Special Report:  
High-density PLDs pack thousands of gates into one chip  pg 76
ULTIMATE CONTROL

No one can give you control of your GPIB test system like National Instruments can.

PERFORMANCE
The NAT4882™ chip makes our GPIB controller boards completely IEEE-488.2 compatible. When the NAT4882 is teamed with the Turbo488® performance chip, you get the maximum IEEE-488 transfer rate of 1 Mbytes/sec for both read and write operations.

Use our industry-standard NI-488® software to control your GPIB instruments and give your test programs maximum throughput, regardless of your choice of personal computers or workstations.

COMPATIBILITY
The NAT4882 controller chip is also compatible with the controller chips of the past, so you get the best of both worlds – complete compatibility with your existing applications and the ability to meet your future requirements.

And when your controller needs change, NI-488 programs are compatible across many different platforms and operating systems – without modification.

UPGRADE PROGRAM
Existing PC, PS/2, and Macintosh customers can upgrade to the benefits of IEEE-488.2 and increased performance through a special upgrade program.

TRAINING
Learn even more ways to improve your test system by taking our hands-on, IEEE-488 training course.

For more information on how you can have the ultimate GPIB control, call:
(512) 794-0100 or
(800) IEEE 488
(Toll-free U.S. and Canada)

For more information on how you can have the ultimate GPIB control, call:
(512) 794-0100 or
(800) IEEE 488
(Toll-free U.S. and Canada)
PROFILES IN PARTNERING

AT&T and Dale®

PRODUCTS: Resistors and Inductors.

OBJECTIVE: Quality improvement and lowered cost of acquisition.

UNITS INVOLVED: AT&T, Columbus (NE), Norfolk (NE), Bradford (PA), and Yankton (SD).

“Quality Leader,” “Demand-Pull” and “Cooperative Vendor” are just a few of the program titles which have helped AT&T and Dale forge an efficient manufacturer-vendor partnership. These steadily-evolving programs are closely linked to the AT&T/Dale relationship which has, since its beginning more than 20 years ago, been directed toward continual quality improvement and lowered cost of acquisition.

Notable in this history is establishment of the first online Electronic Data Interchange between AT&T and a passives vendor and early participation in AT&T programs which have helped form current industry patterns for Just-In-Time delivery and Ship-To-Stock quality.

Today, Dale is ranked as one of AT&T’s top 20 passives vendors. Four Dale locations supply various AT&T Works with metal film resistors, wirewound resistors and magnetic components. Depending on the parts involved, supply is often done on a “demand-pull” basis with AT&T providing a rolling-forecast to enable each location to anticipate shipping requirements. Lag time is further minimized by master purchase orders and by the fact that three Dale locations have been certified under AT&T’s Quality Leader Program. This eliminates need for source inspection by AT&T on specified parts and lot numbers.

At the same time, Dale is an active participant in AT&T’s Cooperative Vendor Program. Quarterly meetings enable quality, management, engineering and procurement personnel from both organizations to discuss upcoming requirements and review performance ratings from all areas involved. According to a Dale spokesperson, “This program is extremely valuable in our inter-department and inter-plant coordination. In particular, it enables us to quickly address problem areas and to focus on upgrading our levels of certification.”

For more information on how Dale’s commitment to effective partnering can benefit your operation, please contact Joe Matejka, Vice President, Quality Assurance, Dale Electronics, Inc., 1122 23rd Street, Columbus, Nebraska 68601-3647. Phone 402-563-6511. Fax 402-563-6418.
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ABSORPTIVE or REFLECTIVE dc to 5GHz

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Check the outstanding performance of these units...high isolation, excellent return loss (even in the “off” state for absorptive models) and 3-sigma guaranteed unit-to-unit repeatability for insertion loss. These rugged devices operate over a -55°C to +100°C span. Plug-in models are housed in a tiny plastic case and are available in tape-and-reel format (1500 units max, 24mm). All models are available for immediate delivery with a one-year guarantee.

SPECIFICATIONS (typ)

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Absorptive SPDT</th>
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<td>500</td>
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<td>(1-9 qty)</td>
<td>ZYSWA-2-50DR (SMA) 69.95</td>
<td>ZYSW-2-50DR (SMA) 59.95</td>
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</table>

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Over the past fifteen years, millions of SBL-units were installed in formidable industrial and commercial applications. Under severe operating conditions, they have earned the reputation as the world's most widely accepted mixers, based on quality, consistent performance in the field, and lowest cost.

In addition to the Ultra-Rel diodes, each SBL contains components that can withstand the strenuous shock and vibration requirements of MIL-STD-28837 along with more than 200 cycles of thermal shock extending from -55 to +100°C. Every Ultra-Rel™ SBL-mixer carries a five-year guarantee.

Unprecedented 4.5 sigma unit-to-unit repeatability is also guaranteed, meaning units ordered today and next year will provide performance identical to those delivered last year.

Tougher SBL-mixers, spanning 25KHz to 2000MHz, with +7dBm, +10dBm, and +13dBm LO models, priced from $4.50 (10 qty) are available only from Mini-Circuits. Don't settle for a substitute or equivalent...insist on Ultra-Rel™ SBLs.

**SBL SPECIFICATIONS (typ).**

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency (MHz)</th>
<th>Conv. Loss (dB)</th>
<th>Isolation (dB)</th>
<th>LO Level (dBm)</th>
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<td>25</td>
<td>+13</td>
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</tbody>
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* Ultra-Rel™ Mixers 5 yr. Guarantee

with extra long life due to unique HP monolithic diode construction, 300°C high temp. storage, 1000 cycles thermal shock, vibration, acceleration, and mechanical shock exceeding MIL requirements.
SPECIAL REPORT
High-Density PLDs

The flexibility of high-density PLDs makes them attractive in many applications, but the lack of a universal yardstick for comparison makes it difficult to find the best choice for your application.—Doug Conner, Technical Editor

DESIGN FEATURE
C++ has C’s familiarity and OOP capability

C++ adds a host of new features to C, including object-oriented programming (OOP) abilities. If you program in C, you can use these features without having to learn a whole new language.

—George Ellis, Industrial Drives

TECHNOLOGY UPDATES
Multichip modules: Lack of standards impedes design issues

Multichip modules can double your circuit’s performance, but limited die availability, heat dissipation problems, and testability issues will also boost your design and production costs. Not every application can justify the extra effort and expense this new technology demands.—J D Mosley, Technical Editor

High-speed monolithic op amps: Low-cost op amps break speed barriers

Today’s $3 monolithic op amps can outdo their $50 hybrid cousins and contend for many discrete closed-loop designs.—Anne Watson Swager, Technical Editor

PRODUCT UPDATE
50-MHz synchronous cache RAMs

Continued on page 7
Our Westcor division's family of configurable AC or DC input fan cooled StakPAC switchers reveals a new world of power density and output flexibility to the system designer...whatever your power needs. Each StakPAC is built with field proven robotically manufactured Vicor VI-200 Series power components providing you the flexibility of a customized supply combined with the off-the-shelf availability of standard catalog products...“first article” StakPACs are typically delivered in 2 weeks.

Compact, up to 6W/in³, low profile StakPACs set the standard for “box” or open frame switchers. Besides meeting conducted EMI standards, custom configured StakPACs are pre-approved to UL, CSA, TÜV and VDE safety standards (DC Mini in process).

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Call VICOR EXPRESS for information and be sure to ask for a StakPAC or DC Mini Handbook: (800) 735-6200 or (508) 470-2900 at ext. 265. Or call Westcor (west coast) at (408) 395-7050.
EDN continues to upgrade the Bulletin Board System (BBS) to make it easier for you to access the information you need, when you need it. The BBS ((617) 558-4241) now has a 220-Mbyte drive, courtesy of Quantum. The additional disk space accommodates 1000 new public-domain and shareware postings as well as more than 50 computerized tutorials, covering all popular programming languages and other topics. The BBS also features an expanded FORTH section. You can access the expanded scientific-calculator program library on the /scLcalc Special Interest Group or the new math-software library on the /math Special Interest Group. Stay tuned for more.
Since we’re one of the largest memory suppliers in the world and the Samsung SRAM program is one of the best, our advertising agency thought we should find a more dignified way to get our new fast 1-megs into your hands.

But we know that once you try them you’ll buy them. And we believe these guys are, once again, overthinking. So: free SRAM it is.

Our fast 1-megs run at 20 ns and are in full production in large quantities now.

<table>
<thead>
<tr>
<th>Part</th>
<th>Organization</th>
<th>Features</th>
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<tbody>
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<td>KM641005*</td>
<td>256K x 4</td>
<td>Separate I/O</td>
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<tr>
<td>KM641001*</td>
<td>256K x 4</td>
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<tr>
<td>KM681001*</td>
<td>128K x 8</td>
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</tr>
<tr>
<td>KM611001*</td>
<td>1M x 1</td>
<td></td>
</tr>
</tbody>
</table>

Like our 256K and 64K parts, which we’re sampling now and will have in full production Q1 1992, they’re part of our major SRAM
commitment. We use our formidable DRAM capacity to make them.

All parts are in DIP and SOJ. Our new 256K and 64K chips run at 15 ns.

So if speed, technology, superb breadth of line, and state-of-the-art parts aren’t enough for you—maybe our free chip offer will be.

When it won’t matter what the agency thinks.
Now you know all the angles.

THIS IS AMP TODAY.
AMP MICRO-EDGE SIMM sockets give you all the advantages you need for maximum packaging flexibility. Straight, slant, and right-angle versions provide just the board-space/stack-height combo you want.

Straight and slant versions come in single or dual styles on .100" and .050" centers. Our latest right-angle versions offer .100" or .050" centers; 50-mil styles give you a choice of .125", .160", or .250" card slot heights to simplify tight packaging with either single- or double-sided modules.

Contact designs offer very low 'cam-in' insertion force and high normal pad forces for easy, secure seating. Contact deflection accommodates all standard JEDEC-specified modules, and contacts 'float' to handle uneven thermal expansion. Choose gold or tin on contact mating surfaces to match your requirements. Liquid crystal polymer housings assure strong, durable ramps; patented metal latches (LCP on .125" ra. styles) provide positive module retention.

For product literature and more information, call our Product Information Center at 1-800-522-6752 (fax 717-986-7575). In Canada call 416-475-6222. AMP Incorporated, Harrisburg, PA 17105-3608.
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Control panel: the HRPG series.
For front panel applications, turn to our RPG series of potentiometers. Offering you full configuration flexibility, improved rotational feel, and small footprint, HP delivers the perfect line of data entry devices for your test, medical, analytical, and computer equipment.

Controlled performance: the HCTL series.
Our new line of high-speed HCTL ICs give you high performance servo control in low-power CMOS. The result: superior performance and more microprocessing power left over for your laboratory, medical, and industrial automation designs.

And because these motion control solutions come from HP, you're assured of our on-going commitment to excellence in service, support, and reliability.

So why take a chance, when you can take control. With motion control products from HP. Call for our free brochure: 1-800-752-0900, ext. 1497.

There is a better way.
CPU LOCAL BUS EXTENDS TO PC ADD-IN CARDS

I/O-intensive peripherals on ISA-based personal computers suffer from an 8-MHz limit on the bus speed. To bypass this bottleneck, manufacturers of ICs for functions such as video graphics and SCSI interfaces developed devices that connect directly to the CPU's local bus. The local bus solution, however, forces designers to put the peripheral interface device on the mother board, limiting design flexibility.

The situation has now changed. The DXBB AT-logic chip set from Opti Inc extends the local bus to a card-edge connector. The company has also defined the extension's pinout on an EISA-type connector, letting the connector carry both ISA and local bus-extension signals. The chip set has two parts, the 82C496 logic chip and the 82C206 peripheral controller. The logic chip works with '386 and '486 CPUs from Intel and AMD and includes an AT-bus controller and a block-interleave dynamic-RAM controller with '486 bursting support. The set costs $27.50 (10,000). An optional write-back cache controller, the 82C497, is also available ($17.50). Opti Inc, Santa Clara, CA, (408) 980-8178, FAX (408) 980-8860.—Richard A Quinnell

32-BIT RISC μC WITH PERIPHERALS LOWERS DESIGN COSTS

The 32-bit Am29200 microcontroller (μC) simplifies designs by incorporating an array of on-chip peripherals that minimizes the number of external components you must add to complete an embedded-control circuit. By attaching ROM, dynamic RAM, and electrical buffers to this μC, you provide all the components necessary for an embedded circuit that can control the hardcopy output of laser printers and fax servers. The RISC μC includes an on-chip ROM controller, RAM controller, 2-channel DMA controller, a 24-bit timer, a wait-state generator, 16 programmable I/O ports, serial and parallel ports, a peripheral interface adapter, an interrupt controller, and a video interface. The chip also contains JTAG diagnostics that decrease debug time and board-level testing. A 168-pin, 16-MHz version costs less than $50 in OEM quantities for 5-MIPS performance. Sampling will begin in April 1992. Advanced Micro Devices, Austin, TX, (800) 292-9263, (512) 462-5651. —JD Mosley

SOFTWARE LETS MAC REPLACE LAB NOTEBOOK

When you work with a scope on your lab bench, you're probably used to keeping sketches of schematics and test setups in a lab notebook, along with scope photos and hand-written notes about things you did or observations you made. GW Instruments's $990 Superscope/488 for the Apple Macintosh lets your computer replace the lab notebook. The software lets you duplicate a DSO's (digital storage oscilloscope's) front panel and screen on the Mac's screen and lets you store and recall captured data and scope setups. By combining the software with a drawing program, such as MacDraw, and a word processor, such as MS Word, you can easily (with no programming) access all the functions you need, not merely to replace your lab notebook, but also to use your data in reports and presentations.

The company also makes IEEE-488 interfaces of the type you'll need to connect your scope to your Mac. For slotted Macs, the interfaces are Nubus boards; for the more compact machines, they are modules that plug into the SCSI port. A $290 IEEE-488 instrumentation library includes software drivers for more than two dozen DSOs from four manufacturers as well as one for a digitizer. GW Instruments, Somerville, MA, (617) 625-4096, FAX (617) 625-1322.—Dan Strassberg

EDN January 2, 1992
**NEWS BREAKS**

**DSOs OFFER 1-MILLION-POINT RECORD LENGTHS**
If you have trouble getting enough timing resolution on your DSO (digital storage oscilloscope) when looking at long waveforms such as those in radar, sonar, and video applications, your troubles may be over. LeCroy has announced memory options up to 1-million points for several oscilloscope models. The 300-MHz model 9310 has two channels that independently operate at 100M samples/sec. The 1M-word memory-length instrument is $9990. A shorter 10,000-word memory-length version of the DSO costs $4990. The 7242B plug-in ($22,900) for the 7200 DSO gives you a 1M-word memory while digitizing two channels at 1G samples/sec. Other DSO models and plug-ins with long memories are also available. LeCroy, Chestnut Ridge, NY, (914) 425-2000.—Doug Conner

**ANALYZER ADDS 100-MHz CAPTURE SYSTEM AND 486 SUPPORT**
American Arium recently bolstered its ML4400 logic-analyzer family with a 100-channel, 100-MHz capture system and enhanced support for Intel's 80486 µP. The 486-support package, Model 32I-486A, can handle all variations of the 80486 CPU, including Intel's 2-chip module that includes a second-level cache. The package offers complete disassembly of the executed instruction stream, including pre-fetched instructions, and handles segmentation and page translation. The new support package can also control the "KEN" cache-fill enable pin found on 486 CPUs. Finally, the package includes support for 10,000 downloadable symbols. Available now, the 32I-486A package costs $2995 as an add-on to the ML4400 analyzer, or you can buy the ML4400I package that includes the 486 support and logic analyzer for $11,985.

Meanwhile, the company's Paladin capture system boosts the capabilities of the analyzer family to work with the industry's fastest RISC and CISC CPUs. The system includes 100 100-MHz channels and can also be configured to provide 50 200-MHz channels. You can add multiple Paladin modules to a single logic analyzer to create more signal-capture capacity. The module provides a trace depth of 8 kbits per channel, and you can opt to expand trace depth to 128 kbits. The module includes 12 levels of triggering and 12 trigger-event recognizers. The module has probes that include signal compensation at the probe tip and that use coaxial cable. The Paladin module costs $13,950 and will be available in February. —Maury Wright

**POWER-FACTOR-CORRECTION IC REDUCES 3RD-HARMONIC**
The ML4821 from Micro Linear helps reduce 3rd-harmonic noise and excessive neutral-wire current in electronic power supplies. The device stores energy in an inductor or taps the stored energy as needed to maintain a sinusoidal current draw from the ac power lines. Without power-factor correction, a typical power supply only draws current during voltage peaks, causing noise spikes in the ac lines at odd harmonics of the line frequency. In a 3-phase system, the spike's 3rd harmonic can potentially add in-phase in the neutral wire, causing excessive current flow.

The device has several features that simplify its use in a system. It can accept ac input voltages from 90 to 260V, letting you use it in a variety of power systems without modifying the circuits. It offers built-in protection against brownout (reduced input voltage) and sudden load removal. The chip's output stage will drive as much as 1A. The $3.55 (100) chip comes in an 18-pin DIP. Micro Linear Corp, San Jose, CA, (408) 433-5200, FAX (408) 432-0296.—Richard A Quinnell
Introducing PLDecoders.

Taking systems to 40 MHz and beyond has become a whole lot simpler with these new, function-specific BiCMOS Decoder PLDs. For RISC, including our highest performance SPARC processors, choose the input-registered versions to capture addresses quickly. For CISC, such as 80X86, we offer output-latched versions that optimize system performance. Choose simple addressing versions at 6 ns for fastest performance, or 7 ns bank select or byte-write versions to suit your application precisely.

Fewer parts, faster performance.

One PLDecoder replaces older, multiple-chip solutions, to save money and board space. PLDecoders are optimized for speed, using an ECL speed path. BiCMOS technology helps save on power. They are specialized for decoding, with the required latches or registers on chip for top performance, and non-essential functions stripped away. As a result, you get optimal performance, to go to 40 MHz, and well beyond.

Programmable design convenience.

Design is eased by PLDs developed specifically to implement memory decoding. Easier than using standard PLDs. Much easier than gate arrays.

Cheaper SRAM.

Since our decoders save you so much time out of the "memory access cycle" you have options. Go for a faster system. Or, at a given speed, use slower, less expensive SRAM. In 40 MHz systems with large SRAM requirements, the savings can really add up.

Call our information hotline.

Get our application notes on the CY7B336-9 family, product profile, PLD Brochure and a terrific Data Book to boot.

PLD Hotline: 1-800-952-6300.* Ask for Dept. C4U.

* (510) 2-652-0720 in Europe. ©1991 Cypress Semiconductor, 3901 North First Street, San Jose, CA 95134. Phone: 1 (408) 943-2600, Telex: 821032 CYPRESS SNJ UD, TWX: 910-597-0753, SPARC is a registered trademark of SPARC International, Inc. Products bearing the SPARC trademark are based on an architecture developed by Sun Microsystems, Inc.
dc to 3GHz from $11.45

**lowpass, highpass, bandpass**

- less than 1dB insertion loss
- greater than 40dB stopband rejection
- surface-mount
- BNC, Type N, SMA available
- 5-section, 30dB/octave roll off
- VSWR less than 1.7 (typ)
- rugged hermetically-sealed pin models
- constant phase
- less than 1 dB insertion loss
- greater than 40dB stopband rejection
- surface-mount
- BNC, Type N, SMA available

**low pass**, Plug-in, dc to 1200MHz

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<td>DC-190</td>
<td>210.300 - 300;600</td>
</tr>
<tr>
<td>PLP-200</td>
<td>DC-190</td>
<td>260.390 - 390;600</td>
</tr>
</tbody>
</table>

Price, (1-9 qty), all models: $11.45

**Surface-mount, dc to 570MHz**

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Passband, MHz</th>
<th>Stopband, MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCLF-21.4</td>
<td>DC-22</td>
<td>32.41 - 41;200</td>
</tr>
<tr>
<td>SCLF-35</td>
<td>DC-45</td>
<td>70.90 - 90;200</td>
</tr>
<tr>
<td>SCLF-135</td>
<td>DC-135</td>
<td>210.300 - 300;600</td>
</tr>
</tbody>
</table>

Price, (1-9 qty), all models: $11.45

**Flat Time Delay, dc to 1870MHz**

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Passband, MHz</th>
<th>Stopband, MHz</th>
<th>VSWR</th>
<th>Group Delay Variations, ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBLP-39</td>
<td>DC-23</td>
<td>78.117 - 117</td>
<td>1.31</td>
<td>2.31</td>
</tr>
<tr>
<td>PBLP-117</td>
<td>DC-65</td>
<td>234.312 - 312</td>
<td>1.31</td>
<td>2.41</td>
</tr>
<tr>
<td>PBLP-156</td>
<td>DC-120</td>
<td>400.534 - 534</td>
<td>1.61</td>
<td>1.91</td>
</tr>
<tr>
<td>PBLP-300</td>
<td>DC-180</td>
<td>600.801 - 801</td>
<td>1.251</td>
<td>2.21</td>
</tr>
<tr>
<td>PBLP-467</td>
<td>DC-280</td>
<td>934.1246 - 1246</td>
<td>1.251</td>
<td>2.21</td>
</tr>
<tr>
<td>PBLP-1203</td>
<td>DC-850</td>
<td>3740.5000 - 5000</td>
<td>1.451</td>
<td>2.91</td>
</tr>
</tbody>
</table>

Price, (1-9 qty), all models: $11.45

**High pass**, Plug-in, 27.5 to 2200MHz

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Passband, MHz</th>
<th>Stopband, MHz</th>
<th>VSWR</th>
<th>Group Delay Variations, ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHP-25</td>
<td>DC-13</td>
<td>13.19</td>
<td>1.81</td>
<td>PHP-400</td>
</tr>
<tr>
<td>PHP-35</td>
<td>DC-25</td>
<td>25.28</td>
<td>1.51</td>
<td>PHP-500</td>
</tr>
<tr>
<td>PHP-100</td>
<td>DC-40</td>
<td>40.40</td>
<td>1.91</td>
<td>PHP-700</td>
</tr>
<tr>
<td>PHP-150</td>
<td>DC-70</td>
<td>70.75</td>
<td>1.81</td>
<td>PHP-840</td>
</tr>
<tr>
<td>PHP-175</td>
<td>DC-70</td>
<td>70.75</td>
<td>1.51</td>
<td>PHP-900</td>
</tr>
<tr>
<td>PHP-200</td>
<td>DC-100</td>
<td>100.100</td>
<td>1.61</td>
<td>PHP-1000</td>
</tr>
<tr>
<td>PHP-300</td>
<td>DC-145</td>
<td>145.170</td>
<td>1.71</td>
<td>PHP-550</td>
</tr>
</tbody>
</table>

Price, (1-9 qty), all models: $11.45

**Bandpass**, Elliptic Response, 10.7 to 70MHz

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Center, MHz</th>
<th>Passband, 1.5 dB</th>
<th>Bandwidth, MHz</th>
<th>Stopbands</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB-10.7</td>
<td>10.7</td>
<td>9.6-11.5</td>
<td>9.9-12.7</td>
<td>7.5-15.4</td>
</tr>
<tr>
<td>PB-21.4</td>
<td>21.4</td>
<td>19.2-23.6</td>
<td>19.7-25.3</td>
<td>15.5-29</td>
</tr>
<tr>
<td>PB-31</td>
<td>31.0</td>
<td>27.3-33.0</td>
<td>27.8-41.6</td>
<td>22.4-62</td>
</tr>
<tr>
<td>PB-60</td>
<td>60.0</td>
<td>55.0-67.0</td>
<td>49.5-78.5</td>
<td>44.4-79</td>
</tr>
<tr>
<td>PB-70</td>
<td>70.0</td>
<td>65.0-77.0</td>
<td>60.0-90.0</td>
<td>51.9-94</td>
</tr>
</tbody>
</table>

Price, (1-9 qty), all models: $11.45

**Constant Impedance**, 21.4 to 70MHz

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Center, MHz</th>
<th>Passband, 0.25dB</th>
<th>Bandwidth, MHz</th>
<th>Stopbands</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIF-21.4</td>
<td>21.4</td>
<td>18.2-25.5</td>
<td>20.0-35.4</td>
<td>18.2-35.5</td>
</tr>
<tr>
<td>PIF-30</td>
<td>30.0</td>
<td>25.3-35.5</td>
<td>29.7-50.0</td>
<td>25.3-50.0</td>
</tr>
<tr>
<td>PIF-40</td>
<td>40.0</td>
<td>35.5-50.0</td>
<td>46.8-100.0</td>
<td>35.5-100.0</td>
</tr>
<tr>
<td>PIF-50</td>
<td>50.0</td>
<td>46.8-100.0</td>
<td>58.0-200.0</td>
<td>46.8-200.0</td>
</tr>
<tr>
<td>PIF-70</td>
<td>70.0</td>
<td>58.0-200.0</td>
<td>68.0-200.0</td>
<td>58.0-200.0</td>
</tr>
</tbody>
</table>

Price, (1-9 qty), all models: $11.45

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Compare the stats:

<table>
<thead>
<tr>
<th></th>
<th>PM 6680</th>
<th>HP 5334 B</th>
<th>HP 5335</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range, A</td>
<td>225 MHz</td>
<td>100 MHz</td>
<td>200 MHz</td>
</tr>
<tr>
<td>Frequency Range, C</td>
<td>2.7 GHz</td>
<td>1.3 GHz</td>
<td>1.3 GHz</td>
</tr>
<tr>
<td>(optional)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Shot Res.</td>
<td>500 ps</td>
<td>2 ns</td>
<td>2 ns</td>
</tr>
<tr>
<td>Max. Reading Rate</td>
<td>2000/s</td>
<td>150/s</td>
<td>125/s</td>
</tr>
<tr>
<td>Base Price</td>
<td>$2,075*</td>
<td>$2,305</td>
<td>$5,000</td>
</tr>
</tbody>
</table>

* GPIB interface optional ($550)

Besides setting a faster pace, the PM 6680 adds new time and frequency analysis tools. Built-in mathematics and statistics functions give you stand-alone processing power that makes it easy to obtain measurements such as drift and rate of drift.

Put those features together with 2000 readings per second and you have a powerful tool for analyzing timing jitter without a controller. The PM 6680 can also characterize VCOs or frequency agile sources quickly and easily.

And a host of new measuring capabilities give you the versatility to address your toughest measurement problems.

Rise time, duty factor, phase, and volt min/max measurements are all standard. Our unmatched arming flexibility enables you to measure rise time or pulse width on selected pulses within a stream. And the PM 6680 boasts six totalizing modes—including up/down counting and counting over a preset time.

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FLUKE CIRCLE NO. 81

EDN January 2, 1992
LEDs still in style

In the September 2, 1991, Ask EDN, you stated that Rohm is phasing out its LED product lines. This statement is completely false. Rohm has no plans whatsoever to curtail the availability of its LED product offerings. Although there has been an international industry-wide increase in demand for LED lamps for the past 12 months, Rohm has made significant progress to comply with this demand.

The temporary international LED shortage has been a classic irony. We believe it was created, in part, by increased LED manufacturing capability. That is, as LED manufacturers strove to increase yield, several new quantity-hungry applications quickly emerged in hotly competitive markets, such as automotive and outdoor-sign industries. Many of these customers require deliveries of millions of pieces. In response to this increased demand, Rohm has increased lamp production in our main factory by 32%.

Improved LED manufacturing technology has contributed two critical benefits to lighting applications, particularly in the automotive and outdoor sign industries. The first benefit is increased brightness. With one LED contributing as much as 3 candlereck, a small cluster of these LEDs can now rival the luminous intensity of a large incandescent bulb. The second benefit is higher reliability. LEDs have typical life cycles of 100,000 hours, compared with 5000 hours typ for incandescent lamps.

The combined benefits of reduced power consumption and heat dissipation, reduced weight, shock resistance, and lower frequency of replacement are driving automotive designers to employ LEDs in place of incandescent lamps in many situations. These applications include instrumentation, dashboard lighting, and even taillights that are easily visible from 1500 feet away. When you consider the number of primary- and aftermarket OEMs and multiply that by the number of applications per vehicle, the sheer volume required is enormous.

Outdoor signs are another bright spot. With signs as large as billboards each requiring tens of thousands of LEDs, demand increases with each new installation. These applications include highway signs, entertainment centers, and information displays.

Added to these new applications is the traditional industrial and consumer electronics market, whose appetite for indicator lights, displays, and graphics continues to increase faster than the overall economy.

Rohm will continue to increase its LED production. We are definitely not phasing out of the LED business.

Ray Ponkey
Product Manager, Optoelectronics
Rohm Corp
Antioch, TN

Ask EDN regrets the error and any unfortunate effects it may have had on your business.

Star Trek tech

I have acquired my own Intel Microprocessor Development System (MDS) 231, and I am trying to locate a source-file listing of the company's famous Star Trek V2.0, which was originally written in Fortran by Matuszek and Reynolds and rewritten and expanded for the Intelleg MDS by Intel's Ron Williams in 1977.

I believe I have located two bugs, and because I have only the object file on disk and the type-written "Guide to Star Trek V2.0," I presume that I need to edit the source file and recompile the object code. To do this, I guess I'll have to obtain a copy of the compiler as well.

I would also appreciate a hint or two as to how to stop the program running on the MDS. Is this possible? If anyone can help, I may yet defeat the Klingons!

M J Garraecay
Birmingham, UK

Have you been keeping up with "Star Trek—The Next Generation"? The Federation is now at peace with the Klingons. In fact, a Klingon, Worf, serves as the USS Enterprise's chief security officer.

However, if any reader has or knows where to get the Star Trek V2.0 source-file listing or compiler, please contact Ask EDN.

What does BNC stand for, anyway?

In response to readers' continually asking what all those acronyms, abbreviations, and initialisms stand for, EDN has been including a box, "Acronyms used in this article," in each Special Report, Technology Update, and contributed article. Starting with the December 19, 1991, issue, we will collect all the acronyms used in the articles and what they stand for and put the information on an acronym page near the back of the magazine.

One initialism that has inspired much internal debate at EDN has been BNC connector. Some editors argued that the BNC stood for baby N connector. Others suggested British National connector and British Naval Committee connector. Still others favored bayonet N connector.

Associate Editor Dave Pryce finally laid the issue to rest when he came across a 1990 article in the Microwave Journal. Apparently the BNC connector was developed jointly by Neill and Concelman, who lent their initials to the connector's name. The B stands for baby because of the connector's small size.

However, we still haven't agreed on how to pronounce the prefix "giga."

Ask EDN solves nagging design problems and answers difficult questions. Address your letters to Ask EDN, 275 Washington St, Newton, MA 02158. FAX (617) 558-4470; MCI: EDNBOS. Or send us a letter on EDN's bulletin-board system at (617) 558-4241: From the Main System Menu, enter SS/ASK_EDN and select W to write us a letter.
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theory.

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CIRCLE NO. 27
More about what's coming in EDN

Last issue I gave you a hint of the changes to come in the January 20, 1992 issue of EDN. Now here is the rest . . .

We'll be running a new page called "Inside EDN" right near the table of contents. This page will tell you more about what's in the issue and why those articles are important to you. You'll also find out why we're covering these subjects and how the editors got the information for you. In some instances, we will also tell you about how we selected the products or companies that we discuss. This page will help you pick out the highlights of the issue.

You'll also notice that we're using consistent labels and formats for each section. We want to make it easy for you to find the things you're interested in. Color-coded title and section bars can help. Nothing irks me more than seeing an interesting title on a magazine's cover and then being stymied as I try in vain to find it in the table of contents. Somewhere in between, the title or subject matter changed. In EDN, we'll stay with consistent titles from the front page, to the table of contents, to the article. Also, page numbers will accompany the titles on the cover. If you see an article you like, why should you have to go to the table of contents first?

We believe in making information as available and accessible as possible. In the past, we've heard complaints about acronyms and abbreviations that go undefined or unexplained. You'll find a new acronyms and abbreviations page in EDN that compiles and spells out all the complex acronyms and abbreviations we've used. Obviously we won't spell out ac, dc, or V, but you'll find VXIbus, VHDL, and FPGA if we've used them in the issue. You'll be able to tear out the pages for later use. I expect this section will be very popular.

Because Design Ideas has always been popular, we've made it easier to find and more comprehensive. You'll notice expanded "Feedback and Amplification" and "Software Shorts" coverage. We're also tinting the Design Ideas pages light blue so that you can find them right away just by bending the magazine to expose the outer edges of the pages. You'll also find the traditional yellow News Breaks pages this way. Look to the News Breaks section for changes, too. We'll be running more items in a typeface and format that makes them easier to read.

One final thing to keep in mind is, as I said in my previous editorial, the changes we've made result from discussions with and comments from readers. Once you look through our January 20, 1992 issue, I'd like to know what you think. We'll continue to evolve and we're always open to new ideas and suggestions. Enjoy.

Jesse H. Neal
Editorial Achievement Awards
1990 Certificate, Best Editorial
1990 Certificate, Best Series
1987, 1981 (2), 1978 (2),
1977, 1976, 1975

American Society of
Business Press Editors Award

Send me your comments via FAX at (617) 558-4470, or on the EDN Bulletin Board System at (617) 558-4241 300/1200/2400, 8, N, 1.
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CIRCLE NO. 28
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TECHNOLOGY UPDATE

MULTIChip MODULES

Lack of standards impedes design issues

Multichip modules (MCMs) are the current high-performance champions that promise to pacify designers' insatiable desire for higher-performance circuits. However, an immature infrastructure makes this a technology that your design team should approach with objective awareness and a healthy budget.

As with any emerging methodology, the early adopters will have to contend with a lack of standards, high fabrication costs, and numerous unresolved design issues. However, with powerhouses such as IBM, Texas Instruments, and AT&T announcing their support for MCM development, the technology should become an established design method within two or three years.

However, the first problem encountered by MCM designers is the limited availability of fully tested bare ICs, commonly referred to as known-good dies. Once an MCM is assembled, if any single die on the substrate is defective, you will have to repair or even dispose of the entire module, thereby escalating costs, lowering yields, and lengthening your time to market.

Consider the case of Cypress Semiconductor's $3200 CYM6002K dual-SPARC CPU module for which the issue of known-good die was a major concern during design. The price of reworking such an expensive module would have significantly escalated production costs. Andy Paul—president of Multichip

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J D Mosley
Technical Editor
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Multichip modules

Technology, a Cypress subsidiary that participated in the development of the SPARC module—sees the problem of obtaining known-good dies as a major MCM stumbling block.

Paul notes that although it seems like a bare die should be less expensive than a packaged IC, most designers find they must instead pay a premium. Volume production is what lowers the price of chips, and currently the demand for bare dies isn't sufficient to offset the necessary manufacturing changes. As a result, bare dies are custom items that command a premium price.

Paul acknowledges that complex chips with 300 or more pins may actually cost less in die form. However, because of their unusually high packaging cost, you should normally expect your MCM to cost more than a comparable pc-board version. That is, unless you can populate your MCM with ICs that are routinely offered as tape-automated-bonding (TAB) components.

TAB involves a leadframe that is etched onto a film carrier. This leadframe is then soldered or welded onto a die. TAB is superior to wire-bonding the die directly to the substrate because of its 0.017Ω resistance, 0.006-pF capacitance, and 2.1-nH inductance. Typical wire-bond characteristics are 0.142Ω, 0.025 pF, and 2.6 nH, respectively. Furthermore, TAB thermal resistance measures 8°C/W, vs the 79°C/W for wirebond circuits. TAB parts can achieve signal speeds in excess of 150 MHz.

TAB frames, in volume, are inexpensive and fully testable at speed. And once tested, they are relatively simple to bond to miniature boards. The TAB infrastructure is more developed than bare-die or flip-chip infrastructures, and TAB parts don't require exotic substrates. As Paul notes, substrates made from silicon and diamond grossly exceed current performance requirements because today's 50-MHz circuits "run very comfortably on high-density FR4 boards—you certainly don't need silicon substrates to do that."

NCR's strategic products manager, Harold Crafts, observes that the OEMs can no longer sit back and wait for IC vendors to develop state-of-the-art components at rock-bottom prices. Military spending is plunging, so government dollars aren't available to fund cutting-edge technology as was true in the past.

When NCR designers require ICs that aren't available in TAB frames, they request a flip chip, perform the TAB design in-house, and obtain a subcontractor to do the TAB tape manufacturing and interlead bonding. And if a flip chip isn't available, NCR engineers will develop a TAB part from wafers—albeit reluctantly. However, the ultimate plan is to get NCR completely out of the TAB loop—a goal Crafts estimates is at least a couple of years away.

Who will foot the bill?

The investment of getting into TAB is what is keeping the supply of TAB ICs low. The IC manufacturers face large capital expenditures in order to convert their production facilities to TAB. In addition, OEMs must develop the capability to do the trimming and forming required to utilize TAB parts. Such expenses limit the widespread use of TAB, which in turn keeps prices high and availability low.

Shiv Tasker, director of marketing for packaging and interconnect at Valid, says that companies proficient in packaging may be in a better position to drive MCM technology than IC manufacturers because such companies can act as neutral intercessors for multiple IC vendors. IBM, for example, is capitaliz-
Multichip modules

Regardless, engineers still frequently find themselves in a redundant loop of design-analyze-fix-analyze-fix-analyze because each design correction results in a new performance problem. And the more complex the design, the less useful simple rules of thumb are, as is the case if you attempt to minimize crosstalk when a 30-line bus spans an MCM.

John Isaac, advanced packaging product manager at Mentor Graphics, says that the EDA vendors aren't merely slacking off. The lack of consistent standards among IC manufacturers for bare-die characteristics and timing models prevents the development of software that can provide signal-integrity analysis and critical-path timing analysis. "You can't aim at a moving target," Isaac notes.

Furthermore, accurate simulation requires consistent IC models. Unfortunately, different IC vendors use different simulators to develop their chips. So, even when the vendors provide models, the models aren't consistent across the industry. To achieve consistency, some entity must either develop an IC-model translator or a unified simulation environment with standardized IC models.

For example, a layout based on timing constraints would incorporate predefined rules to control placement and routing for high-performance designs. Such a performance-driven layout would rely on physical rules for high-speed interconnect and take into consideration details such as differential-
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Accordingly, you need accurate thermal modeling to design MCMs. Simulating modules in terms of heat dissipation and temperature means designing heat sinks for these devices with 3-D thermal modeling. In addition, MCMs can incorporate thermally conductive materials to help manage heat dissipation. By placing metal columns, called thermal vias, through the MCM substrate, you can draw heat away from the die and keep it from dissipating unwanted heat to neighboring devices.

Unfortunately, even after you complete your MCM design, another problem caused by the lack of standardized test strategies arises. MCMs require real-time testing with diagnostics for their components and functions. But to obtain consistent strategies for boundary testing, the IC manufacturers must agree upon one form of built-in system test. The agreed upon test should be a functional testing of the completed module via the I/O pins. This type of test is necessary because the bare die is too small to probe with a bed-of-nails approach.

Texas Instruments is the only US silicon manufacturer that has announced plans to incorporate the Joint Test Action Group (JTAG) self-test standard. JTAG, which is also referred to as IEEE 1149.1 or boundary scan, provides a hardware basis for implementing a basic mechanism for self-test. However, companies must still develop internal test mechanisms to utilize such on-board logic. And because JTAG is a hierarchical test structure requiring test ports at the die, module, and board levels, sophisticated software tools are needed to manage the volume of test data generated by each of the chips in the module.

The principal functions that will evolve from standardized testing include automatic test-pattern generation and test insertion into netlists. Easley predicts test insertion and data management tools will be commercially available within the next year or so.

MEETING OF THE MINDS

Of course all of these timetables rest upon the assumption that technical standards will emerge. Such basic factors as physical size constraints, pin assignments, substrate composition, test methodologies, and electrical specifications have to be defined before MCM design can become as straightforward as ASIC design is today.

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firm stand on the issue of standards, the only other US entity with sufficient clout to facilitate acceptance of de facto standards is the Microelectronics and Computer Technology Corp (MCC). MCC is a cooperative research venture involving 55 North American companies. MCC currently has an assortment of 10 packaging and interconnect projects in progress and at least six more anticipated. The company has targeted MCM development because it encompasses key packaging technologies such as substrate design and development, bonding and assembly, testing, powering, and cooling.

In an effort to reduce cost and turn-around-time problems, MCC developed a high-density interconnect technique for programmable MCMs. The Quick Turnaround Interconnect (QTAI) technique begins with a prefabricated, blank-interconnect array in a copper polyimide (CuPi) substrate. You can mass produce such generic substrates for high-volume cost reduction.

Later, you can automatically route the substrates through thousands of interconnects via software based on a description of the chip-pad placement and a netlist. This routing personalizes the substrate according to customer orders and specific chip sets. MCC estimates that the QTAI approach can reduce turnaround time by 60 to 70%. MCC has successfully demonstrated QTAI by designing, producing, and testing a crossbar-switch MCM with 16 ICs and a 2-Mbyte nonvolatile memory card.

MCC has also begun work on an EDA tool called the Multichip Systems Design Advisor. This project is based upon Valid's Allegro-MCM design package. Other participants in this project include Apple Computer, Tandem, Hewlett-Packard, Harris, and Raychem's Advanced Packaging Systems. These companies will receive training from Valid and early copies of product enhancements in exchange for their involvement in this project. Companies not connected with MCC will be able to purchase this design system at the conclusion of this 2-year project.

So, although the current environment for MCM design may appear almost chaotic, pieces of the infrastructure are gradually falling into place. Although the development pace may not be as fast as your design team might desire, the elapse of the next two or three years may allow the market to prepare applications that will take advantage of the increased performance that low-cost MCMs will provide.

Acknowledgments

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References

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  - Precision stabilization:
    - 0.0005% source, 0.0005% load.
  - Analog programmable.
  - Kepco Group BOP-HV Power Supplies

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- **0-500V, 1000V & 2000V, 200 Watts**
  - Conventional filtering & high speed, user selectable.
  - Precision stabilization:
    - 0.005% source, 0.01% load.
  - Analog programmable.
  - Kepco Group BHK Power Supplies

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Anne Watson Swager, Technical Editor

HIGH-SPEED MONOLITHIC OP AMPS

Low-cost op amps break speed barriers

High-speed op amps are fast approaching commodity status as prices plummet. But don't confuse the word "commodity" with "ordinary." These low-cost devices offer unprecedented levels of monolithic-device performance. New fabrication processes and newly applied current-feedback design methods are resulting in myriad high-frequency devices that match or surpass their hybrid counterparts for a fraction of the cost. These op amps also let you apply closed-loop design techniques at frequencies that were previously impossible.

But remember that no single op amp can do it all, and these high-speed devices are no exception. High-voltage vs low-voltage process tradeoffs and ac-vs-dc performance tradeoffs will always exist. Longstanding compromises still apply; stability comes at the expense of bandwidth. Capacitive loads won't cause many of these op amps to oscillate, but that stability comes at the expense of speed.

And unlike slower amplifiers, high-speed amplifiers have "personality," as Barry Harvey, a designer at Elantec Inc, puts it. High-speed op amps can behave differently under different conditions and can be quite unpredictable. Manufacturers are attempting to strip these devices of their personality and make them easier to use and more forgiving of their environments.

But no high-speed design will ever be free from its high-strung temperament. As tempting as it is to design in an op amp from data-sheet numbers alone, a data sheet simply can't reflect these high-speed devices' performance subtleties. Bench-level evaluation is the only way to ensure that an op amp fits your design requirements.

Because of the compromises op-amp designers are forced to make, few of these new amplifiers fit the description "general purpose." Certain op amps are better performers in certain categories than in others. Even the same op amp can work well at a certain set of supply voltages but more poorly than comparable op amps at other voltages.

Table 1 shows a sampling of the newer low-cost, high-speed devices, but this list can't come close to showing the breadth of the portfolio offered by many of these high-speed op-amp suppliers. Many vendors offer so many high-speed devices that their selection guides categorize the op amps using some secondary characteristic. Such characteristics include accurate settling, low power, high power, low impedance, low drift, etc.

The simplest-looking circuits can demand the highest amplifier performance. Driving cable at video speeds is one such application that new high-speed op amps can accomplish with textbook circuits.

Text continued on pg 56
## Table 1—Representative high-speed, low-cost monolithic op amps

<table>
<thead>
<tr>
<th>Company</th>
<th>Part number</th>
<th>Description</th>
<th>-3-dB bandwidth at gain (MHz at V/V)</th>
<th>Slow rate (V/sec typ)</th>
<th>Settling time to % accuracy (nsec)</th>
<th>Differential gain, differential phase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analog Devices Inc</strong></td>
<td>AD811</td>
<td>Current feedback</td>
<td>140 at 1</td>
<td>2500 (20V out)</td>
<td>50 to 0.1%</td>
<td>0.01%</td>
</tr>
<tr>
<td></td>
<td>AD829</td>
<td>Voltage feedback, externally</td>
<td>50 at 1</td>
<td>230 (1kΩ load)</td>
<td>90 to 0.1%</td>
<td>0.02%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>compensated</td>
<td>120 at -1 (with compensation)</td>
<td></td>
<td></td>
<td>0.04%</td>
</tr>
<tr>
<td></td>
<td>AD845</td>
<td>FET input, voltage feedback</td>
<td>16 at 1</td>
<td>100</td>
<td>310 to 0.01%</td>
<td>N/S</td>
</tr>
<tr>
<td></td>
<td>AD847</td>
<td>Low power, voltage feedback</td>
<td>50 at 1</td>
<td>300</td>
<td>120 to 0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Burr-Brown Corp</strong></td>
<td>OPA621</td>
<td>Low distortion, voltage feedback</td>
<td>500 at 2</td>
<td>500 (2V step, gain = -2)</td>
<td>15 to 0.1%, 25 to 0.01% (2V step, gain = -2)</td>
<td>0.05%</td>
</tr>
<tr>
<td></td>
<td>OPA603</td>
<td>Current feedback</td>
<td>100 at 1</td>
<td>1000 (10V step, gain = 2)</td>
<td>50 to 0.1%</td>
<td>0.03%</td>
</tr>
<tr>
<td><strong>Comlinear Corp</strong></td>
<td>CLC406</td>
<td>Low power, current feedback</td>
<td>160 at 6</td>
<td>1500</td>
<td>12 to 0.05%</td>
<td>0.02%</td>
</tr>
<tr>
<td></td>
<td>CLC430</td>
<td>Current feedback</td>
<td>45 at 2</td>
<td>2000</td>
<td>40 to 0.1%</td>
<td>0.05%</td>
</tr>
<tr>
<td><strong>Elantec Inc</strong></td>
<td>EL2044</td>
<td>Low power, voltage feedback</td>
<td>60 at 1 and 2, 120 at -1</td>
<td>325</td>
<td>80 to 0.1%</td>
<td>0.04%</td>
</tr>
<tr>
<td></td>
<td>EL2073</td>
<td>Precision, voltage feedback</td>
<td>200 at -1</td>
<td>250</td>
<td>13 to 0.1%</td>
<td>0.01%</td>
</tr>
<tr>
<td></td>
<td>EL2120</td>
<td>Current feedback</td>
<td>100 at 1</td>
<td>750</td>
<td>50 to 0.25%</td>
<td>0.01%</td>
</tr>
<tr>
<td><strong>Harris Semiconductor</strong></td>
<td>HA-2481-2842</td>
<td>Low power, voltage feedback</td>
<td>54 at 1/40 at 2</td>
<td>250/375</td>
<td>90/100 to 0.1%</td>
<td>0.03%</td>
</tr>
<tr>
<td></td>
<td>HA-5020</td>
<td>Current feedback</td>
<td>100 at 1</td>
<td>800 (20V step)</td>
<td>100 to 0.25%</td>
<td>0.02%</td>
</tr>
<tr>
<td></td>
<td>HFA 1100</td>
<td>Very fast, current feedback</td>
<td>850 at 1</td>
<td>2500 (5V out, gain = 2)</td>
<td>11 to 0.1%</td>
<td>N/S</td>
</tr>
<tr>
<td><strong>Linear Technology Corp</strong></td>
<td>LT1191</td>
<td>Low voltage, voltage feedback</td>
<td>90 at +1</td>
<td>450 (1kΩ load, gain = -1)</td>
<td>100 to 0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td></td>
<td>LT1220</td>
<td>Precision, voltage feedback</td>
<td>45 at 1</td>
<td>250 (gain = -2)</td>
<td>90 to 0.1%</td>
<td>1.7%</td>
</tr>
<tr>
<td></td>
<td>LT1223</td>
<td>Current feedback</td>
<td>100 at 1</td>
<td>1000</td>
<td>75 to 0.1%</td>
<td>0.02%</td>
</tr>
<tr>
<td><strong>Maxim Integrated Products</strong></td>
<td>MAX404</td>
<td>Voltage feedback</td>
<td>66 at 2</td>
<td>500 (3V step)</td>
<td>70 to 0.1%</td>
<td>0.05%</td>
</tr>
<tr>
<td></td>
<td>MAX457</td>
<td>Voltage feedback, dual video</td>
<td>70 at 1</td>
<td>300</td>
<td>50 to 1%</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>distribution amplifier</td>
<td></td>
<td></td>
<td></td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>National Semiconductor Corp</strong></td>
<td>LM6181</td>
<td>High output drive, current feedback</td>
<td>100 at 1</td>
<td>2000</td>
<td>50 to 0.1%</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td>LM6362</td>
<td>Low power, voltage feedback</td>
<td>50 at 2</td>
<td>300</td>
<td>100 to 0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Texas Instruments Inc</strong></td>
<td>TLE2037</td>
<td>Decompensated, voltage feedback</td>
<td>16 at 5</td>
<td>7.5</td>
<td>N/S</td>
<td>N/S</td>
</tr>
</tbody>
</table>

Notes: Unless otherwise stated, specifications apply to the op amp’s highest operating supply voltage. All op amps available in 8-pin DIPs and SO packages except for the AD811, OPA603, and LM6181 whose SO packages have 16 pins. All op amps are unity-gain stable with the following exceptions: AD829, OPA621, HA-2842, MAX404, LM6362, and TLE2937. Test conditions are included when clearly stated on the data sheet. N/S = not specified; TBD = to be determined.
<table>
<thead>
<tr>
<th>Input offset voltage at 25°C (mV)</th>
<th>Input bias current (µA)</th>
<th>Output Voltage</th>
<th>Current (mA)</th>
<th>Input voltage noise (nV/√Hz) at 25°C</th>
<th>Quiescent current (mA)</th>
<th>Power-supply voltage(s)</th>
<th>Price (100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 max</td>
<td>5 typ</td>
<td>±2.8 or ±12 V</td>
<td>100 typ</td>
<td>1.9 (f = 1 kHz)</td>
<td>18 max</td>
<td>±5 to ±15 V</td>
<td>$3.35</td>
</tr>
<tr>
<td>1 max</td>
<td>0.3 typ</td>
<td>±3.6 or ±12.2 V (5000 load)</td>
<td>20 min</td>
<td>2 (f = 1 kHz)</td>
<td>6.8 max</td>
<td>±5 to ±15 V</td>
<td>$2.95</td>
</tr>
<tr>
<td>0.25 max</td>
<td>5 max</td>
<td>±12.5V (500 load)</td>
<td>25 min</td>
<td>18 (f = 10 kHz)</td>
<td>10 typ</td>
<td>±4.75 to ±18 V</td>
<td>$3.25</td>
</tr>
<tr>
<td>1 max</td>
<td>15 typ</td>
<td>±3 to ±10V min (5000 load)</td>
<td>N/S</td>
<td>15 (f = 10 kHz)</td>
<td>6.3 max</td>
<td>±4.5 to ±18 V</td>
<td>$2.95</td>
</tr>
<tr>
<td>1 max</td>
<td>12 typ</td>
<td>±2.5V (50I load)</td>
<td>N/S</td>
<td>3.3 typ (f = 10 kHz)</td>
<td>28 max</td>
<td>±5 V</td>
<td>$9.95</td>
</tr>
<tr>
<td>5 max</td>
<td>8 typ</td>
<td>±10V min (1500 load)</td>
<td>150 peak</td>
<td>N/S</td>
<td>25 max</td>
<td>±5 to ±15 V</td>
<td>$4.95</td>
</tr>
<tr>
<td>2 typ</td>
<td>30 typ</td>
<td>+3.1 to ±2.7V</td>
<td>70</td>
<td>TBD</td>
<td>5</td>
<td>±5 V</td>
<td>$5.35</td>
</tr>
<tr>
<td>2 typ</td>
<td>TBD</td>
<td>±13V</td>
<td>85</td>
<td>3 typ (equivalent input noise)</td>
<td>11</td>
<td>±15 V</td>
<td>$2.99</td>
</tr>
<tr>
<td>7 max</td>
<td>10 typ</td>
<td>±3.2 to ±13.6V</td>
<td>50 min</td>
<td>15 typ (f = 10 kHz)</td>
<td>5.2 typ, 7.6 max</td>
<td>±2 to ±18V, ±2.5 to ±36V</td>
<td>$1.80</td>
</tr>
<tr>
<td>0.2 typ, 1.5 max</td>
<td>8 typ</td>
<td>±2.5 to 4V</td>
<td>50 min</td>
<td>±2.3 typ (f &gt; 1 MHz)</td>
<td>21 typ, 25 max</td>
<td>±5 V</td>
<td>$7.95</td>
</tr>
<tr>
<td>2 typ, 25 max</td>
<td>20 typ</td>
<td>+3.5V (±5V)</td>
<td>60 min</td>
<td>N/S</td>
<td>17 typ, 20 max</td>
<td>±5 to ±15V, 5V only</td>
<td>$2.80</td>
</tr>
<tr>
<td>1 typ, 2/3 max</td>
<td>14/13</td>
<td>±10.5/11V</td>
<td>15/100</td>
<td>16 (f = 1 kHz)</td>
<td>11 max/15 max</td>
<td>±15 V</td>
<td>$3.75/4.00</td>
</tr>
<tr>
<td>2 typ, 8 max</td>
<td>2 typ</td>
<td>12V min</td>
<td>30 min</td>
<td>4.5</td>
<td>10 max, 7.5 typ</td>
<td>±5 to ±15 V</td>
<td>$2.85</td>
</tr>
<tr>
<td>2 typ, 6 max</td>
<td>10 typ</td>
<td>+2.8V min</td>
<td>60 typ, 40 min</td>
<td>4 typ (f = 10 kHz)</td>
<td>21 typ, 24 max</td>
<td>±5 V</td>
<td>$9.95</td>
</tr>
<tr>
<td>1 typ</td>
<td>N/S</td>
<td>±4 to 7V, 0.25 to 3.8V</td>
<td>50</td>
<td>25 typ (f = 10 kHz)</td>
<td>30 typ</td>
<td>±5 to ±6V, 5V only</td>
<td>$2.40</td>
</tr>
<tr>
<td>0.5 typ, 1 max</td>
<td>20 typ</td>
<td>13V</td>
<td>40 typ</td>
<td>17 typ (f = 10 kHz)</td>
<td>8 typ, 11 max</td>
<td>±15 V</td>
<td>$3.85</td>
</tr>
<tr>
<td>1 typ, 3 max</td>
<td>N/S</td>
<td>12V</td>
<td>50 min</td>
<td>3.3 typ (f = 10 kHz)</td>
<td>6 typ, 10 max</td>
<td>±5 ±15 V</td>
<td>$2.85</td>
</tr>
<tr>
<td>1 typ, 8 max</td>
<td>20 typ</td>
<td>±3V</td>
<td>50</td>
<td>N/S</td>
<td>35 max</td>
<td>±5 V</td>
<td>$2.98</td>
</tr>
<tr>
<td>5 max</td>
<td>20 typ</td>
<td>±2.5V</td>
<td>15</td>
<td>N/S</td>
<td>42 max</td>
<td>±5 V</td>
<td>$5.00</td>
</tr>
<tr>
<td>2 typ</td>
<td>5 typ</td>
<td>+Input: 0.5 typ</td>
<td>12V (1000 load)</td>
<td>100 min</td>
<td>TBD</td>
<td>10 max</td>
<td>±5 to ±15 V</td>
</tr>
<tr>
<td>3 typ, 13 max</td>
<td>7 typ</td>
<td>±13 to 14.2V</td>
<td>25 min</td>
<td>10 (f = 10 kHz)</td>
<td>5 typ</td>
<td>4.75 to 32V</td>
<td>$1.91</td>
</tr>
<tr>
<td>0.02 typ, 0.1 max</td>
<td>0.4 typ, 0.1 max</td>
<td>±13 to 12.9V</td>
<td>N/S</td>
<td>3.3 typ (f = 10 kHz)</td>
<td>3.8 typ, 5.3 max</td>
<td>±5 to ±15 V</td>
<td>$1.42</td>
</tr>
</tbody>
</table>
High-speed monolithic op amps

Process technology is one key

Process-technology improvements have as much to do with these amplifiers' performance as do innovative IC design techniques. Making the connection between process technology and amplifier performance doesn't require a PhD in device physics, just a basic understanding of process implications. Lower-voltage processes lead to higher speed; higher-voltage processes lead to higher precision. Complementary processes, which result in independent and ideally well matched npn and pnp transistors, also lead to higher speed and lower quiescent power dissipation.

Complementary processes have had the greatest effect on amplifier performance. These processes lead to npn and pnp transistors with similar switching speeds, although the npn devices are still somewhat faster. Using complementary processes, designers can produce symmetrical circuits that have efficient output stages and can effectively manage the power within the amplifier. Making a device with a complementary process requires more steps than do other processes, which often—but not always—means more expensive wafers and op amps.

Although process technology has a tremendous impact on a device's performance, you shouldn't make general assumptions about an op amp based solely on its process. According to Bill Gross, design manager at Linear Technology, “There is no single appropriate process for all high-speed amplifiers, just as there is no single definition of high speed.” Each company uses a variety of processes to achieve amplifiers that have the desired specifications.

Because of process advance-

ments, you also can't generalize individual device cost from overall wafer cost. Wafers produced by complementary processes do cost more, but the resultant op amps will not necessarily cost more.

Harris Semiconductor recently announced a high-speed process that the company will use to build many of its future high-speed products. Although each wafer this process produces costs much more than other wafers, the packing density of each device is much greater (Fig 1). More devices per wafer means lower cost per device. The process lets the company build ultrahigh-speed devices, such as the HFA-1110 family. At $9.95 (100), the family costs more than many of the other devices in Table 1, but it also offers 850-MHz-bandwidth parts.

Second sources disappear

One important impact of companies' having proprietary process technologies is the limitations placed on second sourcing. For many years, small companies and even larger companies with their own fabrication facilities built and continue to build high-speed op amps using AT&T's high-speed, complementary low-voltage process. Because AT&T's process was open to everyone, many companies built comparable products with the process and used design tricks to enhance the performance of its own op amps. As a result, companies could easily second source a variety of op amps.

Companies will find it more difficult—but not impossible—to second source the newer low-cost, high-speed amplifiers built using proprietary processes. Thus, your relationship with and confidence in your supplier is increasingly important. Also crucial is the design support the manufacturer offers, such as evaluation boards and macromodels.

Almost all the vendors in Table 1 offer macromodels of their op amps, but be forewarned: These...
Application tips for current-feedback amplifiers

Leaving all theoretical explanations of current-feedback op-amp operation to the experts, following a few simple rules will help you successfully use current-feedback op amps.

First, the most important step in using these amplifiers is choosing the feedback resistor. The value of this resistor affects the bandwidth and peaking of the amplifier's response (Fig A). Either use the value the manufacturer suggests and has most likely specified guaranteed performance for, or select the value according to the graphs supplied in the data sheet. Most of these values will be smaller than 1 kΩ.

You can adjust the value of the feedback resistor to tailor the op amp's compensation for your particular signal bandwidth—no voltage-feedback amplifier provides similar flexibility. To exercise this flexibility, you must understand current-feedback amplifiers' loop-gain mechanisms, a subject Refs 1 and 2 cover in depth. If you so choose, you can use resistors to fine-tune the frequency response of a current-feedback amplifier. Michael Steffes of Comlinear Corp suggests the circuit in Fig B, which increases the amplifier's loop gain without affecting the signal gain.

Second, choose the input-resistor value to set the op amp's gain. If you're using an inverting configuration, be sure the value isn't so low that it overloads the source.

Finally, a warning: Don't place a capacitor directly from output to input. This integrating topology is common for voltage-feedback amplifiers but will cause most current-feedback amplifiers to oscillate. Instead, form an integrator using a modified topology, such as the one Fig C shows.

Fig A—Choosing the exact value of a current-feedback amplifier's feedback resistor (RF) is crucial. As these graphs from the LT1223 (a) and EL2120 (b) data sheets show, this resistor's value directly affects the peaking and frequency response of the amplifier. (AV is voltage gain.)

Fig B—This circuit lets you decouple the feedback resistor from the gain-setting resistor so you can tailor the op amp's frequency response. (Figure courtesy Comlinear Corp)

Fig C—Most current-feedback op amps won't tolerate a capacitor placed directly from output to input. This modified configuration is one suggested integrator from Ref 3.
High-speed monolithic op amps

Macromodels leave out almost as many effects as they include. Elantec clearly states its models' shortcomings on the data sheet. The models approximate frequency response and small signal transients, but not the effects of load capacitance, noise, or slew-rate limitations. You can't rely on macromodels to reveal op-amp performance subtleties.

Current feedback proliferates

In addition to process improvements, current-feedback design techniques have also spurred the high-speed amplifier market. So many current-feedback amplifiers exist today that almost half of the op amps in Table 1 are current-feedback types. You'll find some good explanations of the current-feedback architecture in Refs. 1 and 2 as well as in many companies' application literature. Because of the basic architectural differences between current-feedback amplifiers and voltage-feedback types, following a few key points is crucial to applying them correctly (see box, "Application tips for current-feedback amplifiers").

Current-feedback amplifiers have two basic virtues: Unlike voltage-feedback amplifiers, they don't require huge gain-vs-bandwidth tradeoffs, and their freedom from slew-rate limiting makes them inherently linear at high frequencies. Also, the current-feedback architecture is generally very symmetrical, which leads to low distortion levels. A current-feedback amplifier's ac distortion has nothing to do with its dc specs, nor is it a strong function of the amplifier's bandwidth.

As always, there are exceptions to every rule. In reality, the bandwidth of a current-feedback amplifier still varies somewhat with gain. This variation is primarily due to the op amp's low inverting input resistance. Also, some of these amplifiers still have slew-rate limitations that can affect their linearity. The higher the power-supply current—15 mA seems to be optimal—the better chance a current-feedback amplifier has to be linear. This 15-mA supply current compromises the low distortion of dual and quad op amps.

Also, current-feedback amplifiers don't perform equally well in noninverting and inverting configurations. Unlike a voltage-feedback type, a current-feedback op amp doesn't have two high-impedance inputs. The noninverting input has a high impedance, on the order of 1.5 MΩ, but the inverting input has an extremely low impedance, on the order of 15Ω. Thus, each input has its own level of input bias current.

You can use the inverting configuration for circuits that don't require gain, such as inverted-summing circuits. But because of the inverting input's low impedance, inverting-gain configurations are limited. For example, using a current-feedback amplifier in an inverting configuration restricts your choice of the input gain-setting resistor. After choosing the feedback resistor to set the bandwidth of a current-feedback amplifier, you then choose the input resistor to set the gain. If you want to achieve high inverting gains, such as 10, the input-resistor value needs to be so small that the source would have difficulty driving this low impedance in combination with the inverting input's low impedance.

Even more vexing than the drive problem is the problem of running high-frequency signals through a length of wire or trace—which has inductance—and into the inverting

For more information...

For more information on the high-speed monolithic op amps discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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FAX (303) 226-0564
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Circle No. 7 For Career Info
High-speed monolithic op amps

node. The combination of the inductance and low resistance limits the op amp's frequency response long before any loading effects occur.

Noninverting configurations place no such constraints on the input resistor of current-feedback op amps because of the noninverting input's high impedance. Even in positive-gain configurations, current-feedback op amps do best with moderate gains of 10 to 20, but not as high as 50. However, don't overlook other data-sheet exceptions for noninverting-configuration operation limits. Despite claims to the contrary, some current-feedback op amps do suffer from input slew-rate limits. These limitations prevent their practical use in certain positive-gain configurations (Fig 2).

Common-mode rejection, noise, and accurate settling are not a current-feedback op amp's strong points. The current-feedback device has no differential input stage to cancel out common-mode effects. Its input voltage noise is fairly low; however, current noise on the inverting input is multiplied by the feedback resistor to produce output noise.

For example, the EL2120 has an input noise voltage of 4 nV/√Hz, but its noise current is 20 pA/√Hz. If this amplifier uses a 1-kΩ feedback resistor, the current noise would be 20 nV/√Hz, which would totally overwhelm the noise voltage. The good news is that the current noise decreases as the gain increases. Manufacturers usually recommend feedback-resistor values much lower than 1 kΩ; for example, 330Ω for the EL2120.

Finally, although current-feedback op amps tend to have high slew rates, they also have long thermal settling tails. Thus, these amplifiers can settle very quickly to accuracies of 0.1%, but take much longer to settle to higher accuracies. This feature alone takes current-feedback op amps out of the running for instrumentation applications.

Find the one you want

Once you focus on a few important specs and decide whether voltage- or current-feedback types bet-

![Fig 2—No two current-feedback amplifiers are alike, although they are all architecturally similar. For example, three of these amplifiers operating under the same slew-limited conditions exhibit three very different responses to a 4V_{p-p} high-speed pulse (a). The amplifier in b is well behaved, but those in c and d reveal distortion that is most likely the result of input slew-rate limitations. (Photos courtesy Elantec Inc)
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High-speed monolithic op amps

After suit your design, you'll have numerous op amps to choose from. These devices are specified over an increasingly wide range of power-supply voltages, often for both $\pm 5$ and $\pm 15$V and any voltage range in between. Some low-voltage op amps include specs for 5V operation only. Almost all of these op amps are available in 8-pin DIPs and small-outline packages. Most op amps come in single packages; duals are available but less prevalent.

Most all of these amplifiers are unity-gain stable, and many are stable even while driving capacitive loads. Although the amplifiers don't oscillate when driving capacitive loads, that stability comes at the expense of bandwidth (Fig 3). You should interpret the words "can drive capacitive loads" on the data sheet as "the amplifier slows down and adjusts to the load automatically." Thus, to keep the op amp running at its maximum bandwidth, you still need to keep the load capacitance as low as possible.

Keep in mind that these op amps demand the same respect as any high-speed component. All high-speed designs require extremely careful layout and power-supply decoupling. For this reason, most manufacturers provide evaluation boards that you can use to evaluate the part and emulate the manufacturer's suggested layout.

Application-specific specs

These monolithic op amps are increasingly specialized and specified for applications like broadcast video, HDTV, and communications. Even bandwidth is being specified with more detail than ever before. Instead of providing information on only the $-3$-dB bandwidth of devices, manufacturers specify gain flatness. For example, the AD811 features gain flatness to within 0.1 dB at frequencies as high as 35 MHz. The HFA1100 has a gain flatness of 0.04 dB to 50 MHz and 0.14 dB to 100 MHz.

Almost all these devices include specs for differential gain and phase, the classic measure of distortion for composite video systems. Because the amplitude and phase of a composite signal carry color information, modulating these quantities will cause color distortion. And because video systems often have chains of amplifiers, those amplifiers' specs must be that much tighter than the overall system spec.

For systems with 10 amplifiers and goals of $0.1^\circ$ and 0.1 dB for differential phase and gain, respectively, each amplifier must have a differential phase of $0.01^\circ$ and a differential gain of 0.01 dB. The AD811 and EL2120 comply with these extremely tight requirements.

In addition to video specifications, many of these op amps have video-specific features such as disable pins. The CLC430 and EL2120 have high-speed disables of 100 and 50 nsec, respectively.

As these amplifiers encroach on RF territory, communications specs, such as third-order intercept, are becoming more and more common on data sheets. Third-order intercept is a measure of the change of third-order intermodulation components. The third-order intercept point is the intersection of two plots: output vs power and output third-order intermodulation-distortion components vs input.

Scrutinize data sheets

Despite evolving data sheets, some things never change. Manufacturers can't resist skewing specs to their advantage. The difference between bandwidth and gain-bandwidth product is especially murky for high-speed voltage-feedback amplifiers. For low-frequency amplifiers, you can safely assume that...
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Data from Motorola MVME165 data sheet dated 2/90, and Force CPU-40 data sheet A1 Rev. 1. DRAM measurements shown are with parity. VMEbus transfers are to a 66n-slave.

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**UPDATE**

High-speed monolithic op amps

most unity-gain amplifiers are stable. Therefore, a gain-bandwidth product of 1 MHz implies that at a gain of 1, the bandwidth is 1 MHz.

This assumption doesn’t hold true for high-frequency op amps. It’s imperative to judge a voltage-feedback amplifier by both its gain-bandwidth specification and its minimum closed-loop gain. Because the gain-bandwidth product is confusing and not applicable to current-feedback amplifiers, Table 1 shows the -3-dB bandwidth at some usable level of gain. For voltages-feedback types, don’t forget that the bandwidth will be even lower for higher gains.

The low cost and wide availability of high-speed monolithic op amps lets you design circuits and systems whose costs were previously prohibitively high. But often the simplest-looking and most common-place circuits can put the greatest demands on an amplifier. A video cable driver is a classic example. Driving 150Ω loads is a difficult job, but the amplifiers in Table 1 accomplish it using textbook circuits.

**References**


**Article Interest Quotient**

(Circle One)

High 518 Medium 519 Low 520
Mitsubishi
Shaved 2ns Off
The World's
Fastest SRAM.

Ultra Fast
Talk about cutting-edge technology!
Mitsubishi's 8ns 256K BiCMOS SRAM thrusts you into the next generation of chip design with higher performance and density for ultra-fast cache applications like workstations, minicomputers and digital signal processing systems.

Center Power-Ground Pins
This 32K x 8 SRAM is the first to use a 0.6 micron BiCMOS process plus two pairs of center power-ground pins to reduce noise. The result is blazing speed in a small footprint 32-pin SOJ package.
If that's more speed than you need, this SRAM is also available in 10ns and 12ns access times. For more information, call 408-730-5900 ext. 2106.
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Our new ops

Introducing the op amps that are more than twice as fast as any others. The new Harris HFA-1100 family.
870 MHz of blinding op amp speed. A shocking 2500 volt/μsec slew rate. A low low 11 ns settling time. Harris' unique UHF1 process technology makes all this possible.
It all means these new ops are the top. The top of

HA-2444.
A mux and 4 video op amps in a single chip. Ideal for digitally selectable 4-channel video.

HA-1110.
It's a buffer amplifier, featuring ultra high speed 700 MHz unity gain bandwidth, 2500 V/μsec slew rate and 7 ns settling time.

HA-0005.
High speed in a monolithic design. 420 V/μsec slew rate. 300 MHz bandwidth.

HA-5033.
Buffering video has never been easier. Thanks to a 1300 V/μsec slew rate, excellent differential phase and gain.

CA-3246.
This NPN transistor array covers a wide array of applications — all the way from DC to 1.5 GHz.
really hop.

the broadest line of op amps in the world: the Harris line. So for ops that really hop, to ops at low cost, remember. Nobody gives you more to choose from than Harris. Call 1-800-4-HARRIS, extension 1110.

<table>
<thead>
<tr>
<th>World's Fastest Op Amps</th>
<th>HFA1100</th>
<th>870 MHz</th>
<th>2500 V/µsec</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFA1110</td>
<td>700 MHz</td>
<td>2500 V/µsec</td>
<td></td>
</tr>
</tbody>
</table>

HFA-1130. The same 870 MHz speed as our industry-leading HFA-1100. Plus a 1 ns output clamp.

HFA-1100. This op is tops. It's the world's fastest monolithic op amp at 870 MHz.

HFA-0001. With a 1000 V/µsec slew rate, and 350 MHz bandwidth, this op really hops.

HA-2841. A 40 MHz, low-power version of our industry-standard HA-2541.

HA-5020. Our low-cost version of the EL2020, but enhanced to give you a full 100 MHz bandwidth.
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The cycle time for hyper-page mode is 35ns. Package options are SOJ, shrink ZIP, and TSOP II.

NEC developed the industry's first 256K video RAM. Now we're first again with the 2M VRAM. To find out how our leadership in graphics memories can brighten the marketing picture for your workstation, call NEC today.

For fast answers, call us at:

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Sweden Tel: 08-753-6020. Fax: 08-755-3506.
France Tel: 1-3946-3663. Spain Tel: 1-504-2787. Italy Tel: 02-6709098.
Fax 02-66981329. UK Tel: 0908-691333. Fax: 0908-679260.
Ireland Tel: 01-6794200. Fax: 01-6794081.
Hong Kong Tel: 755-9008. Fax: 796-2404.
Taiwan Tel: 02-719-2377. Fax: 02-719-5951.
Korea Tel: 02-551-0450. Fax: 02-551-0451.
Singapore Tel: 253-8311. Fax: 250-3583.
Australia Tel: 03-8878012. Fax: 03-8878014.
Japan Tel: 03-3454-1111. Fax: 03-3788-6059.

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PRODUCT UPDATE

Synchronous cache RAMs run at 50 MHz

The CY7B173 and CY7B174 synchronous cache RAMs operate at 50 MHz, but they offer more than just high speed. To simplify cache-memory subsystem design, the devices incorporate logic functions such as address latches and burst counters.

Both memories are organized as 32k x 9 bits. They operate synchronously, sampling the address, data, and control lines on the rising edge of the clock input signal. The clock's minimum cycle time is 20 nsec, allowing operation at 50 MHz. Only the output-enable line operates asynchronously, setting the data output lines to high impedance within 7 nsec of de-assertion.

For the memories to respond to a given clock cycle, both the chip select and address strobe lines must be properly asserted. The devices have two complementary chip select lines, allowing you to use two banks of memory in your system without external decoding logic. The devices also have two address strobe lines: one for the system processor and one for the cache controller. Having two address strobe lines eliminates the need for external logic in systems with processors that don't relinquish control in the event of a cache miss.

Both address strobe lines have the same effect during a read operation. The data output becomes valid within 14 nsec of the rising clock edge. For write operations, however, the address strobes have different results. The controller's address strobe causes a write operation to complete in a single clock cycle. The processor's address strobe, however, causes the memory to delay one clock cycle before completing the write operation. This delay lets cache-tag RAM or other logic time identify a cache miss and prevent the write operation if necessary. If both address strobes are active, the processor address strobe takes precedence.

The memories support burst access for read and write operations by supplying an address latch and a built-in burst counter. The CY7B173 has a counter that follows the burst sequence of the Intel 80486 processor. The CY7B174 offers a linear counter. You can use the burst mode with either the processor or the controller address strobes.

The devices operate at 5V and consume 250 mA. They come in 44-pin PLCC (plastic-leaded-chip-carrier) packages and cost $69 (100).

—Richard A Quinnell

Cypress Semiconductor, 3901 N First St, San Jose, CA 95134. Phone (408) 943-2600. FAX (408) 943-2741.

Circle No. 730
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<table>
<thead>
<tr>
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<td>8-Bit, 8 Channel</td>
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<td>4 External</td>
<td>16 Internal</td>
<td>16 Internal</td>
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<td>16 Internal</td>
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<td>I/O Ports</td>
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<td>1-Bit I/O</td>
<td>47 I/O</td>
<td>47 I/O</td>
<td>50 I/O</td>
<td>50 I/O</td>
<td>50 I/O</td>
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<td>Other Features</td>
<td></td>
<td>Security Function</td>
<td>Parallel Handshake Port</td>
<td>Programmable Pull-up for All I/O</td>
<td>15-Byte DFRAM, Prog. Pull-up for I/O</td>
<td>19-Bit Timer</td>
<td>19-Bit Timer</td>
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<tr>
<td>Package</td>
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<td>DP-64S</td>
<td>QFP-64</td>
<td>PLCC-84</td>
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<td>COB*</td>
<td>QFP-64</td>
<td>DC-645</td>
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<td>LCC-64</td>
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</tr>
</tbody>
</table>

*Sell your Hitachi representative for availability.

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Circle #46 For Literature Only
Circle #47 To have Hitachi Representative Call
The growth in PLD size over the past few years has presented designers with a new problem—no universal yardstick for measuring PLD performance. (Photo courtesy Altera Corp)
The lure of programmable logic is inescapable. The technology gives you freedom to change your hardware design up until the last minute, or in some cases, even after it has shipped. The low financial risk and short development times all favor programmable logic devices (PLDs). However, the flexibility of a PLD that works for you in a design works against you when you are trying to nail down just what each product can do.

High-density PLDs offer several thousand usable logic gates with flexibility and speed adequate for many of the same circuits as masked gate arrays. System clock speeds are generally in the range of 10 to 50 MHz, although some chips are now able to push the maximum speeds even higher for select designs. Often high-density PLDs are defined as those with more than 2000 usable gates—but different manufacturers rate usable gates differently by as much as a factor of three. For this article, high-density PLDs are devices in packages with 40 pins or more (this is an objective standard, even though it is not an accurate measure of logic capacity).

The fast-moving, high-density PLD market and its lack of universal specifications makes a marketers' paradise and an engineers' nightmare. To get a full appreciation of what you are up against, consider the following note for a device-timing specification on combinatorial delay and setup times (the company will remain unnamed):

“These limits are derived from worst-case values for a representative selection of the slowest paths through the [device] logic cell including net delays. Some paths may exhibit longer..."
The great flexibility of PLDs that works for you in a design works against you when you are trying to nail down just what each product can do.

delays, although most will be shorter."

The company wants to give the specification the conservative feel of worst case without living up to the real meaning. The specification should read "typical," which is the only way a designer can safely use it.

Most high-density PLD specifications aren't misleading. But they don't go a long way toward helping you answer two of the three most important questions—will my design fit on the chip and how fast will it run. The third question, how much does it cost, manufacturers can clearly answer.

The best way to choose the optimum high-density PLD would be to try your design on all of them and see how they perform. However, with more than a dozen architectures to choose from and multiple chips within most architectures, the possibility of trying your design on each one isn't practical. The disturbing fact is, you may be unable to choose the optimum PLD architecture for your application.

Help for choosing the right architecture is on the way in two forms, but it may take a while to arrive. The first development that may prove helpful is a set of benchmark circuits that will show the speed and comparative capacity of different high-density PLDs. A total of seven PLD and PLD-tool companies are in the process of founding a nonprofit corporation for developing and regulating the benchmarks. The benchmarks will give users a quantitative measure of how the chips perform when programmed for various functions, such as counters and accumulators. The percentage of the chip consumed for these functions and the speed at which the device runs will give a far better measure for comparing PLD performance than is currently possible. Expect to hear more on benchmarks as the effort gets underway.

The need for I/O pins often grows with the logic available on the chip. A large device such as Actel's 1280, rated by the company at 8000 equivalent gates, is available with 176 pins in a pin-grid-array package.

The other helpful development is in software tools that let you try your design on multiple chips. In December, Neocad released some software tools that let you design independently of a target device. After you've entered your design, the software can automatically generate programming information for the target device you choose. The tools accept inputs from many of the design-entry tools already available and outputs the program data for the PLD. The software should be a step in the right direction, but the initial release only supports Actel and Xilinx products.

Until a better solution comes along, you need to learn what you can about the available devices to make an informed decision, even if you can't necessarily choose the optimum chip. When you start to narrow your search, there are a few objective specifications that may help (see Table 1).

The storage method used on a PLD may not seem critical, but the implications may be important to your application. Storage methods brake down into three main categories: one-time-programmable, erasable, and volatile memory.

One-time-programmable and erasable PLDs usually have a design security bit you can set that makes it difficult for someone to copy your design. Volatile-memory-based devices don't offer security because you always have to load them from some nonvolatile source, either an adjacent PROM or a nonvolatile-memory source connected to a computer that loads the device.

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One-time-programmable devices typically offer a long operational lifetime after programming. Some erasable devices only guarantee the programming for 10 to 20 years, depending on storage and operating temperatures or other factors. If extremely long life is important, look for the fine print or ask the chip vendor exactly what the lifetime is.

Erasable PLDs, which let you try again and again until you get your design right, are usually specified for at least 100 write-erase cycles. If developing your design involves many unsuccessful cut and try attempts, you may find it less embarrassing to use an erasable or volatile memory-based device and avoid creating large stacks of useless
one-time-programmable devices.

The infinite ability to re-program volatile-memory-based PLDs may be a nuisance because you need to load the memory every time power is interrupted. Or, re-programming may be a feature you can’t live without.

For example, Quickturn (Mountain View, CA) uses volatile-memory-based chips to emulate ASICs. The company has developed software that converts the internal design of an ASIC into a program for a system containing a large number of Xilinx 3090 devices. The product wouldn’t be possible without infinitely re-programmable devices.

Volatil-memory-based parts might also be an advantage if you want to be able to update a system in the field, either using a new PROM or software updates if the device program is loaded by a computer.

If your circuit needs to operate off battery power, you may be able to narrow your search further. Most of the chips listed in Table 1 have a standby current rating higher than 100 mA or lower than 10 mA. Some are lower than 1 mA.

You should note two things about the standby current rating. First, for some devices, standby current is just the rating when no inputs are changing state (usually specified at inputs of supply voltage or ground), and output loads are zero. For other devices, a standby state is a special state and reactions to changing inputs may not be as fast.

### Table 1—Representative high-density PLDs

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product</th>
<th>Logic cells</th>
<th>Program storage</th>
<th>Program security bit</th>
<th>Standby current, mA (max)</th>
<th>System-wide clocks</th>
<th>Asynchronous clocks</th>
<th>Price (100)</th>
<th>Comments</th>
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<td>Actel</td>
<td>1240</td>
<td>684</td>
<td>OTP-antifuse</td>
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<td>2</td>
<td>Yes</td>
<td>$150</td>
<td>Alternate source is Texas Instruments.</td>
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<td></td>
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<td>1232</td>
<td>OTP-antifuse</td>
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<td>0.350</td>
<td>2</td>
<td>Yes</td>
<td>$300</td>
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<td>AMD</td>
<td>Mach 110</td>
<td>32</td>
<td>EE-CMOS</td>
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<td>2</td>
<td>No</td>
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<td></td>
<td>Mach 210</td>
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<td></td>
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<td>AT2500</td>
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<td>None</td>
<td>Yes</td>
<td>$17.90</td>
<td>Low-power version ($20.40).</td>
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<td>UV-Erasable</td>
<td>Yes</td>
<td>40</td>
<td>(partitioned)</td>
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<td>$57</td>
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<td>Plessey</td>
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<td>Yes</td>
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<td>PLHS5501</td>
<td>None</td>
<td>OTP-fuse</td>
<td>Yes</td>
<td>295</td>
<td>None</td>
<td>Yes</td>
<td>$10.60</td>
<td>Folded NAND structure.</td>
</tr>
<tr>
<td></td>
<td>PML2552</td>
<td>None</td>
<td>UV-Erasable</td>
<td>Yes</td>
<td>10</td>
<td>Partial</td>
<td>Yes</td>
<td>$12.90</td>
<td>Folded NAND structure.</td>
</tr>
<tr>
<td>Xilinx</td>
<td>4003</td>
<td>100</td>
<td>Volatile memory</td>
<td>Not available</td>
<td>8</td>
<td>Yes</td>
<td>$110</td>
<td></td>
<td>Alternate source is AT&amp;T.</td>
</tr>
<tr>
<td></td>
<td>4005</td>
<td>196</td>
<td>Volatile memory</td>
<td>Not available</td>
<td>8</td>
<td>Yes</td>
<td>$292</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. OTP=One-time programmable.
2. Alternate sources are not necessarily for products listed.
3. EE=Electrically erasable.
4. UV=Ultraviolet.
A logic cell on a large-granularity device is equivalent to many more gates than on a small-granularity device. The end effect is more potentially usable gates go to waste.

as when the device is fully powered.

Second, power consumption when the device is operating with many of the gates changing state at 25 MHz may increase significantly over the standby power rating. To reap the benefits of low standby current, you need to operate devices at low clock rates or have periods of low clock-rate operation. Manufacturers' data sheets show how to compute the device current requirements when operating.

Support for clocking requirements

Another possible way to narrow your search is to examine the available clock options. Table 1 divides the clocks into system or global clocks and asynchronous clocks.

A system clock typically means a clock input that fans out to all registers. In the case of Atmel ATV 5000, the system clock has been partitioned so that each clock is distributed to a portion of the device. A system clock usually has a relatively low-propagation time and low skew, but that varies with the particular chip architecture.

The term asynchronous clock as used for Table 1 indicates the ability to have individual registers use a different clock for complete flexibility. You can define all asynchronous clocks to have the same input conditions, and in effect make them system clocks, although skew and propagation time may suffer.

If you will be using the PLD for a completely synchronous design, then one or perhaps a few system clocks are all you need. If you'll be performing some asynchronous clocking operations, you'll need to restrict your choices to devices that provide that capability. Although not shown in Table 1, some devices provide only a common set and clear control for registers. Others give you the option of setting and clearing registers individually.

Discussing comparative features of devices is reasonably objective. But, when you try to compare PLD architectures, the task becomes considerably more subjective. You can, for example, count the number of logic cells in two devices, but deciding what the numbers mean when you are dealing with two different types of logic cells is very difficult. Until benchmarks or better methods of evaluating designs become available, trying to sort out architectural differences and what they mean to you may be your best bet.

All high-density PLDs operate as a group of logic cells with programmable connections between the cells. Many high-density PLDs let you program both the logic-cell connections and some of the functions performed within the logic cells, rather than just connecting the logic cells. In addition, some devices offer more than one type of logic cell. Depending on the logic functions performed in each cell, you can assign architectures different granularities.

The ERA60100 from Plessey has the finest granularity, with each cell consisting of a 2-input NAND gate. A logic cell can also function as a transparent latch and two logic cells can function as a flip-flop. A series of local, short-range, and long-range interconnects provide signal routing among the 2500 logic cells on the chip. Programming the chip requires 27,320 bits of data, giving a rough measure of the flexibility of the device.

The CAL1024 from Algotronix also uses 2-input logic cells that can function as latches. Instead of just the NAND function, the logic cell...
can perform any function of two Boolean variables. The device provides two global signals, but other than that each logic cell connects only with its four nearest neighbor cells. The architecture of this device is best suited to regular logic structures, such as a shift register where the lack of medium- and long-range connections is not a drawback.

As you move up in granularity you come upon Actel’s Act 2 family, which has logic cells that accept as many as seven inputs. The logic cells can perform any Boolean function of two variables, most of three variables, and some functions as high as seven variables. Actel rates its A1280 device with 1232 logic modules at 8000 usable gates, which they claim has the same logic capacity as a masked gate array with 8000 usable gates. Although the claim might be contested by some of Actel’s competitors, the A1280 appears to have the largest logic capacity of any high-density PLD currently in production. With approximately 750,000 programmable antifuses, the A1280 provides the most programmable connections of any PLD.

Quicklogic, a relatively new company, is shipping its first product, the QL8x12, which contains 96 logic cells. Each logic cell accepts as many as 14 inputs and performs any Boolean function of three variables and some to 14 variables. The company claims both high-speed and flexible logic capabilities. An example circuit on a portion of the chip is a 16-bit counter that can be loaded or operated at more than 100 MHz. The chip has about 76,000 programmable antifuses and is rated by the manufacturer as equivalent to a 1000-gate masked gate array.

Still higher in granularity is the Xilinx 4000 family. The company’s 5000-gate 4005 is the largest member of the family currently shipping. Each logic cell in the 4000 family has two 4-input function generators, which can feed into two flip flops, be output directly, or combined to generate larger functions.

The 4000 family has a feature unique among PLDs in that you can use the function generator directly as RAM.

At the highest level of granularity you find the sum-of-products architectures. These devices typically use programmable, wide-input AND gates that feed into fixed- or variable-input OR gates (Fig 1). Although the basic structure of the sum-of-products devices may be similar, don’t dismiss them as all being the same. There is considerable variation in device flexibility.

### Sum-of-product architectures

Table 2 contains data on product terms and how they are distributed within the devices that use sum-of-products architectures. The range of product terms possible in a logic cell (typically referred to as a macrocell in these devices) gives some idea of the flexibility of a particular device. If you can’t get enough product terms in one logic cell, you’ll pay a time penalty to cascade multiple logic cells.

**Table 2—Representative sum-of-product high-density PLDs**

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product</th>
<th>Logic cells</th>
<th>I/O</th>
<th>Buried Registers</th>
<th>Total on device</th>
<th>Per logic cell</th>
<th>Fixed product terms per logic cell</th>
<th>Allocated product terms per logic cell</th>
<th>Shared product terms available to each logic cell</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD</td>
<td>Mach 110</td>
<td>32</td>
<td>0</td>
<td>32</td>
<td>140</td>
<td>4.4</td>
<td>0.4</td>
<td>0 to 12</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mach 210</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>272</td>
<td>4.3</td>
<td>0.3</td>
<td>0 to 16</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Altera</td>
<td>Max 5064</td>
<td>28</td>
<td>36</td>
<td>64</td>
<td>604</td>
<td>9.4</td>
<td>7.4</td>
<td>0</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max 5192</td>
<td>64</td>
<td>128</td>
<td>192</td>
<td>1792</td>
<td>9.3</td>
<td>7.3</td>
<td>0</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Atmel</td>
<td>ATV2500</td>
<td>24</td>
<td>0</td>
<td>48</td>
<td>832</td>
<td>34.7</td>
<td>9</td>
<td>4 to 12</td>
<td>Limited sharing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ATV5000</td>
<td>52</td>
<td>24</td>
<td>128</td>
<td>1232</td>
<td>16.2</td>
<td>7.3</td>
<td>4 to 13</td>
<td>Limited sharing</td>
<td></td>
</tr>
<tr>
<td>Intel</td>
<td>S5C324</td>
<td>24</td>
<td>0</td>
<td>24</td>
<td>384</td>
<td>16</td>
<td>8</td>
<td>0 to 16</td>
<td>0</td>
<td>10 input latches.</td>
</tr>
<tr>
<td>National</td>
<td>MLPL144</td>
<td>24</td>
<td>3</td>
<td>27</td>
<td>132</td>
<td>4.9</td>
<td>0.15</td>
<td>0</td>
<td>128</td>
<td>Programmable AND/OR array.</td>
</tr>
<tr>
<td>Semiconductor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plus Logic</td>
<td>H2010</td>
<td>30</td>
<td>6</td>
<td>36</td>
<td>228</td>
<td>6.3</td>
<td>5</td>
<td>0</td>
<td>12</td>
<td>Input latches; buried logic cells have input or output.</td>
</tr>
<tr>
<td></td>
<td>FPGA2020</td>
<td>36</td>
<td>36</td>
<td>72</td>
<td>456</td>
<td>6.3</td>
<td>5</td>
<td>0</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

See Table 1 for prices.
When comparing high-density PLDs, it's a good idea to include the software in your comparison.

Most sum-of-products devices have some method to redistribute product terms. Therefore, those logic cells needing many product terms can get them, and those that don't need many don't have to waste them. The three methods of distributing product terms are fixed, allocated, and shared (see Fig 2).

Fixed product terms are locked to the input of an OR gate and cannot be redistributed. You can program allocated product terms to one of two or more logic cells. Product term allocation gives you more flexibility than fixed terms, but not as much as shared terms. With allocated product terms, two logic cells that need identical product terms will waste an extra product term to generate the same data twice. Note that when product term allocation is used, you can't have the maximum number of product terms going to all logic cells. For each cell receiving greater than the average number of product terms, another logic cell, usually an adjacent one, must receive less.

Shared product terms give you the most flexibility, requiring you to generate a specific product term only once. Because each logic cell should have some independent product terms, you'll usually see a few fixed product terms in addition to shared terms. The most flexible case of shared product terms is a programmable AND array that feeds into a programmable OR array, as used on National Semiconductor's MAPL144 array.

An interesting variation is the use of an XOR gate after the OR gate on Altera's logic cells (Fig 3). The XOR gate lets you invert the logic for active-high or active-low logic applications. It also lets you apply de Morgan's theorem to use the large number of product terms for a wide sum.

You'll note from the data in Table 2 that some devices devote more product terms to secondary control functions than others. Typical uses of secondary product terms are for controlling register presets, clears, and clocks. The extra secondary-function product terms either provide flexibility that you may need, or wasted gates if you don't need them. It just depends on your application.

Another variation on sum-of-products architectures is the registers in each logic cell. Most have a single register per output logic cell, but Atmel's ATV 2500 and 5000 products offer two registers so that in some cases you can do the work of two logic cells with one.

**Fig 2**—Product-term allocation or sharing provide flexible alternatives to fixed product terms in sum-of-products architectures. Product-term allocation (a) typically lets you switch product terms in groups of four so that logic cells needing more product terms can take them from logic cells that need fewer. Product-term sharing (b) lets you use fewer product terms in a device by using a product term in more than one sum.
A large-granularity product that doesn’t really fit into the sum-of-product architecture is the folded NAND array from Signetics (Fig 4). The FML2552 uses 96 NAND gates that fold back on themselves with 258 inputs on each gate to generate any combinatorial functions. Additional wide-input NAND gates drive latches and flip flops for sequential logic.

**Implication of device granularity**

Trying to make comparisons of the architectures is difficult. Logic-cell granularity can at least help you gain an intuitive appreciation for logic flexibility vs performance.

Fig 5 shows a hypothetical comparison of the relative spread between the maximum possible gates in a particular PLD and the minimum usable gates if you were to try to use the device for many different circuits. The curve in Fig 5 is not based on real data and, obviously, the designs that result in the minimum usable gates are those for which the particular PLD is poorly suited. The figure shows the relative differences between a fine-granularity device and another large-granularity device.

Assuming that both devices have the same maximum number of usable gates, the finer-granularity device should show a higher minimum-usable-gate number. The difference in minimum-usable gates happens because a simple function may consume a logic cell on both the large-granularity device and the small-granularity device. A logic cell on a large-granularity device is equivalent to many more gates than on a small-granularity device. The end effect is that more potentially usable gates go to waste.

For example, consider a design

---

**Fig 4**—A folded NAND array is the basic building block of the FML2552. Ninety-six NAND gates with 258 inputs make up the basic logic element. Additional wide NAND gates drive the flip-flop inputs. The device provides flexible product sharing.

**Fig 3**—Using an XOR gate after the sum-of-products lets the Altera Max family change between active-high and active-low logic. Among other things, being able to invert the active state lets you use de Morgan’s theorem to create wide sum terms from wide product terms. Some manufacturers provide an inversion select at the output of the logic cell, which provides a similar capability.
that uses a large shift register. Most large granularity logic cells offer one register per cell (a few offer two). The smaller granularity devices can still perform the shift register in one logic cell (some will require two), yielding much better efficiency for a shift-register type of circuit. The large-granularity device has many combinatorial gates that just go to waste in the case of a shift register. When a design uses a more balanced set of combinatorial- and sequential-circuit elements, the large-granularity devices show better gate utilization.

In general you should try to find a high-density PLD where the logic you will be implementing will efficiently use the resources of most of the logic cells. Although efficient use of logic cells might point unanimously in favor of the smaller granularity products, the situation isn't quite that simple. Balancing the potentially low usable gates on the large granularity products are the potential disadvantages of the small granularity products.

Small-granularity devices need to have many possible interconnects between the numerous cells. An insufficient number of interconnects is always a concern on small-granularity products. The interconnect problem may require manual intervention in the place and route task to connect a circuit or to enhance speed if automatic place and route was successful, but the circuit ended up too slow. Some device architectures offer considerably more interconnects than others, easing the problem.

Another potential disadvantage of devices with small granularity logic cells is the possibility of low speed for circuits with wide-input functions. To some extent, you can counter the problem by careful design.

For example, to evaluate when a 16-bit-wide down counter reaches zero, you’d cascade the gates so that the LSB is evaluated at the last stage (Fig 6).

---

**Fig 5**—If you were to try many different designs on two PLDs with an equivalent number of maximum usable gates, one with large logic-cell granularity and another on a device with small granularity, you’d probably come up with something similar to the two hypothetical curves shown. Although the shape of the distribution is unknown, the smaller-granularity logic cells should show less variation in equivalent gates due to their greater flexibility. See text for further explanation.

**Fig 6**—PLDs with small-granularity logic cells are often at a disadvantage when dealing with wide inputs because they require multiple levels of logic which cause longer propagation delays. Careful attention to design details can sometimes reduce or eliminate the disadvantage.

Consider a circuit that evaluates the outputs of a 16-bit down-counter to determine when it has reached zero. You can design a circuit with two levels of logic delay using a logic cell capable of creating a 4-input OR function (a). With the same logic cell you can also design the circuit so that the down-count to zero is evaluated with only one logic-level delay, even though the overall circuit has three levels of delay (b).
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Xilinx has relatively large-granularity logic cells, although they are still small in comparison with the logic cells of many sum-of-products architectures. To improve the speed of wide decoding operations, the company’s 4000 family has sixteen 40-bit-wide programmable decoders that can generate a decode in 10 nsec.

The fast, wide decoders are a specific example of a general trend for manufacturers to enhance performance in their evolving architectures by adding new logic cells or new functions to old cells. A further example is fast carry logic on Xilinx architectures. To improve the handling text-based design tools for Boolean equations or state-machine descriptions, you’ll find you can use the same or similar tools for high-density PLDs. You might feel more at home with the sum-of-products architectures that often let you design as though you were using multiple small PLDs with programmable connections.

If you are accustomed to designing with low-density PLDs and using paper-based design tools for high-density PLDs. You might feel more at home with the sum-of-products architectures that often let you design as though you were using multiple small PLDs with programmable connections.

If you are accustomed to designing with low-density PLDs and using text-based design tools for Boolean equations or state-machine descriptions, you’ll find you can use the same or similar tools for high-density PLDs. You might feel more at home with the sum-of-products architectures that often let you design as though you were using multiple small PLDs with programmable connections.

Manufacturers of high-density PLDs

For more information on high-density PLDs such as those described in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN’s Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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FAX (408) 293-7587
Circle No. 662

Quicklogic Corp
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FAX (408) 967-2912
Circle No. 663

Signetics Corp
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Semiconductor Group
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ture changes, so too might their macro library.

Creating your logic design is only half the battle. Next you have to assign the logic to specific logic cells and determine the connections. The software that performs these functions are typically called fitters and place and route tools. Although automatic tools are available to perform the fit, place, and route functions, there are some differences both in the quality of the job they do and in the speed. The speeds can vary from a few minutes on some architectures to an overnight computer run on others.

The differences in the place and route operation may stem from variations in the quality of software or the flexibility of the architecture; most likely both. Many sum-of-products architectures provide universal array interconnects where any logic you can fit in the logic cell can be easily routed. Routing on these devices typically takes a few minutes on most computers. More complex connection schemes take longer.

As soon as high-density PLD companies finish working on device performance benchmarks, they might consider some place and route benchmarks. It’s another hazy subject for a potential high-density PLD user.

Stepping into the future

High-density programmable logic is seeing considerable growth right now, both as new product announcements from existing PLD companies and from new companies entering the high-density programmable logic business. Devices currently in development will more than double current logic capacity to around 20,000 gates. If all goes well, some of them might even be sampling by the first quarter of 1992.

However, you should be careful about using soon-to-be-available chips in your design. As is the case with many highly competitive electronic products, getting them to market as soon as possible is of paramount importance to the manufacturer. Unfortunately sometimes everything but the product makes it to market—the specifications, a delivery date, quantity pricing—but no silicon.

An example is the PA7040 from International CMOS Technology (San Jose, CA). The September 28, 1989 EDN article “PLD architectures require scrutiny” (Ref 1) listed the product in a table noting that the manufacturer said the product would be available in the first quarter of 1990 and gave a price. The PA7040 is now scheduled to be available in the second quarter of 1992. Waiting more than two years for a part in your design will probably kill your project, if not your company.

ICT is by no means the only company to have ever done this: Many IC companies that give price and delivery dates before the product is in production end up being late with the product. Some ICs, such as complex microprocessors, often need lots of pre-release information so you can build a system around them and be ready to ship your product when the first chips come out of production. The whole concept around programmable logic is to have a flexible architecture that is quick and easy to put your circuit design into. If the chip company can’t supply a device and a data sheet to match it, you probably should not consider the device for your design.

Companies should let you know what their future directions are. You also need to know that the company plans to continue the product line and what improvements they are working on. Just be sure you separate today’s real silicon from tomorrow’s promise.

Be extremely careful when an IC company compares its product with a competitor’s. In a lot of literature, the comparisons are often today’s products against the competitor’s older generation product. Even worse, some comparisons are of tomorrow’s products against what the competitor delivers today. Whenever a competitor’s product makes a poor showing, you’d best give the competitor a chance to defend himself.

If the chip company can’t supply a real device and a data sheet to match it, you probably should not consider the device for your design.

References

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C++ has C’s familiarity and OOP capability

C++ adds a host of new features to C, including object-oriented programming (OOP) abilities. If you program in C, you can use these features without having to learn a whole new language.

George Ellis, Industrial Drives

The C programming language is popular with engineers for a couple of very good reasons: C code is efficient, and it gives the programmer direct control of the computer. C++ maintains C’s power and efficiency, yet adds object-oriented programming and other features that you can use without learning a new language. In addition, you can recompile your existing C programs in C++ with few changes, and you can link to compiled C programs and libraries without any changes at all.

The most important feature of C++ is its object-oriented programming ability. OOP offers the benefits of flexible data structures, reusable code, and operators for nonstandard data types.

For engineers who use C for scientific programming, operators for nonstandard data types may be C++’s most important feature. When you define a data type (matrix, for example), you can also define the effects of operators (such as * and /). If you write programs that manipulate nonstandard data types, such as matrices and complex numbers, this capability can be very useful.

Before delving into all of C++’s object-oriented features, however, you might want to consider the language’s other features that, as a C programmer, you can use immediately. These features include:
- improved dynamic memory allocation
- single-line comments
- passing references
- overloading functions
- default values
- in-line functions.

Each of these features either adds convenience to standard C, or lets you avoid a peculiar characteristic of the language. As a group, they let you make your programs more readable, and thus easier to write, debug, and explain.

Improved dynamic memory allocation

Dynamic memory allocation in standard C uses malloc() or one of malloc()’s variations. For example, if you want to allocate space for an array of x integers, you might write

```c
int *dynamic_int;
dynamic_int = (int *)malloc(x*sizeof(int));
```

Notice that you must cast the return value of malloc() as an integer pointer, because malloc() returns a void pointer. Also, you must manually declare the size of
C++ maintains C's power and efficiency, yet has object-oriented programming and other features that you can use without learning a new language.

the variable being allocated (in this case, by using `sizeof`), because `malloc()` allocates memory in bytes.

In C++, you can use the operator `new` instead of `malloc()`. For example,

```c
int *dynamic_int;
dynamic_int = new int[x];
```

You do not need to cast the return value of `new` because `new` itself returns the appropriate type (in this case, an integer pointer). The operator `new` also determines the size of the variable type being allocated, making the `sizeof` operator unnecessary.

**Single lines for short comments**

C++'s provisions for including comments in code retain the standard C comments and also let you use `//` to designate a comment that runs no farther than the end of a line. For example,

```c
//This comment works in both C and C++
//This comment works in C++
```

The `//` is convenient for short comments. The standard C markers are probably better for long comments.

Another C++ improvement involves function arguments. In standard C, arguments of functions are passed by value, not by address; if you need a function to change the value of a variable, you must pass a pointer to that variable. C++ lets you pass references, which are simply pointers in a more readable form. **Listing 1** shows examples of C and C++ functions that change the values of an integer and two members of a structure. Notice that the C++ functions, `Cpp_set_int()` and `Cpp_set_simple()` are more intuitive than the standard C functions, `C_set_int()` and `C_set_simple()`.

Another C++ feature lets you overload functions. Function overloading means that two different functions can have the same name if they have different "signatures." A function's signature is the combination of the function's return type, the number of calling arguments, and the type of each calling argument.

Functions in both C and C++ have signatures, but in standard C, the function prototype defines a unique signature for each function name. In C++, several different functions can have the same name; the compiler differentiates between the functions by examining the signature of the function call. Overloading is particularly useful when several functions perform the same operation on different data types.

For example, consider the C++ program in **Listing 2.**

```c
2. Three functions have the name `average()'; each has a different signature, because the functions' calling arguments are of different types. When the program runs, it calls each function once. The output of the program is

```

```c
Calling the 'integer' average...
average of 1 and 2 is 1.500000
Calling the 'float' average...
average of 1.0f and 2.0f is 1.500000
Calling the 'double' average...
average of 1.0 and 2.0 is 1.500000
```

C++ also lets you specify default values in a function prototype or declaration. If you call a function without specifying all the arguments, the unspecified arguments contain default values. For example, **Listing 3** shows a program that calculates the area of an ellipse. The calling arguments are the major and minor radii. However, if a program calls the function and specifies only the major radius, the minor radius will

```
```
Listing 2—Function overloading

```c
#include <stdio.h>

double average(int first, int second)
{
    printf("Calling the 'integer' average() ...\n");
    return( ((double)first+ (double)second) /2.0 );
}

float average(float first, float second)
{
    printf("Calling the 'float' average() ...\n");
    return( ((double)first+ (double)second) /2.0 );
}

double average(double first, double second)
{
    printf("Calling the 'double' average() ...\n");
    return( (first+ second) / 2.0 );
}

void main()
{
    printf("average of \n\n\n\n\naverage of 1.0f and 2.0f is %lf\n",
    average(1.0f, 2.0f));
    printf("average of 1.0 and 2.0 is %lf\n",
    average(1.0, 2.0));
}
```

Listing 3—Functions with default arguments

```c
double ellipse_area(double major, double minor = 0.0);

void main()
{
    printf("Area of ellipse with major radius = 5.0 and minor radius = 2.0 = %lf\n",
    ellipse_area(5.0, 2.0));
    printf("Area of circle with radius = 4.0 = %lf\n",
    ellipse_area(4.0, 2.0));
}
```

An OOP language such as C++ has three basic characteristics:
- Encapsulation—mixing data and functions into one “object” (a structure or class)
- Inheritance—the ability to derive new objects from old ones
- Polymorphism—the ability to derive new objects from old ones

Encapsulation is the most basic characteristic; it is the foundation of OOP. Inheritance extends encapsulation, letting you build new objects from old ones. Polymorphism extends inheritance in order to help you write more reusable code.

Encapsulation lets you organize data and functions into one object. The data and functions can have a stronger relationship with encapsulation than they can without it. With conventional languages, the design of functions is usually the fundamental step in developing a program. In an OOP language, data and functions are so intertwined that the design of objects can become the foundation of the program.

C++ has two types of objects: classes and structures. They are so similar that they can be used almost interchangeably. Both differ from C structures in that they can have functions as members in addition to data. Member functions belong to objects, and they normally manipulate data in their own objects.

With encapsulation, you can protect both the data and function members of objects. There are two main levels of protection: public and private. If a data element or a function is public, any function can access it; if it is private, only member functions can access it.

Some form of protection is often necessary in a module to keep functions in other modules (often written by different programmers) from improperly manipulating data. For example, consider the structures that take on the default value of 0.0. The function will then treat the ellipse as a circle with a radius of the specified major radius.

So that you can avoid a normal function's call-and-return sequence—along with the associated execution-time overhead—C++ lets you declare a function as `inline`. You write source code as you would for an ordinary function, but your C++ compiler generates object code that is “in-line,” rather than in a separate, callable function. This feature is best for short functions (perhaps two or three lines) in which the call-and-return overhead of a normal function would be significant compared with the function's execution time.

To achieve the result of an in-line function in standard C, you would need to use the `#define` preprocessor command. The square function is an example (Ref 1). The C code

```c
#define square(x)    ( x * x )
```

can be replaced in C++ with

```c
inline double square(double x)    (return ( x * x ));
```

The C++ version is more readable, especially for new C programmers.

C++ has features that do much more than add convenience and clarity to C. The object-oriented programming capabilities of C++ actually change the way you program. It is impossible in a brief space to cover OOP thoroughly, so our focus is on what OOP can do, rather than on how to use it.
Instead of forcing you to pass a pointer to a variable, C++ lets you pass a reference, which is essentially a pointer, but in a more readable form.

many C library functions use to store information about DOS files. The structure ffblk in Borland C++ (Borland International Inc, Scotts Valley, CA) is typical:

```c
struct ffblk {
    char ff_reserved[21];
    char ff_attribute;
    int ff_time;
    int ff_date;
    long ff_size;
    char ff_name[13];
};
```

The user should never change the data in ffblk directly; Borland C++ provides findfirst() and findnext() to change data-member values.

As an experiment, redesign ffblk in C++. The hypothetical object, cpp_ffblk, will have the same data members as ffblk and will protect the data from inadvertent access and manipulation. You can add findfirst() and findnext() as member functions.

The first step in adding member functions is to list the function prototype in the object:

```c
struct cpp_ffblk { // hypothetical C(++) object
    char ff_reserved[21];
    char ff_attribute;
    int ff_time;
    int ff_date;
    long ff_size;
    char ff_name[13];
}
```

Notice that the first data member is the character string ff_reserved[]. You may have correctly assumed that "reserved" implies you should not use or change this string. You can revise cpp_ffblk and specify ff_reserved[] as private, so that only the two member functions can access it:

```c
struct cpp_ffblk { //hypothetical C(++) object
    char ff_reserved[21];
    char ff_attribute;
    int ff_time;
    int ff_date;
    long ff_size;
    char ff_name[13];
    //member functions to fill the data members
    int findfirst(const char *pathname, struct ffblk *this_ffblk, int attrib);
    int findnext(struct ffblk *this_ffblk);
};
```

Notice that the first data member is the character string ff_reserved[]. You may have correctly assumed that "reserved" implies you should not use or change this string. You can revise cpp_ffblk and specify ff_reserved[] as private, so that only the two member functions can access it:

```c
struct cpp_ffblk { //hypothetical C(++) object
    char ff_reserved[21];
    char ff_attribute;
    int ff_time;
    int ff_date;
    long ff_size;
    char ff_name[13];
    //member functions to fill the data members
    int findfirst(const char *pathname, struct ffblk *this_ffblk, int attrib);
    int findnext(struct ffblk *this_ffblk);
};
```

Because you have defined and written the five new member functions right inside the structure, the compiler will make them inline.

The constructor and destructor functions of C++ are useful for allocating and deallocating memory. Each object can have both a constructor and a destructor as member functions. The constructor has the same name as the object (for example, ellipse), and the destructor has the same name preceded by a tilde (‘ellipse’).

Constructors execute anytime space is allocated for an object. For example, if you use the new operator for dynamic memory allocation, the constructor for that object is automatically called. A typical use for constructors is to initialize data members, although you can write a constructor to perform any C++ action, from printing a message on the screen to opening a DOS file.

In the following object, ellipse, which stores the major and minor radii of an ellipse, a constructor sets the radii to zero:

```c
struct ellipse{
    double major;
    double minor;
    double area;
    //This is a simple constructor
    ellipse() { major = 0.0; minor = 0.0; area = 0.0; };
};
```

Now each time space is allocated for an ellipse structure, all the data members will be initialized to zero.
Destructors offer flexibility for removing objects from memory. For example, if a constructor opens a DOS file and allocates memory, a destructor can be written to close that file and deallocate memory. Destructors are used less frequently than constructors.

Define operators for nonstandard data

Another C++ feature, operator overloading, makes programming easier by letting you define operators for your objects. Overloading lets operators invoke different functions depending on the data types of the operands. (You are probably familiar with overloading for math operators; in C, the four algebraic operators (+, -, +, and -) perform different, albeit similar, functions depending on whether the operands are long, int, float, double, or char.)

Operator overloading is especially useful if you frequently manipulate nonstandard data types. For example, Borland C++ provides complex.h, a header file that defines a complex object type. You use the file for complex (as opposed to real) mathematics. Complex.h includes definitions of several algebraic operators for the complex object type and lets you write complex math algebraically. For example,

```c
struct point{
  double x; //x coordinate for point
  double y; //y coordinate for point
};
```

A circle is similar to a point. It has x and y coordinates, but it also has a radius. You can take advantage of the similarities by making the circle a child of point:

```c
struct circle: point{ //circle inherits point
double radius; //circle adds radius
};
```

Now if you define a circle, it has the x and y coordinates from point along with its own radius. For example, you can write:

```c
struct circle a;
a.radius = 1.0;
a.x = 10.0;
a.y = 20.0;
```

The x and y in circle are inherited from point. Similarly, if point has a member function, move(), that moves the point by changing x and y, circle can inherit that function. You don't have to write a new move() function for the new shape.

Inheritance can continue indefinitely. For example, you can think of an ellipse as a circle with an extra radius:

```c
struct ellipse: circle{
double minor_radius;
};
```

Now ellipse has a radius (assumed to be the major radius) from circle, x and y from point, and its own minor_radius.

Objects also inherit overloaded operators from their parents, and they can inherit from multiple parents. For flexibility, you can override inheritance of a specific function if the function in the parent is not appropriate for the child. In general, it is easy to modify a well-written OOP program, because you have the option of using all the functions that have been written for similar objects.

The third major characteristic of OOP is polymorphism. Borland defines polymorphism as “Giving an action one name or symbol that is shared up and down a class, with each class in the hierarchy implementing
In C++, several different functions can have the same name; the compiler differentiates between the functions by examining the signature of the function call.

the action in a way appropriate to itself” (Ref 2).

Suppose you buy a graphics package that can draw, erase, and move a circle, and you need to modify the package so that it will perform the same functions on an ellipse. You would probably derive the code for the ellipse from the existing code for a circle, a more basic shape. You would also probably want to use function names in your new ellipse structure that already exist in circle.

But consider what happens if you rewrite a member function of circle to create a similar function for ellipse. Suppose that move_shape(), a function that the graphics package calls to move any shape, calls a member function specific to each shape, hide_shape(). If you rewrite hide_shape() from circle to make hide_shape() for ellipse, how will move_shape() know to call this new hide_shape()? Remember, ellipse didn’t even exist when move_shape() was written. The answer lies in making hide_shape() a virtual function.

Virtual functions are always member functions. Each structure in a hierarchy can have as a member a virtual function with the same name as a function in another structure. When a general-purpose function (like move_shape()) is called, one of its calling arguments is a pointer to the structure in the hierarchy for the particular shape (such as a circle or an ellipse) the function is to work on. Then, if this general-purpose function calls a virtual function (like hide_shape()), the pointer ensures that the appropriate virtual function will execute.

All of this can be confusing, especially if you’re new to OOP. The important point to remember, though, is that virtual functions let you extend programs without recompilation. The determination of which member function to call occurs at runtime, not at compile time.

Whether or not you plan on doing object-oriented programming, C++ still has many features that make programs easier to write, read, debug, and explain than C. If you want to use OOP, C++ offers the promise of better and more reusable code. In either case, if you already program in C, you won’t have to learn a new language or spend much time rewriting your current C utility routines.

Making the transition to C++ needn’t be expensive, either. For example, the Turbo C++ compiler from Borland International Inc (Scotts Valley, CA) costs less than $100, supports both ANSI C and AT&T 2.0 C++, and comes as part of an integrated environment that lets you edit, compile, link, and debug C++ programs.

References

Author’s biography
George Ellis is a Senior Project Engineer at Industrial Drives in Radford, VA, where he designs electronics and real-time software. He wrote Control System Design Guide (Academic Press, Inc, 1991) and serves on the IEEE Industrial-Drives Committee. George holds both a BSEE and MSEE from Virginia Polytechnic Institute and State University (Blacksburg, VA).

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G.B.W. Gain Bandwidth (Typ) | 45 | 45 | 90 | 100 | 14 | MHz
\( t_s \) Setting Time (to 0.1%) (Typ) | 90 | 90 | 100 | 75 | 340* | nsec
AVOL Open Loop Gain (Typ) | 50 | 7 | 45 | 28 | 450 | V/mV
VOS Offset Voltage (Max) | 1 | 2 | 6 | 3 | 0.9 | mV
IOS Offset Current (Max) | 0.3 | 0.4 | 1 | — | 0.0005 | µA
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To understand the circuit's operation, start by assuming that IC1's positive input is slightly below its negative input (IC2's output is low). The input voltage causes a positive-going ramp at IC1's positive input (trace A, Fig 2). IC1's low output biases the CMOS inverter's output high. The inverter's high state enables current to flow from Q1's emitter through the inverter's supply pin to the 100-pF capacitor. The 2.2-µF capacitor provides high-frequency bypass, maintaining low impedance at Q1's emitter.

Diode-connected Q6 provides a path to ground. The voltage to which the 100-pF capacitor charges is a function of Q5's emitter potential and Q6's drop. When the ramp at IC1's positive input goes high enough, IC1's output goes high (trace B) and the inverter switches low (trace C). This action pulls current from IC1's positive-input capacitor via Q5 and the 100-pF capacitor (trace D). This current removal resets IC1's positive input ramp to a potential slightly below ground, which forces IC1's output to go low. When the 50-pF capacitor's feedback decays, IC1 again switches low, and the entire cycle repeats. The oscillation frequency depends directly on the current derived from the input's voltage.

The 50-pF capacitor furnishes IC1 ac positive feedback, ensuring that IC1's output remains positive long enough for the 100-pF capacitor to discharge completely. The Schottky clamp prevents overdriving the CMOS inverter's input. The Schottky diode prevents...
IC₁'s input from seeing voltages outside its negative common-mode limit.

The circuit must carefully control Q₁'s emitter voltage to get low drive. Q₂, and Q₅ compensate Q₁ for temperature while Q₇ compensates Q₁'s VBE. The two LT1034s are the actual voltage reference, and the LM334 current source provides 35-µA bias to the stack of transistors. The current drive provides excellent supply immunity (better than 40 ppm/V) and improves the circuit's temperature coefficient by using the LM334's 0.3%/°C temperature coefficient to temperature-modulate the voltage drops slightly in Q₂, Q₅, and Q₇. This correction's sign and magnitude directly oppose that of the -120-ppm/°C polystyrene capacitor, thus aiding overall circuit stability.

The Q₁ emitter follower delivers charge to the 100-pF capacitor efficiently; both the base and collector currents end up in the capacitor. The CMOS inverter provides low-loss SPDT reference switching without significant drive losses. The 100-pF capacitor draws only small transient currents during its charge and discharge cycles. The 50-pF, 47-kΩ positive-feedback combination draws insignificantly small switching currents. At zero frequency, IC₁'s quiescent current and the 35-µA reference-stack bias account for all current drain. No other paths for loss exist. As the frequency scales up, the charge-discharge cycle of the 100-pF capacitor introduces a 1.5-µA/kHz increase.

Circuit startup or overdrive can cause the circuit’s ac-coupled feedback to latch. If latchup occurs, IC₁'s output goes high. IC₂, detecting this condition via the inverter and the 2.7-MΩ, 0.1-µF lag, also goes high. IC₂'s going high lifts IC₁'s negative input and grounds the positive input through Q₅. These actions initiate normal circuit action.

Because the charge pump connects directly to IC₁'s output, response is fast. The output settles within one cycle for a fast input step. To calibrate this circuit, apply 50 mV and select R for a 100-Hz output. Then apply 5 V and trim the input potentiometer for a 10-kHz output. EDN BBS/DLSIG #1070

To Vote For This Design, Circle No. 745

---

**Design expands PC bus**

András Pomozi and Tibor Szép
Technical University of Budapest, Budapest, Hungary

The circuit in Fig 1 shows how to configure an extension bus for an IBM PC/XT or PC/AT. The circuitry inside the dashed lines is diagrammatic; you burn this circuitry into a 22V10-25 PAL device.

IBM PC bus lines fall into three categories:

**Output signals**
- Always active output signals: DACK, (i=0, 1, 2, 3, 4, 5, 6, 7), AEN, CLK, RESET, BALE, SMEMR, SMEMW, T/C, and OSC.
- Signals whose direction MASTER controls: Address lines, IOR, IOW, MEMR, REFRESH, and SBHE. These signals are outputs if the PC is the bus master and inputs if an extension-bus card, such as a DMA controller, is the master.

**Input signals**
- Active-high signals: IRJ and DRQ, (j=3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15).
- Active-low signals: MASTER (the expansion-bus master signal), I/OCKL, I/OCHRDY, MEMCS16, I/OCS16, and OWS.

**Bidirectional signals**
- SDₖ (k=0, . . . , 15).
Fig 2 shows the simple interface circuits needed to connect the various classes of PC-bus lines to the extension bus.

This design avoids conflicts between bidirectional signals on the PC and extension buses. The problem solves itself for both memory and I/O write cycles because writing data causes no complications as long as all bus devices have unique addresses. Read cycles are more complex. To read a device on the external bus, the output-enable pins of the bidirectional drivers must be enabled.

In Fig 1 note that the 16-input AND gate will enable the bidirectional drivers if at least one data bit from an expansion-bus device is zero. If the expansion-bus device is not outputting data, the expansion-bus pullup resistors will disable the bidirectional drivers. If the expansion-bus device has to output FFFF HEX, the PC will read the PC-side pullup resistors as FFFF HEX anyway. EDN BBS /DL_SIG #1067

To Vote For This Design, Circle No. 746

Fig 1—With this simple extension-bus circuit and the drivers in Fig 2, you can add extra cards to your PC and provide isolation for experimentation. Note the 16-input AND gate, which handles extension-card data writes.

Fig 2—The four different types of PC bus signals each need a specific driver for the extension bus.
Design Entry Blank

$100 Cash Award for all entries selected by editors. An additional $100 Cash Award for the winning design of each issue, determined by vote of readers. Additional $1500 Cash Award for annual Grand Prize Design, selected among biweekly winners by vote of editors.

To: Design Ideas Editor, EDN Magazine
Cahners Publishing Co
275 Washington St, Newton, MA 02158

I hereby submit my Design Ideas entry.

Name ______________________
Title ______________________
Company ___________________
Division (if any) _____________
Street ______________________
City ______________ State ____
Country ______________ Zip __
Design Title __________________
Home Address __________________

Social Security Number _________
(US authors only)

Entry blank must accompany all entries. Design entered must be submitted exclusively to EDN, must not be patented, and must have no patent pending. Design must be original with author(s), must not have been previously published (limited-distribution house organs excepted), and must have been constructed and tested. Fully annotate all circuit diagrams. Please submit software listings and all other computer-readable documentation on a 5¼-in. IBM PC disk in plain ASCII.

Exclusive publishing rights remain with Cahners Publishing Co unless entry is returned to author, or editor gives written permission for publication elsewhere.

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Date ________________________

SOFTWARE SHORTS

68HC05 acquires 16-bit pointers

Thomas R Hoover,
Valcom Inc, Roanoke, VA

EDN BBS /DL_SIG #1039 has assembly-language subroutines, posted in an ASCII file, that let a 68HC05 access a 16-bit pointer for load and store operations. These routines prove handy now that the 6805 family members have large ROMs.

To Vote For This Design, Circle No. 686

8051 converts letters to upper case

Eric Watson,
Loral Hycor, Woburn, MA

The 8051 single-chip-µP assembly-language routine in EDN BBS /DL_SIG #1040 inputs data from a µP port and tests for a lower-case, alphabetic ASCII character. If a character is lower-case alphabetic, the routine converts the character to upper-case ASCII.

To Vote For This Design, Circle No. 687

C routine prints out error messages

Stephen Ho,
Hewlett-Packard, Milpitas, CA

The simple C routine in EDN BBS /DL_SIG #1041 lets you instrument your code with error messages. The error-message printer works like the standard printf() library routine.

To Vote For This Design, Circle No. 688

These Software Shorts listings are too long to reproduce here; you can obtain the listings from the EDN BBS's Design Idea Special Interest Group ((617) 558-4241,300/1200/2400,8,N,1—from Main Menu, enter ss/DL_SIG, then rkknn, where nnn is the number referenced above).
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EDN January 2, 1992
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As a member of our AD574 family, the pin-compatible AD1674 offers designers unparalleled performance and integration. With the added benefits of an on-chip sample/hold amplifier, DC and AC guaranteed specs, faster throughput, and a list of other features too long to mention here.

In other words, the AD1674 redefines ‘industry standard’ the same way the AD574 did ten years ago.

Why wait for an imitation when you can have the real thing now? Get more information today on the AD1674, AD574, AD674 or AD774 converter family by writing to us at the address below. Or by calling 1-800-262-5643.
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• Support 2-byte-wide transfers to 20 Mbytes/sec
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Ancot Corp, 115 Constitution Dr, Menlo Park, CA 94025. Phone (415) 322-5322. FAX (415) 322-0455. Circle No. 351

80C186/C188 Development Tools
• For runtime source-level debugging
• Support 80C186/C188EA, XL, EB, and EC µPs
The Codetap C186/C188EA, XL, EB, and EC are development tools for the correspondingly named members of Intel's 80C186 and 80C188 µP families. The hardware-based tools, which permit no-wait-state, 20-MHz operation of the target system, cost about 30% as much as full-featured, in-circuit emulators for these µPs. This low cost suits the tools for use by individual members of embedded-system-development teams. The tools work with Intel, Microsoft, and Microtec Research C compilers and include a windowed, source- and assembly-level debugger that runs under MSDOS. $5995.

Applied Microsystems Corp, Box 97002, Redmond, WA 98073. Phone (800) 426-3925; (206) 882-2000. FAX (206) 883-3049. TLX 185196. Circle No. 352

L64901 SPARC Development Tool
• Operates with the vendor's CLAS logic analyzers
• Supports 50-MHz versions of the IC, when available
The CLAS L64901 µP-analysis package works with the vendor's CLAS family of configurable logic-analysis systems. The tool supports the LSI Logic L64901 SPARC µP. Currently, the fastest version of the chip runs at 25 MHz, but when 50-MHz chips become available, the vendor expects the tool to support them. The tool configures the logic analyzer so that address, data, and control signals are grouped on the display. The display uses standard mnemonics and lets you represent addresses symbolically. You probe the surface-mounted IC by attaching a 5.3 x 2.5 x 1.3-in. card. $4950; logic-analysis systems, from $15,950.

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**EDN January 2, 1992**

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**INSTRUMENTS**

**80386SX Emulator**

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- Includes 512 kbytes of overlay RAM

The Codestalker 386SX in-circuit emulator sells for approximately half the price of many 32-bit emulators. It operates at 16 MHz with no wait states. The unit has 512 kbytes of overlay memory that you can split into two banks. Usually, you use bank 0 to define interrupt vectors in low memory (real mode) or to contain the interrupt descriptor table (protected mode). In bank 1, you can place data that, in normal operation, would go in the BIOS ROM. You can also configure the two banks as a single region of the µP's memory. The emulator has four independent hardware breakpoints that you can set anywhere in the µP's address space; you can also set an unlimited number of software breakpoints. The unit's trace buffer captures 4k machine cycles. The source-level debugger is compatible with many C compilers. $9995.

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## OUTPUT LOCATIONS

### 600 Watt FM Configurations

| 12 | #1 M5 |
| 24 | #1 #2 M4 K |
| 30 | #1 #2 #3 M3 L K |
| 48 | #1 #2 #3 #4 M3 K K K |
| 56 | #1 #2 #3 #5 J M3 K K |
| 64 | #1 #2 #6 J #5 J M3 K #3 J #4 J |
| 72 | #1 #7 J #6 J #5 J M3 #2 J #3 J #4 J |

### 1000 Watt FM Configurations

| 11 | AC |
| 21 | AC #1 M7 |
| 31 | AC #3 L #2 #1 M6 |
| 41 | AC #4 G #3 #2 #1 G M6 |
| 51 | AC #5 J #3 #2 #1 G M6 |
| 61 | AC #5 J #6 J #2 #1 |

### 2000 Watt FM Configurations

| 45 | AC #4 #3 #2 #1 |
| 53 | AC #5 G #3 #2 #1 M7 |
| 63 | AC #6 J #4 #3 #2 #1 |

## FM SERIES DIMENSIONS

**VIEW "A"**

**VIEW "B"**

**VIEW "C"**

**VIEW "D"**

**MOUNTING PER VIEW "A"**

**MOUNTING PER VIEW "B"**

**MOUNTING PER VIEW "C"**

**MOUNTING PER VIEW "D"**

**NOTES:**

1. WITH TOP FAN COVER UNIT HEIGHT (13.100).
2. TERMINAL BLOCKS (6-32).
3. STUDS (1/4-20).
4. WITH END FAN COVER UNIT LENGTH (13.300).

**MOUNTING PER VIEW "C" TERMINAL ORIENTATION ROTATED 90° CW**
**DESCRIPTION**

Moduflex switchers form a comprehensive line of open frame power supplies assembled from standard “off the shelf” modules. These subunits and assembly hardware are pre-approved by safety agencies so that certifications can automatically apply to custom models. Additional advantages include first piece delivery within two weeks and the elimination of engineering costs for qualified “OEM” requirements using stock modules.

FM Series are corrected to produce a 0.99 power factor. The resultant input current waveform is nearly a perfect sine wave compliant to the harmonic requirements of IEC 555-2.

Modular construction permits high volume manufacturing with an outstanding quality level and at competitive cost.

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- 5 watts per cubic inch.
- 600-2000 watts output.
- 120 kilohertz design.
- TUV/VDE, UL, CSA.
- All outputs:
  - Adjustable
  - Fully regulated
  - Floating
  - Overload and short circuit proof
  - Overvoltage protected
- Standard features include:
  - System inhibit
  - Fan output

**MODEL SELECTION**

Input modules are available in ratings of 600, 1000, and 2000 watts with corresponding code letters of C, E and G. Refer to Power Code Table.

Output modules are available in ten types ranging in nominal power from 75 to 2000 watts. Refer to Output Code Table for codes and nominal power output.

<table>
<thead>
<tr>
<th>Input Power Codes</th>
<th>Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>600</td>
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<tr>
<td>E</td>
<td>1000</td>
</tr>
<tr>
<td>G</td>
<td>2000</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Output Codes</th>
<th>Nominal Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>75</td>
</tr>
<tr>
<td>K</td>
<td>150</td>
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<td>G</td>
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<td>M7</td>
<td>1000</td>
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<tr>
<td>M9</td>
<td>2000</td>
</tr>
</tbody>
</table>

The Table of Ratings for the various types of output modules lists the maximum current for each type as a function of corresponding voltage rating.

Ratings in the shaded area are Preferred and are stocked for fast delivery.

Note: When computing output load power, multiply the fraction of actual current to max. rated current by the nominal power rating of the output module.

**RATINGS OF OUTPUT MODULES**

<table>
<thead>
<tr>
<th>Nominal Power</th>
<th>75W</th>
<th>150W</th>
<th>300W</th>
<th>400W</th>
<th>500W</th>
<th>600W</th>
<th>750W</th>
<th>1000W</th>
<th>2000W</th>
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</thead>
<tbody>
<tr>
<td>Code</td>
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<td>K</td>
<td>G</td>
<td>L</td>
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<td>M4</td>
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<td>8</td>
<td>10</td>
<td>12</td>
<td>16</td>
<td>21</td>
</tr>
</tbody>
</table>

**HOW TO ORDER**

Select the letter F for power factor correction, then select the letter M to designate the series. Choose the desired configuration of output modules and list the configuration code. Insert the power code letter and follow with the output code numbers for each individual output. Enter a dash and from the option table insert the sum of the option codes. See example below.

<table>
<thead>
<tr>
<th>Options</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power Fail Monitor</td>
</tr>
<tr>
<td>2</td>
<td>Cover (600W only)</td>
</tr>
<tr>
<td>4</td>
<td>End Fan Cover (600W only)</td>
</tr>
<tr>
<td>8</td>
<td>Top Fan Cover (600W only)</td>
</tr>
</tbody>
</table>
## SPECIFICATIONS

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th>DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INPUT</strong></td>
<td>90-264 VAC, 47-63 Hz. 190-264 for 2000W units.</td>
</tr>
<tr>
<td><strong>POWER FACTOR</strong></td>
<td>0.99 at full load.</td>
</tr>
<tr>
<td><strong>HARMONIC CURRENTS</strong></td>
<td>Compliant to IEC 555-2.</td>
</tr>
<tr>
<td><strong>INPUT SURGE</strong></td>
<td>230 VAC – 75A max. 115 VAC – 40A max.</td>
</tr>
<tr>
<td><strong>HOLDUP TIME</strong></td>
<td>20 milliseconds from loss of AC power.</td>
</tr>
<tr>
<td><strong>OUTPUTS</strong></td>
<td>See model selection table.</td>
</tr>
<tr>
<td><strong>ADJUSTABILITY</strong></td>
<td>±5% trim adjustment.</td>
</tr>
<tr>
<td><strong>OUTPUT POLARITY</strong></td>
<td>All outputs are floating from chassis and each other and can be referenced to each other or ground as required.</td>
</tr>
<tr>
<td><strong>LINE REGULATION</strong></td>
<td>Less than ±0.1% or ±5mV for input changes from nominal to min. or max. rated values.</td>
</tr>
<tr>
<td><strong>LOAD REGULATION</strong></td>
<td>±0.2% or ±10mV for load changes from 50% to 0% or 100% of max. rated values.</td>
</tr>
<tr>
<td><strong>MINIMUM LOAD</strong></td>
<td>Main output requires a 10% minimum load for full output from auxiliaries. Main output is #1 on 600W and 1000W units and #2 on 2000W units.</td>
</tr>
<tr>
<td><strong>REMOTE SENSING</strong></td>
<td>On all outputs except type J modules.</td>
</tr>
<tr>
<td><strong>RIPPLE &amp; NOISE</strong></td>
<td>1% or 100mV pk-pk, 20 MHz bandwidth.</td>
</tr>
<tr>
<td><strong>OPERATING TEMPERATURE</strong></td>
<td>0-70°C. Derate 2.5%/°C above 50°C.</td>
</tr>
<tr>
<td><strong>COOLING</strong></td>
<td>A min. of 10 LFS cooling air directed on cooling surfaces over the 600W units for full rating. Two test locations on chassis rated for max. temperature of 90°C. 1000W and 2000W models have built-in ball bearing fan.</td>
</tr>
<tr>
<td><strong>TEMPERATURE COEFFICIENT</strong></td>
<td>±0.02%/°C.</td>
</tr>
<tr>
<td><strong>EFFICIENCY</strong></td>
<td>70% to 80%.</td>
</tr>
<tr>
<td><strong>SAFETY</strong></td>
<td>Units meet UL 1950, CSA 22.2 No. 234, IEC 950, EN 60 950, VDE 0804, VDE 0805, VDE 0806. Certifications in process.</td>
</tr>
<tr>
<td><strong>DIELECTRIC WITHSTAND</strong></td>
<td>3750 VRMS input to ground. 3750 VRMS input to output. 700 VDC output to ground.</td>
</tr>
<tr>
<td><strong>SPACING</strong></td>
<td>8 mm primary to secondary. 4 mm primary to grounded circuits.</td>
</tr>
<tr>
<td><strong>LEAKAGE CURRENT</strong></td>
<td>3.5mA max.</td>
</tr>
<tr>
<td><strong>EMISSIONS</strong></td>
<td>Units meet FCC 20780 Part 15 Class A and VDE 0871 Class A for conducted emissions. Compliance with Class B limits by use of additional external filter.</td>
</tr>
<tr>
<td><strong>DYNAMIC RESPONSE</strong></td>
<td>Peak transient less than ±2% or ±200mV for step load change from 75% to 50% or 100% max. ratings.</td>
</tr>
<tr>
<td><strong>UNDERVOLTAGE</strong></td>
<td>Protects against damage for undervoltage operation.</td>
</tr>
<tr>
<td><strong>OVERVOLTAGE PROTECTION</strong></td>
<td>Standard on all outputs.</td>
</tr>
<tr>
<td><strong>REVERSE VOLTAGE PROTECTION</strong></td>
<td>All outputs are protected up to load ratings.</td>
</tr>
<tr>
<td><strong>OVERLOAD &amp; SHORT CIRCUIT</strong></td>
<td>Outputs protected by duty cycle current foldback circuit with automatic recovery. Auxiliaries have additional backup fuse protection.</td>
</tr>
<tr>
<td><strong>THERMAL SHUTDOWN</strong></td>
<td>Circuit cuts off supply in case of local over temperature. Units reset automatically when temperature returns to normal.</td>
</tr>
<tr>
<td><strong>SOFT START</strong></td>
<td>Units have soft start feature to protect critical components.</td>
</tr>
<tr>
<td><strong>FAN OUTPUT</strong></td>
<td>Nominal 12 VDC @ 12 watts maximum.</td>
</tr>
<tr>
<td><strong>INHIBIT</strong></td>
<td>TTL compatible system inhibit provided.</td>
</tr>
<tr>
<td><strong>SHOCK</strong></td>
<td>MIL-STD 810-D Method 516.3, Procedure III.</td>
</tr>
<tr>
<td><strong>VIBRATION</strong></td>
<td>MIL-STD 810-D Method 514.3, Category 1, Procedure I.</td>
</tr>
<tr>
<td><strong>MECHANICAL</strong></td>
<td>650W – Case 1. – 2.5 x 5.05 x 12 1000W – Case 2. – 5.05 x 5.05 x 12 2000W – Case 3. – 5.05 x 6 x 12</td>
</tr>
<tr>
<td><strong>POWER FAIL MONITOR</strong></td>
<td>Optional circuit provides isolated TTL and VME compatible power fail signal providing 4 milliseconds warning before main output drops by 5% after an input failure.</td>
</tr>
<tr>
<td><strong>FAN COVER</strong></td>
<td>Optional covers with brushless DC ball bearing fan which provides the required air flow for full rating of 600W units. Choice of low profile or top mounted types.</td>
</tr>
</tbody>
</table>

Specifications subject to change without notice.
NEW PRODUCTS
COMPONENTS & POWER SUPPLIES

Clock Oscillator
- Is surface mountable
- 5 mm high
The SO-49 crystal clock oscillator is compatible with HCMOS, CMOS, and TTL. The unit is housed in a hermetically sealed, resistance welded 3-leaded SIP, which measures only 4.5 × 11.8 × 5 mm. Output frequencies range from 625 kHz to 50 MHz, with frequency tolerance measuring ±50 ppm. Rise and fall times equal 50 nsec max below 2 MHz and 20 nsec max above 2 MHz, respectively. Output symmetry equals 45 to 55%, and operating range spans -10 to +70°C. The oscillator operates with a single 5V supply. $2.50 to $3 (1000)

KDS America, 10901 Granada Lane, Overland Park, KS 66211. Phone (913) 491-6825. FAX (913) 491-6812. Circle No. 363

Hybrid Connector
- Designed for pc boards
- Rated for 5A
The Model DSEB hybrid connector combines the advantages of D-subminiature and edge board designs. It's rated for 5A, and you can use it with any pc board requiring a D-subminiature connector. Available in a 25-contact version, the connector accommodates boards ranging from 0.054 to 0.071 in. thick and measures 2.072 × 0.5 in. on the D-subminiature side and 1.588 × 0.35 in. on the edge board side. Design features include a molded housing for accurate pin-socket alignment and selective gold plating (contact areas) to minimize cost. The connector has a built-in locking nut. $2.58 (500).

Dale Electronics Inc, Box 609, Columbus, NE 68602. Phone (605) 665-9301. Circle No. 364

Optical Connector
- For applications requiring high reflectance
- Features a 0.5-dB loss
The ST II fiber-optic connector is designed for applications where high reflectance is required. An angled ceramic ferrule, which incorporates the protruding fiber polisher, ensures a higher return loss than that found in standard ST connectors. Median maximum reflectance is -60 dB. When terminating 8.3/125-µm single-mode fiber, the connector has a 0.5-dB insertion loss. The connector measures 2.14 × 0.375 in. and is well suited for dense panel arrangements. Connector couplings feature a keyed, bayonet latch and are easy to connect and disconnect. The metal couplings come in flanged, threaded, and floating configurations; plastic versions are available in threaded designs. $48.

AT&T Network Cable Systems, 111 Madison Ave, Morristown, NJ 07962. Phone (201) 606-4266. Circle No. 365

Coaxial Attenuator
- Rated for 100W
- Operates to 1.5 GHz
The PE7021 50Ω coaxial attenuator operates over a frequency range of dc to 1.5 GHz and offers attenuation values of 6, 10, 20, and 30 dB. The device's average power-handling capability is 100W, and it can handle a peak of 10 kW max. Maximum VSWR is rated at 1.15:1. The attenuator comes in a package featuring an extruded, black anodized alu-
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201 Broadway
Cambridge, MA 02139
USA

CIRCLE NO. 66

COMPONENTS & POWER SUPPLIES

Surface-Mount Sockets
- Accommodate vapor-phase and infrared-soldering processes
- Offer 84-position capacity

PLCC Series plastic-leaded-chip-carrier sockets feature precision stampings, high-temperature plastic construction, and a body design that has the same board footprint as the chip carrier itself. The liquid-crystal polymer housing accommodates vapor-phase and infrared soldering, and the open construction simplifies inspection of every solder fillet. The sockets are available in 28-, 32-, 44-, 52-, 68-, and 84-lead versions. The solder tails have a slot in the tail for added solder adhesion. The contact design places downward pressure on the PLCC so it remains in the socket. From $1.60 (1000).

Samtec Inc, Box 1147, New Albany, IN 47151. Phone (800) 726-8329. FAX (812) 948-5047.

Circle No. 367

Power Supply
- Has a universal input
- Develops 50W

The PSA-5231 power supply is designed for international applications and features an input that continuously covers a 100 to 240V range. An on/off switch, an IEC ac connector, and a Class B EMI filter are all housed in a 6.77 x 3.15 x 1.89-in. case. The supply develops outputs of 5V at 4A, 12V at 2A, and -12V at 0.5A. Noise and ripple are held to less than 1% of rated output. All outputs feature a load and line regulation of 2%. EMI specs are in accordance with Class B requirements of both VDE and FCC. The supply meets the safety requirements outlined in UL 1950, CSA 1402C, and VDE 0805. $50 (100). Delivery, stock to eight weeks ARO.

Phihong USA, 920 Hillview Ct, Suite 195, Milpitas, CA 95035. Phone (408) 263-2200. FAX (408) 263-2213.

Circle No. 368

Pushbutton Switches
- Feature illuminated display
- Are sunlight readable

Avionics switches and indicators come in full- and split-screen versions with either T-1 or T-1% lamps, which you can replace from the front of the panel. The switches are readable in direct sunlight. The basic design uses a snap-action switch, which is available in either commercial or military versions. The spdt units come with pc-board or solder-lug terminations. The units can meet a variety of illumination, chromaticity, and dead-front specifications. On/off contrast ratios of 80/20% are obtainable in special applications. From $20. Delivery, 8 to 10 weeks ARO.

Eaton Corp, 4201 N 27th St, Milwaukee, WI 53216. Phone (414) 449-6000.

Circle No. 369
Murata Erie. We don't make faxes, cellular phones or satellite systems. But we make things better for those who do.

Whatever the telecom product, when you seriously consider your options in passive components, you'll see we can make a difference.

But how to compare? Well, specs are a start. But the fact is, specs often seem surprisingly similar—much like physical appearances.

There's always individual component cost, a comparison we at Murata Erie heartily encourage. But if you stop there, you could overlook some other very important distinctions.

Think first about product-line breadth. And the measurable advantages that can accompany acquiring most or all your passives from a single source. Then think about Murata Erie's product line, offering virtually any type passive your product requires.

Now consider supplier capacity. Look at our multiple plants in North America and overseas. And ask yourself what other company could routinely ship, for example, 3.5 billion ceramic capacitors per month. Or match our network of local distributors—people ready to respond not only with product but with technical expertise as well.

Finally, try to find a company with more experience. You might begin by asking who pioneered, and continues to pioneer, electro-ceramic technology, the core of numerous electronic sub-technologies ranging from dielectrics to piezoelectrics.

All that done, we think you'll find choosing the right passive component line a simpler task. Getting started is even easier. Write or call us today. We'll show you how, for telecom OEMs, we're making things a lot better. And how we'll do the same for you.

EDN January 2, 1992

MURATA ERIE NORTH AMERICA
2200 Lake Park Drive
Smyrna, GA 30080
1-800-831-9172
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Tango-Schematic is the front end of the popular Tango family of PC-based electronic design software. Users execute all common functions in the same way with Tango’s easy-to-use, “Windows™-like” interface. Tango takes an integrated approach to design, with sheet and component creation, post processing and hard copy generation, all executed from a single program. Our two-level menus, dialog boxes, on-line help and macro support make Tango quick to learn and simple to use.

Tango-Schematic gives you versatility and functionality with: support of homogeneous and heterogeneous components; library search and browse; autopanning and unlimited zoom levels; display of hidden pins to enable splitting power and ground nets; copy commands; and use of a unique snap-to-pin feature for guaranteed wire-to-component connections. Post-processing features include: forward and back annotation, design rule checking and sheet cleanup. Tango, EDIF 2.0, PSpice™, P-CAD™ and other popular net list formats are supported.

Tango-Schematic’s extensive device libraries are provided by SEDCO (specialists in creating electronic design libraries) and contain over 10,000 different symbols each verified for accuracy and each available in its commercial, true ANSI/IEEE and DeMorgan representation.

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<table>
<thead>
<tr>
<th>Vendor</th>
<th>Platform</th>
<th>Operating System/Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadence</td>
<td>Sun/Solbourne</td>
<td>Verilog: Simulation, fault grading, design verification</td>
</tr>
<tr>
<td>IKOS</td>
<td>Kinetics</td>
<td>Simulation, fault grading</td>
</tr>
<tr>
<td>Mentor</td>
<td>HP/Apollo</td>
<td>Design capture, simulation</td>
</tr>
<tr>
<td>Graphics</td>
<td>Sun/Solbourne</td>
<td>Parade: Layout, clock and timing structures</td>
</tr>
<tr>
<td>Synopsys</td>
<td>Sun-4</td>
<td>Design synthesis, test synthesis</td>
</tr>
<tr>
<td></td>
<td>Interface to Mentor, Valid, Viewlogic</td>
<td></td>
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<tr>
<td>Valid</td>
<td>Sun/Solbourne</td>
<td>Design capture, simulation</td>
</tr>
<tr>
<td></td>
<td>DECstation 3100</td>
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<td>IBM RS6000</td>
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</tr>
<tr>
<td>Viewlogic</td>
<td>Sun-4</td>
<td>Design capture, simulation</td>
</tr>
<tr>
<td></td>
<td>PC386</td>
<td>Design check</td>
</tr>
</tbody>
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NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

VHDL Development System For SPARCstations

- VHDL simulator and compiler
- Interactive VHDL source code debugger

V-System/SPARC is a VHDL (VHSIC Hardware Description Language) development system for the Sun SPARCstation platform. Engineers can offload their high-end VHDL development tools for initial development and verification. Subsystems can be defined and tested before integration on high-end development tools. The V-System/SPARC is integrated under Sun's Open Windows. The development environment provides six interactive windows. These windows enable users to view their design hierarchy, scroll through their VHDL source, monitor selected debugging variables and signals, control the simulator, and see the executing processes and the simulator output. You can set VHDL breakpoint directly in the code, single step, and change values on the fly. Compile times are pegged at 15,000 lines/minute and simulation, at 10,000 RTL statements/sec on a Sun IPC. Single-user license, $4995; for DOS and Windows, $495 and $1995, respectively.

Model Technology Inc, 15455 NW Greenbrier Pkwy, Suite 210, Beaverton, OR 97006. Phone (503) 690-6838. FAX (503) 690-2093.

Circle No. 356

Simulation Verification And Analysis Tool

- Verifies results for different simulations
- Compares behavioral and gate-level simulation

The VCAP tool enables engineers to compare different simulation runs and detect differences in performance. You can compare a simulation run against expected results, having the differences flagged for easy reference. These comparisons let you detect differences between design iterations or performance between a behavioral model and a gate-level implementation. It also detects variations between different synthesis runs on a circuit. VCAP also has a mode for timing and pin behavior, producing a report listing minimum and maximum output-pin delays, pin-transition statistics, and input behavior. Also listed are the tester resources required to run the test vectors. VCAP runs on Sun, HP, Intergraph, and IBM PC/AT workstations. Single node license, $3995.

Source III Inc, 3958 Cambridge Rd, Suite 247, Cameron Park, CA 95682. Phone (916) 676-9329.

Circle No. 357

Unix/DOS X-Window Servers

- X-Server for 386/486 supports TIGA boards
- For DOS and SCO or Interactive Unix

X-Windows-applications users can take advantage of the TIGA (TI graphics architecture) PC graphics standard with X Servers. You can use PCs as applications servers, providing an X-Windows interface for applications running on X-Window clients. Software for TIGA/DOS release 2.1 supports the TIGA graphics board, based on the TI 34020 graphics accelerator boards. This version supports DOS 5.0 as well as third-party networking software that links to other PCs or high-end servers. The company is also releasing XSoftware for PC Unix, release 2.1. It supports both SCO and Interactive Unix operating systems for PCs. TIGA graphics boards support workstation class resolutions: monochrome resolutions to 1600 x 1200 and color resolutions to 1280 x 1024. Software for TIGA/DOS and PC Unix, $595 and $495, respectively.

AGE, 9985 Pacific Heights Blvd, Suite 200, San Diego, CA 92121. Phone (619) 455-5600. FAX (619) 597-6030.

Circle No. 358

EDN January 2, 1992
ASIC Standard-Cell Layout Editor
- System extracts layouts and compares schematics
- Contains layout editor with autorouter

The L-Edit mask-layout editor tool enables a designer to do hands-on ASIC standard cell layout. The version 4.0 tool includes a DRC (design rule checker), a built-in pad frame generator, a 32-bit coordinate design space, and a standard-cell place-and-route tool for netlist to layout conversion. It also includes a layout-to-Spice extractor, which extracts circuit parameters for Spice simulation and circuit characterization. A comparator, called LVS, checks circuit conformance to the defining schematic. The tools are integrated and share a common user interface. L-Edit runs on Unix workstations, as well as on IBM PCs and Apple Macintosh computers. Both CIF and GDS-II layout database formats are supported by L-Edit. The tool supports fully scalable CMOS digital and analog circuits. It handles hierarchical, cell-based design, with unlimited layers and hierarchy levels. It supports all-angle, 45°, and 90° polygons and wires. Basic L-Edit layout editor, from $995; extractor, $995; layout vs schematic comparator, $995.

Tanner Research Inc, 444 N Alameda Dr, Pasadena, CA 91107. Phone (818) 795-1696. FAX (818) 795-7937. 

Software-Development Tools

For Motorola 68HC16
- ROMable cross assembler and compiler
- Source-code debugger, ANSI runtime library

This tool set works with Motorola’s 68HC16, a 16-bit microprocessor. The tool set includes an ANSI C cross-compiler, a macro assembler, and an ANSI runtime library. It also includes a set of programming utilities: a linker, librarian, automatic data initializer, object-module inspector, and an absolute hex file generator. The tool set comes with Whitesmith’s CXDB, an interactive source-code debugger. The debugger includes a 68HC16 simulator and an emulation debugger integrated with external in-circuit emulators for real-time debugging control. The debugger supports Nohau, Orion, and Pentic Systems ICEs. Also included is a ROM monitor debugger for testing targets running with an on-chip monitor. The debugger works with standard Motorola evaluation boards. The development package runs on IBM PCs and clones, as well as on Sun, DEC/VAX, and HP workstations. Compiler/assembler/utilities package for a PC, $1600. CXDB debugger, $1500.

Intermetrics Microsystems Software Inc, 733 Concord Ave, Cambridge, MA 02138. Phone (617) 661-0072. FAX (617) 868-2843.

Forth Development System For 68332 Microcontroller
- Forth system with PROM support
- Includes a Motorola 68332 evaluation-kit board

Chipforth, for the Motorola 68332 32-bit microcontroller, is a PC-based Forth development system and a 68332 target board with a minimized Forth kernel. The board is actually the Motorola 68332 evaluation kit with 2 kbytes of on-chip RAM, 64 kbytes of board RAM (32k x 16 bits), an RS-232C (64 baud to 524 kbaud), a parallel-port host communications link, and sockets for EPROMS and static RAM. The host Polyforth system is tightly coupled with the target operating software, which is a Forth subset. This coupling makes it easy to control and debug running target software. The target has a small 200-byte talker program, which links processors and supports interactive debugging. Utilities include a full screen editor, PROM programming support, debug utilities, a target-memory dumper, and disk/print utilities. Chipforth, $3950, including one year of telephone support.

Forth Inc, 111 N Sepulveda Blvd, Manhattan Beach, CA 90266. Phone (213) 372-8493. FAX (213) 318-7130. TLX 275182.

C++/C Development Environment For Sun
- C/C++ compiler, debugger, and editor
- Project-oriented environment

The C++/Softbench development environment for Sun workstations combines an ANSI C and C++ (version 2.1) 1-pass compiler with the underlying Softbench tool integration base. Softbench sets up a low-overhead communications mechanism for integrating development tools and provides encapsulation mechanisms for common user interfaces. With C++ Developer, users can generate a source-code template from a class for building a new instance or subclass. Softedit editor provides syntax and semantic error checking before compile time. And, Softdebug supports object-oriented debugging. Available in February, 1992, $9950 per seat.

Hewlett-Packard Co, 19310 Prune-ridge Ave, Cupertino, CA 95014. Phone (800) 752-0900; (408) 746-5601. FAX (408) 746-5790.
2MM INTERCONNECTION

* Modularity
* High Density
* Flexibility
* Standardization

A NEW HIGH DENSITY modular interconnection system Sofix, based on 2mm Pin spacing, is BORN!

MODULARITY
* Stackable segments; 12, 24, 48 & 96 mm Lengths.
* Easy-to-assemble w/Hot Riveting tool.
* No unused slots at end of modules.

HIGH DENSITY
* Four rows of 2 mm spacing achieves 100% more density than DIN-41612 (Euroconnector).

FLEXIBILITY
* Mix signal, power coax & fiber-optics side-by-side; independent of the module size.

STANDARDIZATION
* SOFIX has been standardized by IEEE 1301.1, IEC917 and accepted by FUTUREBUS+ and SCI Bus EIA IS64.
HOT RIVET
* Hot Riveting tool: To obtain END-TO-END stacking, the 90° connector is revited from the PCB’s rear side, by a plastic mounting peg which gives the connector a firm fit. The Hot Riveting tool is a very slim unit that can be modularized; 1 to 20 rivets at once.

PRESS-FIT
* The Pin connectors for backpanels are available for both solder-to-board or pressfit. Tools for pressfit connectors are available as a BENCHPRESS, for small series; or Automatic Pneumatic Press, for full production.

IDC
* The Cable connectors are designed with IDC (INSULATION DISPLACEMENT CONNECTION) for ease of assembly. Hand tools for lab or field assembly is available, as well as Semi-automatic units for full production.
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CIRCLE NO. 73
NEW PRODUCTS
COMPUTERS & PERIPHERALS

Pencil And Pen Plotters
- Fuzzy logic enhances plot speed
- Plot at 44.5-ips and 4.2g acceleration
The XP-500 Series pencil and pen plotters use fuzzy logic to enhance plot speed. Utilizing a 32-bit CPU and a digital servo, the units plot at 44.5-ips and 4.2g acceleration. Fuzzy logic lets the plotters look ahead from 21 to 41 vectors, evaluating vector length and angle, and then determining the fastest, most efficient vector path to be read, sorted, and plotted. Fuzzy logic also improves circular interpolation. The units can accommodate eight pencil leads, including 0.2-, 0.3-, 0.5-, and 0.7-mm leads. They can also hold eight pens, and you can program the plotters to combine pen and pencil in a single plot. The units contain a 1-Mbyte buffer and have an HP-GL-compatible RS-232C interface. E-size unit, $6300; D-size unit, $4800.

Industrial I/O Controller
- Contains a 10-MHz V-20 µP running DOS 3.3
- Analog and digital modules have high-voltage isolation
The I/O PlexerPCx self-contained remote I/O controller contains a 10-MHz V-20 µP running DOS 3.3 and 1 Mbyte of RAM. A solid-state disk drive consists of either a battery-backed RAM or Flash EPROM having a capacity as large as 256 kbytes. A COM1 port lets you download a control program from a remote host at 115.21 kbaud. A COM2 port drives an internal I/O Plexer network having as many as 4000 I/O points. The unit accepts as many as 16 analog and digital I/O modules that have high-voltage isolation from module to module and module to chassis. The controller also contains a 25W power supply, a real-time clock, and a Centronics printer port. The unit measures 17.25 x 5.0 x 4.15 in. and operates from 0 to 60°C. Controller without I/O modules, $1695; I/O modules, $50 to $120.

NTDS Adapter
- Links VMEbus boards to Navy peripherals
- Supports NTDS type A, B, C, and H data transfers
The NTDS-1 Navy Tactical Data System (NTDS) adapter board works with the VMEbus. It links the company’s PMV 68 MIL-STD-VME computer boards to standard Navy peripherals and provides a full-duplex parallel data path between a VMEbus and an NTDS system. The board conforms to the MIL-STD-1397 specification for type A (slow), B (fast), C (anew), and H single-ended or double-ended data transfers. A 68000 µP and a 4-channel DMA controller control onboard functions. A 64-kbyte dual-port static RAM appears as a block of RAM in the VMEbus system address space. $4425. Delivery, eight weeks ARO.

Mutoh America Inc, 500 W Algonquin Rd, Mt Prospect, IL 60056. Phone (708) 952-8880. FAX (708) 952-8808. Circle No. 379

Dutec, 4801 James McDivitt Rd, Jackson, MI 49204. Phone (800) 248-1632; (517) 750-4700. FAX (517) 750-4740. Circle No. 380

Radstone Technology Corp, 20 Craig Rd, Montvale, NJ 07645. Phone (800) 368-2738; (201) 391-2700. Circle No. 381
Solid-State Disks
- Have 1, 2, or 4 Mbytes of Flash memory
- Operate from 0 to 70°C
The PCF912 and PCF914 family Flash memory boards provide non-volatile memory for ISA bus computers. The boards are additions to the company's line of disk emulators. An onboard BIOS simplifies installation, and diagnostics detect power-up errors. You can populate the boards with 1, 2, or 4 Mbytes of Flash memory. The I/O driver lets you configure as many as four boards as a single physical drive having as much as 16 Mbytes of memory. The boards are resistant to humidity, vibration, and shock, and they operate from 0 to 70°C. PCF912 with 2 Mbytes of memory, $828; PCF914 with 4 Mbytes of memory, $1348 (100).

Memtech Technology Corp, 3000 Oakmead Village Ct, Santa Clara, CA 95051. Phone (408) 970-8900. FAX (408) 986-0656. TWX 910-250-1368. Circle No. 382

DSP VMEbus Board
- Uses four TMS320C40 DSP chips to deliver 1.1 BOPS
- Access to 12 20-Mbyte/sec parallel ports on the front panel
The V-C40 GU VMEbus board contains four TMS320C40 DSP chips. The four chips deliver a total of 1.1 BOPS (billion operations per second). Each chip has two independent 32-bit address buses and six 20-Mbyte/sec parallel communications ports. Twelve of these communications ports are accessible via the front panel. In addition, the board has 64 Mbytes of dynamic RAM and as much as 5 Mbytes of zero-wait-state static RAM. The board also uses the company's proprietary 24-bit parallel bus, called ADBus, to provide high-speed access to the company's I/O boards. The board has slot-1 controller functions and operates as a master or slave. DMA block transfers occur at 35 Mbytes/sec, and the board supports D8, D16, and D32 data transfers. $9995.

Ariel Corp, 433 River Rd, Highland Park, NJ 08904. Phone (908) 249-2900. FAX (908) 249-2123. TLX 4997279. Circle No. 383

Sbus Graphics Card
- Accelerates 2-D graphics on a SPARCstation
- Employs a Weitek W8720 integrated-graphics controller chip
The GXTRA/W single-slot SBus card accelerates 2-D graphics on a Sun SPARCstation. It uses a Weitek W8720 integrated-graphics controller chip for X Windows, Openwindows, and Sunview graphical user interfaces. The card has an 8-bit color frame buffer and a Sun-4 style keyboard and mouse port. It draws, fills, and performs bit-block transfers at 100 million pixels/sec. Different versions support 1600 x 1200-, 1280 x 1024-, and 1152 x 900-pixel resolutions. From $3050.

Tech-Source Inc, 442 S North Lake Blvd, Suite 1008, Altamonte Springs, FL 32701. Phone (407) 830-8301. Circle No. 384

Short-Haul Modem
- Operates over two twisted-wire pairs at 19.2 kbps
- Has an RS-232C port switchable from DTE to DCE RO.
The Model 205 multidrop short-haul modem operates over two twisted-wire pairs and uses a controlled carrier, which switches the role of the master and its slaves in a polled network. You can switch the controlled carrier on manually or via the Request-To-Send (RTS) signal. The modem operates at data rates as fast as 19.2 kbps over a range of 4 miles. You can switch the unit’s RS-232C connector from a DTE (data-terminal-equipment) to a DCE (data-communications-equipment) configuration. The unit derives its power from the Transmit-Data signal. Line-coupling transformers provide double isolation between communicating modems. The unit’s metal enclosure measures 5.0 x 2.0 x 0.85 in. $113.

Telebyte Technology Inc, 270 E Pulaski Rd, Greenlawn, NY 11740. Phone (800) 835-3298; (516) 423-3232. FAX (516) 385-8184; (516) 385-7060. Circle No. 385

2½-in. Disk Drives
- Provide 65 and 130 Mbytes of formatted capacity
- Consume 2W when operating and 5.5W during start-up
The Go Drive 60 and 120 are 2½-in. hard-disk drives for notebook computers. They provide 65 and 130 Mbytes, respectively, of formatted capacity. The average seek time is less than 17 msec, and the sustained data-transfer rate can be as fast as 2.1 Mbytes/sec. The drives weigh 6.2 oz and consume 2W when operating and 5.5W during start-up. Go Drive 60 has a spin-up time of less than 2 sec, and Go Drive 120 has a spin-up time of less than 2.5 sec. Both drives use the company’s lookahead read cache feature, called Discache, which anticipates host requests and stores data in a 32-kbyte buffer. You can use them with the SCSI or ISA bus. Go Drive 60, $395; Go Drive 120, $595.

Quantum Corp, 500 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 894-4000. FAX (408) 894-3205. Circle No. 386
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- Available in two organizations
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Military Op Amp
- 185-MHz bandwidth
- Complies with MIL-STD-883
The OPA676SG/883B is a MIL-STD-883-compliant, switched-input op amp. The two independent differential inputs are selectable by means of an external TTL-compatible logic signal. The op amp features a bandwidth of 185 MHz at a gain of 10, and a settling time to 0.01% of 25 nsec. External compensation allows a range of closed-loop gains. Other specifications include a power-supply range of ±4.5V to ±6.5V, a typical output current of ±30 mA, a maximum bias current of 35 μA, and a maximum offset voltage of ±2 mV. The device comes in a 16-pin ceramic DIP that conforms to MIL-M-38510, Appendix C, Outline D-2. $78.40 (100).

Image-Compression Chip Set
- Optimized for still video cameras
- Simulates the JPEG algorithm
The 031 image-compression chip set consists of the ZR36020 discrete cosine transform (DCT) processor and the ZR36031 image-compression coder/decoder. The chip set performs compression and expansion similar to the proposed Joint Photographic Experts Group (JPEG) algorithm. Optimized for use in still video cameras, the 031 chip set includes a bit-rate control feature to ensure that a predictable number of photos can be stored on the memory card without degrading image quality. Because the chip set does not include image preprocessing functions such as color space conversion, it provides the flexibility for system vendors to build differentiated, value-added products. The chip set operates at a 7.4-MHz data rate, which allows digital still video cameras to capture photos at speeds to 7.5 frames per second. The ZR36020 chip comes in either a 44-pin quad flatpack or a 48-pin ceramic DIP; the ZR36031 chip comes in either a 100-pin quad flatpack or an 85-pin PGA (pin-grid array) package. $99 (1); $25 (OEM qty).

Ground-Fault Interrupter
- Low-power operation
- Meets UL-943 requirements
Added to the company’s line of ground-fault interrupter (GFI) controller ICs, the RV4141 is a low-power, 3-wire device for use in home and industrial ac receptacles and circuit panels. The RV4141 obtains its power directly from the ac line and features a built-in rectifier, a precision sense amplifier, adjust-
able time delay and an SCR interface. The device, which uses only 500 µA of quiescent current, operates in either 110 or 220V systems and meets UL-943 requirements. The RV4141 operates over the industrial temperature range and comes in 8-pin DIPs or SO packages. From $0.55 (1000).

Raytheon Co, Semiconductor Div, 350 Ellis St, Mountain View, CA 94043. Phone (415) 968-9211. Circle No. 373

High-Speed Clock Driver
- Operates to 35 MHz
- Meets 2-nsec skew requirements
The MC74F1803 clock driver is designed for use in systems operating at frequencies as high as 35 MHz with skew requirements of 2 nsec or more. The high-speed, low-power device features separate D-type inputs and multiple synchronous outputs with closely matched propagation delays. The MC74F1803 is available in a standard 14-pin DIP or 14-pin SO package for surface-mount applications. $2 (10,000).

Motorola Inc, MD M538, 2200 W Broadway, Mesa, AZ 85202. Phone (602) 962-2865. Circle No. 374

µP Supervisory Circuit
- Resets at 1V
- Chip-enable gating is 35 nsec
The LTC1255 microprocessor supervisory circuit provides a guaranteed reset assertion down to 1V, thereby preventing µP malfunction at low supply voltages. The chip can also conserve battery power by conditionally saving RAM contents only when necessary. Other features include a watchdog timer, power-fail detection, and chip-enable gating of 35 nsec (max). A charge-pumped FET power switch helps to limit supply current to only 1.5 mA (max). The LTC1235 is available in 16-pin DIP or SO packages. From $3.85 (100).

Linear Technology Corp, 1630 McCarthy Blvd, Milpitas, CA 95035. Phone (800) 637-5545; (408) 432-1900. Circle No. 375

Low-Dropout Regulator
- Generates 2.85V for SCSI terminations
- Comes in small SOT-223 package
The LT1117-2.85 low-dropout regulator is for use in active terminations for the Small Computer System Interface (SCSI) standard. The device provides a regulated output of 2.85V ±1% from the SCSI supply and operates down to a 1V dropout voltage. Output-current capability is 800 mA and quiescent current is 10 mA (max). The regulator also features current-limiting, thermal-shutdown, and ESD protection. The LT1117-2.85 comes in a space-saving SOT-223 surface-mount package. $1.83 (1000).

Linear Technology Corp, 1630 McCarthy Blvd, Milpitas, CA 95035. Phone (800) 637-5545; (408) 432-1900. Circle No. 376

Low-Voltage OTP Memories
- Operate at 3.3V ±0.3V
- Available in 512-kbit and 2-Mbit densities
Optimized for battery-powered applications, the 512-kbit Am27LV512 and 2-Mbit Am27LV020 are one-time-programmable (OTP) memories that can operate at 3.3V ±0.3V. The devices are available in access-time ratings of 200, 250, and 300 nsec. Maximum power consumption is 90 µW in the standby mode and 54 mW when the device is constantly accessed at 5 MHz. Both the Am27LV512 and Am27LV020 come in 32-pin PLCC (plastic leaded chip carrier) packages. Depending on speed rating and density, $13.51 to $38.61 (100).

Advanced Micro Devices Inc, Box 3453, Sunnyvale, CA 94088. Phone (800) 222-9323; (408) 749-5703. Circle No. 377

Smart Battery-Charger ICs
- Sense battery temperature
- On-chip timer limits charging time
Combining fast charging with safety, the TC675 and TC676 ensure proper NiCd and Ni-Hydride battery charging without risking overcharge or potential explosion. You can use the ICs in charger circuits using SCRs and current-limited transformers. The charge cycle begins when the IC detects the presence of a battery connected for recharge. The cycle ends when an external thermistor input stops the charge cycle when the selectable battery-temperature rise is achieved or when an on-chip failsafe timer limits the charging time to 90 minutes. The devices also provide an LED output that allows visual checking of the charge cycle and an automatic trickle-charge function. The TC675 has a trickle-charge select pin; the TC676 has a timer-override reset pin. Package options include 14-pin DIP and 16-pin SOIC. From $7 (10,000).

Teledyne Components, 1300 Terra Bella Ave, Mountain View, CA 94039. Phone (800) 888-9966; (415) 968-9241. Circle No. 378
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Responsible for Physical Design of CMOS VLSI chips. Background in using state-of-the-art CAD tools from Mentor, Cadence, Silver Liscio and others in the performance of chip layout, verification and analysis is essential. Compiled, cell based and custom layout techniques will be used in a networked workstation environment. BSEE a plus.

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Must have 1-2 years experience with the design and implementation of network configurations, as well as familiarity with the following media: Ethernet-10Base-T, 10Base5, 10Base2, RS232, V.55, fiber and Apollo token ring. Operating systems should include Unix, DEC-VMS and IBM-VM, MVS, BS/BA in Computer Science or Electrical Engineering required.

SR. EQUIPMENT ENGINEER
Responsible for the implementation of statistical equipment control systems. BSEE preferred plus 4 years experience in interface electronics and control systems. Must be familiar with most fab equipment and facilities requirements. Qualified applicants should send a resume to: Advanced Micro Devices, MS-556/EDN192, 5204 E. Ben White Blvd., Austin, Texas 78741, Attn: Professional Staffing. You may also call (512) 462-5108 or FAX your resume to (512) 462-5355. We are an equal opportunity employer.

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**Applications Engineer - Dallas, Tx.**

Individual will provide second level technical assistance for customers and liaison between Customer Service and Engineering. Will maintain an in-depth product and system knowledge in order to identify and solve software and hardware problems. Assemble hardware, generate test scripts or programs (C, assembler, or shell language), and modify software drivers. Minimum of 3 years experience with C in a UNIX environment required. Systems administration experience a plus. Prefer BSCS or equivalent experience.

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Software Engineer - Dallas, Tx.
Candidate will develop device drivers for various INTERPHASE products. Experience with UNIX, Kernel I/O, TCP/IP or other protocol experience on super-minicomputer or mini-computer required. Minimum five years writing UNIX device drivers required. BSCS required. MSCS preferred.

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Individual will participate in the development of networking coprocessor products in a real-time environment. Three years experience developing networking software in a real-time UNIX environment required. Working knowledge of TCP/IP, UDP and NFS/RPC desirable. Prefer BSCS, BSEE or equivalent experience. MSCS or MSEE a plus.

Software Performance Engineer - Mountain View, Ca.
Candidate will benchmark and test networking products as well as interface with all OEM's/customers regarding performance issues. Minimum of 5 years experience with UNIX and C programming and 2 years of performance evaluation and benchmarking. Prefer BSCS, BSEE or equivalent experience. MSCS or MSEE a plus.

Software Engineer - Mountain View, Ca.
Individual will install and patch install product related utilities, network management agents and user interfaces. Minimum of 3 years UNIX and C programming required. Experience with the Bourne shell scripts, sed, awk, and systems administration desired. Exposure to NFS a plus. Prefer BSCS or equivalent experience. MSCS is a plus.

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EDN's ACRONYMS AND ABBREVIATIONS

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ASIC—application-specific integrated circuit
CAE—computer-aided engineering
CMOS—complementary metal-oxide semiconductor
CPU—central processing unit
DIP—dual in-line package
DOS—disk operating system
EDA—electronic design automation
FRA—fast radio astronomy
FR4—a low-cost, epoxy-laminated substrate material commonly used with plastic surface-mount packages
HDTV—high-definition television
IC—integrated circuit
JTAG—Joint Test Action Group
LISI—least significant bit
MCM—multichip module
MSB—most significant bit
npp—n-type p-type n-type
OOP—object-oriented programming
pc board—printed-circuit board
PLCC—plastic leaded chip carrier
PLD—programmable logic device
ppn—p-type n-type p-type
PROM—programmable read-only memory
QTAI—quick turnaround internetwork technology
RAM—random-access memory
RF—radio frequency
SOC—small-outline integrated circuit
SOJ—small-outline J-lead, a surface-mount integrated circuit
TAB—tape automated bonding
TSP—thin small-package
TTL—transistor-transistor logic

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