is suddenly reverse-biased. Interval $t_{rr}$ is the time taken by the reverse current to fall to a specified value ($0.25 I_{R_{M(REC)}}$) after the driving source is switched from a forward to a reverse-voltage condition (Fig. 4b).

As expected, the $t_{rr}$ of fast-recovery rectifiers is superior to both standard rectifiers and the C-E diode. And although $I_{R_{M(REC)}}$ values for the C-E diode and standard rectifiers are comparable, the values for the fast-recovery rectifiers are much lower.

**Testing with an inductive load**

To stress the C-E diode, a high-current inductive load (high-Q air-core of about 75 $\mu$H) with currents from 1 to 30 A peak is applied to a Darlington (Fig. 7). When the test circuit's drive transistor, $Q_d$, turns off, inductor current discharges through the Darlington's C-E diode.
5. Forward-switching modulation voltage (a) and forward-recovery time (b)—the two most important characteristics of diodes used for snubbing—compare very favorably with the discrete diodes.

6. Reverse-recovery characteristics of C-E diodes—both reverse-recovery time (a) and peak reverse-recovery current (b)—although reasonably good, are generally not important for diodes used in load snubbing.
The current step function from the inductor flows through the forward-biased clamp diode to produce a narrow-spike modulation voltage, $V_{FM\,(Dyn)}$.

Although the energy contained in the spike is very small (the rise time and average pulse width for all the diodes tested are similar—25 to 70 ns and 100 to 250 ns, respectively, for the 5-to-20-A range), the peak voltage can be quite large—approaching 105 V for a 1N4007 rectifier. However, other rectifiers, including the C-E diode, have overshoot voltage transients of less than 45 V peak. Again, the C-E diode proves to be similar to the other rectifiers, and thus able to perform as effectively when used as a snubber.

Operating C-E diodes in parallel

To evaluate the effects of the C-E diode’s relatively large forward-voltage drop when Darlington devices are operated in parallel, the test circuit of Fig. 8 can be used. The circuit consists of a 6-kHz CMOS oscillator and a time-delay circuit for “dead-time” generation to drive a pair of complementary level translators. The level translators then drive totem-pole output stages, with the top circuit a compound Darlington, and the bottom a triple Darlington.

Two MJ10001 units operate in parallel in each totem-pole output with 0.15-Ω current-sharing resistors placed in each emitter circuit. A wire-wound load resistor simulates a typical 800-W peak inductive load (approximately 1.4 Ω, 10
With ±40-V supplies, each of the output transistors supplies about 12 A peak. Whether only the internal C-E diodes of the MJ10001 are depended upon for snubbing, or whether the various discrete rectifiers, D1 and D2 (shown dotted) are used, output waveforms for all devices are virtually identical—no major differences in transient responses can be noted between the C-E diode and the other rectifiers.

To determine the sharing capability of the C-E diode snubbing currents, the power stage can be operated single-ended by reducing the +40-V supply to zero. Although the top transistors of the totem pole become inoperative, the C-E diodes still act as snubbers for the inductive load. And the current is only snubber current, not masked by the collector current of the normally functioning totem pole.

Randomly selected sets of C-E diodes match currents within ±15%, even though forward-voltage drops vary widely—from about 1.7 to 2.1 V, at 10 A. Clearly, then, there is no correlation between Vf and the current shared by a diode. Current sharing for both emitter and C-E diode is controlled mostly by the 0.15-Ω emitter resistor. Moreover, when compared to standard or even fast-recovery diodes, no major difference in circuit operation can be detected for C-E diodes as a result of variations in reverse-recovery time.

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<table>
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<tr>
<th>Type</th>
<th>Resistance Range</th>
<th>Power Rating At 70 °C</th>
<th>Max Operating Volts</th>
<th>Temp. Coef. Rating (-55 °C to +125 °C)</th>
<th>Maximum Dimensions (Inches)</th>
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<td>Slim-Mox</td>
<td>1 MΩ to 5000 MΩ</td>
<td>5W</td>
<td>18,000 V</td>
<td>±250 ppm</td>
<td>Length 2.08 Height .84 Thickness .86</td>
</tr>
<tr>
<td>Mini-Mox</td>
<td>100 kΩ to 10,000 MΩ</td>
<td>.25 W to 1.4 W</td>
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<tr>
<td>Divider-Mox</td>
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<td>1.5 W to 6.0 W</td>
<td>7.5 kV to 30kV</td>
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<tr>
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<td>Power-Mox</td>
<td>20 kΩ to 7000 MΩ</td>
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<td>Length 3.96 to 6.96 Dia. .89</td>
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CIRCLE NUMBER 45
Use equations to parallel transistors.

To get through the graphical morass, balance your currents with simple arithmetic and straight-line approximations.

When you parallel transistors for increased power, watch out for current hogging. When a current-greedy transistor consumes more of the load than it can handle, you’ve got trouble. And there’s no curing the sick transistor—it’s gone forever. Then the full load falls onto the remaining paralleled transistors, which, in turn, topple like dominoes.

Balancing the parallel currents with emitter resistors is the answer for low-frequency circuits. But selecting these resistors by using all-graphical methods is cumbersome, at best. Practical equations can help you control the current mismatch and ease this once tedious job.

The basic problem is that current division is unequal between the circuit’s parallel legs. In the simple parallel connection shown in Fig. 1a, the differences in the transfer characteristics of Q1 and Q2 (shown in Fig. 1b) indicate that Q1 handles the bulk of the current. Consequently, Q1 dissipates more power than Q2.

One way to compensate for this unequal power dissipation is to select components for their $V_{BE}$-$I_C$ characteristics. But this solution causes transistor stocking and replacement problems.

A better solution, emitter-sharing resistors (see Fig. 2), reduces collector-current differences between transistors by making the drop across these resistors large compared to the $V_{BE}$ differences for their respective transistors.

Graphically speaking . . .

When you employ all-graphical methods to determine mismatch, you assume that $I_C$ is approximately equal to $I_E$. You follow with a load-line approach. For worst-case analysis (Fig. 3), you assume one transistor has maximum transconductance with maximum current and power dissipation and the other transistors have minimum transconductance.

Resistor tolerance is accommodated by drawing two load lines and assigning the minimum-value resistor to the maximum-transconductance transistor. Conversely, the maximum-value resistor is assigned to the minimum-transconductance transistors.

If the $I_C = I_E$ approximation is not appropriate, you can correct for $h_{FE}$ by multiplying the $V_{BB}/R_E$ intercept by $(1 + 1/h_{FE})$. The maximum $h_{FE}$ corresponds to maximum transconductance, and the minimum $h_{FE}$ to minimum transconductance.

While this graphic solution does yield accurate results, it is cumbersome, particularly when you

-- Otto R. Buhler, Senior Associate Engineer, IBM, Boulder, CO 80302.
have to analyze parameter variation or design for a fixed mismatch ratio. But the graphic method can be modified to give you a simplified design procedure that includes equations.

Analytically speaking . . .

A technique more practical than the all-graphic uses linear approximations for the transistors’ $V_{BE} - I_c$ transfer characteristics. With these estimations you compute values for the critical parameters from equations. The emitter resistors ($R_E$), the matching constant for the transistors’ power dissipations ($K$), and the maximum supply voltage ($V_{as}$) are so specified.

Assume that $h_{FE}$ is much greater than 1; then $I_E$ is approximately equal to $I_e$. For maximum mismatch, $Q$, in Fig. 2 has maximum dissipation (implying maximum transconductance for $Q_1$ and minimum resistance for $R_1$). And transistors $Q_2$ through $Q_n$ have minimum dissipation (implying minimum transconductance for $Q_1$ through $Q_n$ and maximum resistance for $R_2 = R_3 = \cdots = R_n$). You then figure in the transfer characteristics to obtain critical parameters (Fig. 4).

Using the circuit of Fig. 2 and assuming that $I_c \equiv I_E$ produces this relationship:

$$I_{c1} R_1 + V_{BE1} = I_{c2} R_2 + V_{BE2} = \cdots = I_{cn} R_n + V_{BE}$$

(1)

From Fig. 4:

$$V_{BE1} = V_{T1} + I_{c1}/m_1$$

(2a)

$$V_{BE2} = V_{T2} + I_{c1}/m_1$$

(2b)

Plugging Eq. 2 into Eq. 1 gives:

$$I_{c1} (R_1 + 1/m_1) - I_{c2} (R_2 + 1/m_2) = \Delta V_T$$

(3)

where $\Delta V_T = V_{T2} - V_{T1}$ (from Fig. 4).

The total current is:

$$I_T = I_{c1} + I_{c2} + \cdots + I_{cn}$$

(4)

For the worst case:

$$I_{c2} = I_{c3} = \cdots = I_{cn}$$

and Eq. 4 becomes:

$$I_T = I_{c1} + (n - 1) I_{c2}$$

(5)

Using Eq. 3 and Eq. 5 to solve for $I_{c1}$ and $I_{c2}$ yields:

$$I_{c1} = \frac{I_T}{(n - 1)} \frac{(R_2 + 1/m_2) + (n - 1) \Delta V_T}{(n - 1)(R_1 + 1/m_1) + (R_2 + 1/m_2)}$$

(6)

$$I_{c2} = \frac{I_T}{(n - 1)} \frac{(R_1 + 1/m_1) - \Delta V_T}{(n - 1)(R_1 + 1/m_1) + (R_2 + 1/m_2)}$$

(7)

Dividing Eq. 6 by Eq. 7 gives you the matching constant, $K$, the power dissipation multiplier of $Q_1$ compared to $Q_2$. It is expressed by:

$$K = I_{c1} \frac{I_T}{I_T (R_2 + 1/m_2) + (n - 1) \Delta V_T}$$

(8)

Rewriting Eq. 8 in terms of a nominal emitter resistor, $R_E$, and appropriate tolerance multipliers, you get:

$$K = I_{T1} (PR_E + 1/m_1) + (n - 1) \Delta V_T$$

(9)

P and N are tolerance multipliers; for example, for a ±5% resistor, $P = 1.05$ and $N = 0.95$. Usually, $K$ is a known desired value, and the value of $R_E$ to get the desired $K$ is unknown. Rearranging Eq. 9 yields:

$$R_E = \frac{I_{T1} (P + N - 1) \Delta V_T}{(K + n - 1) \Delta V_T} \frac{1}{I_T (m_2 - m_1)}$$

(10)

Increasing $R_1$ beyond the value given by Eq. 10 decreases $K$. But this improvement in $K$ is not free—increasing $R_E$ requires increasing $V_{BB}$.

Note, of course, that negative values of $R_E$ cannot be realized.

$I_{c2}$ is given in terms of the total current by:

$$I_{c2} = I_T/(K + n - 1)$$

(11)

3. Graphical analysis of worst-case conditions for three paralleled transistors assumes maximum transconductance for one and minimum for the other two. The maximum transconductance transistor hogs current and dissipates more power than the other two devices.

4. Linear approximations of actual curves are the basis of a simplified specification technique for emitter resistors. The two line-determining points are the intersection between an actual curve and the nominal average current line and the base-to-emitter voltage intercept.
and the maximum supply voltage is:

$$V_{BB} = I_{C1} \left( PR_E + \frac{1}{m_2} \right) + V_T \tag{12}$$

When using Eq. 12 remember that $R_E$ increases as $K$ decreases.

For practical applications, the most useful equations are 5, 8, 9, 10, 11 and 12.

Specifically speaking . . .

Consider sharing 15 A among three 2N3773s that use emitter-sharing resistors with ±5% tolerances. Assume that the currents must match within 20%.

As in Fig. 5, you draw a linear approximation for a typical 2N3773 around the 5-A operating point. A typical transistor has a transconductance of 20.7 A/V and a $V_T$ of 0.64 V. From the specification sheet, the $h_{FE}$ spread is 15 to 60 at 8 A, and the maximum $V_{BE}$ is 2.2 V at 8 A. The typical $h_{FE}$ is 20 at 8 A. So at 8 A, the minimum $h_{FE}$ is 0.75 times the typical $h_{FE}$, and the maximum $h_{FE}$ is 3 times the typical $h_{FE}$.

![Diagram](image-url)

5. Linear approximation for a 2N3773, drawn through the nominal 5-A operating point and 0.64 base-to-emitter voltage intercept, shows a typical transconductance of 20.7 A/V. Max., min. bracket the typical $g_m$ line.

To find $V_T$, assume that the transconductance spread is no greater than the $h_{FE}$ spread. Then the minimum transconductance can be found:

$$(0.75)(20.7) = 15.53 \text{ A/V}.$$  

Draw a minimum transconductance line with this slope from the 2.2-V, 8-A point, and you get $V_T = 1.68$ V. Assume that $V_{T1}$ is 200 mV less than the typical $V_T$ and that (3) $(20.7) = 62.1 \text{ A/V}$, the maximum transconductance.

Now you can draw the maximum transconductance line with:

$$\Delta V_T = 1.68 - 0.44 = 1.24 \text{ V}. $$

For 20% matching, $K = 1.2$. Emitter-sharing resistors with 5% tolerance imply values of 1.05 and 0.95 for P and N. Applying Eq. 10 yields:

$$R_E = \frac{1}{15} \left[ (1.2+3-1)(1.24) + 15 \left( \frac{1}{15.3} - \frac{1}{62.1} \right) \right]$$

$$= 3.88 \Omega$$

The nearest commercial value greater than 3.88 Ω is 4.0 Ω. Now use Eq. 9 to find the $K$ value for this value of emitter resistance:

$$K = \frac{(15) \left[ (1.05)(4) + \frac{1}{15.3} \right] + (3-1)(1.24)}{15 \left[ (0.95)(4) + \frac{1}{62.1} \right] - 1.24}$$

$$= 1.19$$

Note that the increased $R_E$ of 4.0 Ω results in a slightly better match ratio. Next, calculate $I_{C1}$ from Eq. 11:

$$I_{C1} = 15 A / (1.19 + 3 - 1) = 4.70 A$$

Then, from Eq. 8:

$$I_{c1} = K I_{C1} = (1.19)(4.69) = 5.60 A$$

Applying Eq. 12 gives:

$$V_{BB} = (4.7) \left[ (1.05)(4.0) + \frac{1}{15.3} \right] + 1.68$$

$$= 21.73 \text{ V}.$$  

For most applications, this voltage results in too much dissipation for matching. If $Q_1$ can handle higher dissipation, $K$ can be increased. For example, with the given supply voltage, if $Q_1$ can handle 6.0 A, Eq. 5 gives:

$$I_{C1} = (15 - 6.0) / (3 - 1) = 4.5 \text{ A},$$

and then Eq. 8 gives:

$$K = I_{c1} / I_{C1} = 6.0 / 4.5 = 1.33.$$  

Next, Eq. 10 yields:

$$R_E = \frac{1}{15} \left[ (1.33+3-1)(1.24) + 15 \left( \frac{1}{15.3} - 1.33 \right) \right]$$

$$= 1.50 \Omega$$

and, finally, from Eq. 12:

$$V_{BB} = (4.5) \left[ (1.05)(1.5) + \frac{1}{15.3} \right] + 1.68$$

$$= 7.38 \text{ V}.$$  

This value of $V_{BB}$ represents a considerable reduction from the value attained with Eq. 12. If you want to reduce $V_{BB}$ further, use four transistors. $Q_1$ is now dissipating the maximum power allowable.

One variable not considered is the temperature effect due to different power levels of the transistors. By mounting all the transistors on the same heat sink, you can reduce the effect of the differences of power levels. • •

References


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Grounding is a paramount problem in many data-acquisition and process-control systems. Since transducers are often located hundreds of feet from an electronics console or computer, ground loops are hard to avoid.

For example, if a minicomputer is interfaced to a nuclear reactor located 1000 feet away, it is likely that the two equipments' grounds will not be at the same potential. Simply tying all the grounds together with heavy cable may not solve the problem. One possible solution is to float the computer or reactor off ground, but this may not be practical or safe.

Special types of amplifiers address this problem, with varying degrees of success. “Instrumentation” amplifiers, with committed feedback networks, provide high common-mode rejection ratios and excellent dc characteristics. These amplifiers achieve good results at moderate common-mode voltages. High common-mode voltages, however, call for an isolation amplifier with fully floated inputs.

The basic principle

The design presented here achieves a precise unity-gain, input-output relationship for a 0-to-9-V input. Although there’s no dc connection between input and output, the output follows the input to an absolute accuracy of 0.01% over a 0-to-50-C temperature range.

Commercially available isolation amplifiers, such as the Analog Devices 285L, can equal or surpass these specs, but do not approach the 2-ppm/°C drift performance.

Conceptually, the design is simple (Fig. 1). The input voltage is converted to a pulse whose width ranges from 0 to 90 µs. For isolation, the pulse is driven across a transformer whose secondary is referenced to output ground. The data pulse out of the secondary is demodulated by a pulse-width-to-voltage converter to form the amplifier output.

To convert the input voltage to a pulse width, the circuit compares the input with a precision linear-reference ramp that repeats at a rate of

James M. Williams, Senior Engineer, MIT, Dept. of Nutrition and Food Science, Cambridge, MA 02139.
4 kHz. The ramp runs from 0 to 10 V, then is reset to zero by a 4-kHz clock pulse. The output pulse width of the comparator depends on the time the reference ramp takes to slew from zero to the value of the input voltage, \( V_i \).

The secondary of the transformer reproduces the data pulse and uses the pulse to turn on a switchable ramp generator. The ramp starts at 0 V and goes toward 10 V until the data pulse goes low. At that point, the current source stops charging the ramp capacitor, and the voltage across the capacitor equals \( V_r \), which is sampled and stored in another capacitor. The clock pulse resets the system, and the entire cycle repeats.

**The detailed amplifier**

In Fig. 1, transistor pair \( Q_1 \), comparator \( A_1 \), and associated components form the voltage-to-pulse converter. The AD580 (from Analog Devices) in the emitter of \( Q_1 \) is a band-gap voltage reference that stabilizes the differential pair in a current-source configuration. The "B" side of the pair functions as a current source, while the "A" side is diode-connected to compensate for the drift of \( V_{BE} \).

Resistors \( R_1 \) (8 kΩ) and \( R_2 \) (820 Ω) bias the current source to provide 6 mA into the \( C_{1,2} \) combination. Because the tempco of silver mica and polystyrene-type dielectrics are opposite, \( C_1 \) and \( C_2 \) form a capacitor with a zero-temperature coefficient and low soakage. The composite capacitor resets when the clock pulse from the 555 timer resets \( Q_2 \). The pulse is 10 µs long and repeats at a 4-kHz rate (Fig. 2a).

When the clock goes high, \( Q_2 \) turns on and \( C_{1,2} \) resets to zero volts. When the clock goes low, \( Q_2 \) goes off and \( C_{1,2} \) is charged up (Fig. 2b). The resulting repetitive, linear reference ramp forms the input to the AD812 comparator. The 6-mA charging current ensures that the comparator's input-bias current doesn't affect the linearity of

---

1. **Basic to the isolation amplifier** is a voltage-to-pulse converter formed around \( Q_1 \) and \( A_2 \). The pulse is transformed by PE9613 for isolation, then demodulated to provide the voltage output.
the reference ramp.

Voltage \( V_n \) serves as the other input to the AD311. Like the rest of the circuitry in the front end of the amplifier, \( V_n \) is referenced to floating ground. The pulse width at the output of the AD311, which is directly proportional to \( V_n \), drives \( Q_1 \) into conduction (Fig. 2c). The collector of \( Q_1 \) conducts current out of \( Q_{12} \)'s emitter, and the current passes through the PE9613 transformer primary to ground (Fig. 2d).

To keep the transformer out of saturation, the \( Q_{12} \), \( Q_1 \) combination drives the transformer from a 1.2-V potential. Transistors \( Q_6 \) and \( Q_7 \) function as a temperature-compensated emitter follower, biased by the 12-k\( \Omega \) and 1.6-k\( \Omega \) resistors to provide about 1.2 V at \( Q_7 \)'s emitter.

The 500-pF capacitor ensures dynamic stability, and the 47-\( \mu \)F solid tantalum capacitor helps maintain a low impedance at \( Q_7 \)'s emitter when \( Q_1 \) is loaded (when \( Q_1 \) turns on). The 1N914 diode, 300-\( \Omega \) and 10-k\( \Omega \) resistors provide proper damping of the transformer primary. Transistor \( Q_{5a} \), a 2N708, has a low storage charge and provides very fast edges—even in the relatively slow common-emitter configuration.

Transistor \( Q_{14} \) is biased by the clock pulse and prevents the AD311 output from going high during the period that the clock pulse resets \( C_{a1} \). To do so, \( Q_7 \) pulls the AD311 output down when the clock pulse is high. The clock pulse biases \( Q_7 \) through the 0.005-\( \mu \)F/3.9-k\( \Omega \) differentiator network. Because of the differentiator, \( Q_7 \) drives the PE3843 pulse transformer for only 3 \( \mu \)s whenever the 10-\( \mu \)s clock pulse occurs. The pulse appears across the transformer secondary and performs resetting and timing functions in the pulse-width-to-voltage demodulator.

Going back to a voltage level

Once the voltage-proportional pulse is established and driven across the transformer, it must be demodulated. The transformer secondary feeds current into \( Q_7 \) (Fig. 2e), which, in turn, shifts the level of the 1-V pulse and maintains the pulse's fast edges (Fig. 2f). Transistor \( Q_7 \)'s output drives \( Q_{14} \), a switch that turns on a current source (AD812, AD820 transistor pairs) in 10 ns. Another AD580 reference stabilizes the source.

The “A” portion of the 820 functions as the current-source transistor, and the “B” portion provides temperature compensation. The AD812B pair prevents the AD820B pair from conducting in the reverse direction whenever the voltage across the \( C_{3b} \), \( C_3 \) composite capacitor exceeds the AD820B emitter potential (when \( Q_{12} \) is on). The 1-k\( \Omega \), 56-\( \Omega \) and 8-k\( \Omega \) resistors set the bias point for the current source.

Whenever a data pulse exists across the transformer, \( Q_7 \)'s collector is low and \( Q_{12} \) is cut off.

2. Scope traces show the various circuit waveforms: the 555 output—a 4-kHz, 10-\( \mu \)s pulse (A); the reference ramp at the comparator’s negative input (B); the comparator output for \( V_2 = 8 \) V (C); the transformer drive and secondary waveshapes (D and E); and the waveform at \( Q_7 \)'s collector (F). The hop is caused by current sharing between \( Q_{12} \) and \( Q_{14} \). Traces G and H show the voltage across \( C_{a1} \) and at the collector of \( Q_{14} \), respectively. Note that the \( C_{a1} \) ramp starts when “F” is at 0 V.

The current source then charges \( C_{a1} \), which ramps up in voltage until \( Q_7 \) goes off and \( Q_{12} \) turns on. Thus, the current source is cut off very quickly (Fig. 2g).

Capacitor \( C_{a1} \) sits at the maximum ramp voltage until \( Q_{11} \) resets it to zero. Transistor \( Q_{11} \) is driven by the reset pulse from the transformer. Since the reset pulse for the demodulator capacitor, \( C_{a1} \), is only 3 \( \mu \)s long—as opposed to 10 \( \mu \)s for \( C_{a1} \)—\( C_{a1} \), will be reset and ready to start another ramp when \( C_{a1} \) starts its ramp.

The voltage on \( C_{a1} \) after its current source turns off equals the amplifier-input voltage, \( V_n \). This voltage is buffered by \( A_{12} \), a follower, which drives FET switch \( Q_{11} \). When the current source goes off, \( Q_7 \)'s collector is high and turns on \( Q_{11} \). Capacitor \( C_3 \) then charges to the voltage across \( C_{a1} \).

When the clock pulse arrives, \( Q_{11} \) turns on, and \( C_{a1} \) immediately starts to reset to zero. However, the clock pulse biases on \( Q_{11} \). This action turns off \( Q_{11} \), and prevents \( C_3 \) from discharging (Fig. 2h). To ensure that \( Q_{11} \) is off during the entire reset period of \( C_{a1} \), the transformer reset pulse is stretched by the RC combination in \( Q_{13} \)'s base.

Keeping the output pure

Another RC combination—in \( A_{12} \)'s input—provides a delay to compensate for \( Q_{11} \)'s slow 1-\( \mu \)s switching speed. Follower \( A_{12} \)'s response is slowed by the 3-\( \mu \)s time constant of the combination. This slowing down further ensures that the resetting of \( C_{a1} \), doesn't affect \( C_3 \), despite \( Q_7 \)'s slow speed.

Capacitor \( C_3 \) is buffered by \( A_3 \), the final output stage of the amplifier. The 1-k\( \Omega \) resistor in series
3. The amplifier's response to a 20-Hz sinusoid biased on a 2-V level (top). The center trace is the output of $A_2$, the bottom the output of $A_0$ (5 ms/div, 5 V/div).

4. Response to a 200-Hz sinusoid: The input is at the top, and the outputs of $A_2$ and $A_0$ are at center and bottom, respectively (625 $\mu$s, 10 V/div).

5. The fall-time delay through transistor $Q_5$, transformer PE9613, and $Q_6$ and $Q_{12}$ is measured at the AD311 output (top) and collector of $Q_{12}$ (bottom).

6. Rise-time delay is shown at the AD311’s output (top) and at the collector of $Q_{12}$ (bottom). The scope calibration here and in Fig. 5 is 500 ns and 5 V/div.

with $A_3$’s input ensures dynamic stability.

All the provisions discussed ensure that only dc will appear at the amplifier's output for a dc input. Switching spikes and noise are below 1 mV. The amplifier's response is shown in Figs. 3 and 4, and the delays encountered through the circuit in Figs. 5 and 6.

To calibrate the circuit, apply 9.000 V at the input with respect to floating ground. Adjust the 1-k$\Omega$ in the AD812B collector line for 9.000 V at the amplifier output. Next, apply 10 mV at the input and adjust the 1-k$\Omega$ potentiometer at pin 6 of the AD311 for 10 mV at the amplifier output. Repeat this procedure until the adjustments do not interact.

Note that the offset adjustment (the 1-k$\Omega$ pot at $A_3$) is rather unorthodox—the method achieves a zero setting for the circuit by deliberately generating a large offset in the AD311 comparator. The adjustment is needed since $V_{cc}$ saturation prevents $Q_6$ and $Q_{11}$ from resetting their associated capacitors to zero. This “bending up” of the AD311’s inputs increases bias current and $E_{os}$ drift, but not enough to cause worry.

The 56-$\Omega$ carbon resistor in the AD812B collector line trims the entire circuit functionally to achieve the 2-ppm/°C drift. For example, the temperature drift of a standard Allen-Bradley 1/2-W resistor almost exactly compensates the residual-drift characteristics of the circuit from 0 to 50 °C. Compensation results after slight changes in the charging current are delivered by the AD820-822 source to $C_{4,4}$.

The floating front end of the amplifier should be enclosed in a shielded metal box. If the circuit is exposed to moving air or sudden temperature transients, you can obtain optimum isothermal characteristics by putting the amplifier in epoxy resin.

Some typical applications of the isolation amplifier include interfacing a remote computer to an instrument—without grounding problems; building a 500-V floating power supply with 0.01% regulation; and using the isolation amplifier after a chopper-stabilized preamp to obtain a composite amplifier with 100-nV/°C drift, a floating input and 0.01% absolute accuracy from 0 to 50 °C. ■
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<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>V_{CE} = 250V</th>
<th>I_C = 4.0A</th>
<th>Sw. Freq. = 20 KHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converter - Bridge Config.</td>
<td>T.I. TIP-540</td>
<td>MOTOROLA 2N6547</td>
<td>DELCO DTS-519</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DELCO DTS-519</td>
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<td>TRW 2N6583</td>
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Measure phase noise in one of three ways, each of which has some advantages. Quadrature phase detection, for one, lets you avoid dynamic-range limits.

Measuring phase-noise sidebands would be simple if frequency analyzers had dynamic ranges of 160 dB and 1-Hz bandwidths in the gigahertz region. All measurements could then be made around the fundamental frequency of the source. However, since equipment with this performance doesn’t exist, you must use other techniques. Three good alternatives are rf-spectrum measurement, frequency discrimination and quadrature-phase detection.

The sidebands of a signal may represent both amplitude and phase modulation; asymmetry in the sidebands is an indication that both are present. However, in many cases, PM sidebands dominate. For example, if a reasonably clean synthesized signal is multiplied up, for use as a high-frequency reference, the phase-noise sidebands are also multiplied by the same factor—but the AM sidebands are either unchanged or limited.

In such a case, direct rf-spectrum measurements at the multiplied frequency are a good approximation of the phase-noise sidebands. The sidebands are usually corrected and normalized to the carrier to give the relative powers in the sideband phase fluctuations with respect to the carrier level. This ratio is termed $\Psi(f)$.

**Improving resolution**

One way to achieve better resolution is to translate the signal down in frequency to the range of an analyzer with the desired i-f bandwidth. Fig. 1 shows a typical setup that uses a doubly balanced mixer and a low-pass filter. One of the advantages of this technique is that AM sidebands on the measured signal are stripped off.

Two potential problems must be considered. First, the difference frequency will contain sidebands that are folded up from below zero frequency. Whether the sidebands are significant or not depends on the nature of the source being measured. Second, phase-noise sidebands from the reference will be translated down at the mixer. You can avoid this problem by using a source with better phase-noise specifications than the unit under test.

The only way to measure sidebands beyond the dynamic range of the analyzer is to eliminate the carrier frequency. You can do this with a frequency discriminator, as shown in Fig. 2. To ensure that the calibration factor is constant, you must check the linearity of the discriminator over the frequency range of interest. For microwave frequencies, the cavity discriminator is particularly useful.

Perhaps the most versatile setup is a doubly balanced mixer and a low-pass filter as shown in Fig. 1. This technique allows for direct measurement of the phase-noise sidebands without the need to translate the signal down in frequency. The sidebands are processed and normalized to the carrier level to give the relative powers in the sideband phase fluctuations.

**Chuck Reynolds,** Product Engineer, Hewlett-Packard, Loveland, CO 80537.
balanced mixer with the unknown and the reference sources set in phase quadrature, 90°, at the input (Fig. 3). At quadrature, the difference frequency is zero hertz, and the average voltage output is zero. For phase fluctuations much less than one radian, the voltage fluctuations at the mixer output are related to the phase fluctuations by the following equation:

\[ \phi = \frac{V}{K}, \]

where \( K = \) calibration factor in volts/radian.

The calibration process

The system is easily calibrated. Offset one of the sources and observe the resultant beat signal on an oscilloscope. The slope at the zero crossing in volts/radian is \( K \), and for sinusoidal beat signals \( K \) equals the peak voltage of the signal.

The beat signal, as viewed on an analyzer, is the rms value, or 3 dB less than the peak. In terms of the ratio of the sideband voltage to the beat-signal voltage, the power-spectral density, \( S_\phi(f) \), and the sideband power, \( \varepsilon(f) \), are given by the following equations:

\[
S_\phi(f) = V_s - V_n - 3 \text{ dB},
\]

\[
\varepsilon(f) = V_s - V_n - 6 \text{ dB}; \phi(f) << 1,
\]

where \( V_s \) is the sideband voltage in dB corrected for bandwidth and analyzer characteristics, and \( V_n \) is the beat-signal rms level in dB.

The underlying assumption so far is that the reference source has a much lower phase noise than the unknown source. For state-of-the-art sources, you can compare two “identical” sources and assume that the phase noise of either one is 3 dB less than the measured values. Measuring various combinations of pairs of “identical” sources should test this assumption.

Often, sources don’t remain stable long enough for a quadrature-phase relationship to be held during the measurement period. In this case, one of the sources must be adjusted periodically. A phase-locked loop can be used if either source—or both—has a voltage control with which to make small-frequency adjustments (Fig. 4).

To retain a constant relationship between phase and voltage fluctuations, the low-frequency cutoff of the phase-locked loop must be below the lowest frequency to be analyzed. If the breakpoint is moved out—by adding gain in the loop—the voltage fluctuations at frequencies below the breakpoint will represent frequency fluctuations. To calibrate with the phase-locked setup, disconnect the feedback voltage and observe the beat signal as before.

Getting around frequency limits

In practice, phase-noise analysis often covers a frequency range greater than that of a single

---

3. Phase detection at quadrature also eliminates the carrier. The mixer output is proportional to the noise.

4. When source stability is a problem, a phase-locked loop permits automatic adjustment of either source.
5. Two spectrum analyzers provide increased frequency coverage when phase noise spans a wide range. Adding a programmable calculator gives automatic measurements.

6. The beat signal (top) and the 0-to-100-Hz sidebands (bottom) produced by the setup in Fig. 5.

7. Automatically plotted phase-noise sidebands: Each point is the average of many readings.

selective analyzer: So two analyzers can be used. Two units covering the range of 5 Hz to 13 MHz, for example, can test a 10-MHz synthesized source. The setup is a phase-locked system as illustrated in Fig. 5. The 50-kHz analyzer shown, the HP 3580A, has a 1-Hz i-f bandwidth, which provides high resolution with minimal correction factors.

The two scope photographs in Fig. 6 show the beat signal referenced 0.5 dB below the top of the screen (+2.5 dB for correction, −3 dB for peak) and the resulting phase-noise sidebands from 0 to 100 Hz. Notice that the scale is different on the sideband photograph because the input sensitivity is increased after calibration. The discrete 60-Hz modulation signal clearly appears above the phase-noise sidebands.

Making automatic measurements

To improve noise measurements, you can opt for an automatic system. For instance, an automatic spectrum analyzer with a calculator controller can cover the range from 100 Hz to 1 MHz. The programmable power of such a system allows the user to select points that avoid discrete signals and thus quickly determine a phase-noise-sideband envelope over a wide frequency range. The key to this capability is a programmable synthesizer combined with a tracking analyzer that features digital readout and output, rather than a built-in CRT.

The automatic analyzer's internal structure is similar to most spectrum analyzers. The programmable calculator, through software written by the operator, controls both analyzer and synthesizer over a bidirectional interface. And the calculator manipulates data received from the analyzer and plots the normalized, corrected results on an optional digital plotter.

Figure 7 shows the continuation of the phase-noise sidebands analyzed with the 3580A. Numerical averaging of many readings in software enables you to plot a single point at each frequency with a high degree of confidence.

In addition to the improved measurement achieved by an automatic system, the operator interaction provided by the calculator makes such difficult measurements as phase-noise sidebands much simpler. The system leads you through each of the necessary steps of calibration, measurement, data reduction, and plotting.

Programs used to make such measurements are described in Hewlett-Packard application note 207.

Reference

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CIRCLE NUMBER 52
Measure SAW-device characteristics, and pin down the performance of acoustic-wave filters and delay lines. Frequency response and impedance are the key parameters.

If you're working with surface-acoustic-wave (SAW) devices, you'll have to make frequency-domain measurements to determine the device impedance, amplitude and phase characteristics. One way you can find a SAW transducer's impedance requires three steps:

- Measure the interelectrode capacitance, $C_T$, with a special probe station and a sensitive capacitance meter.
- Determine the electrode resistance, $R_e$, by a Q measurement with the same equipment.
- Measure the radiation resistance, $R_a$, with a vector impedance meter or a network analyzer.

Device amplitude and phase characteristics can be measured most efficiently with a network analyzer. If extraneous signals are troublesome, use a gating technique to take care of them. Note that a network analyzer can measure the time delay of both dispersive and nondispersive devices.

The bandwidth and dynamic range of the test system are particularly important to your measurements. In swept frequency-domain measurements, the sweep rate must be kept well below the bandwidth of the system under test so that you don't lose valuable amplitude and phase information.

Since a SAW device is relatively lossy, you need high-gain amplifiers to provide adequate signal levels at both the input and output ports. The preamplifier should provide at least +20 dBm of

Phil Snow, Design Engineer, Tektronix Inc., P.O. Box 500, Beaverton, OR 97005.

1. When measuring device parameters, a probing station makes contact with the electrode pads of an acoustic-wave device without introducing extraneous capacitance. (Courtesy of Hughes Aircraft.)
output, and the output amplifier a relatively low-noise signal (less than 10 dB). Moreover, the amplifiers’ bandwidth should be wide enough to avoid adding distortion to the amplitude and phase-response measurements.

The dos and don’ts of measuring impedance

Knowing the SAW device’s input and output impedance is important when you want to match the device to other components or design an appropriate test-equipment interface. The impedances are a function of the physical geometry of the transducers at the device input and output. The transducers, patterns of interleaved (interdigital) electrodes, translate electromagnetic signals, or vice versa.

To measure $C_T$ without introducing stray or parasitic capacitance, you must set up a special probe station (Fig. 1). The probes should have rounded tips to prevent the transducer metal from being scratched and to make good contact with the transducer’s electrode pads (called sum bars). The capacitance meter should be capable of measuring at frequencies of about 1 kHz to 1 MHz.

The frequency is kept low so that radiation reactance—which becomes a factor at frequencies within the device passband—will not be included inadvertently in the measurement. An accurate, sensitive capacitance meter is required for this measurement (for example, the Tektronix 130 L/C meter, which measures capacity from a fraction of a picofarad to 300 pF).

If the capacitance meter can also measure $Q$, you can determine electrode resistance $R_e$ at the same time. Keep the measurement frequency low enough and well outside the passband of the transducer, and $R_e$ will be the only resistance associated with the $Q$ measurement.

Because the metal thickness of most interdigital transducers is much less than one skin depth—even at frequencies in excess of several gigahertz (thickness typically ranges from about 500 Å to 5000 Å)—$R_e$ is essentially constant for all practical frequencies of operation. Thus, you can assume that $R_e$ equals its dc value.

Reactance can mask results

Since the series-radiation resistance, $R_s$, varies with frequency, you should measure $R_s$ over the device passband. Obtaining an accurate, direct reading with an impedance meter is difficult because the resistance tends to be masked by the relatively large circuit reactance. Even a Smith-chart plot from a direct, swept network analyzer is unsatisfactory because of the generally high reactance-to-resistance ratio.

(continued on page 114)
Revisiting the surface-acoustic-wave device

Surface-acoustic-wave (SAW) devices consist of piezoelectric crystal substrates, with metalized interdigital transducers applied to a highly polished surface (see figure). A SAW's physical size is largely a function of the frequency of operation, bandwidth or delay requirements. (See ED No. 16, August 2, 1975, p. 74 and ED No. 16, August 2, 1973, p. 35.)

The device is gaining in popularity in circuits like bandpass filters, delay lines and compression filters because of its high reproducibility—inherent through relatively simple thin-film and photolithographic techniques. On quartz or lithium niobate, an approximate delay of 1 µs per 3 mm can be achieved.

In the figure, electromagnetic energy applied to the injection transducer is transformed to acoustic energy. The acoustic signal propagates primarily along the surface of the crystal and is transformed back to an electromagnetic signal at the detection transducer. An electromagnetic wave travels about 100,000 times as fast as an acoustic wave.

Since the conventional interdigital transducer radiates acoustic energy equally well in either direction along the axis of propagation, end absorbers are required to suppress acoustic signals that don't travel directly from the input to output transducer.

The frequency of operation of a SAW device is a function of the electrode spacing, and the bandwidth is inversely related to the overall length of the transducers. The acoustic nature of the crystal and the ease of amplitude and time weighting of the transducers make the SAW device suitable for delay lines and filter applications.

Which electrical tests to perform on a SAW device depends to some extent on the device function, that is, whether it is a bandpass-filter or dispersive-delay line. Also, a device mass-produced for the television industry naturally will be tested differently from a state-of-the-art component undergoing evaluation in a research laboratory. In any case, since surface-wave devices can be specified in the time as well as the frequency domain, testing in both domains is necessary.

(continued from page 113)

To circumvent the masking, eliminate reactance $X_r$ from the measurement by connecting an appropriate variable series inductor from one of the transducer's sum bars to ground. This connection will minimize undesirable shunt capacitance effects that can invalidate the measurement if the inductor is inserted in series with the non-grounded sum bar.

The inductor is resonated with $C_T$ and the series resistance measured at each measurement frequency. Either a vector-impedance meter or a network analyzer can indicate the series resistance at resonance.

The series resistance is the sum of three parts:

$$R_m = R_s + R_e + R_i,$$

where

$R_m$ = measured series resistance at resonance,
$R_e$ = series electrode resistance, and
$R_i = L_T/Q_i =$ series inductor resistance (where $Q_i$ is the $Q$ of the inductor $L_T$ at the resonant frequency).

Since you have measured $R_e$ already and since you can determine $R_i$, simply by measuring $L_T$ and $Q_i$, you can calculate the series radiation resistance from Eq. 1.

Impedance points to problems

Transducer resistance and capacitance can also indicate the quality of device fabrication. Opens in the transducer metallization show up as a $C_T$ less than the design value. One or more shorted electrodes result in zero capacitance. Compare the measured value of $R_e$ with either a calculated value (obtained from knowledge of the physical design) or an averaged $R_e$ determined from a number of devices having the same pattern and metallization. Wide variations in $R_e$ indicate irregularities in electrode width or metal thickness.

A typical bandpass-filter frequency response, produced by an HP 8410A network analyzer, is shown in Fig. 2a. The filter's 1-dB bandwidth is 2.5 MHz, centered at 110 MHz. The phase response of the same filter is shown in Fig. 2b. You can take a closer look at the phase response with-
3. Spurious signals can mask true SAW-device swept response (a). You can clean up the response with a sampling technique (b).

in the filter passband by narrowing the analyzer's swept-frequency band to expand each two-pi segment of the phase-response waveform.

Since the bandpass filter of Fig. 2 has double (split) electrodes, it operates with equal efficiency at the third harmonic (110 MHz) and the fundamental (Fig. 2c). The hash near the fundamental stems from electromagnetic feedthrough of the signal, and the extraneous response at twice the fundamental can be traced to bulk-acoustic waves. Note that the filter is not connected to matching networks; only two broadband baluns suppress electromagnetic feedthrough. With matching networks, both the fundamental and bulk-wave interference are considerably reduced.

Avoiding interference problems

The true amplitude-response characteristics of a SAW device can be masked by high spurious signal levels. Typical interference phenomena include triple-transit echo, crystal-end reflections, bulk waves and electromagnetic feedthrough (Fig. 3a). Observe the ripple in the passband and the general filling-in of the side-lobe structure, which characterizes bulk-wave and electromagnetic-feedthrough interference.

With sampling techniques, you can sort out and eliminate interference signals from the measurement. The cleaner frequency response in Fig. 3b is the result of selective gating and sampling (Fig. 4).

The action of the test setup in Fig. 4 is as follows: Pulse generator No. 1 gates switch No. 1 to pass an rf “burst” from the sweep generator. The burst is amplified and fed to the SAW device. The pulse width is set approximately equal to the reciprocal of the device's acoustic bandwidth. This setting provides maximum amplitude for minimum pulse width.

Pulse generator No. 2 is triggered by pulse generator No. 1 to produce a delayed pulse. The delay interval is adjusted to equal the minimum time spacing between the input and output transducers of the SAW device. The delayed pulse then gates switch No. 2, which passes a signal to the network analyzer only during the brief period that the desired rf pulse is present at the output of the SAW device.

To obtain enough samples to reproduce an accurate amplitude response, the pulse-repetition rate—set by generator No. 1—should be much greater than the sweep rate of the rf sweep generator. The upper limit of the repetition rate is set by the maximum time spacing between input and output transducers. Actual pulse rate is best determined empirically, within the limits just defined, for each type of device tested.

(continued on page 116)
When a network analyzer isn't available, a vector voltmeter and counter can substitute. The counter monitors frequency changes, and the voltmeter reads changes in the phase angle. A formula then calculates the device time delay.

When phase information is not important, but amplitude dynamic range is, a combination tracking generator and spectrum analyzer (such as the Tektronix TR 502/TL13) can readily replace the rf sweep generator/network analyzer.

Other test configurations

With a network analyzer, you can measure the time delay of any SAW device, be it dispersive or nondispersive. To determine time delay $t_d$ at a frequency, measure the slope of the phase-vs-frequency response. A small increment ($\Delta\phi/\Delta f$) near the frequency in question is sufficient. Delay is then found from the following formula:

$$t_d \text{ (in sec)} = \frac{1}{360} \times \frac{\Delta\phi \text{ (in degrees)}}{\Delta f \text{ (in hertz)}} . \quad (2)$$

By definition, the time delay of a nondispersive SAW device is a constant for all frequencies in the passband. Thus a linear phase response indicates that the device under test is nondispersive.

The next best method is offered by the test setup shown in Fig. 5. A vector (phase) voltmeter measures the phase-angle change for a given frequency change. In the figure, frequency changes are monitored by the counter, and you calculate the time delay from Eq. 2.

Although highly accurate, the frequency-change method can be rather tedious, especially if the bandwidth is large or the time delay long. You'll need much time to determine the delay across the entire passband of a surface-wave device. • •

A subsequent article will cover time-domain measurements of SAW devices.
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118 ELECTRONIC DESIGN 4, February 15, 1977
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Frequency synthesis with a phase-locked loop is an effective and inexpensive approach to most synthesis problems (Fig. 1). However, to generate signals in the vhf or uhf range with high resolution, a straightforward loop approach requires many decades of a synchronous-counter chain. And the counter must be capable of operating with frequencies in the 150-to-300-MHz range.

An improved loop that includes a digital-mixing circuit (Fig. 2) can do the same job with many fewer high-speed counter stages. Moreover, the synchronous-counter chain runs at a greatly reduced speed, and both the reference-signal frequency and resolution remain the same as in a conventional phase-locked loop.

Although digital mixing has been around for some time, it isn't widely understood; thus a review of the theory and design equations, along with an application of these equations should be useful to many design engineers.

The mixer is a D flip-flop

The mixing operation takes place in a D flip-flop, whose clock input receives a frequency, \( f_c \), that is lower than its D-input frequency, \( f_o \). The relationship of the mixer's output frequency, \( f_q \), to \( f_c \) and \( f_o \) is defined in Fig. 3. Since only the frequency of \( f_q \)'s zero crossings is important, \( f_q \) requires no analog filtering when fed to the divider counter.

When input signal \( f_o \) from a VCO and a sampling signal \( f_c \) from a mixer oscillator are mixed in this manner, each signal can be considered quantized into one bit—ON or OFF. The sampling rate, \( f_c \), is too low for accurate reproduction of \( f_o \) and \( f_c \) is aliased, or “folded,” about the value, \( 1.5 f_c \), plus all higher-order frequencies, \((N+1/2) f_c\), where \( N = 1, 2, 3, \ldots \). The mixer output \( f_q \) never exceeds \( 1/2 f_c \) (Fig. 3a).

The mixer action provides the flip-flop outputs:

Dr. John Nemec, Bipolar Microprocessor Product Planning Manager, Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086.
\[ f_0 = f_0 - Nf_c \]
\[ \text{for } Nf_c < f_0 < (N+1/2)f_c \]  
\[ (1) \]
\[ f_0 = (N+1)f_c - f_0 \]
\[ \text{for } (N+1/2)f_c < f_0 < (N+1)f_c . \]  
\[ (2) \]
Frequency \( f_0 \), the voltage-controlled oscillator (VCO) frequency, becomes equal to the output frequency, \( f_o \), and the mixer output drives the counter. The synthesizer counter in the improved-loop version (Fig. 2) operates with a relatively low-frequency input, \( f_q \), whereas in the basic phase-locked loop of Fig. 1, the counter receives the high-frequency, \( f_o \), directly from the VCO.

Thus, where in Fig. 1
\[ f_o = M_s f_R, \]  
\[ (3a) \]
in Fig. 2, the improved version,
\[ f_o = Nf_c + M_s f_R, \]  
\[ (3b) \]
and \( M_s \ll M_s \).

In both cases, the reference frequency, \( f_R \), is the same and determined by the desired resolution of the synthesized frequencies. Since \( M_s \) (or \( M_s \)) is a whole number with minimum increments of one, \( f_R \) must equal the resolution frequency.

At first glance, the factor \( Nf_c \) in Eq. 3b should be simply maximized to minimize \( M_s \). However, a detailed analysis (Fig. 3a) shows that \( N \) and \( f_c \) can’t be arbitrarily chosen.

Establishing the design criteria

Suppose the circuit operates in the \( N \)th “cycle”—between \( Nf_c \) and \( f_0 \) (Fig. 4). The mixer output with a high \( f_0 \), also is larger than a value of \( f_0 \), which would correspond to an input \( f_0 \). Clearly, from Fig. 3b, if \( f_0 \) falls within the \( f_0 \) to \( f_0 \) range, the mixer-output frequency is always higher than \( f_0 \). Anywhere in this range, then, the error-signal polarity and the negative-feedback configuration pull the VCO frequency back to make the system’s \( f_0 \) (and \( f_0 \)) equal to the desired value, \( f_0 \). Similarly, should \( f_0 \) fall somewhat below \( f_0 \), the error signal in the loop acts to increase \( f_0 \) to \( f_0 \).

However, if \( f_0 \) exceeds the value \( f_0 \), the circuit can no longer return the VCO to \( f_0 \). Although \( f_0 \) exceeds \( f_0 \), the mixer output, \( f_q \) is now less than \( f_0 \). Therefore, when the circuit tries to correct, the frequency of the VCO moves in the wrong direction—completely away from \( f_0 \) until a new lock point is reached that is far outside of the desired \( f_0 \) to \( f_0 \) range.

A similar analysis applies to a desired frequency, \( f_n \), near the lower end of the \( Nf_c \) to \( f_0 \) c slope, where \( f_q \) must remain lower than \( f_0 \).

The VCO range must be restricted

For reliable circuit operation, therefore, the VCO must be restricted to operate within the \( f_n \) to \( f_n \) range, so that the error signal will have the proper sense of direction. And from Fig. 3b, the range of desired output frequencies, \( f_0 \) to \( f_0 \), should be comfortably less than the total range of the \( Nf_c \) to \( f_0 \).

\[ f_n - f_n < (N+1/2)f_c - Nf_c. \]  
\[ (5) \]
Therefore, the sampling-oscillator frequency relationship,
\[ f_c > 2(f_l - f_L), \]  
\[ (4) \]
becomes a criterion for determining the minimum value of \( f_c \).

If the operating range, \( f_n \) to \( f_n \) is centrally positioned on the \( Nf_c \) to \( f_0 \) slope, then
\[ Nf_c + (N+1/2)f_c = f_0 + f_0, \]  
\[ (6) \]
and
\[ f_c = \frac{f_0 + f_0}{2(N+1/4)} \]  
\[ (5) \]
Noting that \( f_0 \) and \( f_0 \) appear symmetrically about \( N+1/2)f_c \),
\[ Nf_c = (f_0 + f_0)/2, \]  
\[ (N+1/2)f_c = (f_0 + f_0)/2, \]  
\[ (6) \]
and
\[ f_0 = 2Nf_c - f_0 \]  
\[ (6) \]
4. A vhf aircraft-radio of 118 to 136 MHz with 25-kHz resolution is synthesized with only three decades of

\[ f_{\text{off}} = (2N + 1) f_c - f_{\text{ir}}. \] (7)

Eqs. 6 and 7 represent the range within which the VCO must be restricted for the system to work properly and provide a safety margin on either side of \( f_{\text{ir}} \) and \( f_c \).

Eliminating the \( f_c \) term between Eqs. 6 and 7 and introducing the relationships

\[ f_{\text{ir, L}} = f_{\text{ir}} - \Delta f, \]
\[ f_{\text{ir, H}} = f_{\text{ir}} + \Delta f, \]

where \( \Delta f \) is the safety range for operation of the VCO below \( f_{\text{ir}} \) and above \( f_{\text{ir}} \), we get

\[ N = 1/ \left[ 2 \left( f_{\text{ir, H}} + \Delta f/2 \right) \left( f_{\text{ir, L}} - \Delta f/2 \right) - 1 \right]. \] (8)

(Since \( N \) must be an integer, any fractional part obtained with Eq. 8 is dropped.)

As a result, given the desired frequency range—from a high of \( f_{\text{ir, H}} \) to a low of \( f_{\text{ir, L}} \)—and safety margins, \( \Delta f \), for the operating of VCO at both ends of the range limit, \( N \) can be determined.

**Detailing a design example**

As an example, consider a frequency-synthesis system for carrier frequencies in the vhf aircraft-radio band of 118.0 to 136.0 MHz, with the aircraft channelized in 25-kHz increments.

As a first step, assume a safety margin for \( \Delta f \) equal to, say, 10 MHz. Then from Eq. 8

\[ N = 1/ \left[ 2 \left( \frac{136 + 5}{118 - 5} - 1 \right) \right] \approx 2 \]

counters that count from 208 to 928. The 56.4-MHz mixer oscillator should be crystal controlled.

Then, from Eq. 5,

\[ f_c = \frac{136 + 118}{2 \times 2.25} = 56.444 \text{ MHz} \]

Note, however, that 56.444 MHz is a value for \( f_c \) based only upon a safety-margin criterion. The exact value must be chosen to provide the desired channel frequencies for integral values of \( M_i \)—in this case 56.400 MHz.

And from Eq. 3b

\[ f_0 = 2 \times 56.4 + 0.025 M_i, \]

\[ M_i(\text{min}) = \frac{118 - 112.8}{0.025} = 208 \]

and

\[ M_i(\text{max}) = \frac{136 - 112.8}{0.025} = 928 \]

The final synthesizer design is shown in Fig. 4. The value of \( M_i \) to be loaded into the counter ranges from 208 to synthesize 118.0 MHz to 928 to synthesize 136.0 MHz.

All of the essential circuit details are shown except for the \( \div M \) counter chain and the 56.4-MHz oscillator for the mixer input. The \( \div M \) counter design is straightforward. The 56.4-MHz oscillator should be a crystal-controlled oscillator for stability.

With the 10131 flip-flop mixer (see Fig. 4), the VCO can run at frequencies to 250 MHz. Uhf operation requires a faster flip-flop. However, compared with the task of constructing a multi-stage counter at these high frequencies, achieving such speeds with a flip-flop is easy.

Electronic Design 4, February 15, 1977
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- Illuminated graticule
- TTL compatible intensity modulation
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- P31 blue phosphor
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• 35nS risetime
• P31 phosphor
• X-Y capability using matched DC amplifiers
• Internal calibration source
• TTL compatible intensity modulation
• 10mV/cm vertical sensitivity

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(including two 10:1/direct probes)

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A 5” triggered scope with TTL compatible Z-axis
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• 35nS risetime
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• 5x magnification sweeps to .2 µS/cm
• Vectorscope capability
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• Internal TV sync separator
• P31 phosphor
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FOR PRODUCT INFORMATION CIRCLE 58
FOR PRODUCT DEMONSTRATION CIRCLE 59
Dick Lee of Siliconix
Speaks On
Making Your Engineers Bigger

Today's engineer is not like the engineer of 30 years ago. In those days he was the introverted slide-rule pusher who was kept in the back room, dealing with formulas, figures and breadboards. That man is gone.

Today, at least in high-technology businesses, he's involved in a wide range of disciplines. He works with chemistry, physics, metallurgy, mathematics, computer science, mechanical engineering and industrial engineering.

Our universities produce young engineers with rounded personalities. We find engineers today, right out of school, who know something about behavioral sciences, transactional analysis, time management—things like that. These people can't be locked in a back room. They are goal-oriented. They have plans about their personal careers. And they want to grow.

If you want to succeed in a technical business, you have to help your engineers grow. But you must guide their growth so they'll be useful to themselves and to the company.

The first lesson in growth is selectivity. You must teach your engineers that it makes sense to be selective—with people, products, markets, customers, pricing, planning—everything. They must learn that everything is a matter of choice.
Second, since all men are not created equal—or, at least, they're not equal in the business world—it's necessary to seek, recognize and reward creativity.

Third, it's wise to encourage a controlled overlap. This expands your engineers' horizons and it helps them work more effectively as it gives them a reason for what they're doing. At Siliconix we overlap functionally between all the classical elements in any organization. We overlap between engineering and manufacturing, between engineering and sales, between sales and manufacturing, and so on.

Fourth, it's necessary to focus on maximizing the congruence of goals. If some of your people are aiming at one goal and others are going in a different direction, you won't be very effective.

Fifth, I think you always have to think about raising the level of effectiveness. It's more important to do the right things than it is to do things right. The distinction is not a mere quibble. It's important to think about effectiveness rather than efficiency. I want my people to be more effective and to worry less about being more efficient.

Finally, I think the age-old communications problem is still a major challenge to engineering managers.

I think an unbelievable number of basic tasks of management all come down to: "How do we communicate among human beings?" We have to worry about all lines of communications involved in proposing, approving and reviewing every project. We have to know if we're dealing with facts or with the rumor mill. It's not always easy.

Now, as you go through these things, you will inevitably face pitfalls. One obvious pitfall is that you may bring in new engineers who have bad habits. There are many engineers around who lack technical excellence. They're not disciplined to seek thoroughness in their work. And in an LSI product today, a design mistake is extremely costly.

Another pitfall you face, especially if you're in a semiconductor company in the Bay Area, is the never-ending problem that the grass always looks greener somewhere else. The competitive pressures for good people here are very high.

A third pitfall is the whole collection of normal human frailties—things like jealousy, greed and the NIH and NIBM syndromes. Most of us are familiar with the Not-Invented-Here problem. But the Not-Invented-By-Me reaction can be even more destructive. A manager has to recognize and cope with these general traits and, if he's in the semiconductor industry, with another factor that comes about because so many people have worked for other semiconductor companies.

If you check through our plant, you'll find one or more of our engineers have come from some two dozen other semiconductor companies. So you find people saying, "We should do it this way because that's the way Company X did it." Or, "We shouldn't do it this way because that's what they did at Company Y—and they were stupid."

A fourth pitfall lies in failing to recognize the individual who might make a great manager. Unfortunately, he doesn't wear a sign. So it's hard to see which fellow should be groomed for management and which should stay in engineering.

All of these challenges and pitfalls are based on dealing with people. And that's the most complex and demanding of management skills.

You have to remember that the key word in the electronics industry is change, and change is often painful. People resent it. Yet they must respond to it if they are to grow and if your company is to grow. But you can't change everybody. People who are unwilling to change over a reasonable period of time must be replaced, or, at least, replaced in a particular responsibility.

You may find that some peoples' management styles and operating styles may be incompatible with the company's direction. You can't have a hip-shooter managing large portions of a 50- or 100-million dollar corporation.

But it may not be easy to see the problem. In one case it may be painfully obvious that some action should be taken. In another case it may not be quite clear.

If you eliminate structures and levels between your top management and the people doing the engineering, that helps make people pretty visible quickly—but not necessarily. It's often possible to find that some of your engineers are working on a pet project that you don't know anything about.

I think that, at Siliconix, we have succeeded a great deal in eliminating that problem by making our junior engineers more conscious of the cost of their time, of techniques for managing their time and of the importance of delegating jobs they don't need to do themselves.

We try to teach our engineers how to do the jobs that need to be done and the jobs that only they can do.
(continued from page 127)

Now some of these problems don't have a simple, neat solution. But let me tell you how I respond to one of the trickiest of them—the problem that the grass always looks greener on the other side. Our approach is simple: We never try to make the highest salary offer to a man we want to hire.

We spend lots of time interviewing and one of the questions that comes up is always: "What do you think you're worth?" Other questions: "Whom else are you interviewing? How are you going to make the choice among the companies you're considering? How important is the absolute dollar figure?"

Sometimes we lose somebody because another company offers him $20 a month more than we've offered. My people often criticize me and say we should have increased our offer by that piddling amount. But I think they're wrong.

If money is that important to a man, he would jump to another company after we trained him if it offered him another few dollars. I think our philosophy really helps us separate the guy who job-hops for money from the fellow looking for an opportunity to grow. ■

Who is Dick Lee?

He got his bachelor's, master's and then in December 1950, at the age of 22, his degree of engineer from Stanford University, "Degree of Engineer"? A strange degree. It was recommended in those days instead of a PhD, except for people who wanted to teach or go into research.

But Dick Lee got tired of all the puzzled queries, so, after five years in industry, "I went back to Stanford and bought a PhD."

He moved to Washington, DC to join Emerson Radio and Phonograph Corp., which was almost entirely a military house. But that was during the Eisenhower administration when there were very few military contracts. In his last major proposal, Lee turned out 900 pages of paper, but the contract went to another bidder. That was just too much frustration.

So he wrote to Mark Shepherd (who later became president of Texas Instruments), and said: "If that job offer you made in 1951 still exists, I accept." And in January 1958 he joined TI in Dallas and organized its applications engineering force, helped develop the first integrated circuit with Jack Kilby and one technician and, in time, became marketing manager for the transistor division.

He left in December 1961 when D. H. Baldwin (the piano company) invited him to become general manager of the company that, three months later, emerged as Siliconix, with Lee as president.

Lee and his wife Pauline have two daughters, 17 and 19, and lots of cars. He loves to tinker with foreign cars and now owns a Mercedes, an Alfa-Romeo and a Capri.

When he's not running Siliconix, a company with more than 730 employees in the U.S., including more than 200 professionals, and when he's not running his automobiles, Lee finds time for his substantial library of recorded music—from opera to rock—and for what he calls a modest art collection.

He frequently hangs work from his own collection at Siliconix, and allows employees to buy them, practically at cost.

He's amused by employee reactions, which range from, "That's the most beautiful painting in the world" to "Please don't make me sit in front of that monstrosity." The paintings, Lee feels, are just one part of the over-all beauty of the Siliconix plant and its surroundings that helps make a pleasant and creative atmosphere.

ELECTRONIC DESIGN 4. February 15, 1977
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BATCH TESTED TO SPECS COPPER

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"Standard practice" can now change for the better—and cheaper. Up to now, industrial transistors have been specified in cans, to get reliability under heat and humidity. Consumer products have been able to tolerate the less expensive but less stable plastics. Now NEC has incorporated 5 technical advances that make these TO-92 plastics the equal of any hermetic metal case for most applications—and you get the lower price to boot!

1. GOLD-PLATED, MULTILAYER METALLIZATION. Because gold is electrically noncorrosive and inert to acids and alkalis. And moisture resistance and bonding strength are greatly improved over aluminum construction.

2. SILICON NITRIDE PASSIVATION. Increases moisture resistance, while protecting against unreliability due to impurities. And, the operating characteristics improve, such as higher dc amplification factor and better noise figure.

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THEY ADD UP TO SUPER SPECS. The two charts shown are only a sampling—NEC's 8-page brochure of TO-92 specifications is the real convincer. Write or call for your copy if you're seriously interested—our line of small-signal transistors for telecommunications, instrumentation, etc. is so broad we can provide almost any device you may require in TO-92. And if you're into hybrids, ask for data on our MINI MOLD transistors—plastics uniquely configured for reliability with big savings in assembly time and cost.

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Or for more information on standards that are something special, contact TRW/UTC Transformers, an Operation of TRW Electronic Components, 150 Varick Street, New York, N.Y. 10013. Area Code: 212 255-3500.
Convert seven-segment numerical code to decimal with simple gates

Any number in seven-segment code can be converted easily to decimal form with, at most, a four-input gate. Indeed, in many cases, a two-input gate with no more than three inverters can do the job.

Table 1 lists each number and its seven segment code. Table 2 provides a minimized logic equation for each number, where the variables a through g correspond to the numerical-display segments. Any one of the ORed terms in the logic equation for each number can be used to identify that number.

For example, Fig. 1 illustrates the three ways the number 0 can be detected. If the segment information comes from a scanned source (a calculator chip), an additional input (Fig. 1c) detects only the desired digit position. But note that with most calculator chips, the display is blanked during the computation period.

Another precaution: Calculator chips that drive LED segments without external current-limiting resistors or internal current sources (FETs) to limit the current. Therefore, the voltage-output change is the voltage swing across the LED—typically only 2 V. Such a small change can’t switch a CMOS gate reliably. But an emitter follower with a current-limiting resistor and LED segment in the emitter can provide the required logic swing. Alternately, a resistor could be used in series with the LED, but this would dim the display.

Raymond G. Kostanty, Consultant, 4185 Del Mar Ave., Long Beach, CA 90807. CIRCLE No. 311

### Table 1. Convert seven segment to decimal

<table>
<thead>
<tr>
<th>Display</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
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<td>0</td>
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<td>1</td>
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<td>1</td>
</tr>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Minus</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 2. Code conversion equations

0 \(= \overline{\text{gd}} + \overline{\text{ge}} + \overline{\text{gf}}\)
1 \(= \text{af} + \overline{\text{ag}} + \overline{\text{abf}} + \overline{\text{acf}} + \overline{\text{abg}} + \overline{\text{acg}}\)
2 \(= \text{ca} + \overline{\text{cb}} + \overline{\text{cd}} + \overline{\text{ce}} + \overline{\text{cg}} + \overline{\text{ef}}\)
3 \(= \overline{\text{def}} + \overline{\text{cfg}} + \overline{\text{efg}}\)
4 \(= \overline{\text{af}} + \overline{\text{ae}} + \overline{\text{abf}} + \overline{\text{def}}\)
5 \(= \overline{\text{be}} + \overline{\text{ab}} + \overline{\text{abe}} + \overline{\text{cbe}} + \overline{\text{dhe}} + \overline{\text{fhe}}\)
6 \(= \overline{\text{be}} + \overline{\text{ae}}\)
7 \(= \overline{\text{ad}} + \overline{\text{afg}} + \overline{\text{aeg}} + \overline{\text{adg}} + \overline{\text{adf}}\)
8 \(= \overline{\text{befg}} + \overline{\text{bcff}}\)
9 \(= \overline{\text{abf}}\)

Minus \(= \text{ac} + \overline{\text{bc}} + \overline{\text{bd}} + \overline{\text{bf}} + \overline{\text{cd}} + \overline{\text{ce}} + \overline{\text{gc}} + \overline{\text{gaf}} + \overline{\text{gbc}} + \overline{\text{gbd}} + \overline{\text{gbf}} + \overline{\text{gcd}} + \overline{\text{gce}} + \overline{\text{gdf}}\)

Any Number \(= (\text{c} + \text{g}) + (\text{c} + \text{a}) + (\text{c} + \text{b}) + (\text{c} + \overline{\text{d}}) + (\text{c} + \overline{\text{e}}) + (\text{b} + \overline{\text{d}}) + (\text{b} + \overline{\text{f}}) + (\text{b} + \text{g})\)

Blank (Minus allowed) \(= \text{gac} + \overline{\text{gbc}} + \overline{\text{gbd}} + \overline{\text{gbf}} + \overline{\text{gcd}} + \overline{\text{gce}} + \overline{\text{gdf}}\)

Blank (Minus not allowed) \(= \overline{\text{abc}} + \overline{\text{ac}} + \overline{\text{bc}} + \overline{\text{bd}} + \overline{\text{bf}} + \overline{\text{cd}} + \overline{\text{ce}} + \overline{\text{cg}} + \overline{\text{bg}}\)

Superscripts:
1. This term cannot be used if display can ever be blank.
2. This term cannot be used if display can show a minus.
3. This term can be used only if number 9 includes segment d.
4. This term can be used only if number 6 includes segment a.
5. This term cannot be used if number 6 includes segment a.
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3MHz to 2350MHz

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DESCRIPTION
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High Output Level-0.7v RMS into 50 ohm
Wide Sweep Width-100kHz to 1100 MHz
High Stability-Less than 20kHz residual fm
Flat Output-Leveling Int Ext. 0.5dB

Price $2695.00 Delivery Stock
Optical couplers isolate, control and monitor to allow 6-kV supply to float

Optical couplers can be used to operate and monitor a floating high-voltage power supply and provide both electrical and mechanical isolation between the control section and the power supply (Fig. 1).

The application is in an image converter with a 6-kV power supply used for a sounding-rocket experiment. Design constraints dictate that the device float at 6 kV. To prevent possible corona problems, it is necessary to have a fully isolated method of switching the power supply on and off, operating the electronic shutter and monitoring the current drain.

Four Monsanto MCT 81 optical couplers provide the necessary isolation. Couplers OC₁ and OC₄ operate as on/off switches to control the main power via Q₁, and the electronic shutter via Q₂, respectively.

Linear-current monitoring is provided by op-amp A₁ and two matched couplers, OC₂ and OC₃. Coupler OC₂ isolates the output signal and OC₃ is part of the feedback circuit of A₂. Even though these couplers are nonlinear, this combination results in a monitoring circuit that has good linearity, little distortion and low gain drift.

The monitor circuit operates as follows: A 1-Ω current-sampling resistor provides the noninverting input of A₂ with a signal voltage proportional to Iᵣ₁. Resistor R₁ establishes the circuit's gain and current range. Set-point resistor R₂ is adjusted to make nominal current read about half scale on the monitor-channel output and provide typically about 2.5 V (Fig. 2).

Since resistors R₁ and R₂ are equal, OC₃ and OC₄ both receive equal input currents. Also, R₁ is chosen so that Iᵣ₃ is equal to Iᵣ₄, thus, the phototransistors of both these couplers operate (continued on page 136)
"Should you make or buy control assemblies?"

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It all boils down to dollars and cents. And the best way to make a business decision is to compare our quotation for making your next customized control assembly against your true cost of making it in-house.

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Potter & Brumfield
at the same point. If the couplers are reasonably well matched, care taken to equalize the conditions for both couplers results in a linear output.

Amplifier A, serves merely as a unity-gain output buffer whose dc-output voltage varies linearly with the current through R.

Since the currents through R1 and Rs combine in R, the circuit provides not only quantitative information on the image-converter's quiescent load current but also on the effect of the electronic shutter.

John Glaab, Electronics Engineer, Observational Astronomy Branch, National Aeronautics & Space Administration, Goddard Space Flight Center, Greenbelt, MD 20771. CIRCLE NO. 312

Approximate the tangent function with a multifunction converter and op amp

You can mathematically approximate the tangent function to within 1.2% by using only a multifunction converter and an op amp.

Electronic computation of such nonlinear functions has frequently been performed by linear-segment approximations. Since a great number of such segments is required to make the actual response fit the desired function, the circuit can become very unwieldy.

However, a multifunction converter can simplify the approximation of nonlinear functions where only moderate accuracy is required. A multifunction converter is simply a logarithmic multiplier/divider that has been adapted to provide powers and roots. With the multifunction unit set for the noninteger power, 3.7, the tangent function can be approximated when the multifunction converter is combined with a summing amplifier (Fig. 1). The response for this combination is described by

$$e_o = -\frac{R_2}{R_1} \left[ \frac{e_i}{E_R} + E_R \left( \frac{E_i}{E_R} \right)^{3.7} \right].$$

Over the e_i/E_R range of one radian, this expression approximates the tangent function within 1.2% as follows:

$$e_o \approx -\frac{R_2}{0.55R_1} E_R \tan \frac{e_i}{E_R}, \text{ for } 0 \leq \frac{e_i}{E_R} \leq 1.$$

The reference voltage, E_R, determines the angular scaling of this expression; the resistance ratio, R_2/R_1, determines the amplitude scaling. With the values shown, the circuit is scaled for a 0-to-10-V output in response to the same input-signal range.

The mathematical approximation dominates the deviations from the true tangent function, except at low signal levels where circuit errors are significant. Mathematical deviation from the tangent is 1.2% maximum over a one-radian range. Beyond one radian, the deviation increases rapidly. Of course, additional deviations result from tolerances of the multifunction exponent, the summing amplifier and resistor ratio error.

The circuit tolerances introduce an error of about 0.1% of full scale, so the net maximum response error is 1.2% of amplitude plus 0.1% of full scale.

References


Jerald Graeme, Manager, Monolithic Engineering, Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85734. CIRCLE NO. 313
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- Input/output edge connector included
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CIRCLE NUMBER 65

ELECTRONIC DESIGN 4, February 15, 1977

KATY INDUSTRIES
INDUSTRIAL EQUIPMENT GROUP

137
Trace symbols on CRT screen without access to the Z axis

Use a digital PROM instead of a special analog ROM, as is done by some makers of expensive scopes, and generate your own symbols on an ordinary oscilloscope. To get the X and Y analog waveforms that trace out the symbols on the CRT, convert the digital outputs of the PROM to analog voltages.

All the hexadecimal characters (Fig. 1) can be generated with high legibility by a $5 \times 3$ matrix. An 8-bit PROM delivers 16 coordinate points that are scanned into a specific symbol. With the first and last points arranged to be adjacent, each character can be traced several times before the beam moves to the next character.

Outputs $Q_0$ through $Q_4$ of a 12-bit counter connected to lower-address inputs $A_0$ through $A_3$ of the PROM produce sequential tracing of the coordinates (Fig. 2). The upper four address inputs, $A_4$ through $A_7$, select a specific character. To smooth the waveforms, a high scanning rate (clock input of 250 kHz or higher) uses the limited frequency response of the two 741 op amps.

To generate horizontal and vertical spaces between the characters, add two staircase signals to the X and Y waveforms. The staircase signals can be derived from simple d/a converters driven by the $Q_7$-through-$Q_{11}$ outputs of the coordinate counter.

The display is not limited to alphanumerics, and the symbols need not be restricted only to a $5 \times 3$ matrix.

Marco Barnig, Swiss Federal Institute of Technology, Department of Electronics, Zurich, Switzerland.

CIRCLE NO. 314

1. Each symbol is defined by 16 points derived from the output of a PROM.

2. The characters are traced by analog signals X and Y. Two op amps convert the digital signals of the PROM and staircase generators (not shown) into the analog voltages.

IFD Winner of October 11, 1976

Walter G. Jung, Pleasantville Labs, 1946 Pleasantville Rd., Forest Hill, MD 21050. His idea "Precision Voltage-to-Frequency Converter Uses Only Single Supply Voltage," has been voted the Most Valuable of Issue Award.

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A high-power semiconductor switch can match the thyristor in its surge-current capability and high blocking voltage, yet has turn-off times nearly as fast as those for transistors. Moreover, the energy required to turn off the device, called a gridistor, is several orders of magnitude lower than that needed to turn off an equivalent thyristor.

Developed by Alsthom-Dre, in Massey, France, the gridistor, is a field-effect device with a p-i-n diode structure that uses a p-type low-resistivity grid in the I region to define a number of channels (see Fig.). The channels can all be blocked simultaneously by the field effect.

High turn-off current capability, with switching in microseconds, is achieved by a high degree of cathode-grid interdigitation. Consequently, the grid's series resistance is reduced considerably.

An experimental gridistor has a 49-mm² metalized cathode area. Each grid finger is about 500 µm long and 40 µm wide. The I channel, less than 10 µm wide, can be blocked by only 10 to 20 V between grid and cathode.

The grids are formed by masked boron diffusion. An epitaxial n-type layer is then grown, followed by an n⁺ diffusion for the cathode. Grooves are etched in the n layer to permit aluminum-grid contacts to be made.

When the grid is not connected, the device works as a p-i-n diode. When the grid is negatively biased, current is blocked. Typical forward-breakdown voltages of 700 V have been achieved with a V₀ equal to 18 V.

Unlike the thyristor, no regenerative action occurs in the conducting state. This lack of regenerative action leads to more uniform dynamic characteristics. Also, the gridistor is not hampered by the thyristor's limitations of di/dt and dv/dt.

Prototype devices have been able to switch currents up to 200 A.

Earth-to-satellite beams can now be synchronized

Processing digital signals from several sources, which is being investigated by the British Post Office for use in satellite communications, will make it possible to satisfy the changing demands of various earth stations. But the method, known as time-division multiple access (TDMA), requires a continuously variable synchronization system that is extremely accurate. Such a system has been developed by Cambridge Consultants of Cambridge, England.

Spot-beam transmissions of a worldwide digital satellite-communications system must be accurately timed to arrive at the satellite at the correct instant and in the right order. This timing requires an accuracy of ±33 ns within a 750-µs cycle time, during which the satellite receiver effectively scans through the signals coming from each of the earth stations. The signals must arrive at the satellite in the right sequence and take into account not only the different and changing path lengths between earth stations and the satellite but also unpredictable atmospheric conditions.

With TDMA, the timing information is relayed via a global beam that is transmitted from the satellite as a series of sine-wave, frequency-modulated carriers. Each ground station has its own carrier frequency within the global-beam transponder. Thus, a spectrum of PM signals is transmitted and received at the satellite, each signal corresponding to one ground station.

At one of the ground stations, a master synchronizer transmits the essential timing information from which all other ground stations derive their standard. Each ground station receives not only the master signal, but also its own looped-back timing signal. Synchronization is achieved by comparing the looped-back signal with the master-signal.

Several problems are involved, the chief one being the poor quality of the global timing signal. Cleaning up the signal demands that averaging be performed within the synchronizer equipment.

The averaging, which can take up to one second, is done partly by digital means because the error contributed by strictly analog averaging components would be too high. The averaging system itself is basically a hybrid with analog filtering down to 300 Hz combined with repetitive phase-error measurement to attain the goal of 30-ns accuracy.

Inaccuracy introduced by the equipment itself is eliminated by measuring errors and subtracting them from the signals.
Here's a new solid state memory that works wherever a reliable, non-volatile, high capacity, fast access digital memory is needed.

Ampex 3220 Series core memories are modular. Individual modules store 32K words of up to 20 bits each, and you can combine as many as 16 modules for a total memory capacity of 512,000 words.

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Size is no problem. Ampex 3220 Series memory modules measure less than 1 by 12 by 16 inches. And you can get a complete system from Ampex, too, complete with cage space for 4, 8 or 16 modules plus power supply, blowers and logic interface.

Versatility is another advantage of Ampex 3220 Series memories. They're physically and electrically compatible with Ampex 1600 Series and with Micro 3000 Series products. And you'll get far wider operating margins, thanks to temperature independent core formulation.

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Arrow-M's leak-free Amber Relays are N₂ gas-filled and sealed in plastic so they're simple to clean with most degreasers and detergent cleaners, without affecting the maximum contact reliability of the relays.

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CIRCLE NUMBER 68
New Products

Four-quadrant multiplier replaces MC1495s

Intech/FMI, 282 Brokaw Rd.,
Santa Clara, CA 95050. (408) 244-0500. $5.25 (1 to 24); stock.

The A-8495 four-quadrant multiplier is a direct pin-for-pin replacement for the MC1495L. The monolithic circuit offers a linearity of \( E_{RX} = 1.5\% \) maximum. Other features include guaranteed feedthrough performance of \( Y_{in} (X_{in}) = 65 \text{ mV} \) \( (120 \text{ mV}) \) max for a 20-V pk-pk, 1-kHz signal on the X (Y) input. The A-8495 can multiply, divide, and square root when used with an op amp. It operates over the 0-to-70-C range and versions are available for the military temperature range. The multiplier comes in a 14-pin ceramic DIP.

CIRCLE NO. 306

Analog switches offered in four configurations

Texas Instruments, P. O. Box 5012,
Dallas, TX 75222. John Spencer
(214) 238-2011. From $1.45 (100-up); stock.

A series of monolithic analog switches, the TL182, TL185, TL188 and TL191, built from BIFET technology, contains ion-implanted JFETs, p-channel MOSFETs, plus bipolar components—all on the same chip. The TL182 is a twin SPST switch, the TL185 is a twin DPST unit, the TL188 is a dual complementary SPST switch and the TL191 consists of two dual complementary SPST analog switches. Both the TL182 and TL188 come in 14-pin plastic DIPs or 10-pin metal-can packages, and the TL185 and TL191 come only in 16-pin plastic DIPS.

CIRCLE NO. 307

1-k CMOS RAMs access data in only 250 ns

National Semiconductor, 2900
Semiconductor Dr., Santa Clara,
CA 93051. Ron Livingston (408) 737-5000. From $12.15 (100-up); stock.

Two 1024-bit CMOS RAMs are available with \( 256 \times 4 \) organizations. The RAMs, known as the MM54/74C920 and the MM54/74C921, come in 22 and 18-pin DIPs, respectively. The 920 has separate data-in and data-out lines, while the 921 has common I/O lines. Both RAMs have an access time of 250 ns (for the commercial version). The 74C920 has the same pin arrangement as the 2101 1-k RAM, with a strobe input to reduce power to about 3 mA. In the standby power-down mode, power consumption is only a few microwatts. Data output and data input are the same polarity in both the 920 and 921. The RAMs operate from standard TTL power supplies, and all inputs and outputs can be interfaced directly with TTL. Complete address decoding, along with two functions (CEL and CES) for selecting chips plus three-state outputs permit easy expansion.

CIRCLE NO. 308

Filler

We learn from HP's Bob Frohwerk, who feels that counting in binary is passe, that there's a nefarious relationship between Halloween and Christmas:

\[
31_{\text{Oct}} = 25_{\text{Dec}}
\]

5-V reference doubles as linear thermometer

Precision Monolithics, 1500 Space
Park Dr., Santa Clara, CA 95050. Donn Soderquist (408) 246-9222. See text.

Developed as a single-chip 5-V reference, the REF-02 provides both a stable 5.00-V output and a temperature-dependent voltage output of \( +630 \text{ mV} \) at 25 C. The temp output has a typical temperature coefficient of \( +2.1 \text{ mV}/^\circ \text{C} \), which can be used to provide temperature readout. Supplies from 8 to 40 V can be used and the unit requires only 1 mA of standby current. The reference voltage tempo is 8.5 ppm/\(^\circ\text{C} \) (maximum) and is not affected by adjusting the output voltage over a 6% range. Typical specifications include turn-on settling time to \( \pm 0.1\% \) of 5 \mu \text{s}, line regulation of 0.007%/V, and load regulation of 0.006%/mA over a 0-to-10-mA range of output current. Output current can be boosted to 4 A with the addition of a 2N6063 pnp Darlington power transistor. The unit comes in a TO-99 package and is available in seven models, ranging in cost from $1.90 to $26.40 in 100-unit quantities.

CIRCLE NO. 309

Low-power Schottky ALU comes in 20-pin DIP

Advanced Micro Devices, 901
Thompson Pl., Sunnyvale, CA
94086. Elliot Sopkin (408) 732-2400. From $2.94 (100-up); stock.

Two low-power Schottky circuits combine the key functions of the Am54/74LS181 4-bit ALU with the convenience of the 300-mil wide 20-pin package. The Am25LS381 performs three arithmetic functions (A minus B, B minus A, and A plus B) and three logic functions (A and B, A or B and A and B) on two 4-bit words. \( \overline{G} \) and \( P \) outputs are provided for full carry-look-ahead operations. The Am25LS251 is similar to the Am25LS381 except that \( C_n + 4 \) and overflow (OVR) outputs are provided for use in cascaded applications. Both devices are available in molded and hermetic DIPs and ceramic flat packages.

CIRCLE NO. 310
INTEGRATED CIRCUITS

Monolithic d/a includes built-in reference

Analog Devices, Route 1 Industrial Park, P.O. Box 280, Norwood, MA 02062. Lowell Wickersham (617) 329-4700. From $9.95 (100-up); stock.

The AD561, a monolithic, 10-bit, d/a converter, contains its own internal reference. It is accurate to ±1/4 LSB, and its monotonicity is guaranteed over the 0-to-70-C operating range. The bipolar converter comes in four versions: The AD561J and AD561K operate over 0-to-70-C temperature range and are accurate to ±1/2 to ±1/4 LSB, respectively. The AD561S and AD561T are specified to the same respective accuracies over the -55 to +125 C range. Converter settling time is 250 ns to 1/2 LSB, and full-scale tempco is 30 ppm/°C max for the K and T versions, 60 ppm/°C for the S and 80 ppm/°C for the J model.

CIRCLE NO. 320

Timebase circuit eases counter design

Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. (408) 996-5500. $4.40 (100-up); stock.

Developed as a frequency counter timebase, the ICM7207A when used together with a 5.24288-MHz crystal and a 7-digit counter forms a complete timer/frequency counter. The 7207A is pin compatible with the company's 7207; however, it additionally has a 0.1 and 1-s count enable window output. Cristals cut for 1 to 10 MHz can be used, and the circuit provides outputs at the crystal frequency, and at 212, 220 or (220 x 10). The CMOS circuit dissipates less than 5 mW when operating at 5 V, and is available in a 14-pin DIP or as unpackaged chips.

CIRCLE NO. 321

4-bit counters come in four technology versions

Raytheon, 350 Ellis St., Mountain View, CA 94040. Ray Solis (415) 968-9211. $1.50 (100-up); stock.

Eight low-power Schottky 4-bit synchronous counters are available across the full range of LS technologies: the new military-standard 9LS, the high-performance 25LS, the military-standard 54LS and the industrial/commercial-standard 74LS devices. The LS161 and LS163 are synchronous, 4-bit binary counters that feature internal look-ahead counting, synchronous or asynchronous clear, and a carry output for n-bit cascading. The LS160 and LS162 are BCD-decide versions of the 161 and 163. The LS191 and LS193 are synchronous 4-bit, binary, up/down counters that have up/down count-mode control, asynchronous parallel-load and individual preset inputs, and are fully cascadable. The LS190 and LS192 are presettable, synchronous, BCD-decade versions of the 191 and 193.

CIRCLE NO. 322

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INTEGRATED CIRCUITS
Series of 16-k RAMs gives choice of access

Texas Instruments, P. O. Box 5012, Dallas, TX 75222. (214) 238-2061. From $81 (100-up); stock.

A 16-k NMOS dynamic RAM, the TMS 4070, is available with a choice of three access times: 350, 300 or 250 ns. All inputs and outputs are fully TTL compatible including clocks, Row Address Strobe, and Column Address Strobe signals. The address and data inputs are latched to simplify system design, while the data output is unlatched for greater flexibility. Typical power dissipation is less than 600 mW, active, and 10 mW, standby. Operation in common I/O systems is simplified by the early write feature of the TMS 4070 and faster access and cycle times are possible if the “page-mode” feature is used. Page-mode address times of 255, 210 and 165 ns are available. The TMS 4070 is supplied in a 16-pin, 300-mil wide ceramic DIP and is rated for operation over 0 to 70 C.

CIRCLE NO. 323

Instrumentation amps have input Zs of 2 GΩ

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 737-5000. 100-up price: $5.50 (LF152); stock.

Known as the LF152 series, the monolithic JFET-input instrumentation amplifiers offer the combined advantages of high-input impedance and high common-mode rejection. The amplifiers have an input impedance of 2 $\times$ 10¹² Ω and a bias current of only 3 pA. At a gain of 100 the minimum dc common-mode rejection (referred to the input) is 100 dB for the LF252/352 models and 110 dB for the premium LF152 unit. A single resistor sets the gain at any value between 1 and 1000. The small-signal gain bandwidth at a gain of 1 is 50 kHz and the full power bandwidth is 25 kHz, both typical. The amplifier models are housed in 16-pin DIPs and require ±15-V supplies from which they draw only 1.8 mA, max. The LF152 is rated for −25 to +125-C operation, the LF252 for −25 to +85 C and the LF352 for 0-to-70-C operation.

CIRCLE NO. 324
To be a social success in Wabash, Indiana it helps to be good at playing basketball and designing coils. Some of us are still working on the basketball. If you're from these parts, people expect you to be good at one or the other. Our engineers are 'bout the best there is when it comes to designing coils. In fact, that's the reason why Wabash coils are famous and why Wabash makes the most molded coils in the United States, including epoxy, nylon, and engineered thermoplastic and thermoset materials. But their basketball game... is awful. So on Saturday afternoons you can expect to find them over at Don Fisher's trying to pick up a few pointers from the kids. But it really doesn't bother them as much as they'd let you think. As Dick Kosiarek, our Coil Engineering Vice President put it, "George McGinnis never designed a coil in his life".

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CIRCLE NUMBER 72
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CIRCLE NUMBER 114

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CIRCLE NUMBER 115

CIRCLE NUMBER 116

Electronic Design 4, February 15, 1977
INTEGRATED CIRCUITS

Quad op amp comes with guaranteed minimums

Raytheon Semiconductor, 350 Ellis St., Mountain View, CA 94040. Dan Anderson (415) 968-9211. From $1.88 (100-up); stock.

The RC/RM4156, a quad op amp, features guaranteed minimums on slew rate and unity-gain bandwidth. In addition, maximum input voltage noise is specified over the audio range of 20 Hz to 20 kHz. The circuit design retains the general-purpose capabilities of 741-type op amps but provides improved ac response over the audio range. Power supply drain for the 4156 is a maximum of ±7 mA for the commercial unit (RC) and ±5 mA for the military unit (RM). The minimum slew rate is 1.3 V/µs, which provides a full-power response of 20 kHz. Minimum unity-gain bandwidth is 2.8 MHz and the input noise voltage is less than 2 µV rms over 20 Hz to 20 kHz. Short-circuit output current is limited to approximately 25 mA and indefinite short-circuits to ground can be handled. The 4156 comes in a 14-pin plastic or ceramic DIP and is available in three temperature versions: 0 to 70, —40 to +85 and —55 to +125 C. Probed wafers or chips are also available.

CIRCLE NO. 325

Priority encoders handle eight input lines

Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, CA 94086. Elliot Sopkin (408) 732-2400. From $1.94 (100-up); stock.

Two eight-line-to-three-line priority encoders, the Am25LS148 and Am25LS2513, are made with low-power Schottky processing. The 148 does priority decoding from eight inputs and provides a binary weighted code of the priority order of the inputs. It is available in a 16-pin package and offers standard totem-pole outputs. The Am25LS2513 is a gated three-state output version of the Am25LS148 and comes in a 20-pin package. Both devices are available in molded and hermetic DIPs and ceramic flat packages.

CIRCLE NO. 326

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CIRCLE NUMBER 75

910 Benicia Avenue, Sunnyvale, California 94086
PHONE: (408) 738-4266 TWX: 910-339-9343
16-k RAM zips along with 150 ns access time

Mostek, 1215 W, Crosby Rd., Carrollton, TX 75006. (214) 242-0444. 100-up prices: $100 (4116P-2); $50 (4116P-3); stock.

Claimed to be the fastest 16-k RAM, the MK 4116P-2 offers a 150-ns access time and a 375-ns cycle time. The chip area is also the industry’s smallest—it measures 122 x 227 mils. The dynamic RAM is housed in a 16-pin DIP. Additional system oriented features of the 4116 include a low power of 462 mW, active, and 20 mW, standby (max); a ±10% tolerance on all power supplies (+12, ±5 V); 128 refresh cycles; on-chip address and data registers; and two chip-select methods. In addition to the usual read, write, and read-modify-write cycles, the unit is capable of delayed-write cycles, page-mode operation and RAS-only refresh. The page-mode feature permits successive memory operations at multiple column locations of the same row address with increased speed without an increase in power. Access time during page mode is 100 ns for the MK 4116P-2 and 135 ns for the MK 4116P-3.

Audio power amplifier delivers 5.8 W

NEC America, 3070 Lawrence Expressway, Santa Clara, CA 95051. (408) 738-2180. $1.67 (small qty); stock.

Able to deliver 5.8 W of audio power, the µPC1156H monolithic audio amplifier features short-circuit protection. The circuit is designed to operate from a 13.2-V supply and feed a 4-Ω load. A 10-pin single-in-line package houses the circuit and an integral metal tab mounts to the heat sink. Overall total harmonic distortion is 0.2%, typical and noise is typically less than 1.4 mV rms.
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Our new series of CDR Ceramic Chip Capacitors is approved to MIL-C-55681.
Like our other Vitramon, Incorporated capacitors, they have a long military tradition — dating back to MIL-C-5.
In fact, our initial order back in 1949 — for the first monolithic capacitor ever produced — went into a military system application. Even before the military created hi-reliability capacitor specifications, we wrote our own.
Military capacitors must be reliable — and that’s the way we’ve always built them. The CDR Chips are no exception.

These monolithic ceramic chips are offered in five body sizes, with both BP (NPO) and BX dielectrics, and with values from 10 to 470,000 pF.
As important, they’re built from the technology backing our 46 styles of “VEE JEM” and “VEE CAL” Chip Capacitors — components that are used in commercial products as precise as heart pacemakers, digital watches, telecommunications circuits and microwave devices.

“Want more information on our high quality chip capacitors? Call us at (203) 268-6261.

Vitramon North America
Division of Vitramon, Incorporated
Box 544, Bridgeport, Conn. 06601

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Selection Guide for Ending Surge & Lightning Troublespots

APPLICATIONS

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Also TII-300 FailSafe Protector for Telephone Station applications.

TII 3-Electrode Heavy-Duty Gas Tube Surge Arresters reduce maintenance, protect equipment and personnel. The packages shown are most often used for retro-fit applications in existing equipment. New equipment manufacturers can choose from more than 60 standard TII packages, all designed for 20-year service life. Call or write for new booklet entitled "Surge Protection for Sensitive Electronic Equipment."

TII-317 & TII-352
Heavy-Duty Standard Duty spade-ended primary arresters are simple to install.

TII-425 offers direct plug-in convenience plus the additional protection of a circuit breaker.

TII-710-025 handles up to 10 balanced line pairs in a single unit.

TII-410 & TII-411
Powerline Surge Protectors complete with covers, with line cord (TII-411) and without (TII-410) for 115 VAC application.

INTEGRATED CIRCUITS

Memory support circuits connect to 4-k RAMs

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 737-5000. From $1.35 (100-up).

A complete family of memory interface circuits enables designers to optimize performance of 4-k RAM systems. The circuits perform various timing, control and data transfer functions. Included are the DS3671, 3642, 3672, 3643, 3644, 3673 and 3674 clock drivers, the DC3645, 3676 refresh counter/drivers, the DS3645, 3675 latch drivers, the DS3649, 3679, 36149 and 36179 hex drivers, the DS3648 and 3678 multiplexer/drivers, the DS3640 and 3670 quad tri-share port driver and the DS3647 and 36177 quad I/O registers.

CIRCLE NO. 329

Single chip drivers handle up to 225 V

Dionics, 65 Rushmore St., Westbury, NY 11590. (516) 997-2474, 1000-up prices: $1.41 (210), $2.06 (220); stock.

Two series of high-voltage driver circuits, the DI-210 and 220, are designed to interface between MOS or TTL and gas-discharge displays. The DI-210, an eight-line segment driver, can handle 150 V dc. It is a switched constant-current sink and can be current programmed by a single external resistor. The DI-220 handles a maximum voltage of 225 V dc. Otherwise it is essentially identical with the DI-210. Both drivers are housed in 18-pin DIPs. The DI-210 and DI-220 replace the company's earlier part numbers, DI-298N and DI-258N, respectively.

CIRCLE NO. 330

Electronic Design 4, February 15, 1977
TRW’s new Transient Voltage Suppressors are low-cost insurance in 8.2 to 200V circuits

Our new solid state Transient Voltage Suppressors rapidly lower their shunt impedance to limit voltage until the fuse or circuit breaker shuts down the system. An extension of TRW Zener technology, they are capable of almost instantaneously changing impedance from a very high standby value to a very low conducting value when they are subjected to high energy surges. In operation, they effectively shunt damaging effects by clamping voltage at predetermined levels, and have proved effective against secondary lightning effects, load switching and human errors.

TRW’s Transient Voltage Suppressors (TVP’s) are 100% surge-tested before shipment, have a very fast response time, lower leakage currents, tighter tolerances and can be customized to your design by computer analysis. They are currently available in .5 Joule, 1.0 Joule and 1.5 Joules power-energy packages.

The potential for these relatively inexpensive TVP’s is enormous. Fill in the coupon below for detailed specifications and samples as required.

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An Electronic Components Division of TRW, Inc.
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☐ I would also like samples. My application is
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CIRCLE NUMBER 79
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Sizes range from 1.50" x 1.13" x 0.88" to 4.13" x 2.68" x 6.0"; in blank versions or with a complete choice of coaxial connectors; painted or unpainted; with or without printed circuit card guides; with mounting flanges or bottom mounting plates. All models supplied with aluminum covers and mounting screws.

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CIRCLE NUMBER 80

INTEGRATED CIRCUITS

CMOS analog switches perform like JFET units
Siliconix, 2201 Laurelwood Rd., Santa Clara, CA 95054. Jim Gra- ham, (408) 246-8006. From $3.50 (100-up); stock.

The DG300 series of monolithic CMOS analog switches are third-generation designs. They approach the multichip JFET switches in performance while retaining the low-power, high-voltage and low-cost advantages of CMOS. The units can switch and isolate 30-V signals, however, they switch at up to four times the speed. There are eight latchproof models from which to choose. All have analog-signal and power-supply ranges of ±15 V. The switches conduct signals in either direction with no offset voltage, and will block 30-V pk-pk signals in the OFF state. The series consists of the DG300 and DG-304 dual SPST, the DG301 and DG305 SPDT, the DG302 and DG-306 dual DPST and the DG303 and DG307 dual SPDT switches. Models DG300 to DG303 are directly compatible with low-voltage CMOS logic, open-collector TTL or DTL; the DG304 to DG307 are CMOS compatible. The DG300 series specifications for R_{SW(N)} are: 30 Ω, typical, 50 Ω maximum at 25 C, while leakage currents are 1 nA max at 25 C. Maximum switching times are 150 ns for turn off and 250 ns for turn on at 25 C for the DG304 to 307.

CIRCLE NO. 331

8-bit shift registers offer 35-MHz clock
Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, CA 94086. Elliot Sopkin (408) 732-2400. From $1.42 (100-up); stock.

Two low-power-Schottky shift registers with gated serial inputs, the Am25LS164 and Am54/LS164 are 8-bit serial-in/parallel-out units. They offer guaranteed maximum clock frequencies of 35 MHz and 25 MHz, respectively. The Am25LS164 offers an improved noise margin and twice the fan-out over the military temperature range compared with the Am54/74LS164. Both registers come in 14-pin DIPs and ceramic flat packages.

CIRCLE NO. 332
New From Micro Devices
A Unique Slow-Blow Current Limiter.

It's the new MICROTEMP 5P Series MultiProtector: A versatile, yet extremely accurate slow-blow current limiter that lets you design-in protection for a specific current requirement within a precise time and current window.

No other commercially available slow-blow fuse even comes close to matching the 5P's ability to handle high current surges without being derated.

5P's unique opening mechanism design guarantees life time rating stability and excellent surge absorption. Conventional slow-blow fuses operate through a metallic, current carrying element making them extremely susceptible to surging and derating. Thanks to its patented non-current carrying temperature sensitive opening mechanism, the MICROTEMP® thermal cutoff reacts only when current put through the heater element generates temperatures capable of triggering the exclusive pellet-type opening mechanism.

When properly applied, 5P will not nuisance trip reducing costly and annoying "in warranty" service calls.

Here's more:
- current values—500 milliamps to 3.5 amps
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- can be designed to withstand surges up to 100 amps for 10 milliseconds
- operates within 130% of rated current

Recognized under the Component Program of Underwriters' Laboratories, Inc. UL File #E59187.

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| DIFFERENTIAL | .06°C to 10°C |
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| VIBRATION  | 20G at 2000 cycles per second |
| LOAD       | 5 M.A. to 5 amps |
| SIZE       | length 5/16 and up |
|            | diameter 3/32 and larger |

All types of mountings. Simple, no moving parts and they are low cost, ranging from $2.10 each up (depending on model and quantity).

We find it simple to solve temperature control problems. Let us have yours.
**INTEGRATED CIRCUITS**

**S/h circuit acquires signals to 0.01%**

Datel, 1020 Turnpike St., Canton, MA 02021. Eugene Zuch (617) 828-8000. $7.95 (1 to 9); stock.

A sample-and-hold amplifier, the SHM-LM-2, requires only a user-selected external holding capacitor. It is internally configured as a unity-gain follower. Acquisition time for a 10-V change to 0.01% is 6 $\mu$s when a 1000-pF capacitor is used and 25 $\mu$s for a 0.01-$\mu$F capacitor. Other specifications include an aperture time of 100 ns, a bandwidth of 1 MHz and an input impedance of 10$^{10}$ $\Omega$. Hold-mode feedthrough is less than 0.005% and hold-mode droop is 200-$\mu$V/ms typical, at 3 V. Included on the chip is the oscillator and its feedback resistor. For operation only three external components are needed: a fixed capacitor, a trim capacitor and a 4.194304-MHz crystal. A test speed-up feature provides other frequency outputs including 2048, 1024, 34.133, 16, 1 and 1/6 Hz. Devices are packaged in 14-pin plastic DIPs.

**Oscillator/timebase provides four outputs**

Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. (408) 996-5000. $4.40 (100-up); stock.

The ICM7213, a fully integrated micropower oscillator and frequency divider, has four buffered outputs suitable for interfacing with most logic families. The outputs deliver one pulse per second, one pulse per minute, 16 Hz, and a composite signal of 1024+16+2 Hz. All outputs of the CMOS circuit are TTL compatible. Power may be either a two battery stack or a regular power supply greater than 2 V. Current drain is 100 $\mu$A, typical, at 3 V. Included on the chip is an inverter-amplifier for a 32-kHz crystal oscillator, a countdown chain, and counters for seconds, minutes, hours, date, and months. The display section contains seven-segment decoders plus level translators and drivers to provide high-voltage ac drive for each display segment. These devices are supplied in chip form only and are available from stock in unit packs of five chips at $33.25 per pack.

**CMOS timing circuits drive liquid crystals**

RCA, Route 202, Somerville, NJ 08876. (201) 685-6423. See text.

Three CMOS timing circuits, designed to drive liquid-crystal displays, operate from a single battery cell. The CD22001H, CD22002H and CD22003H are two-button-controlled devices for five-function (CD22001H and CD22002H) and six-function (CD22003H) timekeeping. The CD22003H also includes a 15-minute, 1-second stopwatch with 1-second resolution. All devices contain an inverter-amplifier for a 32-kHz crystal oscillator, a countdown chain, and counters for seconds, minutes, hours, date, and months. The display section contains seven-segment decoders plus level translators and drivers to provide high-voltage ac drive for each display segment. These devices are supplied in chip form only and are available from stock in unit packs of five chips at $33.25 per pack.

---

**Bodine’s PM drive family grows**

New 32D permanent magnet Control Motors and 32D-SF right angle gearmotors, perfectly matched with Bodine speed/torque controls. Continuous duty ratings of 1/12, 1/10 and 1/8 Hp at 2500 Rpm. See your Bodine Distributor or write for Cat. CDC-PM.

**New 32-frame PM motors and gearmotors!**

Upgrade existing designs. New 8080 Emulator delivers 5 times increased performance. Reduces micro-code writing time, too. Order Part #3000KTB080SK.

**Signetics**

**Bodine Electric Company**

Bodine Electric Company, 2500 W. Bradley Place, Chicago, IL 60618.
Low-cost scope challenges more expensive rivals

Philips Test & Measuring Instruments, 400 Crossways Park Dr., Woodbury, NY 11797. (516) 921-8880. See text.

To get many of the features found in the Philips PM 3214 25-MHz scope, ordinarily you'd have to get a unit with twice the bandwidth and pay double the price. The lineup of features includes:

- Auto triggering to 40 MHz, with the trigger level derived from the signal's peak-to-peak amplitude.
- Simultaneous display of main and delayed time bases in the alternate mode.
- Alternate time-base displays on both channels so that four traces can be viewed.
- Composite triggering to display two signals unrelated in time, frequency or phase.
- Decoupled triggering on both the main and delayed time bases, an important feature for work with digital pulses or variable-duty-cycle waveforms.

Another triggering facility is a TV display with frame (TVF) or line (TVL) triggering at the touch of either of two buttons. If you'd like to trigger at an exact point on a signal, simply push the level control instead of "auto." Furthermore, you can trigger both channels and both time bases from any of several sources: internal, external, channel A, channel B, composite or the 60-Hz line.

Horizontal deflection can be formed not only by the time bases but by any of the sources as well. Use this feature for X versus Y or X versus Y_A/Y_B displays.

Of course, the Philips unit also offers the usual capabilities of mixed sweep: separate display of main or delayed time base, intensification of the main by the delayed, and so on.

The main sweep runs from 0.5 s/div to 200 ns/div, while the delayed spans 1 ms to 200 ns/div. Ten-times magnifiers extend both sweeps. The delay is continuously variable with a 10-turn pot between about 0 and 10 times the coefficient of the main time base. Since the main and delayed bases occupy separate sections of the unit's front panel, adjustments are easy, and you can see at a glance what the settings are. Also, since channel B can be inverted, you can subtract dc levels from, say, a 60-Hz ripple.

Sensitivity is 2 mV over the full 25-MHz bandwidth. Screen size covers 8 x 10 cm, and the accelerating potential is 10 kV. The unit weighs just 18.5 lb and can operate from almost any line voltage and frequency. For $245 more, you can get a battery-operated version. Delivery takes four weeks.
INSTRUMENTATION

Signal generator covers 40 CB channels

Hickok, 10514 Dupont Ave., Cleveland, OH 44108. (216) 541-8060. $199; stock.

Model 256 rf generator is designed for 40-channel CB transceiver service. Five-band frequency tuning covers channels 1 through 40 on an expanded tuning range. Frequencies of 100 kHz through 16 MHz and any other, current or bands to provide all i-f requirements including: 455 kHz, 10.7 MHz and any other, current or future. Precision frequency selection is accomplished by connecting the output jack to a frequency counter for continuous monitoring. A calibrated/attenuated output control provides rf signal output of 100,000 µV down to less than 1 µV for receiver sensitivity checks.

CIRCLE NO. 336

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CIRCLE NUMBER 87

EIA interface monitor slips into pocket

International Data Sciences, 100 Nashau St., Providence, RI 02904. (401) 274-5100. $185; stock.

Model 60 EIA interface monitor and breakout panel is a portable, pocket-sized test set providing access to all 25 conductors of the EIA RS232 interface. Twelve LEDs monitor the status at the source of 12 primary signals, and two additional LEDs sense either positive or negative voltage levels greater than ±3 V. Model 60 is powered by two penlite batteries capable of over 100 h of continuous operation. No power is consumed when not in use.

CIRCLE NO. 337

X-Y recorders come in three versions

Philips Test & Measuring Instruments, 400 Crossways Park Dr., Woodbury, NY 11797. (516) 921-8880, $1500 to $3465.

Three new X-Y recorders include an economical standard A-4 model, a multipurpose A-4 recorder, and a two-pen A-3 format instrument. The two-pen A-3 model complements an existing single-pen A-3 version. The standard A-4 recorder, PM 8041, has sensitivities from 2 mV/cm to 1 V/cm in nine switched ranges, while the multipurpose PM 8141 has a maximum sensitivity of 50 µV/cm. Both offer a writing speed of 75 cm/s and acceleration of 8800 cm/s². The PM 8152 is a two-pen model with 15 input ranges.

CIRCLE NO. 338

ELECTRONIC DESIGN 4, February 15, 1977

158
INSTRUMENTATION

Count savings with low-cost 10-MHz counter

Systron-Donner, Ten Systron Dr., Concord, CA 94518. (415) 676-5000; $295; 30 days.

Model 6202B frequency counter measures from 20 Hz to 10 MHz. An outstanding feature of this solid-state counter is a complete set of adjustable input controls, including a three-position (X1, X10, X100) attenuator switch and an offset control. This makes it possible for the Model 6202B to make accurate measurements of complex, nonsinusoidal waveforms. The variable offset control has a fixed preset trigger position. Four selectable gate times range from 0.1 Hz to 100 Hz. Minimum sensitivity is 25 mV rms for inputs to 1 MHz; 50 mV rms for inputs from 1 to 5 MHz; and 100 mV rms for all inputs above 5 MHz.

CIRCLE NO. 339

Spectrum analyzer gives narrow bandwidth

Rockland Systems, 230 W. Nyack Rd., West Nyack, NY 10994. (914) 633-6666. $9875; 60 days.

Model FFT 512/S-17 real-time spectrum analyzer offers a narrow-band power readout that permits power measurements over the full analysis range of 0 to 100 kHz or any portion of it. Measurements may be displayed in V rms, (V rms)$^2$, or dBV (0 dBV = 1 [V rms]$^2$). The only limits to the bandwidth and frequency range over which measurements may be made is the 400-line resolution and the frequency range of the instrument. Optionally, the FFT 512/S-17 can be equipped to make power measurements in the millihertz region.

CIRCLE NO. 340

Programmable source wears many hats

Interstate Electronics, 707 E. Ver mont Ave., P.O. Box 3117, Anaheim, CA 92803. (714) 772-2811. $3195 base price; 30 days.

Model SPG-800 programmable generator is specifically designed as a multiple signal-source building block for automatic test equipment. With field installable plug-in circuits, the SPG-800 can provide a true pulse generator, a frequency synthesizer or a function generator in one package, all controlled by one IEEE-499-compatible software set, with two levels of built-in test feedback to the controller. The SPG-800 operates over 0.1 Hz to 13 MHz, with 4-1/2-digit resolution and provides amplitudes up to 15 V pk-pk into 50 Ω.

CIRCLE NO. 341

BIPOLAR MICROPROCESSING #3

THE INDUSTRY’S LEADING FAMILY OF BIPOLAR MEMORIES TO PICK FROM.

Widest selection of RAM's, ROM's, PROM's, FPLA's from one source. Signetics. The right memory fits saves time, optimizes system performance.

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Cut wiring time in half with Kulka’s new Wire Reddy™ terminal boards. Either brass or cost-saving steel screws are in place and ready to receive wire ends or terminals. Other time-saving hardware in the line are Klipitites™ and wire wraps. All are in Kulka’s catalog.

520 S. Fulton Ave., Mt. Vernon, NY 10551 Tel: 914 644 4024

CIRCLE NUMBER 88

Electro nic Design 4, February 15, 1977

CIRCLE NUMBER 89

159
**INSTRUMENTATION**

**Portable generator offers VCF input**

Exact Electronics, 455 S.E. 2nd Ave., Hillsboro, OR 97123. (503) 648-6661. $295.

Model 119P portable VCF function generator offers a dynamic frequency range from 0.02 Hz to 2.2 MHz with sine, square, triangle and variable time symmetry of all waveforms for ramp and pulse operation. A VCF input allows the generator to be varied either up or down over a range of 1000:1. Minus 10 V dc will increase the frequency three decades from a minimum multiplier setting and 10 V dc will decrease the frequency three decades from a maximum multiplier setting.

**Analyzer captures 8 data streams to 50 MHz**

BP Instruments, 10691 S. De Anza Blvd., Cupertino, CA 95014. (408) 446-4322. $3,375; 6 wks.

Model 50D portable logic analyzer can simultaneously capture eight digital data streams at sample rates to 50 MHz. Like its 20-MHz predecessor (Model 20D), the 50D works with virtually any externally triggered scope or X-Y display to present multiple-trace timing diagrams. A true-sample mode allows the user to exclude all glitches that endure for a sample period or less. A dual-memory feature provides two 8 x 512-bit semiconductor memories, each of which can simultaneously capture up to eight data streams. All 16 data streams can then be viewed on a two-channel scope.
Pulse generators offer IEEE Bus option

E-H Research Laboratories, 515 11th St., Box 1289, Oakland, CA 94604. (415) 834-3030. $1050; stock.

All pulse generators in the company's 1500 series are now compatible with the IEEE Standard 488-1975 digital interface and can be connected directly into any programmable test system using this program bus. The 488 Bus complements the other standard digital interface options available for the 1500 series, including parallel programming, serial by ASCII character and serial 16-bit word.

Low-pass filter rolls off at 120 dB/octave

Unigon Industries, 1 Park Ave., Mount Vernon, NY 10550. (914) 699-7545. $850/channel; stock-45 days.

Model LP-120 is a 120-dB/octave-rolloff, variable-frequency, low-pass filter. Cutoff frequencies are selected by front-panel pushbuttons or by a remote TTL computer-compatible I/O bus. Nominal cutoff frequencies can be set from 1 Hz to 15 kHz in decimal sequence. Solid-state switching ensures frequency selection in less than 10 µs.

'Carry on' with British hand-held DMM


A hand-held, five-function multimeter locates all the circuitry, switching and the digital display in the probe handle. Digimeter measures dc voltage, ac voltage, dc current, ac current and resistance. It selects voltage ranges automatically and can be operated from four nickel-cadmium batteries or from a plug-in power supply. The unit measures 8.3 x 2 x 1.8 in.

This counter is different.

What makes Systron-Donner's new 6202B different from other low cost counters? The fact that it can accurately measure most of the signals encountered in low frequency applications. Here's why:

• Three-position attenuator: x1, x10, x100. (avoids false counting) • Offset control allows measurement of non-sinusoidal waveforms • Four selectable gate times from 0.1 Hz to 100 Hz • 25 mV rms sensitivity • Advanced input circuitry to assure error-free measurements • 10 MHz frequency range • Rugged and reliable • Only $295 (U.S. price).

In short, it's a super workhorse counter. It's the one low cost counter you can depend on. Find out more.

SYSTRON DONNER
10 Systron Drive
Concord, CA 94518. Phone (415) 676-5000

BIPOLAR MICROPROCESSING #4

DREAM UP YOUR OWN CONTROLLERS WITH THE 8X300 DESIGNER'S KIT.

You do the programming, we supply all the parts—one 4K PROM half programmed, half available for you to program with diagnostic and demo program, even PC board.

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CIRCLE NO. 344

CIRCLE NO. 345

CIRCLE NO. 346

CIRCLE NUMBER 91

CIRCLE NUMBER 92

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INSTRUMENTATION

Four-digit DMM carries low price tag

*Non Linear Systems, P.O. Box N, Del Mar, CA 92014. (714) 755-1134, $190; stock.*

At $190, the LM-40 4-digit DMM (10,000 counts full scale) is an alternative to 3-1/2-digit DMMs (2000 counts full scale) that cost as much or more. DC voltage accuracy is 0.1%. Sensitivity for DC and AC V is as low as 100 µV. For resistance, sensitivity is 100 mΩ. AC and DC voltage ranges of 1, 10, 100 and 1000 V are provided. Resistance ranges include 1, 10, 100, 1000 and 10,000 kΩ. The LM-40 comes complete with test leads, rechargeable batteries and a charger unit. Package size is 1.9 x 2.7 x 4.0 in. and power consumption is less than 3 W.

CIRCLE NO. 347

Data-comm tester diagnoses, shows errors

*Datason Corp., Church Rd. and Roland Ave., Mount Laurel, NJ 08057. (609) 234-5700. $7500; 45 days.*

Datascope D-601B portable data-communications test instrument pinpoints problems in systems hardware and software by monitoring data-communications channels and showing exactly what was sent and received over the data link—using ASCII, EBCDIC or hexadecimal displays. Errors caused by software bugs, equipment malfunctions or line troubles are immediately visible in full detail, thus reducing time spent tracing problems. The D-601B provides both a CRT display and a magnetic tape recording of all traffic at the business-machine interface of any standard modem at speeds to 9600 bps for recording and 80,000 bps for display.

CIRCLE NO. 348

Board testers handle analog/digital circuits

*Computer Automation, 18651 Von Karrmen, Irvine, CA 92713. (714) 833-8830, $17,450 w/o instrumentation.*

Model 4707 adds the capability of automatic analog and hybrid circuit-board testing to the company's Capable 4000 series of computer-controlled test systems. The 4707 is a general-purpose combination of hardware and software options in one add-on package. The package consists of an IEEE-compatible bus for interfacing analog instrumentation; a four or five-bus by 32-pin switching-matrix module; an instrumentation matrix (connecting up to 10 instruments to the analog bus); and a complete control software package. Also included is programmed guided fault isolation.

CIRCLE NO. 349

That's why we build Wild Rover® keyboards with a switch designed for over 10,000,000 cycles. Multiple contact points distribute circuit energy, provide more positive switching action and reduce contact wear. Our PCK switch has excellent noise characteristics, too. Less than 5 milliseconds bounce on leading and trailing edge. REFAC offers standard 12 and 16 key keyboards. We'll also build custom keyboards to your specification with special legends or encoding. Or, if you prefer, we can supply our PCK switch as a component for your own keyboard assembly operations. For more information on our keyboards and PCK switches, give us a call. We can have literature in the mail today.

REFAC electronics corporation
P.O. BOX 809 • WINSTED, CONN. 06098 • 203-379-2731
CIRCLE NUMBER 93

Electronic Design 4. February 15. 1977
Cordless solder gun lends you a 'third hand'


Did you ever wish you had a third hand when soldering? The Model 7900 kit supplies it in the form of a cordless solder gun, solder magazine, plug-in recharger, beveled and chisel-point plug-in tip, and instruction book. It works like any other solder gun, except that you can advance the solder by squeezing the trigger all the way back. The 16 available tips heat in 5 to 10 seconds.

Plastic pouch packs premeasured portions

Allied Resin Corp., Weymouth Industrial Park, East Weymouth, MA 02189. (617) 337-6070. 25-gm pouch: $1.40 (25-up)

A line of flexible, transparent plastic pouches holds premeasured amounts of epoxies, urethanes or RTV silicones. Called Acu-Pak, the packages hold 7, 25, 50 or 100 grams. The pouches can be separated into compartments by removable dividers to hold two-part resins. The components mix when you remove the dividers and knead the pouch. Snip off one corner of the punch to dispense the resin.

Wrapped-wire tool has built-in bit and sleeve

OK Machine & Tool Corp., 3455 Conner St., Bronx, NY 10475. (212) 994-6600. $34.95; stock.

The BW-630 wraps 30 AWG wire onto square terminals measuring 0.025 in. The tool comes complete with a built-in bit and sleeve, and a holder for C-sized batteries. The BW-630 also prevents overwrapping. It weighs 11 oz.
Wrapped-terminal posts are diverse, inexpensive

Auto-Swage Products, 726 River Rd., Shelton, CT 06484. Robert Mikulski (203) 929-1401. From $1.41/1000; stock.

Swaged from a range of materials, wrapped-terminal pins of the Wrapost series are available in a wide range of standard and custom configurations. The pins have precise, burr-free, conical ends, and come with precious or base-metal plating. Evaluation samples are available on request.

CIRCLE NO. 353

Heat-pipe system keeps equipment cool & clean


Did you ever have to fix a piece of equipment, then find everything inside the cabinet was buried under a layer of grime? The Model HP1 heat exchanger now makes it possible to seal off the cabinet hermetically. A blower draws the hot cabinet air through the bottom section of the HP1 heat pipe bank, while a second blower circulates room air through the top section of the heat pipes. For power dissipation up to 2 kW, the HP1 maintains an interior temperature of 16 F above ambient.

CIRCLE NO. 354

Dielectric foam offers low weight, loss and K


Eccostock GT-22 is a syntactic foam with outstanding dielectric properties: K is 1.46 and the loss tangent is 0.006. In spite of the low weight of 22 lb per cubic foot (density 0.55), the foam absorbs less than 1% of water after 16 h immersion at 1500 psi (105 kg/cm²). It is available in rod and sheet form (12 x 12 x 1 in.).

CIRCLE NO. 355
Transfer your data with a light beam


To transfer your data securely, unaffected by rf and other noise, over a distance of 2000 ft, all you need is the Model 1010 laser system. It does not require FCC licensing, and because the laser beam is harmless, the system has HEW approval. Voice or video can also be transmitted.

CIRCLE NO. 358

CRT terminal thinks small and cheaply

Research Inc., P.O. Box 24064, Minneapolis, MN 55424. Jerry Medley (612) 941-3300, $1450.

With a size of only 13.5 x 15.5 x 21-in. an X-Y cursor-addressable terminal can be leased for $65 per month. The Model 3841 features wide/narrow character display, RS-232 and current-loop interface, and a choice of 15 speeds from 50 to 9600 baud. The standard model with 12-in. screen weighs 43 lb.

CIRCLE NO. 357

‘Personal’ mini needs no peripherals

Olivetti Corp. of America, 500 Park Ave., New York, NY 10022. Bruce E. Lerner (212) 371-5500. From $7950, 4-8 wks.

One box does it all—in put via extended keyboard (95 keys), 32 character visual display, 80-column thermal printer that outputs 80 character/s, up to 80 kbytes of RAM, and floppy disc. The P5050 is programmable in extended Basic, and although self-sufficient, supports a large variety of peripherals.

CIRCLE NO. 356

Design better equipment

OEM servo recorder

Esterline Angus original equipment Miniservo® recorder gives more design freedom. The basic unit lists at just $320, with generous quantity discounts available. Your customers benefit from reliable simplicity, easy use, and state-of-the-art. Nationwide repair network backs every unit.

Short specifications: 100 mm-wide Z-fold or rolled servo chart recorder with 100 MVDC (10 MV optional) and 4 chart drive choices, 0.5 sec. response, ±0.5% accuracy, disposable ink/pen cartridge. Request Bulletin F612. Esterline Angus Instrument Corp., P.O. Box 24000, Indianapolis, IN 46224, Tel. 317-244-7611.

CIRCLE NUMBER 97

ELECTRONIC DESIGN 4, February 15, 1977
Inside Anzac Amplifiers

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CIRCLE NUMBER 100

DATA PROCESSING

This APL compiler runs on any PDP-11


The APL-11 compiler operates with all PDP-11 processors (RT-11, RSTS/E), provided you have a terminal with the APL character set, such as the new DECwriter II (Model LAA37). APL is a sophisticated language, used in financial, educational, and scientific applications. Deliveries for the new compiler are scheduled for late spring 1977.

CIRCLE NO. 359

Versatile modem can be serviced world-wide

Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077. Carl A. Plog (503) 644-0161. $350-$800; 2 wks.

The Model 4931 modem is specifically designed for Tektronix terminals of the 4010 family. It offers 300 bit/s for full duplex systems and 1200 bit/s as well as 1200 bit/s with 5 bit/s reverse channel for half duplex systems. The modem works on unconditional voice grade lines with DAA, such as Bell CDT 100A. World-wide service is available.

CIRCLE NO. 360

Interactive program stops system crashes


InterTest, an interactive test controller program, was developed primarily for IBM's CICS and CICS/VS systems. The program makes debugging faster and easier for the user. InterTest diagnostics alert the user interactively (before the system crashes) to potential problems such as main storage destruction or errors in applications programs. Other features include: multithread testing from one terminal, dynamic error correction and retry, diagnostic message routing and status display, and on-line viewing and correction of memory or file storage. Leasing and rental arrangements are available.

CIRCLE NO. 361

Electronic Design 4, February 15, 1977
Million-point display takes the 'stairs' out

Genisco Computers, 17805-D Sky Park Circle, Irvine, CA 92714. William Huber (714) 556-4916. $20,000 (20 up).

If the 'stairs' in a typical 512-by-512-point graphic display are bothersome in your application, the Model GCT-1024 display could be your salvation. The 1024 x 1024 raster is generated by a proprietary logic circuit that provides instruction times as fast as 150 ns, and 51 mnemonic instructions. Accessories include graphic tablets and cursors, a joystick assembly, and special keyboards. Units with up to 16 gray scales are available as options.

CIRCLE NO. 362

Half-million bytes in the palm of your hand

Wango Inc., 504 5 Jandy Pl., Los Angeles, CA 90068. (213) 390-8081. $300 (OEM qty.).

A little 5-1/2 in. diskette, called Micro-Floppy, holds up to 498.6 kbytes, and plays on the Model 82 drive. Unformatted capacity is 109.4 kbytes on 35 tracks, and average random seek time is 370 ms. The Model 82 has an MTBF of 8500 power-on hours, with no routine maintenance. It measures 3.25 x 5.75 x 7.95 in.

CIRCLE NO. 363

HP minis now talk fast to IBM maxis


With the remote job entry subsystem (RJE), the HP 1000, and (after modifications) HP-2100 or HP-21MX systems can communicate with IBM 360 and 370 series batch-oriented computers, much as an IBM 2780 terminal does. Using the IBM Bisync protocol, the RJE/1000 transfers data (e.g. from real-time data acquisition, control, or automatic testing) at up to 9500 baud. The RJE/1000 operates directly with HASP in IBM's operating system, and offers a choice of EBCDIC and ASCII code.

CIRCLE NO. 364
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CIRCLE NUMBER 103

DATA PROCESSING

High-speed plotter is user-expandable

Zeta Research Inc., 1043 Stuart St., Lafayette, CA 94549. Ralph Manildi (415) 284-5200. $27,400; 6 wks.

The Model 5036 plotter combines the speed of the earlier Model 3600 plotter (up to 7.5 in./s) with the flexibility of a PDP-11 minicomputer. The user-expandable system can be used on-line as well as off-line. When connected to a remote-batch terminal, input transmission rates can be as high as 19,200 bits/s. The built-in PDP-11 transforms the input data into vectors so that the plotter can operate near maximum speed most of the time. A 12-in. model (5012) is also available, at a cost of $16,950.

CIRCLE NO. 365

High-capacity discs boast fast transfer


With a transfer rate of 806,000 characters per second, the Model 6060 disc drive can move a lot of data into large Eclipse and Nova systems. The Model 6060’s moving-head disc pack really packs it in; the density of 4040 bits per inch achieves a capacity of 96 megabytes. As an option, for $5000 more, the Model 6061 stores 192 megabytes. Dual-access capability, error detection and correction, and the separation of command channels from read/write channels enhance the system’s versatility. Discs can be shared by two Data General computers, under software control.

CIRCLE NO. 366

The Accuracy Policy of Electronic Design Is:
- To make diligent efforts to ensure the accuracy of editorial matter.
- To publish prompt corrections whenever inaccuracies are brought to our attention. Corrections appear in "Across the Desk."
- To encourage our readers as responsible members of our business community to report to us misleading or fraudulent advertising.
- To refuse any advertisement deemed to be misleading or fraudulent.

This statement of accuracy appears in every issue of Electronic Design. Staff members are imbued with it, from their very first day.

Electronic Design
50 Essex Street
Rochelle Park, New Jersey 07662
(201) 943-0550

ELECTRONIC DESIGN 4, February 15, 1977
Low-profile SS relay is hermetically sealed

Teledyne Relays, 3155 W. El Segundo Blvd., Hawthorne, CA 90250. (213) 973-4545. $16.50 (1000 up).

Model 683-1 low profile solid-state relays packaged in a hermetically sealed metal DIP enclosure withstand military and aerospace environments. Using hybrid IC construction, the relay employs a proprietary constant-current microcircuit for a TTL and HiNIL-compatible input control range of 3 to 15 V dc. A dual photovoltaic optocoupler provides high output current combined with low OFF-state leakage. Positive feedback provides snap-action to prevent damage from slowly ramped inputs. Designed to meet the requirements of MIL-R-28750, the new DIP relay operates over a temperature range of -55 to 115 C with 50 µs ON and 150 µs OFF maximum response time and no self-generated EMI.

CIRCLE NO. 367

Indicator displays fault until manually reset

Minelco, 136 S. Main St., Thomaston, CT 06787. (203) 283-8261. Under $10 (OEM qty); stock.

Bite indicators, Model BHGD24, for high-density stacking on PC boards of instrument panels have dual coils and meet or exceed military specifications (which?). The indicators operate on a pulse of 20 ms or greater. A “fault” display continues until the “no-fault” color is manually reset. Single-coil units (BHGD) are also available. The indicators operate without filaments, springs, hinges or bearings. Standard voltages of 1.5 through 28 V dc are available. Standard colors are red, white, black, green, yellow, orange and blue. Units are threaded for either front or rear panel mounting, or can be obtained with press-fit sleeves.

CIRCLE NO. 368

Panel-light holder snaps into place

Freund Precision Inc., 223 E. Helena St., Dayton, OH 45404. (513) 228-8269. $1 (OEM qty).

The new Pop-It panel-light holder cuts assembly labor to the bone. It eliminates the need for the old-style threaded body and nut used to assemble parts on a panel. This easy snap-in collet arrangement allows assembly of the light base into any kind of panel up to 0.080-in. thick. The assembly is locked into the panel by four keys in the molded chrome-plated lens part. The unit comes assembled with the bulb installed in a separate lens assembly. Various colored lenses are available.

CIRCLE NO. 369
When Signetics claims our bipolar microprocessors make your design resources go further

How can you switch to bipolar from MOS microprocessing without obsoleting your existing designs? How can you reduce hardware design time, reduce programming time, reduce debugging time? How can you try it before you buy it?

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6. Introductory Designer's Kit. A $230.00 value, for $100.00. You get 12 parts and 1 manual to let you work with bipolar, design with bipolar, program...
with bipolar, and prove out all the advantages for yourself. The parts you need to actually try out Signetics' 3000 Total System.

7 A description of all design support systems. Read all about 'em. SMS ROM Simulator, SMS McSim Prototyping System, Microassembler, SMS McCAP Assembler and more, all in the microprocessor book.

8 Field Applications Engineers that know bipolar microprocessing. They have the industry's best support systems at hand to help you solve your design problems. They will show you exactly how Signetics' total bipolar microprocessor capabilities will make your design resources go further.

Now you know when Signetics claims to reduce your hardware design time, to reduce your programming time, and to reduce your debugging time... Signetics supports it. Start saving time in the future by mailing the coupon today.
COMPONENTS

Solid-state relays in a military package

Teledyne Relays, 3155 W. El Segundo Blvd., Hawthorne, CA 90250. (213) 973-4545. $88.10 (1000 up).

A line of military solid-state ac power relays packaged in rugged hermetically sealed aluminum cases withstands military and aerospace environments. The new 652 Series uses inverse/parallel SCRs for output switching over the frequency range of 45 to 440 Hz. Input drive circuitry is logic compatible with input control ranges of 3.8 to 9 V dc for the Model 652-1 and 9 to 32 V dc for the Model 652-2. The relays feature optical isolation and zero-voltage turn-on, and are designed to meet the requirements of MIL-R-28750. Other features include a temperature range of −55 to 110 °C, a dv/dt rating of 200 V/µs, a transient peak-voltage rating of 600 V and a peak surge current rating of 10 times the steady-state for 16 ms.

CIRCLE NO. 370

Miniature toggle-switch kit contains 286 parts

Oak Industries, Inc., Crystal Lake, IL 60014. (815) 459-5000. $87.50 (unit qty); stock.

A 286-piece kit of miniature toggle and pushbutton switches with complementary caps, dress nuts, and wrench gives engineers a complete selection for use in designing circuits and systems. The kit includes single through four-pole switches with a variety of toggle and pushbutton actuators.

CIRCLE NO. 371

PB switch mounts on PC boards

Switchcraft Inc., 5555 N. Elston Ave., Chicago, IL 60630. (312) 792-2700. $1.45 (1000 up).

A miniaturized momentary-action pushbutton switch with molded-box construction and PC terminals allows high-density mounting on PCs or flat, flexible cable. The new Hi-D switch can be specified with 1-A, 1-B or 1-C contacts and the switch body has a one-piece construction of molded nylon. Contact springs are precision formed of a special nickel-silver alloy; integral contacts have silver or gold plating. A choice of red or black pushbutton is available.

CIRCLE NO. 372

When it's time to switch...
Photodetector for lasers offers 150-ps rise time

Lasermetrics, Inc., 111 Galway Pl., Teaneck, NJ 07666. (201) 837-9090. $575 (unit qty); stock to 60 days.

High-speed photodetectors, series 3117, detect the optical pulse outputs of lasers operating between 0.4 and 1.2 µm. Ultrafast silicon photodiodes mounted in tuned coaxial-strip line assemblies can accommodate optical signals ranging from mode-locked picosecond and Q-switched nanosecond pulses to slow dc light-level variations. A selectable dual-voltage power supply provides normal or high-sensitivity outputs. The higher-voltage setting improves output signal linearity. The unit matches a 50-Ω load.

CIRCLE NO. 373

Power Darlingtonsswitch fast with L loads

Motorola Semiconductor Products, Inc., P.O. Box 20294, Phoenix, AZ 85086. (602) 244-4284. $4.50 to $9.50 (100-999); stock.

High-speed MJ10004 through MJ10007 npn power Darlingtonss (400 to 450 V at 1 to 2 A, sustained) are characterized for real-world, inductive-load applications. Fall and storage times are 100 and 850 ns, respectively, for the MJ10004/5 and 90 and 780 ns, respectively, for the MJ10006/7. These time intervals are typical when switching an inductive load of 180 µH with the devices clamped at their rated $V_{CEX}$ and at case temperatures of 100°C. To reduce turn-off times, reversed diodes parallel the input base-emitter junctions. Due to the nature of their construction, the devices also contain reverse collector-emitter diodes.

CIRCLE NO. 374

Seven-segment displays come in three colors


A group of 0.3-in. seven-segment displays provides high-efficiency red (5082-7610 series), yellow (5082-7620 series) and green (5082-7530 series). Each series is available with a common anode and left-hand decimal, common anode and right-hand decimal, common cathode and right-hand decimal, and ±1 universal overflow and right-hand decimal. The units are designed for low-current multiplex operation—as low as 3 mA per segment for the high-efficiency red devices. At an average forward current per segment of 20 mA, typical luminous intensity 1430 µcd for the high-efficiency red, 1200 µcd for the yellow and 765 µcd for the green. Typical forward voltage for all colors is 2.2 V.

CIRCLE NO. 375

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**DISCRETE SEMICONDUCTORS**

**Npn transistors handle 50 W at 900 V**

International Rectifier, 233 Kansas St., El Segundo, CA 90245. (213) 322-3331; $2.25: IR708 (100 up).

A new series of 900-V power transistors with power-dissipation ratings to 50 W, designated IR708 and IR709, has a continuous collector current rating of 3 A. Collector-emitter saturation voltage for the IR708 is 2 V at a collector current of 1 A, and for the IR709, 1 V at 2 A. Fall time for each unit is 1.5 µs. The IR708 and IR709 transistors are suited for applications in video horizontal deflection circuits, high-voltage switching power supplies and switching regulators.

**CIRCLE NO. 376**

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**3 φ bridges stand-off voltages to 5000 V**

Solid-State Devices Inc., 14330 Valley View Ave., La Mirada, CA 90638. (213) 921-0660. $7.50 to $40 (100 up); stock.

Two new series of miniature three-phase bridge-rectifier assemblies, SDA 113 and SDA 168, provide an average output current of 3 A with 50 to 5000 V p-i-v per leg. The SDA 113 medium-voltage series consists of seven 3-A models with p-i-v per leg from 50 to 1000 V. Allowable peak one-cycle forward-surge is 50 A; allowable peak recurrent forward-surges are 10 A. Maximum reverse-current is 5 µA at 25 C. The SDA 168 high-voltage series consists of seven models with p-i-v per leg from 1000 to 5000 V. They are rated at 3 A at 25 C ambient with no heat sink and 5 A when used with a heat sink that maintains the case temperature below 55 C. Peak one-cycle forward surge-current is 150 A and peak recurrent forward-current is 75 A.

**CIRCLE NO. 377**

---

**Pellet transistors cover 2 to 6 GHz**

Microwave Semiconductor Corp., 100 School House Rd., Somerset, NJ 08873. (201) 469-3311. $37 to $65 (100 up); 30 to 60 days.

Emitter-site ballasted power transistors, series MSC 85000, in pellet form offer the circuit designer flexibility of choice of the frequency range, power output, supply voltage and circuit topology. Miniature coaxial or stripline packages feature low loss, low parasitics and rugged metal/ceramic hermetic enclosures. The coaxial devices are available in common-base or common-emitter configurations. The stripline devices in addition, come in a common-collector arrangement. Four basic families in the series can handle from 0.6 to 1.3 W between 2 to 6 GHz.

**CIRCLE NO. 378**

---

**When "Real Estate" is important measure our Capacitors against their capacitors.**

If your circuit boards are victims of the capacitor population explosion, Siemens can help solve your problem. We produce over 5 million capacitors a day and know how to put the most c-v value into the smallest package.

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Siemens Corporation, Components Group
186 Wood Ave. South, Iselin, N.J. 08830 (201) 494-1000

**SIEMENS**
POWER SOURCES

Full open-frame line gives you OVP

Alpha Power, 9020 Eton Ave., Canoga Park, CA 91304. Thomas Ingeman (213) 998-9873. $24.95-$82.00 (100 qty); stock to 2 wks.

Unlike other open-frame power supply families, all 40 of the OEM-111 series boast nonadjustable overvoltage protection as a standard feature. Also, instead of the usual TO-3 power transistors mounted through the chassis, these supplies use plastic versions of the 2N3055, derated to 3 A and mounted between frame and circuit board for servicing ease. All units operate from 105 to 210 V, 47 to 63 Hz, but you must derate the output by 10% for 50 Hz. These units give you 5, 6, 12, 15, 20 or 24 V dc. Additional features include: ±5% output adjustment and ±0.15% regulation for rated-line or 100%-load change.

Supply stays cool, so does your board

Semiconductor Circuits, 306 River St., Haverhill, MA 01830. (617) 373-9104. Under $80; stock.

Two models of ES and EA PCB-board supplies, whose only difference is their input-ac pin spacing, provide full-rated output of 12 V at 1.2 A from 120 to 170 Hz and 120 to 250 V, 50 to 60 Hz. The units are a typical case-temperature rise of 10 C under full-load and a smooth, well-damped response to input-power switching and abrupt load changes. Regulation is 0.15% for line and load. Output ripple and noise are 5-mV rms. The module's regulator is claimed to dissipate four times less power than series-pass types and gives more than 60-dB line-transient immunity. The modules have MTBFs in excess of 150,000 hours and outputs protected via foldback limiting. They operate from 105 to 210 V ac at 50 to 440 Hz and measure 2.4 x 3.5 x 2 in.

Invertron power sources provide 800-Hz line power. They are primarily intended for testing military avionics equipment using the new higher-frequency line power. The series includes single, two and three-phase models with output ratings from 100 VA (single-phase) to 30 kVA (three-phase). A plug-in oscillator, driving a high-power linear amplifier, determines the output frequency. All units feature distortion of less than 0.9%, line regulation of 0.25%, amplitude stability of 0.25%, load regulation of 1% (settable to 0.01%), ac noise of 80 dB below full output, operating range of 0 to 55 C and overload protection. A single unit gives you several output-voltage combinations when you stack its output-voltage taps.

CIRCLE NO. 379
CIRCLE NO. 380
CIRCLE NO. 381

Thank you for the Vendor Excellence Award, Raytheon...our Zeners worked hard for it.

Hi-Rel Zener Diodes are one of our most important product lines. And when Raytheon commended Siemens for our excellence in this area we were understandably proud. (We were one of 30 vendors so honored, out of an evaluation group of 4000.)

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CIRCLE NUMBER 110

POWER SOURCES

Small dual-switcher delivers 750 W
LH Research, 1821 Langley Ave., Irvine, CA 92714. (714) 546-5279. From $750; 8 wk.

Switching-regulated power supply Model MM-520 gives you two outputs, each up to 375 W, in a package that is 5.1 x 6.5 x 13.5 in. You have a choice of any combination of 2 V at 75 A, 5 V at 75 A, 127 V at 31 A, 15 V at 25 A, 18 V at 21 A and 24 V at 15 A. This switcher features up to 80% efficiency and 1% or 50-mV pk-pk output ripple and noise, and 0.4% line and no-load to full-load regulation. The unit operates with full rating to 40 C and derated to 60% at 70 C. For cooling, an integral fan is provided. Response time is 200 µs to 1% after a 25% load change.

CIRCLE NO. 382

Unfloppy supplies handle disc loads

SMS series of six multiple-output regulated-dc supplies is intended for floppy-disc and peripheral memory systems with similar input-output requirements. These multiple-output units provide combinations of 5, 12, 15 and 24 V dc, regulated to within plus or minus 0.1% for line and load, with a typical ripple of 50 mV. All models have adjustable outputs of ±5% for fine-tuning key voltages. The modules feature short-circuit and current-limiting protection for both the memory system and the power supply itself. The 24 V dc output handles surge currents of 200% of rated output for up to 500 ms to accommodate start-up and end-drive functions. The units operate from inputs of 115/230 V ac (±10%), 47 to 440 Hz. Over-voltage protection circuits are standard on all +5 V dc outputs, and optional for other voltages. Logic-inhibit and remote-programming circuits that keep critical voltages on in desired sequences during turn-off modes are optionally available.

CIRCLE NO. 383

MONOLITHIC CRYSTAL FILTERS

TAKE A MONOLITHIC TO LUNCH
Every day, thousands of people, in countries around the world, take our monolithic filters to lunch, or maybe home to dinner (in paging receivers which can call them to a fire, an emergency operation, or a poker game). Size, ruggedness, and low cost are important in this application. Our standard 10.7 and 21.4 MHz monolithics offer all three. Many paging receivers operate in urban, dense signal areas, and there our VHF monolithic filters can simplify front-end design and reduce intermodulation. If you're thinking about paging, or any other production application of monolithic filters, call for PTI - the standard in monolithic crystal filters.

STRAIGHT STORY...

... about linear phase (constant group delay) monolithic filters. Three new four-pole models in our low-priced Comline® series offer a delay variation of 10 µs max. over the specified 3 dB bandwidth (+6 kHz.) for land mobile radio applications requiring data transmission or improved impulse response. Center frequency is 10.7 MHz. Spec sheet available. Just ask for models 5182, 5261, and 5262.

What's your application? Whether it's one of the above or something brand-new we'll be glad to work with you. Just give us a call, or a brief note outlining your requirements. We'll take it from there.

Piezo Technology Inc.
2525 Shader Road
Orlando, FL 32804
(305) 298-2000
The Standard in monolithic crystal filters.

CIRCLE NUMBER 111

Electronic Design 4, February 15, 1977
High-power dc/dc units fit on PC boards

Datel Systems, 1020 Turnpike St., Canton, MA 02021. Eugene Zuch, (617) 828-8000. From $69; 4 wk.

The 2 × 2 × 0.75-in. (5-W) UPM and the 3.5 × 2.5 × 0.875-in. (10-W) BPM series of dc/dc converters are intended for PC-card use. Together, the two series have a total of 34 models with either single or dual outputs. Operating from 5, 12 or 28-V inputs they deliver single outputs of 5, 12, 24 and 28 V and dual outputs of ±12, ±15 and ±18 V. They feature accuracy of ±1%, tempco of 0.02% and isolation of 100 MΩ. Additional characteristics include: max output noise and ripple, 20mV pk-pk (2-mV rms); max back-ripple current, 1% of input; max capacitive coupling, 50 pF; min breakdown, 300 V dc; and transient recovery time, 50 ms. All units provide output current limiting. They operate from -25 to +71°C and you can store these converters from -55 to +85°C.

CIRCLE NO. 384

60-Hz switchers have low ripple


Unique in that they retain 60-Hz magnetics, Series-100 switching supplies eliminate the usual 20-kHz switching problems of spikes on the output, high-ripple content, radiation into associated equipment, and power-line feedback. These dc supplies feature pk-pk ripple of less than 2 mV and max no-load to full-load regulation of less than 3 mV. Additional features include: continuous overload and short-circuit protection, thermal protection and a max tempco of 0.003%/°C. Outputs of 5 V at 5 A, ±15 V at 75 A, or just about any combination of single and dual outputs in the 25-W range are available.

CIRCLE NO. 385

CIRCUI T NUMBER 112

Circuits happen Faster and Easier with Super-Strip.™

Now, whenever you'd like to give a circuit a try, you can build it up nearly as fast as you can dream it up with Super-Strip™, the faster, easier and less expensive solderless breadboards from A P Products. When you build your circuit on a Super-Strip, everything stays as good as new. Once you're through, you can use everything again and again. Instantly. Put a Super-Strip to work for you. Eight distribution lines handle signal and power, and 128 five-tie-point terminals can handle 9 ICs and then some. It's a whole lot easier than printing a circuit and a whole lot handier than haywire.

CIRCLE NO. 113

EDGEB ORD CONNECTORS

CIR CUI T NUMBER 112

CIRCUIT NUMBER 113

ELECTRONIC DESIGN 4, February 15, 1977
To test linear IC's you can spend $6,000 or $100,000. Which makes sense?

It makes good sense to use an inexpensive Computest Model 735 at incoming inspection to identify bad devices. For under $6,000, the 735 identifies defective linear IC's as rapidly as a $100,000 "everything" machine.

The Computest 735 tests op-amps, regulators, sense amplifiers, comparators and custom linear circuits. It sequences through 14 tests automatically, provides simple go-no/go analysis and data logging output to record why the device failed, the failed limit and the failed value.

The Computest 735 makes a lot of sense in your incoming inspection application. We will be happy to tell you why. Contact Cliff Small.

Siemens Corporation
Measurement Systems Division
3 Computer Drive, Cherry Hill, N.J. 08034 (609) 424-2400
DIP active filter is accurate and stable


The UAF41, a hybrid active filter in a 14-pin DIP, gives you 0.002%/%C frequency tempco, better than ±1% frequency accuracy, and ±0.01%/°C Q tempco. This filter provides simultaneous low-pass, bandpass and high-pass transfer functions. An uncommitted op amp in the package lets you sum the high-pass and low-pass outputs to get the band-reject or notch function. You compute three or four resistor values to establish the natural frequency and Q. Typical specs include: Q range of 0.5 to 500; dc-to-50-kHz noise of 200-µV rms at Q = 50 and 20-V pk-pk output swing with ±18-V supplies. Power supply range is ±5 to ±18 V. Specification temperature range is −25 to +85°C.

70-MHz amplifiers claim low noise

TRW RF Semiconductors, 14520 Aviation Blvd., Lawndale, CA 90260. Warren Gould (213) 679-4561. $31.51 (100 qty); 4 wks.

Boasting a typ noise figure of 4 dB the CA2875 and 2875R hybrid rf gain blocks are intended for i-f amplification in microwave radio-relay systems. Both amplifiers have third-order intercepts of +42 dBm. The CA2875 operates from +15 to +24 V while the R version uses a negative supply. Other features include a return loss of better than 30 dB at both the input and output ports, phase linearity from 30 to 110 MHz and a wide dynamic range. These units operate at center frequencies of 70 MHz and provide nominal gains of 17.5 dB from −40 to +100°C.
Think
"DESIGN-AS-YOU-ORDER"

Think of the expense and time involved in designing and building your own power supply, and how those resources can be applied to designing and building other components.

Now think about the exclusive Arnold Magnetics "Design-As-You-Order" system. You simply order your custom power supply from proven "off-the-shelf" sub-modules... no engineering charges, no lost design time. Just fill in our "easy-to-use" specification form, we'll do the rest. Your miniaturized, high efficiency power supply arrives encapsulated and pre-tested.

See if these parameters meet your needs:
- Inputs: Single or dual; 60Hz, 400Hz, 12VDC, 28VDC, 48VDC and 115VDC.
- Regulated Outputs: single or isolated multiple; 5 to 300VDC.
- Line and load regulation to 0.1%
- Power: 3—160 watts (up to 3.9 watts/in²).
- Other catalog power supplies with outputs to 5000VDC and power to 200 watts.
- Capability to design and build to your special needs.

Send for a free "Design-As-You-Order" Power Supply Kit today!

ARNOLD MAGNETICS CORPORATION
11520 W. Jefferson Blvd.
Culver City, Ca. 90230 (213) 870-7614
CIRCLE NUMBER 119

MODULES & SUBASSEMBLIES

Hybrid voltage regulator adjusts over 5 to 20 V

Fairchild Camera and Instrument Corp., Analog Products Div., 464 Ellis St., Mountain View, CA 94042. (415) 962-3816. $7.50 (100- up); stock.

An adjustable voltage regulator, the 78 HGKC, can handle load currents of 5 A and can be adjusted for an output voltage from 5 to 20 V. The hybrid regulator has built-in short circuit and safe area protection. A four-pin TO-3 package houses the circuit. The desired voltage rating can be set by two external resistors or by a single external potentiometer.

CIRCLE NO. 388

Low-profile s/d boasts internal r/s

Analog Devices, Route 1 Industrial Park, P. O. Box 286, Norwood, MA 02062. Joseph Codispoti (617) 329-4700. From $35; stock.

Not only does the SDC-1700 s/d converter shave the height of existing units by half, but the 12-bit device also eliminates the need for external Scott-T transformers—even at 60-Hz operation. The low-profile 3.125 x 2.625 x 0.4 in. module converts three-or-four wire synchro or resolver inputs into 12-bit binary. The device boasts ±0.8 arc-minutes of guaranteed accuracy at min-tracking rates of from 5 rps at 60 Hz to 75 rps at 2.6 kHz. Models of these tracking converters are available for frequencies from 50 Hz to 2.6 kHz and for inputs from both high-level and lower-level synchros. The 521 version operates from 50 to 1200 Hz and, with external resistors, accepts inputs from high-level as well as low-level synchros.

CIRCLE NO. 389

Compress a
1969, $8750...

8-Bit, 10MHz A/D Converter

1977, $1150
8-Bit, 11MHz A/D Converter

HIGH-SPEED A/D CONVERTER
MATV-0811
8-Bit • 11 MHz • 20 Cu. in.
$1150

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505 EDWARDIA DRIVE • GREENSBORO, N. C. 27409
(919) 292-6427

CIRCLE NUMBER 120

ELECTRONIC DESIGN 4, February 15, 1977
**Electronic thermometers**

Electronic thermometer applications of the REF-02, a 5-V reference, is described in an application note. Complete theory of operation and design schematics are provided including a discussion of bandgap-voltage-reference design. Precision Monolithics, Santa Clara, CA

CIRCLE NO. 390

**A/d converter interface**

*Interfacing the 8700 A/D Converter with the 8080A µP System* describes the basic techniques for interfacing, and the advantages in size and cost. Included are specific block diagrams, hook-up circuits and interrupt routines. Teledyne Semiconductors, Mountain View, CA

CIRCLE NO. 391

**Alphanumeric displays**

A 12-page design and application guide is intended to help the user of the HP HDSP-2000 display. A complete electrical description is given with detailed diagrams, followed by the theory of device design and operation. Hewlett-Packard, Palo Alto, CA

CIRCLE NO. 392

**Plastic parts**

*A Look at Problem Solving with “Vespel” Parts* describes the properties of custom-made plastic parts, provides comparisons of “Vespel” parts’ base resins with other plastics and offers typical solutions to design problems. Du Pont, Wilmington, DE

CIRCLE NO. 393

**Thermal-stress analysis**

A 16-page manual describes thermal-stress analysis for contraction voids in polyethylene cable. Stress-strain relationships are discussed and correlations of computer data with outputs are shown. Union Carbide, Wire and Cable, New York, NY

CIRCLE NO. 394
SCHOTTKY BARRIER RECTIFIERS
WITH $T_J=150°C$

VERY LOW FORWARD VOLTAGE DROP ($V_F$)
Because of the large metal-barrier-to-silicon junction, $V_F$ ranges are from 550 mV, $I_F = 1$ A, to 620 mV, $I_F = 40$ A. This results in less heat dissipation, low power loss, and greatly improved efficiency.

EXTREMELY FAST RECOVERY TIMES ($t_{rr}$)
Typically ≤ 10 nsec. Schottkys are ideally suited for low-voltage power supplies, free-wheeling diode and flyback diode applications, and polarity protection in high-speed switching circuits.

MAJORIT Y CARRIER CONDUCTION
In addition to fast recovery, Schottky barrier construction results in high surge capacity and low stored charge. Schottkys are not subject to conventional P-N diode forward and reverse recovery transients caused by minority carriers.

OTHER VARO SCHOTTKY FEATURES ARE:
- -65 to +150°C junction operating temperatures
- 1A, 3A, 5A, 15A, 30A and 40A ($I_Q$) ratings
- 20V, 30V, and 40V (VRRM) ratings
- Low reverse leakage
- Epoxy axial lead, DO-4, DO-5, and TO-3 package configurations
- Competitive pricing

Try one in your circuit; you will see for yourself these advantages and more.

For more information and data sheets on all Varo Schottky Barrier Rectifiers call Mike Hawkins, 214/272-4551

Electro has developed a new competitively priced line of molded plastic magnetic sensors for use in producing input signals for the control of speed and position. Consider the reliability and economy offered by Electro magnetic sensors proven in these applications:

- Engine timing (position and synchronization)
- Closed-loop motor speed control
- Mixer/blender speed sensing
- Conveyor speed monitoring
- Anti-skid control sensing systems
- Turbine RPM monitoring and control.

Electro magnetic sensors provide many advantages including: non-contact sensing of any ferrous metal object; trouble-free operation under all conditions such as dust, dirt, oil and other adverse environments; -65°F to +300°F operating range.

Send us your system input sensing specifications. We will provide you with the most economical solution!
**Evaluation Samples**

**Wirewound resistors**

RW series resistors come in MIL-R-26 styles; namely, the 1-W RW70, 2.5-W RW69, 3-W RW79, 5-W RW74, 7.5-W RW67 and the 10-W RW78. RCD Corp.

*CIRCLE NO. 395*

**Drafting aids**

Multicolor PC drafting aids save drafting time and allow the designer greater flexibility in creating more accurate master artwork. Samples are available along with a four-page bulletin describing these products. Bishop Graphics.

*CIRCLE NO. 396*

**Rectifier bridges**

The Model PKF quick-disconnect rectifier bridge operates at 12 A and joins existing 6, 8 and 10-A models. All are available for 50, 100, 200, 400, 600, 800 and 1000 peak reverse-voltage operation. Surge current is 150 A. Dielectric strength is 1500 V rms. Size is 0.89-in. max diameter. The design can be chassis or heat-sink mounted. Electronic Devices.

*CIRCLE NO. 397*

**Toggle switches**

Miniature toggle switches in SPDT (GT-124) and DPDT (GT-126) feature a tactile-resistant detent mechanism. Housing is moisture-resistant; size is 0.4 × 0.712 × 0.369 in. over-all height. CW Industries.

*CIRCLE NO. 398*

**Coding forms**

Coding forms for those who work in assembly or machine language are bound together in pads of 50 sheets. The pads are formatted to accept code of any µPs. Columns include address, code, label, instruction and notes. Codes can be written in either octal or hex form. The pads sell for $1.95 each postpaid. Walton Electronics, Box 503, Bethany, OK 73008.

*INQUIRE DIRECT*
Relay Miss every 2-Billion Cycles

We tested 129 of our new Series E Relays at loads from dry circuits to 3 Amps. After 35-billion operations, only 10 single-cycle misses were monitored.

Series E Relays offer:
- Indefinite life
- No contact bounce
- Operation in all positions
- Contacts stable to ±0.015 ohms over life
- 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.

Power supplies
Ac-dc and dc-dc miniaturized, submodular, high-efficiency power supplies are described in a 12-page catalog. Electrical and mechanical specifications are included. Arnold Magnetics, Culver City, CA

DIP switches
Dimensional drawings, electrical and mechanical specifications and materials and finishes of DIP switches are shown in an eight-page catalog. Grayhill, La Grange, IL

Portable carrying cases
Deep-drawn aluminum portable carrying cases are featured in a 12-page catalog. Zero Manufacturing, Burbank, CA

RFI/EMI shielded cases
Low-cost RFI/EMI shielded cases are described in a 20-page catalog. Circuit boards, feedthroughs and rf connectors along with a comprehensive group of gaskets to solve shielding problems are noted. Compac, Smithtown, NY

Fifth Dimension, Inc.
P.O. Box 483
Princeton, N.J. 08540
Tel: (609) 452-1200

CIRCLE NUMBER 127

GOOD BOOKS ARE HARD TO FIND.

WHY HIDE YOURS?

We are always looking for well-written manuscripts, or book proposals, for works on topics of interest to professional engineers that will advance their understanding of the state of their art.

What have you been working on?
What can we do for each other?
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CIRCLE NUMBER 403

CIRCLE NO. 404

CIRCLE NO. 405

CIRCLE NO. 406

Electronics Design 4, February 15, 1977
**Film capacitors**

A 20-page catalog describes film capacitors for instrumentation, data processing, telecommunications, industrial controls and special applications. The Potter Co., Wesson, MS

*CIRCLE NO. 407*

**Relays**

Electromechanical, dry-reed, mercury-wetted-reed, time delay, interval-timer, hybrid and solid-state relays, and precision snap-action switches are covered in a catalog. Potter & Brumfield, Princeton, IN

*CIRCLE NO. 408*

**Product digest**

Products developed, manufactured and marketed by Beckman are illustrated and described in a 28-page catalog. Beckman Instruments, Fullerton, CA

*CIRCLE NO. 409*

**Conductor cables**

Dimensions, descriptions and other engineering data on conductor cables from 2 conductor to 51 pair types are given in a four-page catalog. Atlas Wire and Cable Co., Yonkers, NY

*CIRCLE NO. 410*

**Semiconductor etchants**

An 18-page catalog covers etchants used on silicon, gallium, phosphide, dielectrics and metallization. Transene, Rowley, MA

*CIRCLE NO. 411*

**Motor-actuator controller**

An electric-step controller with PI action is described and illustrated in a four-page bulletin. The bulletin includes functional and switching diagrams, specifications and ordering data. Siemens, Iselin, NJ

*CIRCLE NO. 412*

**Interconnections**

A 36-page catalog lists all of the company's interconnection products. Elco Corp., El Segundo, CA

*CIRCLE NO. 413*
VIBRATION!  
IC's Backing Out?

EMC's SHORT Contact for SHORT Leads

Many newer IC's have shorter or highly tapered leads. If plugged into longer standard terminal contacts, lateral pressure caused by the angle of the contacts vector into a constant potential ejection force. Add a little vibration from nearby equipment, and out they come. EMC's new four-finger Short Contacts move the lateral pressure well up onto the body of the lead... grab and hold leads even .095 inches long. Specify Short Contacts in EMC's full line of sockets and packaging panels... field-proven for over a full year in actual usage. Phone or write Electronic Molding Corp., 96 Mill St., Woonsocket, R.I. 02895. (401) 769-3800.

Punched Tape

ROYTRON

ROYTRON Readers, Punches and Combination Reader/Punches are offered in over 20 standard configurations.

Paper Tape/Edge Punch Card
Punches (50-60 cps)

Paper Tape/Edge Punch Card
Readers (50 cps)

Combination Paper Tape Reader/Punch
Reader (50/150/250 cps)
Punch (60 cps)

ROYTRON is manufactured in the U.S.A.
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In-Plant Service
High Reliability
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Litton Q.E.M. Products
34 Maple Avenue, Pine Brook, N.J. 07058/(201) 575-8100
IN U.K. — ADLER BUS. SYSTEMS/OEM PRODS., Airport House, Purley Way, Croyden, Surrey, England
IN FRANCE — SWEDA INTERNATIONAL/OEM, 103-107 Rue de Tocqueville, 75017 Paris, France

CIRCLE NUMBER 131

CIRCLE NUMBER 132

ELECTRONIC DESIGN 4, February 15, 1977
Screws and studs

A catalog features screws and studs. Specifications are given in both inches and millimeters. Illinois Tool Works, Shakeproof Div., Elgin, IL

CIRCLE NO. 414

Card packaging system

The Customatic custom card packaging system is described in a 10-page brochure. Scanbe, El Monte, CA

CIRCLE NO. 415

CATV coaxial cable

Physical and electrical characteristics for more than 60 CATV coaxial cables are specified in a 20-page guide. Belden, Geneva, IL

CIRCLE NO. 416

Insulating material

Specifications and illustrations of insulating materials can be found in a 44-page catalog. Sizes, colors and shrinkage ratios are featured in easy-to-read coded charts. Cole-Flex, West Babylon, NY

CIRCLE NO. 417

μP-based products

Microprocessor-based products—from the LSI-11 microcomputer through the PDP-11V03 computer system—are described in an eight-page bulletin. The bulletin details the elements of LSI-11 hardware and firmware, software and both mechanical and environmental specifications. Digital Equipment, Marlborough, MA

CIRCLE NO. 418

Personal calculator digest

The Hewlett-Packard Personal Calculator Digest, 32 pages, includes sections on thermal printing, testing, servicing, CMOS, PMOS and NMOS circuits and RPN language. Hewlett-Packard, Corvallis, OR

CIRCLE NO. 419
ANY VOLTAGE
2.6 to 34.0
ANY TOLERANCE
1% 2% 5% 10%
At Any Test Current
Compare These Prices
On 1% Tolerance Diodes

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LARGE STOCK
GOOD DELIVERIES
Send for complete rating data and other tolerance prices.

Semiconductor Division
SCHAUER MANUFACTURING CORP.
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CIRCLE NUMBER 135

NEW LITERATURE

Motor controls
Features of motor controls are explained in an eight-page brochure.
Allen-Bradley, Milwaukee, WI

CIRCLE NO. 420

Power supplies
Over 1000 models of standard power supplies are covered in a catalog. The catalog contains specifications, photographs, outline drawings and voltage/current rating charts for every unit available.
Power/Mate, Hackensack, NJ

CIRCLE NO. 421

Numeric printer
Specifications, features and details on the NP-7 thermal numeric printer are included in a four-page catalog. Included are photos of the printer and printout, instructions and illustrations.
Gulton Industries, Measurement & Control Systems Div., East Greenwich, RI

CIRCLE NO. 422

Fixed resistors
Comprehensive technical specifications on more than 20 different resistor configurations, ranging from 0.05 W, at 0.01%-tolerance, noninductive thin-film resistors to 250-W high-power wirewounds, are contained in a 28-page booklet.
TRW/IRC Resistors, Philadelphia, PA

CIRCLE NO. 423

Solid-state relays
Ac and dc solid-state relays are covered in a six-page catalog.
Theta-J Relays, Reading, MA

CIRCLE NO. 424

Servo-system components
Performance and application information for industrial servo system components, which include motor pots, amplifiers, power supplies, command pots and dials, are presented in a 12-page brochure.
Beckman Instruments, Helipot Div., Fullerton, CA

CIRCLE NO. 425

Connectors
Solutions to connector problems are presented in a 12-page brochure entitled Special Electrical Connector Products & Cable Assemblies. Viking Industries, Chatsworth, CA

CIRCLE NO. 426

Rental instruments
A 74-page electronic test equipment rental catalog features over 140 photos of instruments and new indexing and prices. Special sections cover the general-purpose interface bus (IEEE 488) and video-training tapes.
U.S. Instrument Rentals, San Carlos, CA

CIRCLE NO. 427

Scientific Encyclopedia
The fifth edition of Van Nostrand's Scientific Encyclopedia is mammoth. In one 12.6-lb, $67.50 volume, it covers more than two dozen fields of science and technology, with more than 2.2 million words in 7200 entries covering 2382 pages. As might be expected in a work of this breadth, there can be regrettable omissions—like microprocessor. One might feel, too, that an entry like "Integrated Circuit" might deserve more than 19 lines and an illustration of diode-transistor logic, even if it were necessary to sacrifice some of the 370 lines devoted to "Electronic Tube." Van Nostrand Reinhold Co., 450 W. 33 St., New York, NY 10001.

INQUIRE DIRECT

Electronic Design 4, February 15, 1977
When you do business with SAE, you’re well connected. We make edgeboard connectors, flat flex cable interconnection systems, switches, logic panels, backplanes and IC sockets. And that’s just the beginning.

We also supply complete wiring and sub-assembly services, printed circuits, card files, MIL-C-5015 and other extreme environment connectors, transformers, chokes, delay lines and RF filters.

We’re a growing, broad-line supplier of electronic OEM hardware, ready to quote and deliver anything from a wide selection of individual components to a completely assembled interconnection system.

Component specs are in our catalog, and guidance on ways to save time and money is as close as an SAE sales rep. If you haven’t yet made The OEM Connection, do it now. Write Stanford Applied Engineering, 340 Martin Avenue, Santa Clara, California 95050. Phone (408) 243-9200. TWX 910-338-0132.
UL-Listed Switcher!

Priced at only $595** and now UL-listed (to save you time and money), our supercompact, 80% efficient, 5V, 120-amp LH 700 switcher gives you all the advantages you want in a switcher:

- **Compact size** — 8"W. x 10"L. x 5"H.
- **Multiple outputs** — 1, 2 or 3 outputs.
- **Primary output** 5V DC, 120 amps; other outputs ±12V or ±15V DC, 8 amps.
- **Forced air cooling.**
- **80% efficiency primary output,** 75% average on others.
- **Fully regulated outputs.**
- **Over-temperature protection; RFI line filtering.**
- **Over-voltage protection standard on primary, optional on secondaries.**
- **Externally selectable AC inputs 115/230V, 47 to 63 Hz.**

*File No. E52634
**10 to 24 pieces

World's largest switcher manufacturer!

The LH 700 typifies the high-reliability, easy-to-maintain switchers LH Research offers. Nobody packs more power in smaller packages or offers a broader line of switchers than LH Research. 1 through 6 outputs. Up to 2.45 watts/in³. Up to 65 watts/lb. Up to 80% efficiency. At less than 65¢/watt in quantity.

LH RESEARCH, INC.
1821 Langley Avenue, Irvine, CA 92714
(714) 546-5279

CIRCLE NUMBER 137

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Motorola's 2N6306 and 2N6308 power transistors for high-speed switching applications are now available in JAN, JANTX and JANTXV MIL-S-19500/498 versions.

**CIRCLE NO. 428**

Nicolet Scientific has reduced the price of its Model UA-500A-1 500-line, dual-memory, real-time analyzer to $9850 from $12,500.

**CIRCLE NO. 429**

The Westinghouse 1N3259 series of high-power rectifiers has received JAN qualification.

**CIRCLE NO. 430**

Technical enhancements in Honeywell's Series 60/Level 66 large-scale systems involve major performance upgrades, multiple processor configurations and expanded memory capabilities.

**CIRCLE NO. 431**

Signetics is second-sourcing Intel's and Texas Instruments' 4-k dynamic RAMs. The 4-k x 1 device, designated 2680, is fabricated using N-channel silicon gate MOS technology.

**CIRCLE NO. 432**

Exar Integrated Systems has slashed prices 30 to 40% off the XR-2240 CN and CP programmable timing circuits. The new prices are $2.75 for the CN in 100 quantity, down from $4.68, and $2.58 for the CP, down from $3.60.

**CIRCLE NO. 433**

Texas Instruments is offering two dual op amps, the LM358 and LM-2904. Both are second source for the National devices with the same designations.

**CIRCLE NO. 434**

---

Data Acquisition in a Nutshell

Industry's First DAS in a DIP

- 8-channel, 8-bit
- Complete. Includes: Multiplexer, Sample-and-hold Addressing logic A/D converter
- Adjustment free
- High performance ±1/2 LSB linear from 0° to 70°C or -55° to +125°C
- Expandable to 256 channels
- Hermetic 32-pin DIP
- Low cost
- 90-kHz throughput rate

MN 7100
$140.00* in 100 quantity

Micro Networks Corporation
324 Clark Street, Worcester, MA 01606
(617) 852-5400 TWX 710-340-0067

CIRCLE NUMBER 138

ELECTRONIC DESIGN 4, February 15, 1977
Engineers: Imagine Southern California

Hughes/Missile Systems is looking for a lot of good engineers. With imagination.

Hughes Aircraft Company/Missile Systems Group, Canoga Park, California, is a highly respected, prestigious firm, noted for leadership in technology and for a long-term record of stability and growth. Creative engineering is our business, and we do it in a campus-like facility. You'll have a real chance to apply your skills to major missile programs:

* Circuits Engineers
  Experience in design, development of RF/IF, digital, analog circuits for missile-guidance systems. Must know applicable state-of-the-art components.

* Systems Analysts
  Tasks involve system function design, solving systems-engineering problems. Experience in signal processing, controls, assembly language, performance analysis, weapon-system integration.

* Electronic Product Engineers
  Develop conceptual product designs for state-of-the-art electronic systems, and mechanize designs in low-cost hardware.

* RF Systems Engineers
  Experience must include microwave-systems design and test, with emphasis on digital signal processing.
  Degree from an accredited institution required. Send resume to: Engineering Employment, Hughes Aircraft, Fallbrook at Roscoe, Canoga Park, CA 91304.

Selected companies with recent reports are listed here with their main electronic products or services. For a copy, circle the indicated number.

Park Electrochemical. Adhesive bonding films; metal and plastic nameplates; diecast and plated parts; aluminum and plastic sheet decorative trim and copper-clad materials.

Astrosystems. Electroni c and electromechanical devices for the control, measurement and display of physical parameters involving motion.

Coherent Radiation. Advanced laser modulation systems.

Datum. Minicomputers; minicomputer-directed data-acquisition and control systems; computer-peripheral controllers and systems; timing instrumentation; digital cassette recorders and rotating drum memories.

Incoterm. Intelligent computer display terminals and software and peripheral equipment.

Nashua. Image-forming, adhesive or magnetic recording materials.

Scan-Data. Computer data entry.

Data Disc. Disc memory, tape memory, graphic display and video.

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ELECTRONIC DESIGN
50 Essex Street
Rochelle Park, N.J. 07662
ELECTRONIC DESIGN 4, February 15, 1977
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<td>Ceramic Chip Capacitors</td>
<td>SPLIT-CHIP is a new concept in ceramic chip capacitor technology. These new units have two broad electrodes on one face and eliminate conventional wrap-around end terminations. This new concept provides lower cost and easier assembly. SPLIT-CHIPS are available in five standard sizes from .040” x .030” to .130” x .090” and .015” thick and in all popular dielectrics and capacitance ranges. JOHANSON DIELECTRICS, INC., Box 6456, Burbank, CA 91510 213-848-4465</td>
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<td>We have a wide range of standard displays and can special design for a low design cost. Quick delivery on all displays. Contact—Sharp Corporation, Semi Conductor Division, Overseas Marketing, 2613-3, Ichinomoto Tenri, Nara, Japan, Tel: (07436) 5-1321 Telex: 5522364 SHAPEL J</td>
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Which COS/MOS option is best for your design?

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