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RC224ATF
• CCITT V.22 bis, V.22 Bell 212A and 103 operating modes
• EIA TR002.288 AT commands
• Group 3 send and receive fax modes
• ANSI/EIA 578 Service Class 1 fax commands
• Single voltage (+5 volts)
• 2-device version available
• AccelerATor™ Kit

RC9624DP/RC9624AC
• CCITT V.22 bis, V.22, V.21, V.23, Bell 212A and 103 modes
• V.29, V.27er, V.21 Channel 2, Group 3 send/receive fax capabilities
• Voice interface
• DTMF generation/detection
• HDLC framing
• Single voltage (+5 volts)

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The new MAN-amplifiers series... another Mini-Circuits’ price/performance breakthrough.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>FREQUENCY RANGE (MHz)</th>
<th>GAIN (dB)</th>
<th>MAX. OUT/PWR (dBm) (typ)</th>
<th>NF (dB)</th>
<th>DC PWR (12V, mA)</th>
<th>PRICE (ea.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAN-1</td>
<td>0.5-500</td>
<td>28</td>
<td>10</td>
<td>8</td>
<td>4.5</td>
<td>60</td>
</tr>
<tr>
<td>MAN-2</td>
<td>0.5-1000</td>
<td>19</td>
<td>1.5</td>
<td>7</td>
<td>6.0</td>
<td>85</td>
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<tr>
<td>MAN-1LN</td>
<td>0.5-500</td>
<td>28</td>
<td>10</td>
<td>8</td>
<td>2.8</td>
<td>60</td>
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<tr>
<td>†MAN-1HLN</td>
<td>10-500</td>
<td>10</td>
<td>0.8</td>
<td>15</td>
<td>3.7</td>
<td>70</td>
</tr>
<tr>
<td>†MAN-1AD</td>
<td>5.500</td>
<td>16</td>
<td>0.5</td>
<td>6</td>
<td>7.2</td>
<td>85</td>
</tr>
</tbody>
</table>

†Midband 10\(\mu\)p to \(\mu\)f = \(\pm 0.5\)dB  †dB Gain Compression  †Case Height 0.3 in.

Max input power (no damage) + 15dBm, VSWR in/out 1.81 max.
Active Directivity (difference between reverse and forward gain) 30 dB typ.
Truly incredible...a superfast 3nsec GaAs SPDT reflective switch with a built-in driver for only $19.95. So why bother designing and building a driver interface to further complicate your subsystem and take added space when you can specify Mini-Circuits’ YSW-2-50DR?

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**SPECIFICATIONS**

<table>
<thead>
<tr>
<th>YSW-2-50DR</th>
<th>dc-500MHz</th>
<th>500-2000MHz</th>
<th>2000-5000MHz</th>
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</thead>
<tbody>
<tr>
<td>Insertion loss, typ (dB)</td>
<td>0.9</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Isolation, typ (dB)*</td>
<td>50</td>
<td>40</td>
<td>28</td>
</tr>
<tr>
<td>1dB compression, typ (dBm @ in port)</td>
<td>20</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>RF input, max dBm (no damage)</td>
<td>22</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>Video breakthrough to RF, typ (mV p-p)</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise/Fall time, typ (nsec)</td>
<td></td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

*typ isolation at 5MHz is 80dB and decreases 5dB/octave from 5-1000 MHz

Mini-Circuits

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CIRCLE NO. 124
COMPUTERS & PERIPHERALS
SPECIAL ISSUE

SPECIAL REPORT
Cache design

Most high-performance systems can benefit from cache memory. However, designing one isn’t trivial; to avoid wasting your precious cash, you need to know how and why the cache works.
—Michael C Markowitz, Associate Editor

DESIGN FEATURES
Designers’ guide to subranging A/D converters—Part 2

Part 1 of this 3-part series on subranging A/D converters covered the architectures and operation of these specialized devices. Part 2 continues with a discussion of their critical dynamic parameters and specifications.—Ray K Ushani, Datel Inc

Design a digital synchronizer with a low metastable-failure rate

When you’re attempting to synchronize asynchronous data to a system clock, don’t let metastability ruin your design. Carefully considering this problem during the design phase can save you headaches down the line.—Steven R Masteller, Allied-Signal Aerospace, Bendix Engine Controls Div

TECHNOLOGY UPDATES
Digital-paper storage: Flexible optical media boost data density

If you need to store data by the terabyte, watch for digital paper. At one-half cent per megabyte, it may become the archival medium of the nineties.—Chris Terry, Associate Editor

Continued on page 7
You are required to explain why you have exceeded virtually every industry standard for CMOS PLDs. We understand that to obtain samples of the part in question, along with supporting documentation, you can be reached at:

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**CAUSE FOR CITATION:**
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**POSTED SPEED:** 10 ns
**CLOCKED SPEED:** 7.5 ns
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TECHNOLOGY UPDATES (CON’T)

The IEEE-488.2 standard: IEEE-488.2 products are just now appearing

Long on promise, short on delivery, the IEEE-488.2 standard may one day reduce the work of writing test-system programs. But that day hasn’t arrived just yet.—Steven H Leibson, Senior Regional Editor

ATE pin electronics: Versatile ICs reach beyond ATE systems

IC manufacturers have developed pin-electronic circuits that serve as building blocks for ATE systems. But these ICs aren’t limited to ATE applications.—Doug Conner, Regional Editor

EDITORS’ CHOICE

CAE router

PRODUCT UPDATES

Continuous-time programmable filter
X-Window package
Microcontroller family
Fast ADC with S/H amplifier

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EDN April 25, 1991
THE SHOCKING REASON THE TELECOMMUNICATIONS INDUSTRY TURNED TO OMRON.
Recently, the telecommunications industry needed a new breed of low-signal relay—a relay that could withstand a shocking 2,500 volts, almost double the present standard, yet small enough for dense PCB mounting. They turned to Omron.

Omron responded with the G6N relay. It not only withstands a 2.5KV surge between coil and contacts, its footprint is almost 40% smaller than the previous standard. The G6N is the latest product to join Omron's family of low-signal relays for telecommunications, computer peripherals, office automation and more.

Why did the telecom industry turn to Omron? Because we not only have the broadest line of relays, switches and photomicrosensors in the industry, we also have a proven track record of innovation. Last year alone, we invested over $170 million in R&D, employed over 1,000 R&D engineers and introduced nearly 100 new products. The telecom industry was also impressed with our highly-automated manufacturing systems, which enable us to provide products of consistent quality in high volumes. The G6N, for example, undergoes 100% automated inspection on 13 critical performance parameters.

With more than 90 affiliates and subsidiaries, 1,500 sales locations and 17,000 employees worldwide, Omron also met the telecom industry's need to provide product and service support around the globe.

Omron's ability to meet the rigorous demands of the telecom industry may come as a shock to some people. But it effectively demonstrates our ability to meet the control demands of any industry.

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At 15 ns

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Fast Universal CMOS PLD Family
At 10 ns

PAL16L8-5

Fast Bipolar PLD Family
At 5 ns
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Faster still are our seventh generation bipolar PAL devices. Complete families of 16L8-5s, 20L8-5s, and the 22V10-10s. And for real speed freaks, we're now shipping a 4.5ns bipolar PAL device—the world's fastest TTL programmable logic.

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ne glance at the full array of options Motorola offers in real-time, and you'll see why it's become the developer's platform of choice. For both target and host environments, no other single vendor has anything like it.

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Yet another reason to choose Motorola is our unending commitment to open standards. Our real-time platform gives you standards-based choices at various levels of integration. The centerpiece of this non-proprietary approach is VMEexec, our wide-open, totally integrated development environment. VMEexec allows you to use standard UNIX* interfaces to write a single set of application code, and then reuse it for other projects. Better still, you can combine any software product that conforms to these standards. VMEexec includes a high-performance real-time executive, a strong run-time connection to UNIX-based systems, flexible and efficient real-time I/O and file systems, as well as powerful development and debug capabilities. And because VMEexec is integrated with the hardware, you can begin software development even before the hardware is available.

If you're thinking about real-time, you should be thinking about time to market, and that's all the more reason to think Motorola. Especially when you consider that we can help speed product integration by serving as a single source for boards, software and systems. Add to that the industry's best applications expertise and design support, ranging from small embedded control systems to multi-processor simulation. Then factor in Six Sigma quality control. And remember that Motorola gives you the industry's only true migration path from CISC to RISC in both the development and run-time environments.

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Until now, there's been no volume supplier of the leading-edge 256K CMOS EEPROM, so supplies have been short.

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- .025" square header and socket sets
- .050" centerline micro interconnects
- Low profile, standard and elevated strips
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SOFTWARE FINDS FAULTS AND CREATES TEST PATTERNS

CX-Test from Crosscheck Technology Inc provides a method of embedding test electronics onto an ASIC. The software creates test patterns and provides fault analysis using such manufacturing defects as bridging and open transistors in addition to the standard stuck-at faults. According to your vote (EDN, January 3, 1991, pg 41), it was the most innovative test and measurement product of last year. The software's embedded circuitry acts as a bed-of-nails tester to ensure high fault coverage for integrated circuits. The technology is available in arrays from LSI Logic (EDN, March 14, 1991, pg 18). The technology presents four design limitations: you must provide initialization and functional vectors; the circuit can't rely on stored charge at any node; you can't use internal free-running oscillators; and you must reserve four pins for the test bus.

The software accepts netlists and functional simulation patterns in Verilog or LSI Logic's Lsim format and creates patterns for synchronous and asynchronous designs and for circuits containing ROM and RAM. To run, the software requires at least 32M bytes of memory on Sun-3 and Sun-4 workstations. Cost depends on your configuration and ranges from $25,000 to $50,000. The software is currently available in LSI Logic design centers and will be available to ASIC designers in the fall. Crosscheck Technology Inc, San Jose, CA, (408) 432-9200, FAX (408) 432-0907. LSI Logic, Milpitas, CA, (408) 433-4584, FAX (408) 433-7241. —Michael C Markowitz

ASIC FOUNDRY SPINS OFF DESIGN-TOOL GROUP

In a move to make its design tools less proprietary, VLSI Technology Inc has spun off its design-tool business unit and made it a separate company. The new company, Compass Design Automation, will take the existing products and develop them for other vendors' ASIC processes and alternative CAE environments. Compass began its operations with 160 employees from the parent company. Compass Design Automation, San Jose, CA, (408) 433-4880, FAX (408) 434-7820. VLSI Technology, San Jose, CA, (408) 434-7726, FAX (408) 434-7931. —Steven H Leibson

486-BASED COMPUTER CACHE USES UNUSUAL ARCHITECTURE

Mosel's Simulcache consists of the MS441 cache controller and MS443 intelligent dual-port memory chips for 486-based systems. The chip set provides a concurrent write-back cache for 80486 µPs. Unlike other write-back schemes, these devices don't connect in parallel with main memory on the CPU bus. Instead, the dual-port devices fit between the CPU and the rest of memory, including memory-mapped I/O ports.

The controller absorbs CPU memory transactions and reorders them to meet the system's needs. It provides burst read and write between the CPU and cache, allows direct access between CPU and noncache memory, and handles read misses by simultaneously passing data to the CPU while updating the cache. The intelligent memories use an internal 128-bit memory bus, support 4-word bursts with 8-nsec access times, and offer 2-way set associativity. Samples of both devices will be available in the second quarter of 1991 with production slated for midyear. The cache controller costs $65 and the intelligent memories cost $9 (10,000). Mosel, Sunnyvale, CA, (408) 733-4556, FAX (408) 733-2271. —Richard A Quinnell
IC MULTIPLIES AND DIVIDES ACCURATELY

The $10.55 AD734 from Analog Devices Inc is a high-accuracy, low-distortion analog multiplier/divider. The device performs the mathematical function \( W = \frac{XY}{U} \), where \( X \), \( Y \), and \( U \) are fully differential, analog-input signals. Operating with a small-signal and full-power bandwidth of 10 MHz, the device exhibits a slew rate of 480V/µsec, a S/N ratio of 94 dB, and a guaranteed conversion accuracy of 0.26% for high-grade devices. As a 4-quadrant multiplier, the IC can function as an oscillator, filter, or voltage-controlled amplifier. When connected as a 2-quadrant divider, the device can function as an AGC amplifier or an rms-to-dc converter. In multiplier mode, the denominator voltage \( U \) can be supplied internally from a 10V buried zener reference. Analog Devices Inc, Norwood, MA, (617) 329-4700, FAX (617) 326-8703.  
—Anne Watson Swager

12-BIT, 10M-SAMPLE/SEC ADC MODULE RUNS ON ±5V

The CLC922 ADC module from Comlinear Corp works in systems that need to perform 12-bit, 10M-sample/sec A/D conversions but have limited power supplies. The module incorporates an input amplifier, a low-jitter track-and-hold section, an onboard voltage reference, a 12-bit quantizer with error correction, and output latches. The device uses ±5V power supplies and consumes 4.1W. Guaranteed specs include a S/N ratio of 65 dB min, THD of −63 dB at 404 kHz and −57 dB at 4.996 MHz, 1-LSB-max differential nonlinearity, and no missing codes. The device also has a spurious-free signal ratio of 60 dB min. (This rating measures a converter’s clean dynamic range.) Industrial and military versions of the module cost $470 and $1565 (100), respectively.

The company’s CLC925B uses the same low-power circuits, but requires a 15V power supply in addition to the ±5V supplies. The additional power-supply voltage increases the module’s power consumption to 4.2W. Industrial and military versions cost $449 and $1490 (100), respectively. Comlinear Corp, Fort Collins, CO, (303) 226-0500, FAX (303) 226-0564.—Steven H Leibson

DESIGN AUTOMATION CONFERENCE EXPANDS PROGRAM

This year the Design Automation Conference takes place at the San Francisco Moscone Center on June 17 to 21. Targeting CAD tool users, developers, and managers, the conference has evolved over the years from a strictly technical conference to a combination of technical presentations and product exhibits. More than 130 exhibitors will demonstrate their tools, and more than 64 of the exhibitors will give technical presentations. In addition, more than 40 technical conference sessions and seven tutorials are scheduled.

The conference program includes two industry-oriented panels on June 18. The first panel, “Global Strategies For Electronic Design,” focuses on the interdependency of design-automation, and ASIC and systems companies, and their impact on global competition in the 1990s. The second panel, “Implementing the vision: Electronic design in the 1990s,” will focus on the broader needs of system design.

You can obtain a free pass to the first day of the exhibits by registering before May 17. After May 17 registration is $20. One-day passes for technical sessions, including the panels, are $75. For more information, call MP Associates, (800) 321-4573 or (303) 530-4333, FAX (303) 530-4334.—Doug Conner
Faster circuits for faster systems: Here's the good book.

The 1991 Cypress Semiconductor Data Books are hot off the presses. Highlights include:

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- **Static RAMs.** Biggest selection of high-speed devices, including our 10ns BiCMOS 64Ks.
- **VME Bus Controllers.** The space-saving solution for a broad range of processors.
- **CMOS PROMs.** The broadest line of high-performance PROMs, to 512K densities. We'll fill your order fast.
- **Specialty Memories.** Including ultra-high-speed FIFOs.
- **Multichip Modules.** Including 32-bit space and time savers.
- **And much more.** All in our new Data Book.


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EMULATOR SUPPORTS 68302 µP

The 68302 UEM in-circuit emulator from Softaid Inc debugs Motorola’s 68302 µP-compatible systems. The $6495 device provides 256k bytes of emulation memory, a 4k-byte-deep trace buffer, and 151,072 hardware breakpoints. You can set complex breakpoints using the emulator’s 5-level nested-trigger specifier using a specific sequence of events, data values, machine cycles, and address accesses. A pass counter lets you delay the breakpoint by as many as 65,536 cycles. The source-level debugger included with the emulator lets you trace and debug your code in its native appearance using C, PL/M, or assembly language. The debugger works with the emulator’s 256-bin real-time performance analyzer, so you can optimize your software on a function-by-function basis even when you’re programming with a high-level language. The emulator will be available in May. Softaid Inc, Columbia, MD, (301) 964-8455, FAX (301) 596-1852.—Steven H Leibson

HIGH-DENSITY GATE ARRAY FEATURES SPECIALIZED LIBRARY

The LCA200K gate-array family from LSI Logic has 20,000 to 200,000 usable gates in a 0.7-µm, 3-metal-layer CMOS. The family also has a library of more than 1000 specialized macrocells. The cells include conventional logic, MIPS and SPARC CPUs, phase-locked loops for removing interchip system-clock skew, backplane drivers, and differential receivers. Although the chip runs at 5V, its I/O drivers are compatible with 3.3V logic. The I/O drivers also support the JTAG scan-test technique. NRE costs start at $75,000. LSI Logic, Milpitas, CA, (408) 433-4340, FAX (408) 434-6457, contact John Daane.—Richard A Quinnell

LOW-COST CPU CHIP EXPANDS 80486 µP FAMILY

Intel’s 80486SX, a derivative of the basic 80486 µP, is a 32-bit µP chip that can upgrade 80386-based computer designs. The $269 (1000) chip is binary-code compatible with earlier 80386- and 80486-family µP chips. The company claims 16-MIPS performance at 20 MHz. The chip preserves the 32-bit data-bus architecture of its parent, but lacks floating-point math. The company expects to offer a $799 device that will supply floating-point math. For now the chips are simply basic 486 chips with disabled and unpowered floating-point math circuits. As production volume increases, the company will delete the floating-point math section of the 486 so that the derivative chip exists as a separate device. Pinouts of the two chips are not the same. The derivative chip is available in pin-grid-array and plastic packages. Intel Corp., Santa Clara, CA, (408) 987-8080.—Jon Titus

DSP CARDS OFFER FAST, 16-BIT, FIXED-POINT PROCESSING

A pair of plug-in DSP cards from Spectrum Signal Processing Inc bring the signal-processing abilities of the Texas Instruments TMS320C50 to the IBM PC/AT bus. The $3495 system and $2495 processor boards combine the signal-processing µP with 32k bytes of program memory and 32k bytes of data memory. You can expand both memory areas to a maximum of 128k bytes. The system board includes two 16-bit ADCs and two 16-bit DACs capable of 50-kHz conversion rates. The boards also provide a 2.7×3.4-in. prototyping area for additional circuits. Loughborough Sound Images (Loughborough, England) developed the boards. Spectrum Signal Processing Inc, Burnaby, British Columbia, Canada, (604) 438-7266, FAX (604) 438-3046. —Steven H Leibson
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HARDWARE MODELER STARTS A FAMILY

In an effort to lure more system designers into simulation, Logic Modeling Systems will deliver a lower-priced modeler. The 68020-based LM500 and 68040-based LM1200 hardware modelers aid system simulation by allowing you to augment your software models with actual devices configured as models. The 68020-based modeler, which starts at $35,000, models devices with as many as 160 pins. The $87,000, 68040-based modeler simulates 320-pin devices. Both modelers allow simulations to use multiple hardware models, limited only by total pin count—480 signal pins total for the 68020-based modeler and 2560 for the 68040-based modeler. Although its library of models numbers 600 and includes such devices as the i486, 29050, 68040, and R3000A, the company estimates you can build a model for any device you need in less than two days. Both modelers will be available by the end of June. Logic Modeling Systems Inc, Milpitas, CA, (408) 957-5200, FAX (408) 945-9181.

—Michael C Markowitz

AUDIO INSTRUMENTATION AMP FEATURES LOW INPUT NOISE

A distortion-cancellation network on the input of the INA103 monolithic instrumentation amplifier drops the device’s input-voltage noise figure to 1 nV/√Hz typ and its THD-plus-noise rating to 0.0009% (gain = 100, 1 kHz). The amp’s offset voltage is 52 µV max, and the input-offset voltage drift is 1.25 µV/°C. On-chip resistors give the device a gain of 1 or 1000 without additional components, and an external resistor can vary the amp’s gain from 1 to 1000. At a gain of 1000, the amp provides a flat frequency response to approximately 20 kHz. A device packaged in a 16-pin plastic DIP costs $4.85 (1000) and ceramic-packaged devices are also available. Burr-Brown, Tucson, AZ, (602) 746-1111, FAX (602) 889-1510, TWX 910-952-1111, contact John Conlon. —Steven H Leibson

TRANSMISSION-LINE ANALYSIS TOOLS UPGRADED

Quantic Laboratories offers a range of transmission-line analysis tools from its Boardscan board screener up through detailed 2- and 3-D analysis using its Greenfield products. The board screener includes signal-integrity specs such as overshoot, undershoot, settling time, noise margins, time delays, and crosstalk. The analyzers’ component libraries of drivers and receivers accept Spice transistor-based device models and behavioral models for increased simulation speed. The products are now available unbundled so you can obtain only the tools you need. The board screener starts at $15,000, and the analyzers start at $24,000. Quantic Laboratories Inc, Winnipeg, Manitoba, Canada, (204) 943-2552, FAX (204) 957-1158. —Doug Conner

VIDEO ACCELERATOR STANDARD FEATURE FOR WORKSTATION

The SPARC-based S4000 series of color workstations from Solbourne Computer includes accelerated 2-D graphics at no additional cost. Prices range from $11,495 for a diskless workstation with 8M bytes of RAM and a 16-in. color monitor to $22,095 for a workstation with a 400M-byte disk drive, 40M bytes of RAM, and a 19-in. color monitor. The company’s SGA20 accelerated color-frame buffer provides the improved graphics. The buffer can draw 530,000 2-D vectors/sec and can fill areas on the screen at 215M pixels/sec. The workstations accept as many as three SGA20s if you need multiple displays. Solbourne Computer Inc, Longmont, CO, (303) 772-3400, FAX (303) 772-3646. —Steven H Leibson
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EDN April 25, 1991
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<table>
<thead>
<tr>
<th>Part #</th>
<th>Features</th>
<th>ROM</th>
<th>RAM</th>
<th>Package</th>
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<tbody>
<tr>
<td>65511</td>
<td>32 I/Os, 2x8-bit timers, watchdog timer, serial I/O</td>
<td>4KB</td>
<td>128B</td>
<td>40-DIP/44-PLCC/QFP</td>
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<td>65512</td>
<td>32 I/Os, 3x8-bit timers,</td>
<td>8KB</td>
<td>128B</td>
<td>40-DIP/44-PLCC/QFP</td>
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<td>65P512</td>
<td>1x16-bit timers, serial I/O</td>
<td>64-PLCC/QFP</td>
<td></td>
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<td>65513</td>
<td>Same as 65512 with 24 8KB</td>
<td>128B</td>
<td>64-SDIP/40-PLCC/QFP</td>
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<td>65P513</td>
<td>additional I/Os</td>
<td>68-PLCC</td>
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<tr>
<td>65524</td>
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<td>384B</td>
<td>64-SDIP/40-PLCC/QFP</td>
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<td>65P524</td>
<td>PWM, 8-bit A/D, additional RDM/RAM</td>
<td>68-PLCC</td>
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<td>66201/</td>
<td>48 I/Os 16KB</td>
<td>512B</td>
<td>64-SDIP/40-PLCC/QFP</td>
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<td>66P201</td>
<td>10-bit A/D</td>
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<td>66P207</td>
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<td>66P207</td>
<td>2x16-bit PWM</td>
<td>68-PLCC</td>
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<td>1KB</td>
<td>64-SDIP/40-PLCC/QFP</td>
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<td>66P201</td>
<td>Transition detector</td>
<td>68-PLCC</td>
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<tr>
<td>66P201</td>
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<td>1KB</td>
<td>60-QUF</td>
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<td>60-FQFP</td>
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<td>16KB</td>
<td>512B</td>
<td>64-SDIP/40-PLCC/QFP</td>
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<tr>
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<td>2x8-bit timers, serial interface</td>
<td>68-PLCC</td>
<td></td>
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</tbody>
</table>
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EDN April 25, 1991

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Questions about PLL article

I'd like to comment about the article, "Technique eases design of phase-locked loops" (EDN, August 20, 1990, pg 141). I appreciate seeing this subject published.

However, I found two weak areas in the article. The first area involves the included C-language listings, Listing B-Key routines used in optimizing PLLs based on the 4046 IC. When including source code, sparse commenting and the inclusion of calls to subroutines not included in the listing only add to a reader's difficulty in understanding the code. I refer to the subroutine calls, components() and scan2(). What does "components" do for the program? If it is to read component values, then which components?

Also related to the listing problem is the vagueness of program execution. Which subroutine is executed first, last? In my opinion, had Fred Salvatti omitted the C-code listings, he would not have hindered the technical quality of the article.

The second area with which I'm concerned involves the last paragraph. "You can obtain...the program...for $19.95. Send your request to the author." Surely the cost of a 5½-in. floppy disk cannot be as high as $20.00. It appears that Fred Salvatti intends to make a profit, small as it may be. That being the case, wouldn't this work classify as an advertisement, and if so, should you not charge the author for advertising space? One might infer that EDN employed unfair discriminatory advertising practice.

Concerning Glenn's first question: What does "components()" do? Components() is the function that displays the 4046 menu. In answer to Glenn's second question, scan2() is the function that responds to selections from the 4046 menu.

As to my making a profit, my time is worth more than $25 an hour. It takes me about an hour to copy the program to a disk, test the disk for correct operation, write a personal letter explaining something about the program, package the disk, address the package, and finally go to the post office to mail.
At this point I’m already in the hole more than $5, not to mention all the hours it took to develop the equations and write and debug the program. Surely as an engineering manager, Glenn can see that there’s no way I’m making a profit. And, incidentally, I did this work on my own time.

How do engineers, et al, fare in the marketplace?

In the article, “The Job-Hunting Blues” (EDN, January 21, 1991, pg 230), Julie Schofield is too kind to big business. Businessmen are politicians who find some gadget to sell the government or other big business. They [receive] a little money from bankers and a lot of money from suckers; they find talented, but naive people, and they put together a little military machine that obeys the tenets of Socrates, Adam Smith, F W Taylor, Gantt, and others. The politicians and their cronies get rich! The exploited talent and the exploited labor get old or stale. When people see riches passing under their noses, they may want to share in those riches. But people are expendable, so they get expended.

I could let off steam for thousands of pages, but you get the message.

Robert C Gibson Consulting Engineer Aurora, IL

Who did it?

We inadvertently neglected to let you know that Intel Corp supplied the cover photograph for EDN’s March 28 Software Engineering Special Supplement. Apologies to all concerned.
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Operations Manager

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EDN April 25, 1991
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lowpass, highpass, bandpass, narrowband IF

- less than 1dB insertion loss  •  greater than 40dB stopband rejection
- 5-section, 30dB/octave rolloff  •  VSWR less than 1.7 (typ)  •  meets MIL-STD-202 tests
- rugged hermetically-sealed pin models  •  BNC, Type N; SMA available
- surface-mount  •  over 100 off-the-shelf models  •  immediate delivery

low pass dc to 1200MHz

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>PASSBAND, MHz (loss &lt;1dB)</th>
<th>STOP BAND, MHz (loss&gt;20dB)</th>
<th>VSWR pass-stop</th>
<th>PRICE</th>
</tr>
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<tbody>
<tr>
<td>PLP-10.7</td>
<td>14</td>
<td>19</td>
<td>1.7</td>
<td>11.45</td>
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<td>PLP-21.4</td>
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high pass dc to 2500MHz

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<tr>
<th>MODEL NO.</th>
<th>PASSBAND, MHz (loss &lt;1dB)</th>
<th>STOP BAND, MHz (loss&gt;20dB)</th>
<th>VSWR pass-stop</th>
<th>PRICE</th>
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<td>PHP-50</td>
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<td>14.95</td>
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</table>

bandpass 20 to 70MHz

<table>
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<tr>
<th>MODEL NO.</th>
<th>CENTER FREQ, MHz</th>
<th>PASS BAND, MHz (loss &lt;1dB)</th>
<th>STOP BAND, MHz (loss&gt;20dB)</th>
<th>VSWR pass-stop</th>
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<tr>
<td>PFB-21.45</td>
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<td>PFB-40</td>
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<td>100</td>
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narrowband IF

<table>
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<tr>
<th>MODEL NO.</th>
<th>CENTER FREQ, MHz</th>
<th>PASS BAND, MHz (loss &lt;1dB)</th>
<th>STOP BAND, MHz (loss&gt;20dB)</th>
<th>VSWR pass-stop</th>
<th>PRICE</th>
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<td>9.5-11.5</td>
<td>15.6</td>
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<td>19.2-23.6</td>
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<td>PBPA-30</td>
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<td>PBPA-60</td>
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<td>63.0-77.0</td>
<td>74.0</td>
<td>51.0</td>
<td>18.95</td>
</tr>
</tbody>
</table>

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FLUKE

CIRCLE NO. 102

EDN April 25, 1991
Have you been stumped by a design problem so long that you don't know who to turn to? Are you having trouble locating parts? Finding companies? Can't interpret a specsheet? Ask EDN.

This department will serve as a forum to solve nagging problems and answer difficult questions. EDN's editors will provide the solutions. If we can't solve a problem, we’ll find an expert who can, or we’ll print your letter and ask your peers for help. We can’t answer every question, but we’ll try to publish the ones that will help you most in your job.

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. You can reach us at (617) 558-4241 and leave a letter in the /ask_edn Special Interest Group.

Searching for synchronous ICs

Is there a PWM current-mode integrated circuit that can be synchronized to a like circuit by merely connecting one pin of each IC together? This synchronization would be similar to that achieved by connecting two SG1525As. I'd appreciate your help.

Michel Masse
Woodland Hills, CA 91364

Associate Editor Dave Pryce replies: The synchronization you refer to for the voltage-mode SG1525A usually takes the form of a sync input to the oscillator section of the PWM regulator. This sync pin enables the user to slave together multiple units or to synchronize a single unit using an external clock.

A number of current-mode regulators have a sync input pin to the oscillator. Among them are the CS-3865 from Cherry Semiconductor; the LT1846, SG1846, and UC1846 from Linear Technology, Silicon General, and Unitrode, respectively; and the SG1528/SG1530 combination current-mode/voltage-mode chip from Silicon General.

Check with these companies to determine if these chips will perform properly in your particular application. For example, the CS-3865 is a dual unit, and the sync pin may only serve to control each internal unit. Each company offers an extensive line of switching regulators and can provide capable applications support:

Cherry Semiconductor Corp
2000 South County Trail
East Greenwich, RI 02818
(401) 885-3600
FAX (401) 884-0790

Linear Technology Corp
1630 McCarthy Blvd
Milpitas, CA 95035
(408) 492-1900
FAX (408) 434-0507

Silicon General
11861 Western Ave
Garden Grove, CA 92641
(714) 898-8121
FAX (714) 893-2570

Unitrode Integrated Circuits
7 Continental Blvd
Merrimack, NH 03054
(603) 424-2410
FAX (603) 424-3460.

Short persistence pays off

Can you tell me where I can purchase CRT projection tubes with short persistence—less than 1 msec? We need such tubes for shuttered 3-D video projection.

Mohammed Arif
Heinrich-Hertz-Institut für Nachrichtentechnik
Berlin, Germany

Among the companies that sell such tubes are

Hitachi America Ltd
2210 O'Toole Ave
San Jose, CA 95131
(408) 435-5800

Video Display Corp
1868 Tucker Industrial Dr
Tucker, GA 30084
(404) 938-2080

Litton Systems Inc
Electron Devices Div
1215 S 52nd St
Tempe, AZ 85281
(602) 968-4471.

Another obsolete part

I am trying to locate an A/D converter once manufactured by National Semiconductor. The part number is MM5863N, and the device is at least 10 years old. National Semiconductor no longer makes it or has a second source for it. Can you help me locate a source for this device?

Tony De Carvalho
Repair and Product Development Manager
Webb Communications Inc
Tampa, FL

If any reader has a secret stash of MM5863Ns, please drop Ask EDN a line.
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EDN April 25, 1991
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EDN April 25, 1991

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to Price Wars

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~IM

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41st Electronic Components and Technology Conference, Atlanta, GA. Jim Bruorton, Publicity Chairperson, ECTC, KEMET Electronics Corp, Box 5928, Greenville, SC 29606. (803) 963-6621. May 13 to 15.

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EDN April 25, 1991

CALENDAR


American Consulting Engineers Council Annual Convention, Baltimore, MD. ACEC, 1015 15th St NW, Washington, DC 20005. (202) 347-7474. May 19 to 23.

International Semiconductor Manufacturing Science Symposium (ISMSS), Burlingame, CA. SEMI, 805 E Middlefield Rd, Mountain View, CA 94043. (415) 964-5111; (415) 940-6901. May 20 to 22.


Midwest Electronics Exposition, Minneapolis, MN. Leslie Tolworthy, Miller Freeman Expositions, 1050 Commonwealth Ave, Boston, MA 02215. (617) 232-3976. May 21 to 23.


Troubleshooting and Maintaining IBM & PS/2 (short course), St. Louis, MO. Center for Advanced Professional Development, 1820 E Garry St, Suite 110, Santa Ana, CA 92705. (714) 261-0240. May 22 to 23.

International Symposium on Computer Architecture, Toronto, ON, Canada. Prof Z G Vranesc, Dept of Electrical Engineering, University of Toronto, Toronto, ON, M5S 1A4, Canada. (416) 978-5032. May 26 to 30.
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If you fail to consider potential EMI and RFI problems at the design stage, meeting FCC or foreign standards and your own performance requirements can become an expensive and time-consuming task. Often, it involves costly corrective shielding measures, complex design retrofits, and possibly compromised system performance.

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Remedial EMC controls: A negative trade-off in volume, weight, efficiency, and cost.

When a system exceeds restrictions, designers are often forced to trade efficiency for acceptable EMC performance—with undesirable results. As a finished design is modified to accommodate necessary remedial shielding measures, weight and volume inevitably increase, and overall efficiency drops.

Planned EMC controls and testing during the design phase, on the other hand, not only help you maintain the integrity of the original design, but allow modifications in favor of greater system efficiency. In computer design, for example, EMC considerations such as selecting lower clock frequency, maintaining the smallest possible circuit layout areas, utilizing multi-layer boards, and minimizing the use of multiple shielding all contribute to optimum design efficiency.

The three EMC design techniques.

Achieving EMC is largely a function of three control techniques: Suppression, Isolation, and Desensitization. Through a combination of these methods, undesirable signals (EMI/RFI) are suppressed at their origin... generating circuits are isolated... and susceptible circuits are desensitized. When applied from the beginning, these techniques help you create fully integrated designs that offer both optimum performance and the best possible production economies.

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After implementing proper circuit-design controls, the most significant EMC design technique to reduce interference and susceptibility is effective shielding.

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Shielding not only contains radiated electromagnetic fields, but significantly reduces internal and circuit path coupling and overall common-mode coupling. In many cases, shielding eliminates the need for EMI filtering. In instances where filtering is required for conducted emissions, shielding can augment the performance characteristics of the filter.

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Tom Redfern, National’s
Director of New Product Development, Interface/Peripherals Group, talks about the challenges of mixed
analog + digital technology.

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“Traditional bus protocols are
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accommodate the wide data paths
and high transfer rates demanded
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64-bit microprocessors.

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active participant on the IEEE’s
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we invented the Backplane Transceiver Logic (BTL) that makes
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“Our first Futurebus+ chipset
contains five devices, and they
employ some of the most advanced
analog + digital integration ever
achieved. Our BTL drivers, for
example, let the digital CPU send
information to the digital memory
over the analog bus at peak rates
of 2-3 Gbytes/second!

“This is the future— and we’ve
got it today.”

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“To reach system-on-chip
performance, you’ve got to inte-
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“Well, CLASIC does that.

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ADC1251 A/D Converter

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ADC1251 A/D Converter

Hard Disk
Synchronizer/ENDEC

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and VLSI digital isn't easy. box for doing that job than time and a ±1/2 LSB non-linearity accuracy while dissipating 113mW max at ±5V.

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"To achieve these levels of integration, you need powerful tools in the hands of experienced designers.

"We've got them. A full range of process technologies, including fourth generation bipolar ECL and BiCMOS, which give us 0.8µ lithographies with bipolar F_T of 15GHz and 50ps gate delays.

"We also have some of the most advanced design tools in the industry, developed through our strategic alliance with Cadence.

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"This is the leading edge—and we're leading it."

Putting it all to work for you.

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Built on solid ground and rich in corporate resources, SMM has grown and diversified in step with the rapid changes in the electronics industry. By constantly keeping one eye on the future, we have become a major supplier of semiconductor packaging materials, solid laser crystals, and optoelectronics devices, among other high technology products, as well as a leader in metal refining and in the mining of gold and other precious metals.

From minerals to megabytes, Sumitomo Metal and Mining Co., Ltd. is a total manufacturer, providing new materials for a better tomorrow.
Everyone knows that the US is in a recession. We are bombarded daily with the awful news—unemployment is up, sales are down, companies are retrenching, consumers aren't buying. Almost all of the economic and business reports tell of gloom and doom. Historically, though, the news is worst just before things turn around. Now is the time to look at the positive news and its effect on all of us.

The crazy pattern of borrowing and lending in the 1980s appears to have ended. Banks are more cautious about whom they lend money to, and with good reason. The companies that get credit are the ones unburdened with debt—the ones most likely to survive and to lead recovery. Interest and mortgage rates have also come down considerably in the last few months as the Federal Reserve loosens credit. More people are thinking about buying real estate. Here in New England, an area in which the real estate market has been badly depressed, some agents believe the devaluation of property is at an end.

Oil prices, which shot up at the start of the Middle East crisis, continue to drop and may go lower still if OPEC decides against strict limits on oil production. Cheaper energy and raw-material costs help spur a recovery. Now that the war is over and oil prices are dropping, people are showing signs of confidence that the recession will also end. Retail sales rebounded from −0.9% in January to 0.5% in February. In December, sales were −1.5%. The increase from month to month seems small, but combined with other signs shows a pattern of economic improvement. I'm not an economist, and I cannot make quantitative predictions. However, the fact that most of the economic news in a recent issue of Business Week was bad convinced me that we're ready for a steady recovery this year. Over the years I have noticed that when the business press convinces itself times are bad, the economy starts to pick up.

Here in the US there's a tendency to look at the worst and ignore the best. Recovery depends on you and me, and we can start by concentrating on the positives. People are still doing business in this country. Let's talk about it. Let's talk about the orders we are getting and why we got them. Let's be enthusiastic about the good people who work for us and concentrate on keeping them as valued employees. Let's promote ourselves as fair and reliable working partners. Let's trumpet the new technologies and products we're developing, and let's hail our breakthroughs and achievements. We've got a lot of good news to spread. I'm all ears.

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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So now you can cut something from your design: PALs and GALs. Because our Classic parts give you a combination of speed, density and flexibility you won't find in other PLDs.

All of which helps you cut the time it takes to produce a superior design.

For example, our 20-pin, 8-macrocell EP330 is the perfect replacement for over 20 types of PALs and GALs. It stretches counter frequencies to 125 MHz while sipping one-fourth the power of a standard PAL. And its quiet output switching circuitry allows the EP330 to run faster in-system than a 10ns 16V8.

Our 24-pin, 16-macrocell EP610 delivers 60% more logic density than a 22V10. And unlike a 22V10, the 15ns EP610 consumes a mere 20μA in standby. And its registers
can be programmed for D-, T-, JK- or SR-operation or for asynchronous clocks.

To replace multiple PALs and GALs with a single chip, try our 44-pin EP910 or 68-pin EP1810. Both offer superior logic density and greater I/O at a lower cost than any other mid-range CMOS PLD.

Our Classic EPLD family also helps you get to market faster. Thanks to a host of powerful logic development tools from Altera and third parties.

What's more, we offer the industry's broadest, most flexible line of CMOS PLDs. With devices ranging from 20 to 100 pins, and logic densities from 8 to 192 macrocells, there's an EPLD for every logic design task.

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Bring the Modulation Domain designing on a higher level.
to your lab and start

These days, designers face problems that require a level of understanding beyond the scope of conventional measurement techniques. The Modulation Domain can give you that level of understanding. With a new dimension in signal measurement that makes it possible to analyze frequency, time-interval, and phase over continuous time. And now, HP brings the Modulation Domain to your lab with high-performance analyzers that give you insight into your designs you’ve never had before.

The HP 53310A streamlines Modulation Domain analysis with a simplified user interface, one-button signal acquisition and real-time measurements for fine-tuning your designs. It gives you continuous frequency and time-interval measurements for analyzing modulations in RF and microwave signals. Characterizing VCOs, phase-locked loops, and electromechanical devices. Locating sources of jitter. And much more.

The HP 5372A is ideal for gathering in-depth Modulation Domain information in single-shot events. In addition to frequency and time-interval measurements, it also displays phase over continuous time. And analyzes even the most complex signals with incredible detail.

Find out how to take your design skills to new heights. Call 1-800-752-0900. Ask for Ext. 1852, and we will send you a Visitor's Guide to the Modulation Domain on floppy disk. That way, you’ll be up on all the latest developments.

There is a better way.
Goes great
If you've been following the developments in high-density multichip modules, you know the great promise that lies there.

If you've been leading the developments, however, you know the great problem that lies there.

Namely, the search for a polymer dielectric that can make multichip modules truly practical.

For which reason we are pleased to introduce you to new bisbenzocyclobutenes (BCBs) from Dow.

BCBs offer big advantages over the polyimides you may have been experimenting with. To start, they simply perform better—by about 50%. And in the process, they simplify manufacturing and lower your overall costs.

**CHIPS WITHOUT RIDGES.**

Where does BCB's advantage come from?

For one thing, from its extremely low dielectric constant. In general, you can get away with layers 25% thinner than you'd need with polyimides. This means higher density and, therefore, higher performance.

You also get much better leveling than with polyimides. BCB planarizes more than 90%, compared with the 30% or less typical of polyimides. This nearly ridgeless surface reduces crosstalk and improves etching as well.

And BCB can take the heat, literally. It shows great thermal stability at curing temperatures. This, together with its naturally low modulus, gives you a finished module created with less stress than one made with most polyimides.

**NO MORE SOGGY CHIPS.**

Water, a byproduct of the polyimide curing process, is the enemy of the multichip module. It complicates manufacturing and robs polymers of their dielectric appeal.

BCB, on the other hand, produces no water. So there's no need for additional drying during manufacture. And since it vigilantly resists moisture (absorbing just 0.25% of its weight after 24 hours at 100°C), the dielectric properties you design in, stay in.

BCB also offers excellent adhesion to aluminum, copper, silicon dioxide—and to itself.

So there's no need for the metal tie layers other dielectric materials require.

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All in all, this means you can manufacture high-density modules faster, with fewer rejects and, therefore, less expensively with BCB. And wind up with modules that perform far better than they would with polyimides.

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jOMEGA's harmonic-balance simulator gives you fast optimization of linear and nonlinear circuits with simultaneous access to circuit response in both time- and frequency-domains. And jOMEGA has advanced features, like manufacturing yield optimization and optional board layout, that let you make manufacturing tradeoffs during engineering design.

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Call Us Today, Let Us Show You How jOMEGA Can Make the Difference on Your Next RF Design!
We'd like to send you an informative product brochure which describes the many features of jOMEGA. Call us at (800) 624-8999, ext. 155. Or if you prefer, contact us by FAX at (818) 889-4159. In Europe, call (49) 8105-24005 or FAX (49) 8105-24000.

CIRCLE NO. 92
Flexible optical media boost data density

“Digital paper” is a write-once optical data-storage material that provides prodigious advantages, including:

- Far greater data density than any other medium
- Chemical stability that makes it immune to wide variations in ambient temperature and humidity
- An archival life of at least 15 years
- Extremely low cost to the user (one-half cent per megabyte).

The potential applications for digital-paper storage already number in the hundreds. The list of applications is starting to look more and more like a sci-fi description of a 22nd-century all-purpose material. So far, however, only two commercial manifestations have reached the production and marketing stages: write-once optical tape and small identification tags.

The small tags can hold more than 1000 bits of information in a space less than one square centimeter and can be read from a considerable distance. Current uses for such tags include identifying machine-tool bits and providing instructions for their use. You can also use similar tags to hold positioning data; mechanisms that employ these tags can identify the position of a moving part with an accuracy of ±1 µm relative to a previously established reference point.

The optical tape comes in two formats, one for 35-mm open-reel drives (1 terabyte per reel) and the other for half-inch IBM 3480-compatible cartridges (50G bytes per cartridge).

In addition, ICI Imagedata employed Bernoulli Optical Systems Corp (Boulder, CO) to perform a considerable amount of research and development work on Bernoulli-effect floppy-disk drives that employ digital paper as their storage medium. ICI Imagedata expects to license this technology to disk-drive manufacturers. If drive manufacturers fulfill ICI’s expectations, we may see 2-in. floppy disks—that hold 100M bytes per side—within a year or two.

The name “digital paper” was coined by the developing company, ICI Imagedata, a Wilmington, DE-based subsidiary of the British chemical firm, Imperial Chemical Industries (ICI) Ltd. The name was intended to suggest that this data-storage medium could become a reliable electronic replacement for almost all archival paper and paper derivatives such as microfilm and microfiche. In practice, however, the name has proven highly confusing and misleading to potential users, who tend to associate the bulk, fragility, and erasability of wood-based paper with the name.

Al Conover, president and CEO of Lasertape Systems (which makes IBM 3480-compatible optical cartridge drives) prefers to call the material “digi-
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Digital-paper storage

tal optical tape" (DOT). His sales team finds that this name, by its similarity to the widely known DAT (digital audio tape), more forcibly suggests the high capacity and high performance inherent in the medium. Lasertape Systems has trademarked the new name and its abbreviation. However, they encourage any vendor of devices that employ the material to use both trademarked monikers (with suitable acknowledgement).

Physical characteristics

David Owen, development executive for storage products at ICI Imagedata, points out some of digital paper's technical advantages over other media. Some of these advantages hold good even in applications that currently use erasable rather than write-once optical media.

First, the high data density (200M bits/in.²) makes the medium attractive for applications in which space is at a premium. The high data density goes hand-in-hand with a high data-transfer rate (currently 3M bytes/sec, potentially upgradeable to 6M or even 12M bytes/sec) that allows fast searching—you can find any file within a 200M-byte space in less than 1 sec, and any file on a 50G-byte cartridge in less than 15 sec. For Creo's 1-terabyte open-reel drive, average access time is 28 sec, and worst-case access time is 60 sec.

Second, the flexibility of the medium makes it potentially usable in a startling variety of forms. You can cut the material into disks, strips, or tapes, as well as sheets, creditcards, security badges, and odd-shaped identification tags.

Third, the chemical stability maintains data integrity. By contrast, when you cut magnetic recording web into tapes, it's not always possible to maintain a perfect seal at the cut edges; such sealing defects in metal-particle tapes can greatly reduce data life. Humidity can start corrosion at the outer edge of an unsealed tape, and this corrosion can spread inward toward the center of the tape.

Wear is not an academic issue

Al Conover adds several other advantages of optical tape over magnetic tape. Wear on the DOT, for example, is minimal, mainly because reading and writing do not require physical contact between the head and the tape. Furthermore, in Lasertape's drives the active layer is on the outside of the tape and does not come into contact with rollers and guides. A low-friction coating over the active layer improves the physical flow of the tape by helping to reduce binding between layers on a reel.

Of course, you don’t have to worry about wear if you're using erasable or write-once magnetothermal media or magnetic hard disks (unless a head crash occurs). But if you're using magnetic tape storage, tape wear is by no means an academic issue—it's a serious problem in industrial-strength applications. For example, video rental companies are finding that significant picture deterioration starts to appear after a video tape's tenth rental, and the tape becomes almost unviewable after 15 to 20 rentals. Playing the tape on a variety of old and inadequately maintained machines both abrades the recording surface with dirt and corrupts the picture data with residual magnetic fields that are never degaussed. If the recording were on DOT, however, this deterioration would be eliminated.

As yet there are no VCR drives that can use DOT, but such drives will become a necessity for HDTV. Current VHS tapes could hold only about ten minutes of HDTV material, whereas currently available 50G-byte DOT cartridges could hold about eight hours of HDTV material. These cartridges certainly have the bandwidth needed for video recording, and they would be extremely resistant to the deterioration of magnetic tapes experienced by rental companies today.

The economics are attractive

By now you may be saying, "Sounds wonderful, but why should I switch to a new medium? What's it going to cost me? What about my old drives? Isn't there a catch somewhere?" The answers to these questions will depend on how much data you need to store.

If you need only a few hundred megabytes, then digital paper won't do much for you. If you need to store as much as a terabyte (10¹² bytes) of data at a time, then you're stuck with Creo's $225,000 35-mm optical tape recorder for the moment. Of course, if your application

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<th>Table 1—Lasertape Systems' digital optical tape</th>
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<td>Item</td>
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<tr>
<td>Capacity</td>
</tr>
<tr>
<td>Transfer rate</td>
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<tr>
<td>Average seek time</td>
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<td>50G bytes</td>
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<td>3M bytes/sec</td>
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<tr>
<td>600 m/sec (200M bytes)</td>
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<tr>
<td>15 sec (50G bytes)</td>
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<tr>
<td>&lt;10⁻¹² (corrected)</td>
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<td>19 x 8 in. rack mount</td>
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<td>SCSI-1 and SCSI-2</td>
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<td>Fully 3480 plug compatible</td>
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<tr>
<td>Autorloader for 10 cartridges</td>
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<tr>
<td>Drive: $25,000</td>
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<tr>
<td>Autorloader: $1500</td>
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EDN April 25, 1991
needs that much storage on a reel, the price shouldn't be any great shock to you.  
But if you need to store tens or a few hundreds of gigabytes, look seriously at Lasertape Systems’ DOT cartridge drives from three points of view: drive replacement costs; savings on media; and savings on the labor costs of mounting and dismounting magnetic cartridges.

There’s no question that a DOT drive costs more ($25,000) than the corresponding IBM 3480 magnetic cartridge drive ($15,000 to $20,000). But this difference may turn out to be smaller than it seems. Consider that a DOT cartridge drive is little more than a standard IBM 3480 drive with an optical read/write head instead of a magnetic head. Falling prices of laser diodes and Bragg cells (a component of the scanner) are likely to make the price difference negligible within a year or two.

DOT cartridge drives require no changes to the operating system or file system because the DOT drives, like IBM 3480 drives, employ the SCSI interface. Furthermore, DOT cartridges follow the 3480 standard for writing data—no catalogs, merely a series of variable-length records.

You can save as much as $3500 in media costs each time you use a DOT cartridge rather than a 3480 cartridge. A 200M-byte 3480 cartridge costs $5, whereas the DOT cartridge costs $250. But the DOT cartridge holds 50G bytes (250 times as much as the magnetic cartridge), so the cost per megabyte comes down from $0.025 to $0.005. If you completely fill your magnetic cartridges, one DOT cartridge will replace 250 3480 cartridges, and you’ll save $1000 and about three cubic feet of storage space. However, most users don’t fill every 3480 cartridge they store. So, one DOT cartridge may replace as many as 750 average 3480 cartridges—if you fill the DOT cartridge—saving you $3500 and about ten cubic feet of storage space.

Remember, too, that your application often may need to store large volumes of data without needing more than a few gigabytes on line. At these times, mounting and dismounting cartridges can become a labor-intensive—and hence, expensive—operation. Switching to DOT cartridges is likely to reduce the number of mounts and dismounts and therefore your running costs.

The banking industry is just one example of a high-volume user that needs to be able to access archived documents quickly. Banks capture images of checks digitally and then transfer the images to microfiche for archiving. The labor involved in transfer and storage is quite costly. Many such records are never looked at again, but when an image is required for verification, further considerable labor costs are entailed in retrieving it. Check-image storage could benefit from DOT technology.

Another banking application that could benefit is the overnight London-to-New York funds-transfer service. This service would like to log every transaction included in a transfer, but has found that present media do not have either the performance or the capacity to create such an on-the-fly log. Using standard data storage, transactions currently have to be recorded only upon reaching their final destination. DOT has both the capacity and the performance needed to create a complete log either at London or at the New York center where transactions are regrouped geographically for retransmission to the destination banks.

Likewise, many sites that handle medical records already have as many as 1 million IBM 3480 cartridges (200M bytes each), and the number is increasing daily. That makes for much mounting and handling. A switch to DOT could greatly reduce both media and handling costs at these sites.

What makes a DOT system inexpensive to purchase and run is that it’s an extension of well-understood 3840 technology. The substrate of DOT is identical to that of 3840 magnetic tape (see box, “How digital optical tape works”). In fact, except that optical cartridges are built to slightly tighter mechanical specs than magnetic cartridges, a standard 3480 drive has no way of telling whether magnetic or optical tape is loaded. In building their optical subsystems, Lasertape Systems could retrofit an optical head (which has no moving parts) to any IBM 3480-compatible drive.

Compatibility with the 3480 extends to the device interface. Effectively, the operating system (OS) uses a magnetic cartridge as a write-once medium; there are no catalogs or directories on the tape, and you cannot perform the record

<table>
<thead>
<tr>
<th>Table 2—Creo Products’ 1003 optical tape recorder</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>Capacity</td>
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<tr>
<td>Transfer rate</td>
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<td>Seek time</td>
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<tr>
<td>Bit error rate</td>
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<tr>
<td>Dimensions</td>
</tr>
<tr>
<td>Interfaces</td>
</tr>
<tr>
<td>Price</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Count On IDT

The R3001 RISCController™: The Embedded Processing Solution

The R3001 is the first derivative of the R3000 processor designed specifically for embedded control applications. Compared to the Intel 960 and AMD 29K processors, the R3001 is the most cost-effective solution for these applications—we have the data to prove it! Call and ask for KIT CODE 0091A to get an R3001 Performance Comparison Report.

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When cost-effective performance counts

IDT Integrated Device Technology, Inc.
How digital optical tape works

Digital optical tape (DOT), also known as digital paper, consists of four basic layers (Fig A):
- a substrate of Melinex polyester,
- a metallic reflecting layer,
- a dye-containing polymer layer,
- a protective overcoat.

It's worth noting here that the DOT substrate material is the same as the substrate material of the magnetic tape used in IBM 3480 cartridges. Hence, manufacturers can produce DOT tape using many of the standard methods. Not needing significantly altered production methods, DOT media costs shouldn't adversely affect the cost of DOT systems.

Writing to DOT

To write data to the DOT, the system turns a laser beam on or off. Unlike the ablative techniques of WORM drives, which burn holes in the metallic reflector, the DOT pyroplastic technique merely deforms the dye-polymer layer, producing a pit (Fig B). Because the dye-polymer layer is a very poor conductor of heat, the heat produced by the laser beam does not spread nearly as rapidly as it does when burning a WORM reflector layer, which is highly conductive. Thus, the heating effect of the laser is confined to a very small area of the DOT active layer.

As a result, the pits can be as small as 1 micron in diameter and have very sharp edges. Spacing between longitudinal tracks can be as small as 1.6 microns. The small pits with their steep edges produce very sharp transitions between pit and no-pit conditions and permit data to be written and read at rates as high as 3M bytes/sec. Conventional ablative WORM techniques cannot support such high data-transfer rates. In a WORM disk, losses due to absorption and scattering of the laser beam produce pits whose edges slope more gradually than those of a DOT system.

Reading from DOT

A DOT drive reads data from the tape by means of a low-power laser beam that cannot deform the active layer but can detect the presence or absence of a pit. In the absence of a pit, the distance between the top surface of the active layer and the bottom surface adjacent to the metallic reflector is a whole number of half wavelengths of the laser light. Thus, reflections from the top and bottom surfaces of the active layer reinforce each other. When the beam encounters a pit, however, the distance between top and bottom surfaces of the active layer is not a whole number of half wavelengths, so the reflected rays partially or completely cancel each other (Fig B).

The optical head

Lasertape Systems Inc and Creo Products Inc have taken different approaches to creating multiple tracks. Lasertape Systems, in the interests of robust miniaturization, uses a purely electronic scanner; the creation of 40 tracks on a 3480-compatible optical cartridge does not require any physical movement.
Fig C—A DOT tape scanner has no moving parts; the angle at which the beam emerges from the crystal depends on the radio frequency applied to the crystal via a transducer.

of the head. Instead, Lasertape's method shifts the laser beam by passing it through a crystal to which they have attached a transducer (Fig C). Applying a radio frequency of approximately 100 MHz to the transducer creates a supersonic flexing action in the crystal. The angle at which the laser beam emerges from the crystal varies with the precise frequency you apply to the transducer. This type of scanner is small enough to allow an optical head to be retrofitted to a standard 3480 drive. The drive records one track at a time in alternate directions for a total capacity of 50G bytes.

Creo did not have to contend with such rigid size constraints, and therefore adopted the scheme shown in Fig D. An array of laser diodes (one for each of the 32 tracks on the tape) send their beams into a collimator. The collimated beam is then positioned and focused on the tape track to be used. A slide running in an air bearing performs the positioning; a lens focuses the collimated beam. The optical encoder of the positioning mechanism turns on the appropriate diode in the laser-diode array. The slide also directs the reflected beam to the sensor associated with the current track. Again, there are 32 sensors in the sensor array (not shown in the diagram). The system writes 32 bits across the tape in one direction, then steps the tape and writes 32 bits in the other direction. Each physical record is 32 bits wide by 20,000 bits long, for a total of 80K bytes. An 880-meter reel of tape has a total capacity of 1 terabyte (1000 gigabytes).
Cheyenne™ 7130A

Set your sights on the highest capacity and performance available in an inch-high, 3.5-inch form factor disk drive. Maxtor's Cheyenne Series Model 7130A delivers peak specs including an unsurpassed 130MB of formatted storage.

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CIRCLE NO. 35

<table>
<thead>
<tr>
<th>3.5-Inch Disk Drive Comparison Criteria</th>
<th>Maxtor Cheyenne 7130A</th>
<th>Conner Model 30104</th>
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<tr>
<td>Capacity (formatted)</td>
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<td>Cache size</td>
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<tr>
<td>Seek time</td>
<td>15ms</td>
<td>19ms</td>
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<tr>
<td>MTBF</td>
<td>150,000 hours</td>
<td>40,000 hours</td>
</tr>
</tbody>
</table>

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305-477-2228
Wyle Laboratories
1-800-289-9953

EDN April 28, 1991

TECHNOLOGY UPDATE

Digital-paper storage

Digital-paper storage updates or random data replacement that characterize magnetic or erasable-optical disks. You erase everything in the cartridge only when all of that data can be discarded or has already been moved to some other medium. The OS expects to write and read only a series of variable-length records, using tracks in alternate directions. DOT systems fulfill all of these expectations. The only differences the OS must take into account are that each track of a DOT holds far more data, and a DOT has 40 tracks instead of the 18 of a standard magnetic cartridge.

A DOT cartridge is potentially erasable and reusable, although nobody has implemented the careful reheating that would be needed to remove the pyroplastic deformations (pits) from the dye-polymer layer.

Large-volume techniques

The Creo open-reel DOT recorder can store 1 terabyte (1000 gigabytes) on a 12-in. reel of 35-mm tape, which satisfies the requirements of most satellite data-logging applications.

But, if you've made the decision to go with Lasertape Systems' 50G-byte cartridges for the sake of compatibility and cost reduction, you may some day find your data requirements outgrowing your system. In that case, you can immediately expand your system by adding Lasertape Systems' $1500 auto-loader, which allows a single drive to handle ten cartridges for a total capacity of 500G bytes. If you're still under capacity, your existing controller will handle three more drives, each equipped with an auto-loader, yielding a total capacity of 2 terabytes for the four drives (40 cartridges).

And if you still don't have enough capacity (23 million ASCII pages on each of 40 cartridges), there are silo and ATL systems that can handle as much as 64 petabytes (1 petabyte is 10^15 bytes). That should accommodate all of your data and the 2050 AD edition of the Encyclopedia Galactica!

For more information . . .

For more information on the digital-paper products 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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119 Discovery Park
3700 Gilmore Way
Burnaby, BC V5G 4M1
Canada
(604) 437-6879
FAX (604) 437-9891
Circle No. 700

ICI Imagetdata
Concord Pike
Wilmington, DE 19897
(302) 886-8494
Circle No. 701

Lasertape Systems Inc
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Campbell, CA 95008
(408) 370-9064
FAX (408) 370-9120
Circle No. 702
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+5V IN/-5V OUT INVERTER
POWERS 100mA LOADS

MAX660 Plus 2 Capacitors Deliver 95% Efficiency

Using two low-cost capacitors, Maxim's new MAX660 charge-pump voltage inverter converts a 1.5V to 5.5V input to a -1.5V to -5.5V output. The charge pump's 100mA output replaces switching regulators, eliminating the need for inductors and their associated cost, size and EMI. For instance, with a 5V input, the MAX660 delivers 100mA at -4.35V. Compact 8-pin DIP and SOIC* packages coupled with a 95% power-conversion efficiency make the MAX660 ideal for battery-powered applications.

- Only 2 Capacitors, NO Inductors
- 10kHz and 45kHz Internal Oscillator
- Voltage Inverter Mode: \[ V_{OUT} = -V_{IN} \]
- Voltage Doubler Mode: \[ V_{OUT} = 2 \times V_{IN} \]
- 1.5V to 5.5V Input Voltage Range
- 200mA No-Load Supply Current
- Only $2.95†

Maxim's new MAX660 voltage inverter powers 100mA loads.

FREE DC-DC Converter/Power Supply Design Guide

Design Guide includes: 
- Application Notes
- Complete Data Sheets
- Free Samples

Simply circle the reader response number, contact your Maxim representative or Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086, (408) 737-7600, FAX (408) 737-7194.

* SOIC packages available after August, 1991
† FOB USA, 1000-up

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- On-Chip Track/Hold
- Easy-to-Drive (RIN < 500 MΩ) Inputs
- On-Chip Voltage Reference:
  - 40 ppm/°C Max Drift
- 100% Tested DC and Dynamic Specs
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- 60 µs Conversion Time
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Faster Upgrades for 7578/7582 at No Extra Cost

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FREE A/D Converter Design Guide

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CIRCLE NO. 94
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150Vp-p FAULT PROTECTION!

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- 1pC Charge Injection
- 4.5 mW Power Dissipation (±15V supplies)
- Single-Supply (+10V to +30V), or Dual-Supply
  (±5V to ±18V) Operation
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- Plug-in Upgrade of DG508/509 for only $4.70
  (1000-up)*

Fault Protection: MAX378-150V, DG508-0V!

The MAX378/379 provide ±75V of fault protection with supplies off, and ±60V with supplies on — the highest in the industry! Unlike other fault-protected multiplexers, both input and output pins are current limited to only nanamps under overvoltage conditions. This protects sensors, signal sources, ADCs, or other valuable circuitry from destruction.

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- 1.2 μA max Supply Current
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- Input Voltage Range Includes Neg Supply Rail
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The MAX406 maintains linearity under heavy load conditions and is capable of sourcing as much as 2 mA from a 9V battery. The output swings rail-to-rail while the input voltage range extends to the negative supply rail. The new device operates from voltages as low as 2.4V while maintaining widest input and output voltage ranges.

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Call your Maxim representative today for applications information, data sheets and samples. Or, write Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086, (408) 737-7600, FAX (408) 737-7194.  

* From 3V supplies

MAX406 VS. ALTERNATIVES

<table>
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<th>Device (TA = 25°C)</th>
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<th>VOS mV max</th>
<th>IB pA typ</th>
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<td>NO</td>
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</tbody>
</table>


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EDN April 25, 1991 CIRCLE NO. 96
Sony's family of 1-Meg SRAMs gets larger and larger all the time.

Our newest additions will include an industrial-grade temperature range, synchronous ASM (Application Specific Memory), and a low, 3-volt power requirement.

We've also adopted all of the industry's most popular package styles, making our family more compatible with all of your PCB designs.

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THE IEEE-488.2 STANDARD

IEEE-488.2 products are just now appearing

When first adopted in 1975, the IEEE-488 (GPIB) standard brought order to the chaotic instrumentation world. Prior to this standard's appearance, an army of incompatible instrument-interface schemes made test-system design a nightmare.

The present roster lists thousands of instruments and instruments with GPIB ports. This adherence to the standard aids the assembly of "rack-and-stack" instrumentation systems, but the unique command sets, syntax requirements, and data structures employed by the many products still give test-system programmers headaches.

The IEEE-488.2 standard, adopted in 1987, attempts to resolve many of the remaining problems. Products designed before this standard arrived obviously don't offer its capabilities, but newer products that do have IEEE-488.2 features give you a taste of the future.

First, you should understand that the IEEE-488.2 standard augments the original IEEE-488 spec and does not replace it. To signify the coexistent nature of the two specs, the IEEE changed the number of the original standard to IEEE 488.1. That standard specified the electrical and mechanical characteristics of the interface. It also introduced the concept of talkers, listeners, and controllers. Talkers place data on the bus; listeners consume that data; and controllers assign the roles of talker and listener to the instruments connected to the bus. One IEEE-488 bus accommodates as many as 15 devices.

The IEEE-488 standard also specified the byte-level handshake mechanism and defined the bus-control mechanisms. In the interest of maximizing flexibility, the standard's creators intentionally did not specify message protocols and loosely stipulated that data be transmitted using any "standard" alphanumeric, binary, or BCD code. The IEEE-488 spec did not further define what these standard codes might be. In addition, the creators loosely defined the IEEE-488 standard's method for polling the status of an instrument requesting service over the bus.
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The IEEE-488.2 standard

The flexibility permitted by the original IEEE-488 standard did indeed encourage innovative instrument design. In fact, vendors innovated in nearly every direction. Although all of the resulting products communicated over the IEEE-488 bus, every instrument seemed to speak a different dialect. The resulting cacophony created the test engineer's equivalent of the Tower of Babel. Engineers producing test programs had to employ different software handlers for each new instrument. Thus, the original IEEE-488 standard made the job of physically connecting instruments to controllers much easier but did little though all of the resulting products activated in nearly every direction. As a result, every instrument saw the same bus usage by developing additional standards. Their work culminated in the IEEE-488.2 spec, which the IEEE adopted in 1987. The IEEE-488.2 standard specifies codes, data formats, message protocols, and common commands to address some of the software-related problems encountered by users of diverse products incorporating the IEEE-488 bus.

The new standard also requires the complying product to have a minimum set of capabilities, including the ability to both talk and listen. The standard adds rigor to the design of complying equipment but does not require vendors to adopt the IEEE-488.2 specification; they can continue to use just the IEEE-488.1 spec.

One of the key components of the IEEE-488.2 standard deals with the possibility that instruments conforming only to IEEE-488.1 might be mixed with IEEE-488.2-compliant equipment on one bus. The IEEE-488.2 spec introduces the ideas of "precise talking" and "forgiving listening" to accommodate such mixed systems.

Talk precisely

Precise talking restricts the way an IEEE-488.2-compliant instrument can generate messages. For example, a data message containing a reading expressed as a floating-point number must always be transmitted as a floating-point number, not as another number type. Thus a 1V floating-point reading may be sent as the string "+1.000E+0" or "+1.0E+0" but not as "1" which is an integer or "1.0" which is a fixed-point value. Precise talking simplifies test software because your program need only accept floating-point numbers if that is all it expects. However, you must remember that equipment conforming only to the older spec may generate messages in any format. If you are working with a mix of old and new instruments, you must still write smarter code to cover all cases.

Forgiving listening is the opposite of precise talking. A piece of IEEE-488.2-compliant equipment must accept messages in any legal numeric format. A forgiving listener will accept and correctly evaluate a 1V reading expressed as "1" (an integer), "1.00" (a fixed-point value), or "+1.00E+0" (a floating-point number). This requirement excuses you from having to precisely format commands you send to IEEE-488.2-compliant equipment. Once again however, you'll need to be more careful when writing programs for mixtures of old and new equipment. Older listeners aren't always so forgiving.

In conjunction with forgiving listening and precise talking, the IEEE-488.2 standard specifies several message formats. Text messages use the 7-bit ASCII code, binary blocks are sent most-significant byte first, and binary floating-point numbers employ the IEEE-754-1985 standard format. The IEEE-488.2 standard also contains...
precise definitions for integers, fixed-point numbers, and floating-point numbers expressed as ASCII strings.

Common commands unify

The IEEE-488.2 standard's designers also provided more ways to exert control over equipment on the bus through a set of common commands. Some of these commands are required in all devices, some are optional, and some are required only if the device has certain features such as the ability to respond to a parallel poll on the bus. All of the common commands must start with an asterisk, whereas the standard forbids device-dependent commands to use an asterisk as the leading character. A list of these common commands appears in Table 1.

The common commands do not control measurements. Instead, they manage the operation of an instrument. Internal-operation commands standardize the way you instruct an instrument to perform a calibration cycle, execute a self-test program, reset to a known state, or learn a setup. Synchronization commands allow you to control the sequence of operations in an instrument. Device-trigger commands define a sequence of events that will occur when the instrument receives an IEEE-488.1 group-execute-trigger (GET) command. (The GET command is a way to activate several instruments simultaneously.)

An optional autoconfigure command group allows a controller to detect instruments on the bus and assign them a bus address. Currently, most IEEE-488 equipment employs DIP switches on a back panel to set this address. Using the autoconfigure commands, a system can theoretically configure itself when powered up and can automatically adapt to newly added equipment. Because the autoconfigure feature is optional, and because you can mix IEEE-488.2-compliant and older equipment on the same bus, you may find this new feature somewhat useless now. It does, however, seem to have a useful future.

Standardizing requests

The IEEE-488.2 standard's status and event commands give a test program far more control over an instrument's use of the IEEE-488 bus' service request (SRQ). The SRQ line allows an instrument to request service over the bus asynchronously. The SRQ is the IEEE-488 bus' interrupt. Many existing instruments allow the system programmer to define events that may cause such an interrupt, but IEEE-488.1 doesn't specify how. Consequently, use of the IEEE-488.1 standard's service request varies from instrument to instrument. The IEEE-488.2 standard specifies an extended-status model and the status-and-event command group that at least make an attempt to
The ADC-00145 is a 14-bit resolution, 200nsec update rate (5MHz) track/hold and A/D converter hybrid in a 40 pin TDIP package. Containing T/H, A/D, data registers, tri-state output buffers, timing circuits, and precision references, the ADC-00145 is the fastest and smallest digitizer of its kind. The ADC-00145 operates over a temperature range of -55°C to +125°C with military processing available. The hybrid gives very high performance (75dB signal-to-noise ratio and 78dB harmonics) with a low power dissipation of 2.9W.

The ADC-00145 uses a two-step A/D conversion algorithm. The application of a pulse to the Encode Command pin initiates the conversion cycle. The track/hold samples and stores the analog input, then a flash ADC generates a coarse encode of the sampled voltage and stores its 8 bits in the MSB register. At the same time a high-speed DAC and amplifier converts the 8 bits to an analog voltage, and subtracts it from the original input. Next, the flash ADC generates a fine encode of the subtracted voltage and stores these 8 bits in the LSB register. Digital error correction combines coarse and fine data to yield a 14-bit output. This process is repeatable at a 5MHz rate.

Many factors contributed to achieving the ADC-00145’s technical breakthroughs in speed, size, and power. Foremost among them were the high-speed T/H, DAC, and the gain amplifier; all are DDC proprietary designs and single custom monolithics. In addition, judicious use of thin- and thick-film hybrid technology resulted in minimum layout area.

With its high speed, small package, and wide operating temperature range, the ADC-00145 is ideal for the most demanding military and industrial data conversion applications. Typical applications are radar, infrared, and sonar digitizing, medical and nuclear instrumentation, and high-speed data-acquisition systems.

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The IEEE-488.2 standard standardize this capability. For detailed information regarding the IEEE-488.2 standard's status mechanisms (Ref 1).

You may not be surprised to discover that all of these marvelous new features have not caused a stampede. Instrument vendors have shown an understandable reluctance to change the designs of products that already work well existing systems. Nevertheless, you will find that new IEEE-488 equipment often complies with the IEEE-488.2 spec.

The most visible type of the new, compliant products is the IEEE-488 controller card. In this crowded and hotly-contested market, vendors constantly seek ways to outdistance the competition, and compliance with the IEEE-488.2 standard is certainly one way to leapfrog ahead. However, you must scrutinize a controller card's conformance with the IEEE-488.2 spec because you may not be getting all that you expect. The standard lists several optional features, and not all features are offered by all controller cards.

Table 2 lists several representative IEEE-488 controller cards that support the IEEE-488.2 standard. With the exception of National Instruments, all of the card vendors use either the 7210 controller chip from NEC (Mountain View, CA) or the 9914A from Texas Instruments (Dallas, TX).

IC remedies flaws
National Instruments developed its own controller chip, the NAT4882, to alleviate what the company claims are problems and deficiencies with the other controller ICs. The one clear deficiency of NEC’s 7210 is that it provides no way to sense the state of the SRQ line, and the IEEE-488.2 standard requires this sensing capability. Vendors that use NEC’s 7210 for IEEE-488.2-compliant controller cards provide an alternate mechanism for sensing the SRQ line’s state. The Texas Instruments 9914A does not use the IEEE-488.2 standard’s preferred mechanism for requesting service via the SRQ line, although it does use a method allowed by the spec. The NAT4882 uses the preferred method of requesting service in both the 7210 and 9914 emulation modes.

Because the hardware differences caused by the IEEE-488.2 are slight, you need to make few modifications to an IEEE-488 controller.
TECHNOLOGY UPDATE

card to achieve compliance. To create compliant products, vendors have altered the software for these controller cards, but the changes are largely invisible. If you look at data sheets for the controller cards listed in Table 2, you'll find few specific software features that support the IEEE-488.2 requirements. Again, that's because the IEEE-488.2 spec augments and fills in the details of the IEEE-488.1 standard instead of replacing it.

The biggest changes made by the IEEE-488.2 standard occur in the test-equipment firmware and test-system software. The common commands added by the IEEE-488.2 standard are just text strings sent using mechanisms established in the IEEE-488.1 standard. Further, the extended status- and event-reporting model created by the IEEE-488.2 spec is controlled and interrogated using these common command strings. Consequently, the changes made to the controller-board software are largely invisible.

Software hasn't changed

This transparency allows you to use existing software for test-system program development. For example, TransEra claims that its HT Basic language packages need no changes to be compatible with the IEEE-488.2 spec. The company's language products run on DOS-based PCs and include I/O drivers for most of the IEEE-488 controller cards listed in Table 2. HT Basic emulates HP Basic (formerly called Rocky Mountain Basic). Hewlett-Packard supplies HP Basic with its 82300C and 82324A Measurement Coprocessor boards. HT Basic runs on the PC's processor and costs $625 to $925. HP Basic runs on the 68000-family µP residing on the Measurement Coprocessor board and is part of the product. Like TransEra, Hewlett-Packard says it has made no changes to HP Basic relating to the IEEE-488.2 standard.

You'll find most of the changes wrought by the IEEE-488.2 standard in the newest test equipment. For example, Hewlett-Packard's $11,300 1652B logic analyzer, introduced in 1990, complies with the IEEE-488.2 specifications. The product combines a 100-MHz, 80-channel logic analyzer with a 400M samples/sec, 2-channel digital sampling oscilloscope. As an instrument with a large number of functions and capabilities, the 1652B makes

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- Future Domain SCSI
- Bi-directional PS/2 Printer Port
- 2 Serial Ports - Up to 115K Baud
- Future Domain SCSI
- IDE Interface
- Floppy Interface
- VGA/Flat Panel Interface
- Double Sided
- Manufactured In-House (U.S.A.)
- Landmark V1.14
- Speed at 20MHz

<table>
<thead>
<tr>
<th>COMPARE FUNCTION</th>
<th>DTI CAT 970 386SX</th>
<th>Competitor 1 386SX</th>
<th>Competitor 2 386SX</th>
</tr>
</thead>
<tbody>
<tr>
<td>16, 20MHz CPU - Shipping Now!</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Up to 16M RAM Onboard</td>
<td>✔</td>
<td>Up to 4Mb</td>
<td>Up to 5Mb</td>
</tr>
<tr>
<td>Noise Reduction Circuitry For FCC Class B</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>PS/2 Mouse Support</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Keyboard Support</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>On-Board Battery Real Time Clock</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Bi-directional PS/2 Printer Port</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2 Serial Ports - Up to 115K Baud</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Future Domain SCSI</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>IDE Interface</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Floppy Interface</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>VGA/Flat Panel Interface</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Double Sided</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Manufactured In-House (U.S.A.)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Landmark V1.14</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Speed at 20MHz</td>
<td>25.6</td>
<td>25.6</td>
<td>25.6</td>
</tr>
</tbody>
</table>

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### Table 2—Representative controller cards for IEEE-488.2 systems

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product</th>
<th>Host Bus</th>
<th>Maximum transfer rate (bytes/sec) (See Note)</th>
<th>IEEE-488 software interface</th>
<th>Price</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Equipment Corp</td>
<td>Max488</td>
<td>Apple Macintosh II</td>
<td>&gt;650,000</td>
<td>Language extensions and subroutines for Quickbasic, Turbo Pascal, C, and Hypertalk</td>
<td>$450</td>
<td>Package includes Hyper-card interactive test stack.</td>
</tr>
<tr>
<td>PC &lt; 488</td>
<td>IBM PC</td>
<td></td>
<td>350,000</td>
<td>DOS device driver and language extensions for Basic, Quickbasic, Turbo Pascal, C, and Fortran</td>
<td>$450</td>
<td>Package includes interactive test program, printer/plotter redirector.</td>
</tr>
<tr>
<td>PS &lt; 488</td>
<td>IBM Microchannel (short card, fits IBM P70)</td>
<td></td>
<td>320,000</td>
<td>DOS device driver and language extensions for Basic, Quickbasic, Turbo Pascal, C, and Fortran</td>
<td>$450</td>
<td>Package includes interactive test program, printer/plotter redirector.</td>
</tr>
<tr>
<td>Hewlett-Packard Co</td>
<td>82300C</td>
<td>IBM PC/AT</td>
<td>110,000</td>
<td>HP Basic</td>
<td>$1695</td>
<td>Software runs on an on-board 68000 auxiliary processor.</td>
</tr>
<tr>
<td></td>
<td>82324A</td>
<td>IBM PC/AT</td>
<td>350,000</td>
<td>HP Basic</td>
<td>$2795</td>
<td>Software runs on an on-board 68030 auxiliary processor.</td>
</tr>
<tr>
<td></td>
<td>82335A</td>
<td>IBM PC/AT</td>
<td>205,000</td>
<td>Command libraries for Vectra Basic, GW Basic, Quickbasic, Compiled Basic, Pascal, C, Quick C, Turbo C, and Turbo C++</td>
<td>$525</td>
<td>Package includes printer/plotter redirector.</td>
</tr>
<tr>
<td>Iotech</td>
<td>Personal 488plus</td>
<td>IBM PC/AT</td>
<td>300,000</td>
<td>DOS device driver and subroutines for Basic, C, and Pascal</td>
<td>$395</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personal 488/2plus</td>
<td>IBM Microchannel</td>
<td>300,000</td>
<td>DOS device driver and subroutines for Basic, C, and Pascal</td>
<td>$495</td>
<td>Board has a 40-line digital I/O port.</td>
</tr>
<tr>
<td></td>
<td>Power 488</td>
<td>IBM PC/AT</td>
<td>1,000,000</td>
<td>DOS device driver and subroutines for Basic, C, and Pascal</td>
<td>$495</td>
<td>Board has a 40-line digital I/O port and five 16-bit timers.</td>
</tr>
<tr>
<td></td>
<td>Power 488CT</td>
<td>IBM PC/AT</td>
<td>1,000,000</td>
<td>DOS device driver, subroutines for Basic, C, and Pascal</td>
<td>$595</td>
<td></td>
</tr>
<tr>
<td>National Instruments</td>
<td>GD-GPIB</td>
<td>Grid System 1500</td>
<td>400,000</td>
<td>DOS device driver or Microsoft Windows dynamic-link library. Interfaces for several programming languages also offered.</td>
<td>$695</td>
<td>Package includes interactive bus-control program.</td>
</tr>
<tr>
<td></td>
<td>GPIB-PCII/IIA</td>
<td>IBM PC</td>
<td>&gt;400,000</td>
<td>DOS device driver or Microsoft Windows dynamic-link library. Interfaces for several programming languages also offered.</td>
<td>$395</td>
<td>Package includes interactive bus-control program.</td>
</tr>
<tr>
<td></td>
<td>GPIB-SE/30</td>
<td>Apple Macintosh SE/30</td>
<td>1,000,000</td>
<td>Device manager calls and interfaces for Quickbasic, Think C, MPW C, and Hypertalk</td>
<td>$495</td>
<td>Package includes interactive bus-control program.</td>
</tr>
<tr>
<td></td>
<td>GPIB-SPARC1-B</td>
<td>Sun Sbus</td>
<td>1,000,000</td>
<td>Multitasking software driver</td>
<td>$995</td>
<td>Package includes interactive bus-control program.</td>
</tr>
<tr>
<td></td>
<td>GPIB-98 Turbo</td>
<td>NEC PC-9801</td>
<td>1,000,000</td>
<td>DOS device driver or Microsoft Windows dynamic-link library. Interfaces for several programming languages also offered</td>
<td>¥117,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LC-GPIB</td>
<td>Apple Macintosh LC</td>
<td>1,000,000</td>
<td>Device manager calls and interfaces for Quickbasic, Think C, MPW C, and Hypertalk</td>
<td>$495</td>
<td>Available with 68882 floating-point unit for $745.</td>
</tr>
<tr>
<td></td>
<td>MC-GPIB</td>
<td>IBM Microchannel</td>
<td>1,000,000</td>
<td>DOS device driver, Microsoft Windows dynamic-link library, OS/2 driver, Unix driver. Interfaces for several programming languages also offered.</td>
<td>$495</td>
<td>Package includes interactive bus-control program.</td>
</tr>
<tr>
<td></td>
<td>NB-GPIB</td>
<td>Apple Macintosh II</td>
<td>800,000</td>
<td>Device manager calls and interfaces for Quickbasic, Think C, MPW C, and Hypertalk</td>
<td>$495</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VXIpc-030</td>
<td>VXI</td>
<td>1,000,000</td>
<td>Device manager calls and interfaces for Quickbasic, Think C, MPW C, and Hypertalk</td>
<td>$14,800</td>
<td>An Apple Macintosh SE/30 on a VXI card with an IEEE-488 interface port.</td>
</tr>
<tr>
<td></td>
<td>VXIpc-386</td>
<td>VXI</td>
<td>1,000,000</td>
<td>DOS device driver</td>
<td>$9000</td>
<td>An 80386-based PC on a VXI card with an IEEE-488 interface port.</td>
</tr>
</tbody>
</table>

**Note:** Actual transfer rates depend more on the host bus and the software than the interface card. The absolute maximum transfer rate over the IEEE-488 bus is 1M bytes/sec. Actual performance can be less than the maximum.
The IEEE-488.2 standard

a good candidate for the IEEE-488.2 standard's abilities. The 1652B's status register follows the standard's guidelines and it understands the required common commands.

If you need to create IEEE-488.2 test systems, you'll be happy to know the necessary controller boards and software already exist. As time passes, the growing number of instruments that comply with the IEEE-488.2 spec will allow your test programs to become somewhat less complex. When all the instruments in your system understand the IEEE-488.2 common commands, you will be able to create standard routines to manage much of the test-system's overhead. However, until you can equip an entire system with IEEE-488.2-compliant instruments, your programming job really won't be any easier than it has been. Even one exception to the IEEE-488.2 rules forces you to create unique software for the nonconforming instrument.

Reference


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But it's not magic—this transition requires much labor. Exchange and terminal equipment must synchronize with intermediate circuits—a critical task requiring transformers that can transmit pulse signals with start-up and transient response characteristics.

The Challenge of Miniaturization
Another major challenge is miniaturization: along with outstanding performance, the DC-DC converters and AC-DC isolation chokes used in communications equipment must offer thinner, more compact configurations.

An Unsurpassed Lineup Of Surface Mount Transformers
Tokin offers the most exceptional line of surface mount transformers available—from high density mounting to low height installations, DC-DC converters, and pulse transformers. We match our customers' needs with the finest materials, most innovative designs and the most appropriate magnetic circuits. A strategy that ensures the best transformer technology available.

Give us a call and see what Tokin can do for you.

Features
- Thin, compact configurations are ideal for high-density mounting
- Flawless magnetic circuit designs offer high-inductance properties
- Multi-terminal configuration enables discrete circuit applications
- Convenient for automatic mounting with robots or other machines

Applications
- DC-DC converters, pulse transformers, and a wide range of ISDN response and communications equipment

<table>
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<th>Shapes and Dimensions</th>
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CIRCLE NO. 88

EDN April 25, 1991
Each StakPAC output is factory configured utilizing Vicor's robotically manufactured power converters...VI-200 series modules. Consider the advantages of a StakPAC customized for your system needs with automated power modules:

USER DEFINABLE OUTPUTS—The use of proven standard catalog modules offers the features of a custom without the associated risk or investment.

STANDARD MODELS—Many preconfigured standards available.

QUICK DELIVERY—Typical delivery 1 week or less for custom or standard evaluation units.

COMPACTNESS—Low profile packages provide up to 6 watts/cubic inch, twice the industry norm.

UL, CSA, TUV SAFETY AGENCY APPROVAL—All StakPAC configurations are approved, standard or custom.

EMI—FCC/VDE Level A, conducted.

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For technical information contact Westcor at (408) 395-7050 or FAX (408) 395-1518 or call Vicor.

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23 Frontage Road
Andover, MA 01810
AUTOMATION CONTROLS

From Parker, the leading producer of motion control components and systems for industrial markets

Innovative Positioning Systems Combine Daedal Tables and Compumotor Controls

Daedal Division is the most recent addition to the growing Parker Hannifin motion control group. Daedal specializes in the manufacture of custom positioning systems as well as standard components including ball slides, stages, and motorized linear and rotary tables. Together, Compumotor and Daedal provide complete solutions. With fully compatible components from machine controllers, drives and motors to mechanical positioning tables and feedback systems, each system is manufactured, tested and shipped from a single supplier. The net result is an integrated system, tailored precisely to the demands of a specific application.

Feed-to-Length Application Solutions

"Everything has been thought of before, the problem is to think of it again."—Johann W. von Goethe.

Each machine design requirement may be unique, but most can be characterized within a basic application category. At Compumotor, our focus is to prevent 're-inventing the wheel.' One such application category, involves the repeated feed of material a specific distance to a stationary position, followed by some other process. Examples include: Thermoforming for tire rubber or plastic film; Labeling/cutting of optical fibers, paper or plastic bags; Drilling; Milling; Bending; Stamping; Core Cutting; and Indexing for a variety of industries.

Compumotor has been providing tailor-made, high performance motion control solutions for more than ten years. With contributions from industry experts, Compumotor has compiled this expertise into a Feed-to-Length Application Handbook to help machine designers and engineers make informed decisions about their applications—to improve machine flexibility and productivity. This reference provides information on important application considerations and insight to application solutions. For a copy of this handbook, contact your local Compumotor Automation Technology Center.

An automated system for testing bar-code scanners, from Hewlett Packard, combines Compumotor and Daedal technology.

Supply of Material
Material Feed Process
Finished Material Handling

Parker
Dispensing Excellence—Four Axis Motorized Syringe

A unique process requires a metering/dispensing system to apply highly volatile liquid catalysts to a new product. The first catalyst must be applied in a touching off manner from a syringe; the second requires dispensing of 0.3 microliter volumes in a circular path. Inaccurate mechanics and human error in the existing design resulted in liquid flashing and low yields.

Daedal and Compumotor combined efforts to meet system requirements. Daedal tables surpass the customer's specifications for accuracy and repeatability at 0.0001 inches. This, coupled with extremely smooth motion of the Daedal tables, prevent liquid flashing. The transverse cross roller table carrying the X-Y-Z positioning system provides excellent rigidity and stiffness to the syringe needle motion.

Compumotor's Model 4000 provides a self-contained control for all four axes of motion including the circular interpolation capability. An encoder option on the motor verifies position and provides stall detection.

Motion Requirements
- Multi-axis controller—4 axis control of syringe motion
- Contouring—Circular dispensing paths
- High accuracy lead screw stages—Syringe placement to 0.0001 inches
- Microstepping motor resolution—Smooth dispensing of .3 micro-liter liquid volumes
- Incremental encoder feedback—Ensure position integrity and stall detection

Products Used
- Indexer—Compumotor Model 4000
- Motor/Drives—Compumotor S57-102-E (4)
- X/Y/Z motorized positioning system—Daedal Ball-Bearing Linear Tables
- Transversing positioning system—Daedal 4" Cross Roller Table

Checkered Flag for High-Speed Feed-to-Length

Problem: A machine manufacturer for the paper, film and foil industry was challenged with an application in which labels were to be printed and cut at high speeds. The design in use had a geared servo motor and drive attached to nip rollers for the material feed. Printing and cutting operations were activated with the feed rollers at rest. This design had unacceptable end-of-move overshoot when throughput requirements were increased. A new design required lower settling times, improved accuracies and adjusting for label shrinkage through the use of registration marks.

Solution: The Dynaserv Direct Drive motor from Compumotor replaces the servo system and its inaccurate mechanical transmission. Directly attached to the feed nip rollers, the Dynaserv provides true servo positioning without harmful backlash. The internal construction of the Dynaserv compensates for the large feed roll inertias better than other motor technologies. These advantages provide the printing operation with a compact solution for high press speeds with minimal end-of-move overshoot.

The Model 500 Indexer provides command signals to the Dynaserv, and I/O interface to the printing and cutting operations. Material feed distances are fully adjustable, and determined by the registration mark on the label. Operator interface is simple thumbwheel input of press speed and feed distance. Nonvolatile storage of the 500 Indexer's command program provides cost-effective stand-alone press control.
The Dynaserv, a direct drive servo from Compumotor, is a natural replacement for index table applications.

Index tables—commonly used in industries such as machine tool, cellular manufacturing, welding and large inertia positioning—require accurate rotary positioning while supporting a large load. Mechanical indexing tables requiring gears and cams to produce the desired motion are typically used for these applications. Gears introduce backlash, frictional inaccuracies, and greatly reduced cycle time. The internal clutch of a mechanical table is noisy and subject to wear. In addition, specific cam curves must be ordered for each table required. This adds set-up time and cost, especially if many different tables are needed.

The Dynaserv features a high torque to motor size ratio with stability at all speeds. 1,024,000 step/rev controlled to one step is achievable. A flat speed-torque curve provides greater controllability—with smooth rotation across the system's full dynamic speed range. Because the unit is gearless, faster settling time is realized. This serves to increase productivity, and creates a virtually maintenance-free unit.

The ZXF Servo System from Compumotor incorporates a full-functioned velocity and position follower with a digital signal processor-based servo drive in a cost effective package. The ZXF is ideally suited to improve performance in positioning applications such as thermoforming, packaging, labels, tire making, pick and place, automated assembly, winding and stamping. Encoder following capabilities allow the ZXF to be applied in processes requiring operations between separate operations. Features include:

- Velocity and position following
- Recede and advance while following
- Registration while following
- Following a pulse and direction or quadrature encoder signal
- Following data entry through external thumbwheels or RS232 terminal

Programming is easy with Compumotor's powerful and standard extended X-programming language.

Circle 305

Follow with the Leader

The ZXF Servo System from Compumotor incorporates a full-functioned velocity and position follower with a digital signal processor-based servo drive in a cost effective package. The ZXF is ideally suited to improve performance in positioning applications such as thermoforming, packaging, labels, tire making, pick and place, automated assembly, winding and stamping. Encoder following capabilities allow the ZXF to be applied in processes requiring operations between separate operations. Features include:

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- Following a pulse and direction or quadrature encoder signal
- Following data entry through external thumbwheels or RS232 terminal

Programming is easy with Compumotor's powerful and standard extended X-programming language.

Circle 305

Daedal offers a variety of metric products for increased systems compatibility, especially in the European and Pacific Rim markets. All components are manufactured to meet current metric standards for both industrial and scientific applications. The new Daedal metric engineering guide highlights these products, most of which are in stock and ready to deliver. The guide features: Manual positioners including ball slides, 1-3 axis linear stages, rotary stages, manual and digital micrometers. Motorized positioning table selection includes ball bearing linear tables, open frame tables, rail tables, cross roller tables and rotary tables.

Tables are available in standard and precision grades, and in single and multiple axis configurations. Travel lengths to 3050 mm (rail table) and payloads to 130 kg are available with life ratings in excess of 2.5 million meters. Rotary tables are available in diameters to 300 mm and loads to 90 kg.

Other points of interest: Daedal stocks more than 1,500 leadscrews and ball screws to tailor table performance to specific applications. Positioning tables and controls are integrated and tested as complete systems.

When your components and systems must measure up, look to Daedal for solutions.

Circle 306

This bag-maker takes advantage of the accuracy and repeatability of the ZXF Servo System.
A company whose business it is to test and judge quality, demands high standards for equipment—it’s their job. Daedal accepted a positioning challenge for one such company, Ultran, in State College, Pennsylvania.

In ultrasonic non-destructive materials testing, an Ultran NDC 7000 Imaging System looks for defects in materials without damaging them. The system requires fine resolution, extreme rigidity, and straight-line accuracy. And because a variety of sizes and weights of material are tested, flexibility in test-equipment configurations is essential.

Daedal worked with Ultran to establish a system that met requirements of existing applications. And flexibility was built in at the onset so Ultran’s system can grow with changing needs. The Ultran imaging system is stored on CAD disk and application alterations can be recalled and designed quickly, avoiding the time and talent needed for redesign.

In the new system, square rails replaced ball bushing rods, contributing greater rigidity and support throughout the full length of travel. The square rail table construction is ideal for the varying travel lengths and often heavy payloads of this application. Constructed with efficient, double-nut ball screws, the gantry system provides high-speed positioning over travel lengths to 24 by 36 inches.

Ultran will continue to require variations of this system and worked with Daedal to establish a base system for upcoming projects. A standard application has been established, and any variations are easily accommodated such as length, width, payload and Z-axis travel. This helps the company’s long-term budgeting and ensures quick turn-around of new products.
IC manufacturers have developed pin-electronic circuits that serve as building blocks for ATE systems. But these high-performance ICs aren't limited to ATE applications.

**ATE Pin Electronics**

Automotive test equipment (ATE) pin electronics must meet severe demands for speed and timing accuracy. To serve the particular requirements of ATE, IC manufacturers have developed high-performance, moderately priced chips for use as pin drivers, comparators, time-delay generators, and combinations thereof. These chips not only simplify life for ATE designers, but they can also function well in other electronic applications.

To understand what ICs for pin electronics can do, you need to understand the basic functions performed by pin electronics. If you are not familiar with ATE pin electronics, see the box, "Basic ATE pin-electronic functions."

**Pin Drivers**

In high-performance ATE applications, pin drivers output high-quality waveforms. The waveforms need to have a minimum of ringing and undershoot/overshoot. Edge transitions need to be fast and repeatable for accurate timing calibration. Pin-driver ICs typically have slew rates from about 1.5 to greater than 10V/nsec for some GaAs ICs from Gigabit and Triquint (Table 1). Devices such as the 16G061A dual pin driver from Gigabit offer variable edge rates for compatibility with different logic families.

Although pin drivers need low propagation delays, accurately calibrating pin-driver timing places emphasis on stable propagation delay through the IC. Sensitivity to temperature, duty cycle, and other conditions affecting the propagation delay is more important than the absolute value of the delay. High-speed pin drivers also need to have accurate edge-to-edge matching (a measure of the difference in propagation delay between rising and falling edges).

To achieve the high speeds typically needed for ATE applications, pin drivers are usually ECL compatible. However, some pin-driver ICs will also accept TTL or CMOS logic levels.

A measure of the speed capability of a pin driver is the maximum toggle rate of the device. The maximum toggle rate defines how fast the pin driver can output data and still slew to the final value before changing to the next output state. The maximum toggle rate typically decreases as the voltage difference
ATE pin electronics

between the output logic-high and logic-low states increases.

You should note how well isolated the output of the driver is when you switch the driver to the off or high-impedance state. Some devices have off-state leakage currents lower than a µA. Other pin drivers in the off state still load the circuit lower than a µA. Other pin drivers have off-state leakage currents with a 50Ω termination to -2V.

You need high isolation when the pin driver is in the off state, some switches the driver to the off or high-impedance state. Some devices output of the driver is when you need high isolation when the pin driver is in the off state, some have off-state leakage voltages can vary. If you have to buffer the voltage references for each pin driver, you'll need to factor in the additional PCB-board space, power, and cost.

Pin-driver ICs provide a general-purpose building block for driving digital signals in applications whose logic levels need to be varied. You can use these ICs to build ATE, but you can also use them for the output of variable-level pulse generators. Pin driver ICs can even drive 50Ω transmission lines, although they may not be able to do so over their entire output voltage range.

**Table 1—Representative pin-electronic devices**

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product</th>
<th>Key features</th>
<th>Price (100)</th>
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</thead>
<tbody>
<tr>
<td>A. Pin drivers and combined products</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Analog Devices</td>
<td>AD1321</td>
<td>100-MHz toggle rate; -2 to 7V output range; 200-nA max off-state leakage.</td>
<td>$45</td>
</tr>
<tr>
<td>AD1322</td>
<td>200-MHz toggle rate, otherwise same as AD1321.</td>
<td>$85</td>
<td></td>
</tr>
<tr>
<td>Brooktree</td>
<td>BT698</td>
<td>Pin driver, comparators, dynamic loads; 125-MHz toggle rate with 1V swing; -3 to 8V operating range.</td>
<td>$130</td>
</tr>
<tr>
<td>Comlinear</td>
<td>CLC600</td>
<td>200-MHz operation; -2 to 7V output range; 40-nA typ off-state leakage.</td>
<td>$42.50</td>
</tr>
<tr>
<td>Gigabit</td>
<td>16G061A</td>
<td>Dual pin driver; 800-MHz bandwidth; variable slew rate: 2.5 to 17 inline; 50-µA off-state leakage.</td>
<td>$95</td>
</tr>
<tr>
<td>Pulse Instruments</td>
<td>PT40B</td>
<td>100-MHz clock rate; 0.3 to 8V output range; 10-pin S/D hybrid.</td>
<td>$36.25*</td>
</tr>
<tr>
<td>Triquint</td>
<td>TQ8330</td>
<td>100-ns rise and fall times for 1V swing; -3 to 3V for 50Ω loads.</td>
<td>$115</td>
</tr>
<tr>
<td>B. Comparators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Devices</td>
<td>AD1317</td>
<td>Dual comparator with latch; 100-µA input-bias current; inputs switchable to high-impedance state.</td>
<td>$25</td>
</tr>
<tr>
<td>AD96685</td>
<td>Latching comparator; -2.5 to 5V input range.</td>
<td>$4.60</td>
<td></td>
</tr>
<tr>
<td>AD96687</td>
<td>Dual version of AD96685.</td>
<td>$6.40</td>
<td></td>
</tr>
<tr>
<td>AD9696</td>
<td>TTL-compatible comparator; 45-ns propagation delay.</td>
<td>$3.50</td>
<td></td>
</tr>
<tr>
<td>AD9698</td>
<td>Dual version of AD9696.</td>
<td>$6</td>
<td></td>
</tr>
<tr>
<td>Brooktree</td>
<td>BT687</td>
<td>Dual latching comparator; 20-µA input-bias current; -3.3 to 3.3V input range.</td>
<td>$12</td>
</tr>
<tr>
<td>BT688</td>
<td>-4.0 to 10.2V input range; 2-µA typ input-bias current; 2.8-ns propagation delay.</td>
<td>$20</td>
<td></td>
</tr>
<tr>
<td>BT681</td>
<td>-4 to 8.2V input range; 2-µA typ input-bias current; 2.6-ns propagation delay.</td>
<td>$37</td>
<td></td>
</tr>
<tr>
<td>C. Time-delay generators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Devices</td>
<td>AD9500</td>
<td>8-bit digital delay generator (ECL); 2.5-ns to 10-µsec range; 100-MHz max trigger rate.</td>
<td>$16</td>
</tr>
<tr>
<td>AD9501</td>
<td>8-bit digital delay generator (TTL/CMOS); 2.5-ns to 10-µsec range; 50-MHz max trigger rate.</td>
<td>$8.60</td>
<td></td>
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<tr>
<td>Brooktree</td>
<td>BT604</td>
<td>8-bit digital delay generator; 4- to 40-ns delay range; 120-MHz, programmable on the fly.</td>
<td>$33</td>
</tr>
<tr>
<td>BT622</td>
<td>Dual-channel delay line; independently adjust rising and falling edge; 10-, 20-, 30-ns ranges.</td>
<td>$37</td>
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<tr>
<td>BT624</td>
<td>Quad version of BT622.</td>
<td>$46</td>
<td></td>
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<tr>
<td>D. Dynamic loads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Devices</td>
<td>AD1315</td>
<td>Complete dynamic load; ±50-mA range; -2 to 7V compliance range.</td>
<td>$40</td>
</tr>
</tbody>
</table>

*Price for quantities of 1000 or more.*

**Fast comparator, stable delay**

Every electronic engineer is familiar with the performance of analog comparators, but the performance requirements placed on comparators for ATE applications are particularly demanding. ATE applications typically place three tough requirements on comparators.

First, the comparator must be fast. Propagation delays of a few nanoseconds are acceptable, but, as is the case for pin drivers, a stable propagation delay is very important.

Second, the comparator needs a relatively wide input-voltage range. ATE applications typically need a -2 to +7V range, although more is desirable. However, narrower voltage ranges make it easier to design a comparator for speed.

Third, ATE applications often need comparators with a low input-bias current for use in testing low-power CMOS devices. But it is easier to make fast comparators when you can use relatively high input-bias currents.

Like many engineers, ATE designers can't always buy what they need, so they sometimes have to design around the comparator. In the past you might have bought a fast comparator with a limited input-voltage range and a low input impedance. You'd have to add your own circuitry to buffer and scale the inputs to get the needed voltage range and input impedance. Now you can buy comparators off the...
Basic ATE pin-electronic functions

The overall function of ATE pin electronics is to drive input pins and measure outputs. To keep ATE general purpose, the pin electronics are usually designed to support both drive and measure functions on every channel.

Pin drivers for ATE provide inputs to the device under test (DUT). Pin drivers (Fig A) typically support three states: logic-high, logic-low, and a high-impedance or off state. You program the logic high and low levels with analog voltage inputs. The programmable range of the high and low states is typically -2 to +7V, providing sufficient range for compatibility with TTL, CMOS, and ECL voltage levels.

When measuring a DUT's outputs, the test system switches the pin driver to an off state and measures the output levels with comparators (Fig A).

If you go by the data-book specifications, a device's logic high doesn't occur until the voltage exceeds the minimum logic high, and its logic low doesn't occur until the voltage falls below the maximum logic low. Because ATE systems normally test using data-book specifications, designers usually use two comparators in a window-comparator arrangement. The test system latches the output of the two comparators at the programmed test time, and the state of the comparators shows whether the output pin was in a high, low, or intermediate state.

Testing ICs to data-book specifications also requires testing output-drive capabilities. Output-drive testing verifies the current a device output can source in a logic-high state or sink in a logic-low state. Dynamic-load circuits provide the current sinks and sources needed by ATE to test the output drive.

Fig A diagrams the basic operation. Positive and negative current sources connect to the output pin of the device under test through a diode quad. When the output voltage drops below the threshold voltage set on the opposite side of the diode quad, the DUT must sink the current from the current source. Conversely, when the DUT output voltage goes above the threshold voltage, the DUT must source current to the dynamic load. Dynamic-load circuits, although important in ATE systems, don't have wide application in other electronics systems.

---

**Fig A**—The basic ATE pin-electronic devices are drivers, comparators, and dynamic loads.
ATE pin electronics

shelf that measure up well against ATE requirements. Hence, you can design with more freedom.

Comparators available from both Analog Devices and Brooktree, some of which have TTL-compatible outputs, offer a range of performance capabilities.

For example, Brooktree’s BT681 dual comparator has attractive performance not only for ATE applications but also for instrumentation, line-receiver, and other thresholding applications. The comparator can track inputs that slew at 4V/nsec over a range from −4 to +8.2V. The typical input-bias current is 2 µA, but you can reduce it to 100 nA with a selectable power-down mode when you can afford to trade speed for a lower input-bias current. A level-select control lets you reduce the complementary ECL output swing from a nominal 800 mV to 400 mV. The reduced amplitude lets the comparator follow short pulses while maintaining timing specifications.

Remove timing skew

High-performance ATE systems also use time-delay generators extensively. The delays are used both to remove timing skew in systems and to create time increments smaller than standard clock cycles.

Time-delay circuits provide the general capability of distributing precisely time-aligned signals throughout any electronic system. For ATE systems, time-delay circuits can remove timing skew to make the outputs of all pin-driver channels in the system reach the device under test simultaneously.

Typical time-delay ICs offer resolutions in the tens of picoseconds. For this type of time-delay generation, the stability of the time delay is important, as is the recycle time on the time delay. The recycle time is the time you need to wait for the delay circuit to reset before it can accept another trigger.

Another application for time-delay circuits is generating periods. Whether on ATE or on any other electronic equipment where you need to generate variable periods from a digital clock, you’ll need some way to create time increments that are not full clock cycles.

For example, if you have a 100-MHz clock in a system and you need to generate a 30-MHz clock, you need to create clock pulses every 33.333 nsec. Starting from your system clock, you count out three 10-nsec clocks plus a 3.333-nsec delay for the first cycle. The second 30-MHz clock cycle is 66.667 nsec from the beginning, so after the sixth pulse you count out a delay of 6.667 nsec. The third clock cycle coincides with the tenth system clock pulse. In this example, the circuit controlling the time delay must switch the delay rapidly from 0 to 3.333 to 6.667 nsec and repeat.

When you need a time-delay circuit for applications such as period generation, you need circuits that can be set to new values rapidly, sometimes within one clock cycle. Designers refer to the ability to accommodate these rapid changes as “changing timing on the fly.”

Time-delay circuits contain . . .

Fig 1 shows the typical components of a time-delay IC. One input of a comparator receives a voltage ramp, typically generated using a current source to charge a capacitor. The other input to the comparator is an adjustable voltage reference that determines when the comparator will change state. A trigger input allows the current source to begin charging the capacitor. When the capacitor charges to the voltage of the reference input, the comparator...
THE POWER STRUGGLE

...IS OVER. At Unitrode Integrated Circuits, we have the right power management IC for a myriad of power supply and motor control applications. We're working smarter than ever to help our customers deliver their products with innovative solutions for the highest performance control of switching power supplies and fractional horse power DC motors. We guarantee a continued commitment to uncompromised quality. From designing your most sophisticated custom requirement, to offering you new world standards with our catalog products, no other company can offer you the circuit and application 'know-how' you need today!

### PWM's
**The Current Mode Leader**

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<tr>
<th>Military</th>
<th>Commercial</th>
<th>Commercial</th>
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<tbody>
<tr>
<td>UC1823</td>
<td>*UC1823A</td>
<td>UC3823</td>
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<td>UC1851</td>
<td>UC3851</td>
<td>UC3851</td>
</tr>
</tbody>
</table>

*Improved Versions*

### Resonant Controllers

<table>
<thead>
<tr>
<th>Military</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC1860</td>
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<td>UC1861</td>
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### Power Factor Controllers

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>*UC1852</td>
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<tr>
<td>UC1854</td>
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*Available Mid-1991

### High Power FET Drivers

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<tr>
<td>UC1705</td>
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<td>UC1707</td>
<td>UC1711</td>
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<td>UC1708</td>
<td>UC3708</td>
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### F.H.P. Motor Drivers

<table>
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<td>UC1620</td>
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<tr>
<td>UC1625</td>
<td>UC3625</td>
</tr>
<tr>
<td>UC1655</td>
<td>UC3655</td>
</tr>
</tbody>
</table>

*Advanced Information*

| UC3724 | High Side Driver Pair |
| UC3725 | High Side Driver Pair |
| UC3875 | Phase Shifted PWM     |
| UC3908 | Load Sharing Control  |
| UC3825A| High Frequency PWM    |

*Samples Available Early 1991

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CIRCLE NO. 69
**Technology Update**

**ATE pin electronics**

For more information . . .

For more information on the pin-electronic products 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.

<table>
<thead>
<tr>
<th>Company</th>
<th>Address/Direct Line</th>
<th>Access Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Devices Inc</td>
<td>851 Woburn St, Wilmington, MA 01887</td>
<td>(508) 657-7900</td>
</tr>
<tr>
<td>Comlinear Corp</td>
<td>4800 Wheaton Dr, Fort Collins, CO 80525</td>
<td>(303) 226-6500</td>
</tr>
<tr>
<td>Brooktree Corp</td>
<td>9550 Barnes Canyon Rd, San Diego, CA 92121</td>
<td>(619) 452-0090</td>
</tr>
<tr>
<td>Gigabit Logic</td>
<td>1908 Oak Terrace Lane, Newbury Park, CA 91320</td>
<td>(815) 696-9610</td>
</tr>
<tr>
<td>Pulse Instruments</td>
<td>1234 Francisco St, Torrance, CA 90502</td>
<td>(213) 515-5353</td>
</tr>
<tr>
<td>Triquint Semiconductor Inc</td>
<td>Group 700, Box 4835, Beaverton, OR 97076</td>
<td>(503) 641-4227</td>
</tr>
</tbody>
</table>

Some other specifications to watch for on time-delay circuits are how linear and monotonic the delay is. If you can measure when you have set the time delay correctly, then you don’t necessarily need a perfectly linear time delay versus voltage. As long as the time delay is monotonic, you can reach the correct value within a few trials. If you’ll be changing the time delay on the fly or don’t have a way to measure the accuracy of the setting, then linearity may be important.

Delay circuits may respond only to a rising or falling edge and output a fixed pulse, or they may delay both the rising and falling edges. Some time-delay ICs that delay both the rising and falling edges allow you to adjust the two edges independently.

You don’t need to be an ATE designer to benefit from the time-delay ICs available. Any time you need to create short, stable time delays adjustable with fine increments, you should consider time-delay ICs.

**Article Interest Quotient**

(Circle One)

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processors are part of a close-knit neighborhood of Intel SuperScalar i960 microprocessors. So you get software compatibility across the board as well as an easy performance path up to 100 MIPS.

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Vicor GmbH Tel: 49-8031-42083 • Fax: 49-8031-45736
CAE router uses reconstruct algorithm to increase pc-board layout efficiency

The Tango family of CAE software for PCs now includes an automatic circuit board router that uses a “reconstruct” routing algorithm. The Tango-Route Pro software also performs a pass on completed pc-board layouts using manufacturing-improvement algorithms. These algorithms eliminate extra vias between layers and reduce trace lengths by angling signal routes at 45°.

The reconstruct algorithm allows Tango-Route Pro to handle circuit-layout roadblocks differently from other routers. Router software that uses traditional “rip-up and retry” algorithms removes hundreds of previously placed signals when a roadblock occurs. Such software routes the removed signals in random order on successive retries, solving roadblocks by time-consuming trial and error. Tango-Route Pro analyzes all of the previously placed signals that prevent routing a new signal and reconstructs a single blocking trace to solve routing conflicts.

The Tango router supports board designs as large as 32 x 32 in. and features a resolution of 1 mil. You can lay out boards having as many as 4000 components, 10,000 signal nets, and 256 connectors. The CAE package supports as many as 15 layers—10 signal layers, 1 power layer, 1 ground layer, and 3 miscellaneous layers.

The Tango-Route Pro software can analyze a circuit design and automatically set routing parameters such as number of layers, grid size, and even general signal direction for specific layers. You can change any settings via Tango’s standard user menus.

You can set design rules such as pad-to-pad, track-to-track, and pad-to-track on a layer-to-layer basis. The software also uses T-routes in the pc-board layout, which makes trace lengths shorter and therefore uses less copper. During the manufacturing pass, the router’s special algorithms reduce trace lengths even further.

The software saves the results of each routing pass during operation and at any user-specified interval. Therefore, you can recover from power or human interruptions and resume routes in progress. You can monitor designs in progress on screen, and check the status of operations via user menus. The router also generates a report that documents statistics pertinent to all routing passes.

The Tango-Route Pro software costs $5500 and is available now. The program runs on 80386- (with a 387 numeric coprocessor) or 80486-based computers with MS-DOS 3.3 or later and a minimum of 4M bytes of RAM. The software supports Hercules-compatible monochrome, EGA, VGA, and numerous high-resolution video cards. You must also own Tango-PCB circuit-board-layout software to use the router.

—Maury Wright

Accel Technologies Inc, 6825 Flanders Dr, San Diego, CA 92121. Phone (619) 554-1000. FAX (619) 554-1019.

Circle No. 730
Continuous-time programmable filter spans 1.5 to 15 MHz

The IMP42C55 is a continuous-time lowpass filter IC with a programmable cutoff frequency. Because the device is tailored for serial data recovery, you can also adjust the filter’s zeros, allowing you to reshape pulse signals.

The IC provides four filter elements with second-order frequency responses, called biquads. The first biquad section forms an all-pass filter for phase equalization. You can program the section’s center frequency and Q, or, if you don’t need equalization, you can program the IC to bypass the section.

The remaining sections implement a sixth-order Bessel filter with programmable cutoff frequency. Two of the sections offer programmable zeros, letting you adjust the filter’s response to rising and falling edges separately. The effect on pulse signals is to narrow the pulse while making the pulse shape more symmetric.

The 16-pin CMOS IC requires no external filter components. Instead, an on-chip, phase-locked-loop (PLL) control circuit locks onto a user-supplied reference clock to set the filter’s cutoff frequency. Because each filter section uses a transconductance amplifier, the ratio of the amplifier’s conductance to an integrating capacitor sets the filter’s pole. The PLL control circuit sets the filter’s cutoff frequency by adjusting the amplifier’s conductance ratio in two ways: changing the capacitance and changing the conductance current.

Each filter section forms its integrating capacitor from a bank of eight individually switchable capacitors. The control circuits switch in and out of the eight capacitors as needed for coarse frequency adjustments. The control circuit makes fine adjustments by injecting bias currents into the amplifiers.

The control circuit derives its intelligence from the reference clock. By feeding the clock into a master biquad and developing an error signal from the biquad’s quadrature output, the circuit can tune the master biquad to operate at the desired cutoff frequency. The same error signal tunes the four biquads in the Bessel filter, forcing them to track the master biquad. The control circuit also tracks and adjusts for IC process variations and environmentally induced drift in the amplifiers and will hold the cutoff frequency within 10% of the frequency setting.

You program the IC through a 3-input serial interface. You clock in an 8-bit serial data packet (3 bits of address and 5 bits of data), then activate a strobe line to load the data into control registers within the IC. You can also read back the value of any register on a fourth line. The filter remains operational while you enter data, allowing you to dynamically adjust the filter’s response as your signal changes.

You can vary the filter’s cutoff frequency over a range of 10:1 by programming a reference-frequency prescaler in the PLL control loop. The prescaler yields the cutoff frequency of

$$f_c = \frac{3}{2} \frac{k}{f_{REF}},$$

where $i = 1-4$ and $k = 7.17/(3.17 + n)$, and where $n = 0-7$. The IC supports a cutoff frequency between 1.5 and 15 MHz.

The IMP42C55 comes in a 16-pin, $15$ DIP or $15.25$ SOIC package. The filter consumes 100 mA when active and 250 µA when programmed into power-down mode. It uses TTL-compatible control lines and accepts 1V p-p analog signals. Both versions are available in sample quantities.

—Richard A Quinnell
International Microelectronic Products Inc, 2830 N 1st St, San Jose, CA 95134. Phone (408) 432-9100. FAX (408) 434-1335. TLX 499-1041.

Circle No. 732

A phase-locked loop ensures the stability of this programmable sixth-order Bessel filter IC. The lowpass filter offers a cutoff frequency ranging from 1.5 to 15 MHz.
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Fax (44) 79881-2117
X-Window package provides user interface for embedded real-time applications

OS-9 real-time operating-system users can add X-Window-based graphical user interfaces to their 68000-based embedded real-time systems. The OS-9/X-Window software package provides a complete X-Window client implementation. You can use the software in OS-9-resident development environments and Unix- or MS-DOS-based cross-development applications. The X-Window implementation is compatible with a variety of networked X-Window servers, and the company offers embedded X-Server support for OS-9 and specific graphics boards.

The software package complies with the X-Window version 11 release 4 package from MIT. The product includes X-Client support including X-Window development libraries, runtime client programs, sample source code for client programs, and the MIT Tab window manager. You can expect the company to add an OSF Motif window manager to the package in the third quarter of this year.

The X-Window development libraries include Xlib (X-window library), Xt (X toolkit intrinsics library), Xaw (X athena widgets library), Xm (X miscellaneous utilities library), and Xdmcp (X display manager control protocol library). Runtime client programs enable programmers to perform system-level functions, such as initializing and starting up the X-Window package. The xterm program, for example, lets you open terminal-emulation windows.

The package includes sample source code for several X-Window-client programs including maze, xcalc, and xclock. The package also includes a Unix-compatible library, which adds OS-9 system functions that emulate Unix functions found in X-Window routines. You can therefore port applications from Unix to OS-9, and vice versa.

Initially, the package provides X-Window-server support for OS-9 systems that use the MMI-250 graphics board from Vigra Inc (San Diego, CA). The package also includes sample X-Window-server source code that users can port to other boards.

For now, users can port industry-standard windowing packages to their systems and provide operators with graphical interfaces. The development tools included in the OS-9/X-Window package simplify developing graphics-based application programs. X-Window real-time systems can operate in X-Window networks of heterogeneous systems.

All members of the OS-9/X-Window family are available now. The full X-Window client development package costs $995. You can buy the client runtime package, a runtime version ready for delivery, for $195. Full source code for the client development package costs $15,000. The server source code package costs $150.—Maury Wright
Microware Systems Corp, 1900 N W 114th St, Des Moines, IA 50322. Phone (515) 224-1929. FAX (515) 224-1352.

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Microcontroller family features configurable 8- or 16-bit registers

The H8/300 microcontroller (µC) family features an 8-bit external bus and a 16-bit internal bus, although the ALU is 8 bits. The µCs' internal register scheme is a feature that makes this family unusual; under software control, you configure the 16 8-bit or 8 16-bit registers. In addition, the µCs' register-to-register operations allow each register to act as an accumulator.

Although the CPU uses an 8-bit ALU, both 8- and 16-bit adds and subtracts execute in one instruction cycle (two clock cycles). An $8 \times 8$-bit multiply and a division of 16-bit dividends by 8-bit divisors occupy seven instruction cycles. At 10 MHz, these add/subtract instructions execute in 200 nsec, whereas the multiply/divide instructions execute in 1400 nsec. The family's 57 instructions are either 2 or 4 bytes, but they aren't compatible with other µC instruction sets.

Software support, running on IBM PCs and sometimes VAX workstations, includes a real-time kernel based on the Industrial TRON (The Real-time Operating System Nucleus) specification. Ready Systems (Sunnyvale, CA) is developing another kernel, based on the VRTX-RTOS. C-language development tools are available from Avocet (Rockport, ME), Microtec Research (Santa Clara, CA), and Software Environments (Dallas, TX).

The µC family also features a fuzzy-logic compiler, developed by Togai Infralogic (Irvine, CA). Other development tools such as assemblers, simulator/debuggers, librarians, and ICEs are available from Hitachi or third-party developers.

The 10-MHz H8/310 includes 8k bytes of EEPROM, 10k bytes of masked ROM, 256 bytes of RAM, and a 1-bit I/O pin. The pin enables fast data transmission and prevents serial ports, four external interrupts, and 16 internal interrupts. These µCs are available in 6-, 8-, and 10-MHz versions. Prices range from less than $9 (OEM qty) to $14.25 (100).

The H8/330 µC includes an 8-bit, 8-channel ADC; 16k bytes of masked ROM or one-time-programmable EPROM; 512 bytes of RAM; 15 bytes of dual-port RAM; an 8-bit, a 16-bit, and two PWM timers; and a serial port. The controller also offers 27 interrupt sources, 9 of which are external. These µCs cost less than $10 (OEM qty) and $17.45 (100). Samples of the 310, 320, and 330 devices are currently available.

Samples of the high-end 350 µC won't be available until later this year. The chip contains an 8-bit, 16-channel ADC; 32k bytes of masked ROM or one-time-programmable EPROM; and 512 bytes of RAM. It features one 19-bit, two 16-bit, two PWM, and six 8-bit timers. Under software control, you can configure these timers in many ways. This model offers 56 interrupts, 9 of which are external. Depending on quantity, these devices cost $15 to $25.

—Michael C Markowitz
Hitachi America, Semiconductor and IC Div, 2000 Sierra Point Pkwy, Brisbane, CA 94005. Phone (800) 448-2244.

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FAX (201) 534-5672
ADC betters predecessor in speed, sampling, and cost

The AD1674 pin-compatible ADC from Analog Devices includes a S/H amplifier and is four times faster than the company’s AD574A converter. The guaranteed conversion rate of the $18 (100), 12-bit ADC is 10 µsec. In stand-alone mode, the device has the same interface requirements as the AD574A and AD674A converters; in full-control mode, slight control-timing modifications are required.

The ADC’s internal S/H amplifier avoids problems that are common to other auto-zeroing amplifiers by performing secondary sampling at the output. The additional sampling reduces hold-mode settling time, resulting in a 1-µsec acquisition time, a full-power bandwidth of 1 MHz, and 12-bit performance over the -55 to +125°C temperature range.

The monolithic ADC also includes a 10V reference, a clock, and 3-state output buffers. The device’s dc specifications include an integral nonlinearity of ±1/2 LSB and no missing codes at 12 bits. The company tests and specifies the device for ac performance. The converter has a minimum signal-to-noise and distortion ratio of 70 dB, a maximum total harmonic distortion of -82 dB, and a maximum intermodulation distortion of -80 dB.

The converter’s power-supply requirements are either 5 and ±12V or 5 and ±15V. Bus access time is typically 75 nsec, 150 nsec max. The device uses laser-trimmed scaling and offset resistors to provide four calibrated input ranges: 0 to 10V, 0 to 20V, ±5V, and ±10V.

<table>
<thead>
<tr>
<th>Features</th>
<th>AD574A</th>
<th>AD674A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum conversion time</td>
<td>35 µsec</td>
<td>10 µsec</td>
</tr>
<tr>
<td>Resolution</td>
<td>12 bits</td>
<td>12 bits</td>
</tr>
<tr>
<td>Internal S/H Amplifier</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Minimum signal/noise + distortion ratio</td>
<td>Unable to specify</td>
<td>70 dB</td>
</tr>
<tr>
<td>Pin and package</td>
<td>28-pin DIP and SDIC</td>
<td>Pin and package compatible with AD574A</td>
</tr>
<tr>
<td>Maximum power consumption</td>
<td>725 mW</td>
<td>575 mW</td>
</tr>
<tr>
<td>Price (100)</td>
<td>$22.60</td>
<td>$18</td>
</tr>
</tbody>
</table>

The converter is available in five different grades specified over three temperature ranges of 0 to 70°C, -40 to +125°C, and -55 to +125°C. The converters come in 28-pin plastic DIPs and SOICs and 28-pin ceramic DIPs.

Anne Watson Swager
Analog Devices Inc, 181 Ballardvale St, Wilmington, MA 01887. Phone (617) 397-1428. FAX (617) 326-8703. Circle No. 731

ASK EDN
Have you been stumped by a design problem? Are you having trouble locating parts? Ask EDN.

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With the development of the new Enhanced Serial Communication Controller (ESCC2), Siemens has demonstrated a new genius in high-speed multi-protocolling. The ESCC2 (SAB 82532) offers an extraordinary range of protocol options at a high-speed transfer rate of up to 10 Mbit/sec in synchronous mode. Supporting X.25 LAPB, ISDN, LAPD, HDLC, SDLC, and both ASYNC and BISYNC, the ESCC2 offers outstanding capabilities for a wide variety of applications. And it is as adaptable as it is powerful. The ESCC2's flexible 8/16-bit bus interface allows it to easily adapt to either Intel or Motorola microprocessors. Plus, it provides direct 8/16-bit accessibility to all registers, as well as DMA and both vectoring and non-vectoring interrupt modes. This ensures efficient data transfer to and from host system memory, for fast, accurate and reliable multi-protocolling.

For superior performance and flexibility, the ESCC2 features clock recovery up to 4 Mbit/sec, storage capability of 64 bytes in each of its four on-chip FIFOs and four encoding schemes: NRZ, NRZI, FMx and Manchester. In addition, it offers user-programmable features such as 16/32-bit CRC, time slot assignment, and an 8-bit parallel port. The result is an excellent CMOS device with only 40 mW power consumption for all kinds of multi-protocol applications.

For more information on the ESCC2, or to find out how you can receive your inexpensive PC-based evaluation kit (EASY532), call 800-456-9229, or write: Siemens Components, Inc. 2191 Laurelwood Road Santa Clara, CA 95054-1514 And put the communications genius of Siemens to work for you.
Challenging the limits of is the core of our success

For NCR, it's defined by the very things that drive our industry. The changing technology that is the core of what we do. And people who join you in a partnership and provide service that actually exceeds customer expectation.

Because our designers avidly pursue new ideas, they can help make the complex a bit simpler.

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Those resources include industry-leading products like mixed-signal ASICs, Ethernet and SCSI, already considered standards. Or, when your latest design requires a custom solution, these products become the cores for unique devices – providing ever-increasing levels of integration in ever-decreasing space. Moreover, because you can design systems to higher levels of abstraction... you're free to explore a universe of limitless applications... and still save time, money and reduce the...
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TE-158 Telephone Control Card:
Take total control over your telephone communication. Direct telephone line interface gives you control over line connect/disconnect, touch-tone decoding and encoding, and detects call progress. Set your computer to dial out automatically, to keep trying if busy signal, control voice synthesizer, tape recorder with complete in/out capability. FCC approved.

Relay Card:
8 individually controlled industrial relays. 5A at 120VAC, SPST.

RE-140: $142

8 Bit A to D:
8 Analog inputs.
0.5-1.5V, 20mV steps.
7500 readings/sec.

AD-142: $142

Temperature Sensor:
Range 0-200°F. 10mV/°F Resolution with AD-142.

TS-111: $12

Digital Input:
8 opto-isolated inputs. Read voltage presence or switch closures.

IN-141: $65

Latched Digital Input:
8 opto-isolated inputs. Each input individually latched to catch switch closures and alarm loops.

LI-157: $85

Smart Quad Stepper Controller:
On board microprocessor controls four motors simultaneously. Uses simple commands like “MOVE ARM 10.2 (INCHES) LEFT”. Set position, ramping, speed, units. Many inputs for limit switches etc. Stepper motors available.

SC-149: $299

NEW
FA-154 High Speed 12 Bit A/D Converter:
Blinding speed at low cost! Convert at 10 μs. Eight input channels accepting 0-5V signals. Special onboard variable gain amplifier lets you read signals less than 1LSB (1.2μv).
For value combined with speed in data acquisition and signal processing, this converter leads the pack!

FA-154: $179.00

Temperature Sensor:
Range 0-200°F. 10mV/°F Resolution with AD-142.

TS-111: $12

Digital Input:
8 opto-isolated inputs. Read voltage presence or switch closures.

IN-141: $65

Latched Digital Input:
8 opto-isolated inputs. Each input individually latched to catch switch closures and alarm loops.

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For value combined with speed in data acquisition and signal processing, this converter leads the pack!

FA-154: $179.00

24 line TTL I/O:
Connect 24 signals, TTL 0/5V levels or switches. (B255A)

DG-148: $72

DA-147: $149

D/A converter:
4 Channel 8 Bit D/A converter with output amplifiers.

AN-146: $153

A-Bus Adapters:
IBM PC/XT/AT & compatibles.

AR-133: $69

MicroChannel Adapter:
Parallel Adapters also available for Apple II, Commodore 64, TRS-80.

AR-170: $93

Serial Processors:
Built in BASIC for off-line monitoring, logging, decision making.

SP-127: $189

These products work with IBM PC, Apple II, Commodore and Tandy, etc. Our serial interfaces let you use any computer with an RS-232 port.

For a complete list of products and pricing, please refer to the catalog in the back of the magazine.
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Designers of successful portable products face a constant struggle to reduce system size, weight, complexity and power consumption. Our single-chip CMOS EIA-232-D line driver/receiver does just exactly that. For more information, contact NEC today.

<table>
<thead>
<tr>
<th>Device</th>
<th>Driver</th>
<th>Receiver</th>
<th>Standby mode</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>µPD4711A</td>
<td>2</td>
<td>2</td>
<td>o</td>
<td>20-pin DIP/SOP</td>
</tr>
<tr>
<td>4712A/B</td>
<td>4</td>
<td>4</td>
<td>o</td>
<td>28-pin DIP/SOP</td>
</tr>
<tr>
<td>4713</td>
<td>3</td>
<td>3</td>
<td>o</td>
<td>24-pin DIP/SOP</td>
</tr>
<tr>
<td>4714</td>
<td>3</td>
<td>5</td>
<td>o</td>
<td>28-pin DIP/SOP</td>
</tr>
<tr>
<td>4715</td>
<td>5</td>
<td>3</td>
<td>o</td>
<td>28-pin DIP/SOP</td>
</tr>
</tbody>
</table>

For fast answers, call us at:
USA Tel: 1-800-632-3530. Fax: 1-800-729-9288. Germany Tel: 0211-650302. Telex: 8569960.
The Netherlands Tel: 040-445-845. Telex: 51923.
Spain Tel: 1-419-4150. Telex: 41316. Italy Tel: 02-6709108. Telex: 315355.
UK Tel: 0908-691133. Telex: 926781. Ireland Tel: 01-6754200. Fax: 01-6754081.
Hong Kong Tel: 755-9098. Telex: 64501. Taiwan Tel: 02-719-2377. Telex: 22372.

CIRCLE NO. 71
Deciding how to implement a cache is like buying a car: after you decide which car, you have to choose the color, leather or cloth upholstery, power or crank windows, whether you want a big engine or better economy, and more. Like buying the car, your cost and the system’s performance is highly dependent on your selections.

Most high-performance systems can benefit from cache memory. However, designing one isn't trivial; to avoid wasting your precious cash, you need to know how and why the cache works.

Michael C Markowitz, Associate Editor

A cache is a small, fast, and, therefore, more expensive memory that acts as a buffer between a device that uses large amounts of memory and its large, slow, and less expensive main memory. The cache's purpose is to reduce average memory-access time. This reduction is achieved by maximizing the probability of finding a memory reference in the cache (the hit rate), minimizing the access time to information that is in the cache, and minimizing the penalty of accessing data that is not in the cache. Generally, caches fit between CPUs and main memory; however, they can also operate between main memory and the computer's disk drives (see box, "Caches crush disk access times").

Caches are effective because of two properties of software programs: spatial and temporal locality. Spatial locality asserts that because programs are generally composed of subroutines and procedures that execute sequentially, they often use data and instructions whose addresses are proximate. Temporal locality recognizes that since many programs contain loops and manipulate data arranged in lists and arrays, recently used information is more likely to be reused than older information.

Since a cache operates by anticipating data- and instruction-location accesses in memory, you would expect that large caches offer greater performance than small caches. Generally this is true; however, several factors may blunt or invalidate the gains expected by increasing cache size. First, you can expect diminishing returns as you incrementally increase the size of your cache. Where adding a 16k-byte cache might offer dramatic performance improvement over a system with no cache, doubling the cache to 32k bytes could add only half as much performance (Table 1). Then, application software and architectural considerations may limit the gains of a cache.

Consider how the µP and the cache work with the memory subsystem during read operations. Without a cache, when the µP needs data, it makes a request to the dynamic RAM (DRAM). It then waits while the DRAM (whose 65-nsec access times are considered high speed) accesses the data and puts it on the bus. With a cache, the µP asks 10 to 25-nsec static RAMs (SRAMS) for the data. The cache controller checks to see
if the cache-data SRAM has the data. Tags, or partial addresses stored in the cache-tag SRAM, tell the cache controller whether or not the cache contains the requested data. If the data is in the cache—a hit—the controller sends the data to the µP. If the data isn’t in the cache—a miss—the µP must get it from the DRAM.

Caches can wait for the cache controller to indicate a miss before instigating a DRAM access. These serial caches are called look-through caches. Alternatively, parallel, or look-aside, caches access DRAM and cache-data SRAM concurrently. If the controller finds its data in the cache, it aborts the DRAM access cycle. Look-aside caches are easier to
A cache subsystem consists of a memory to store data, a way to catalog the data, and a controller that acts as a traffic cop.

design and offer faster memory-subsystem performance, but tie up the memory bus during all memory accesses. As a result, DMA and other attempts to use the memory must stall the CPU. Look-through caches pay higher cache-miss penalties and are more complex, but they only use the memory bus during cache misses. If your cache has a hit rate of more than 90%, these penalties may be a minuscule por-

Caches crush disk-access times

Accessing information from a hard disk takes tens of milliseconds, where main-memory reads take hundreds of nanoseconds. Therefore, a disk cache can greatly improve system performance, especially in I/O-intensive system applications and in systems with small main memories. In designing a system, you must match your disk subsystem and cache design to your choice of operating system, host bus, and host architecture.

You can choose to add a disk cache in several forms. You can use SCSI- or IDE-disk drives that include embedded controllers and typically include a cache on the controller. Some manufacturers of intelligent SCSI host-bus-adapter boards include a cache. Likewise, manufacturers offer caching host-bus-resident controller boards for device-level-interface St-506/412 and ESDI drives. And you can choose to dedicate a portion of your system's main memory as a disk cache.

SCSI and IDE drives use 32k- to 256k-byte read-ahead caches to prefetch data that the system will likely request soon. The onboard controller simply continues to read sequential data after satisfying a system I/O request and therefore depends on the theory of spatial locality to operate efficiently. Quantum Corp (Milpitas, CA (408) 432-1110) pioneered the idea of an on-drive cache and offers among the most comprehensive on-drive cache designs.

You can create more than ten active cache segments on Quantum drives via an operating-system driver—essentially the equivalent of making a main-memory cache set-associative. Multiple segments ensure a greater hit rate in multitasking systems. Quantum's drives can also continue to prefetch data while servicing an I/O request from previously cached data. The drives use a least-recently-used algorithm to flush data when segments become full.

A cache-based drive can respond to a read request in less than 5 msecs on hits compared with typical seek and latency delays of 20 to 50 msecs on misses. Companies such as Data Technology (Milpitas, CA (408) 262-7700) perform similar prefetch operations with its host-resident controller boards for use in IBM-compatible PCs. The company's boards use an algorithm that evaluates recent disk accesses to predict whether future accesses are sequential or random.

You do not need a special operating-system driver for better performance from caches on drives, controller boards, and host adapter boards. But, all of these techniques require a 1- or 2-stage movement of data from the cache to main memory. In all three cases, the data is transferred across a system bus. SCSI-based systems must also transfer data across the SCSI bus, incurring delays from bus arbitration and the data transfer. Such caches, therefore, eliminate the electromechanical delays of disk drives, but still suffer from some overhead.

Main-memory caches simply set aside a partition of memory for disk caching. Such caches typically don't perform prefetch operations, but operate on the temporal-locality theory that the system will request once-used data again. Caches in main memory incur the least overhead on hits because retrieving the data requires only a memory-to-memory block move. But either your operating system or an application program must control a main-memory cache.

In IBM-compatible PC designs, you must consider the delays caused by a relatively slow system bus compared with an operating system that doesn't have cache support. Drive- and board-resident caches provide the simplest integration path and don't infringe on the limited 640k-byte main-memory map of MS-DOS. However, main-memory cache programs, such as PC-Kwik from Multisoft Corp (Beaverton, OR (503) 644-5644), can perform better and don't use much of your 640k bytes when run in expanded or extended memory.

The Unix operating system, conversely, includes a main-memory cache by design. And many Unix gurus believe that money for extra memory is best spent increasing main-memory size rather than adding auxiliary caches. Others think the combination of a drive-based cache with the main-memory cache provides the best performance, because the two caches operate differently.—Michael C Markowitz and Maury Wright
tion of overall system performance.

If the data that the µP needs isn't in the cache, the microprocessor gets the data from slower main memory. Since temporal locality suggests that this data is likely to be needed again, while the CPU is accessing this data, the cache is also putting the requested data into its data SRAM. Spatial locality implies that nearby information will also be needed, so the cache also requests and stores several additional bytes of information. The cache needs to keep an inventory of its contents so that it can react the next time the processor asks for this data. The tag SRAM keeps the list of information by using a portion of the requested data's high-order address, called the tag.

The number of bits in the tag depends on how big the tag RAM is, how big the cache is, and the block or line size of the cache. A block, or line, is the minimum number of bits of code or data that move between main memory and cache during a transfer. Although spatial locality recommends larger block sizes, your design must balance the block size against the time and bandwidth it takes to transfer the data on the memory bus.

In order to indicate a match, logic compares each tag to the appropriate bits from the requested data. The amount of comparison logic depends on the cache's mapping policy. Allowing any block of data to map to any location in the cache demands that you compare each block's tag to the requested tag. As a result, either you need a small cache, large block sizes, or fast comparison logic to build a cache that fully associates memory with the cache. In addition to the comparison logic, you also need logic to determine which data to replace, called the replacement policy, determines which information in the cache is least valuable and can be overwritten by new information.

Comparison and replacement logic isn't the only consideration with mapping policy. At the other extreme from a fully associative cache is one that maps each location in memory to only one location in the cache—a direct-mapped (or 1-way set-associative) cache. If the system executes a program that loops between two addresses that map to the same cache location, every memory access will be a cache miss. As a result, the computer will thrash, continually overwriting data that the cache will actually need with data its algorithms think it will need.

### Table 1—Cache hit rates

<table>
<thead>
<tr>
<th>Cache configuration</th>
<th>Hit rate (%)</th>
<th>Cache size (bytes)</th>
<th>Associativity</th>
<th>Line size (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>1k</td>
<td>Direct</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>8k</td>
<td>Direct</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>16k</td>
<td>Direct</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>32k</td>
<td>Direct</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>32k</td>
<td>Two-way</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>64k</td>
<td>Direct</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>64k</td>
<td>Two-way</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>64k</td>
<td>Four-way</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>128k</td>
<td>Direct</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>128k</td>
<td>Two-way</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>32k</td>
<td>Direct</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>64k</td>
<td>Direct</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>64k</td>
<td>Two-way</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>128k</td>
<td>Direct</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

EDN April 25, 1991
Read operations occur more frequently than write operations, therefore it makes sense to optimize your cache for reads.

You can limit the amount of comparison and replacement policy logic by restricting where data can go in the cache. For example, if you only allow data at a particular address in the DRAM to map to four locations in the cache, you need only compare four tags to the requested tag. If a cache miss occurs, you load the new information into one of the four possible sites. Restricting the mapping locations to one or two further reduces the complexity of the design.

A fully associative cache won’t thrash because it uses a replacement policy that saves recently used data and instructions. The disadvantage of a fully associative cache is its cost. A cache that minimizes thrashing, but doesn’t use as much comparison logic, restricts data in memory to a finite number of banks, called ways, in the cache. Generally, the performance improvement of building a system containing more than four ways is not worth the added complexity of the design. A 2-way set-associative cache allows each location in memory to map to two locations in the

### Table 2—Representative ICs and chip sets for cache-based systems

<table>
<thead>
<tr>
<th>Company</th>
<th>Part number</th>
<th>Part type</th>
<th>Features</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT&amp;T Microelectronics</td>
<td>7C180 and 7C174</td>
<td>Cache-tag SRAM</td>
<td>4kx4-bit memory with 10- to 25-nsec access times. 8kx8-bit memory with 12- to 25-nsec access times.</td>
<td>$22.85/28.10 (100) for 10/12 nsec DIPs</td>
</tr>
<tr>
<td></td>
<td>7C183 and 7C157</td>
<td>Cache-data SRAM</td>
<td>8kx16-bit memory with 25- to 45-nsec access times. 16kx16-bit latched, self-timed memory with 20- to 33-nsec access times.</td>
<td>$22 (100) for 25-nsec DIPs $74.90 (100) for 20-nsec PLCCs</td>
</tr>
<tr>
<td>Austek Microsystems</td>
<td>A38202SX and A38202</td>
<td>Cache controller with integrated tag RAM</td>
<td>Supports 16k- to 64k-byte (SX) or 32k- to 128k-byte, two-way set-associative or direct-mapped, write-through caches.</td>
<td>$31.74 (1000) for 20-MHz A38202SX $57.01 (1000) for 33-MHz A382022</td>
</tr>
<tr>
<td>Chips and Technologies</td>
<td>Peak/sx</td>
<td>Chip set with cache controller for 80386sx-based systems</td>
<td>Supports 16k or 32k bytes of cache with a programmable two-way set associative or direct-mapped, write-through cache.</td>
<td>$69 (1000)</td>
</tr>
<tr>
<td></td>
<td>Peak/DM</td>
<td>Chip set with cache controller for 80386sx-based systems</td>
<td>Supports as much as 256k bytes of direct-mapped cache.</td>
<td>$64 (1000) for 25-MHz set $78.20 (1000) for 33-MHz set</td>
</tr>
<tr>
<td>Cypress Semiconductor</td>
<td>7C064</td>
<td>Cache tag, controller, and memory-management unit</td>
<td>Provides control for 64k-byte direct-mapped cache for Sparc. 604 is uniprocessor version and 605 (due late '91) supports multiple processors.</td>
<td>$431 (100)</td>
</tr>
<tr>
<td></td>
<td>7C157</td>
<td>Cache data SRAM</td>
<td>16kx16-bit SRAM that offers a self-timed write mechanism and latched data inputs and outputs.</td>
<td>$83 (100)</td>
</tr>
<tr>
<td>Elite Microelectronics</td>
<td>Eagle</td>
<td>Chip set with cache controller and tag RAM for 386- and i486-based systems</td>
<td>Supports 32k to 128k bytes of two-way set-associative or direct-mapped, buffered write-through cache. Also includes DRAM controller for efficient DRAM refresh and memory access.</td>
<td>$168 (1000) for 33-MHz set</td>
</tr>
<tr>
<td>Eteq Microsystems</td>
<td>Cougar</td>
<td>Chip set with cache controller and tag RAM for 386- and i486-based systems</td>
<td>Supports 16k to 512k bytes of direct-mapped, buffered write-through cache. Also includes DRAM controller for efficient DRAM refresh and memory access.</td>
<td>$33 (1000) for 33-MHz set</td>
</tr>
<tr>
<td>Fujitsu Microelectronics</td>
<td>MB8299-25</td>
<td>SRAM</td>
<td>32kx9-bit SRAM with 12-nsec output enable access time, 25-nsec memory access time.</td>
<td>$17.50 (10,000)</td>
</tr>
<tr>
<td>Integrated Device Technology (IDT)</td>
<td>71589</td>
<td>Cache-data SRAM</td>
<td>32kx9-bit SRAM that offers a burst mode that can be synchronized to the CPU, and a synchronous write capability.</td>
<td>$79.25 (100) for 33-MHz version</td>
</tr>
<tr>
<td></td>
<td>71B256, 61B238, and 71B258</td>
<td>BiCMOS SRAM</td>
<td>32kx8- and two 64kx4-bit SRAMs. 5- to 6-nsec output enable times and 12- to 15-nsec address access times.</td>
<td>$69.25 (100) for 15-nsec '256 $86.75 (100) for 12-nsec '296 and '258</td>
</tr>
<tr>
<td>Intel</td>
<td>82395SX and 82395DX</td>
<td>Integrated controller, tag and data SRAM</td>
<td>8k- (SX) and 16k- (DX) byte—cascadable to 64k bytes—four-way set-associative, cache that uses a pseudo-least-recently-used replacement policy and has a 16-byte line size.</td>
<td>$44 (100) for 20-MHz SX devices $90/100 (1000) for 25/33-MHz DX devices</td>
</tr>
<tr>
<td>Matra Design Semiconductor</td>
<td>C395e/C415</td>
<td>i386- and i486-based chip set with controller and tag SRAM</td>
<td>Supports 32k- to 256k-byte and 128k- to 256k-byte, two-way set-associative, four-way set-associative, or direct-mapped caches with copy-back or write-through policies.</td>
<td>$60/72 (10,000) for 25/33-MHz C395e sets $99/119 (10,000) for 25/33-MHz C395e/C415 sets</td>
</tr>
</tbody>
</table>
cache. Similarly, a 4-way set-associative cache maps each memory location to four locations in cache. Conceptually, each way is a page, and each location in memory can map to only one location on a page.

Choosing which location on the page to map the data to is the function of the replacement policy. A 2-way cache often uses a least-recently-used (LRU) policy to decide which of the two memory locations to overwrite. An extra bit at each location tracks accesses and keeps the data that was most recently needed.

**Guess which data you won’t need**

A 4-way set-associative cache offers more replacement alternatives. Random replacement is the simplest to implement, though using such a policy may violate temporal locality. First-in, first-out (FIFO) replacement stacks all of the information in the cache and deletes the oldest—even if it is the most recently used. A variation of the LRU policy, called not-most-recently-used or pseudo-LRU, recognizes the importance of temporal locality and the logic efficiency of random replacement by tracking and protecting the most recently used information and randomly overwriting the information at the appropri-

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<table>
<thead>
<tr>
<th>Company</th>
<th>Part number</th>
<th>Part type</th>
<th>Features</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micron Technology</td>
<td>56C0816 and 56C2816</td>
<td>i386- and i486-compatible cache-data SRAM</td>
<td>8x16- and 8x18-bit SRAMs that include address latch and multiplexing between two RAM banks.</td>
<td>$15.71 (1000)</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>M5M51014, M5M51001, M5M5155, and M5M5180</td>
<td>SRAM</td>
<td>25-nsec, 1Mx4-bit SRAM, available in June. 25-nsec, 1Mx4- or 256kx4-bit SRAM. June delivery. 15-nsec, 64kx4-bit SRAM with OE. June delivery. 20-nsec, 8x8-bit SRAM with OE.</td>
<td>$85 $85 $25 $10</td>
</tr>
<tr>
<td>Mosel</td>
<td>MS441</td>
<td>Integrated cache controller for i386- and i486-based systems</td>
<td>Uses two concurrent 386486 bus controllers along with dual-port memories to allow background write back while read and write cache hits continue. Supports 2k-block, 64k-byte, two-or one-way set associative cache.</td>
<td>$65 (10,000)</td>
</tr>
<tr>
<td></td>
<td>MS443</td>
<td>Dual-port burst SRAM</td>
<td>16kx9-bit, dual-port SRAMs with parity, input and output registers to buffer bursting and memory accesses.</td>
<td>$9 (10,000)</td>
</tr>
<tr>
<td>Motorola</td>
<td>62486, 62940, and 62950</td>
<td>Application-specific SRAM</td>
<td>32kx9-bit memories for memory subsystems for 80486, 88840, and Sparc microprocessors.</td>
<td>$57.20 (500)</td>
</tr>
<tr>
<td></td>
<td>4180</td>
<td>Cache-tag SRAM</td>
<td>4x4x8-bit 18-nsec tag SRAM.</td>
<td>$10.40 (500)</td>
</tr>
<tr>
<td>NEC Electronics</td>
<td>46710 and 46741</td>
<td>BICMOS SRAM for R3000-based systems</td>
<td>8x20-bit x2-bank and 16kx20-bit x2-bank memories with address latches and 15-nsec access times.</td>
<td>$45 (1000)</td>
</tr>
<tr>
<td>Quality Semiconductor</td>
<td>8885, 8886, and 8888</td>
<td>SRAM</td>
<td>All CMOS 16kx4-bit SRAMs with access times as fast as 10 nsec. '85 has 2 CSs, '86 offers OE; both with separate I/O lines. '88 has common I/O.</td>
<td>$30.54 (1000)</td>
</tr>
<tr>
<td>SGS Thomson</td>
<td>41S80, 48574/90, and 4202</td>
<td>Cache-tag SRAM</td>
<td>4x4- , 6kx8- , and 2kx20-bit memories with address-compare access times as fast as 12 nsec. Used to design 32k- to 128k-byte caches.</td>
<td>$13 (1000)</td>
</tr>
<tr>
<td>Silicon Connections</td>
<td>SC5204 and SC4109</td>
<td>SRAM and self-timed RAM</td>
<td>5204 is an 8-nsec, 256kx4-bit BICMOS RAM. 4108 is a 5-nsec, 64kx9-bit self-timed RAM. Both available third quarter of 1991.</td>
<td>$330 (1000)</td>
</tr>
<tr>
<td>Texas Instruments</td>
<td>2155, 2163, and 2164</td>
<td>Cache-tag SRAM</td>
<td>2kx8- (2155) and 16kx5-bit cascadable SRAMs with 3-state (2163) or open Drain (2164) Match Output. The 2155 supports the 68030 burst-fill capability.</td>
<td>$19.58 (10,000)</td>
</tr>
<tr>
<td>Toshiba America</td>
<td>55187 and 55188</td>
<td>Cache-data SRAM</td>
<td>2kx8-bit SRAMs. Configurable for either direct-mapped or 2-way set-associative caches. Control logic for 2-way cache is on-chip Memory access time of 20, 25, and 30 nsec.</td>
<td>$11 (1000)</td>
</tr>
<tr>
<td>VLSI Technology</td>
<td>82C325 and 82C335</td>
<td>Cache-controllers (these devices are part of 386SX- and DX-based chip sets)</td>
<td>Supports as much as 32k bytes (325) and 64k bytes (335) of cache memory with look-aside, write-through architectures. Implements 2-way set-associative cache with least-recently-used replacement.</td>
<td>$40 (500)</td>
</tr>
</tbody>
</table>
Cache design

Different ways to maintain temporal locality.

Replacement, mapping, and look-through or look-aside architectures are all related to memory-read operations. Because in most applications, memory reads account for the majority of memory accesses, you are wise to prioritize your design to speed read operations. However, don’t ignore memory writes.

If the data is in the cache when the CPU tries to write data to memory, you have two alternatives. The simplest approach is to write the data to both the cache and main memory. This write-through approach ensures data coherency between cache and memory. The penalty for using a write-through scheme is the wait states that the DRAM controller imposes as a result of the write operation. You can attenuate this penalty somewhat by using a buffer that writes the data from the cache to the memory, relieving the CPU of that responsibility.

Snooping maintains coherency

Copy back is a more complicated scheme for writing information to cache and main memory. This technique maintains a bit that stores the coherency of the cache and DRAM memory. If the data is inconsistent, or dirty, then whenever the cache controller decides to overwrite the dirty location, it must first copy the valid data back to the DRAM. Similarly, if another device requests the data from the DRAM, the cache controller must monitor, or snoop, the bus to copy back the dirty data to the DRAM before the DRAM supplies that data to the other device. (For a detailed discussion of snooping and cache coherency, see “Protocols keep data consistent,” EDN, March 14, 1991, pg 41.)

Deciding what to do on a write operation that causes a cache miss is more difficult than deciding what to do when a write operation results in a cache hit. Temporal locality suggests that information read from a cache once is likely to be read again. Equivalency would suggest that an address recently written to is likely to be accessed again. However, reading recently written information is application dependent and is generally not as common as rereading memory locations you recently read. In addition, write operations consume a small percentage of a system’s operating time.

Two-way set-associative caches (a) are more complex than direct-mapped caches (b), and as a result, cost more. However, 2-way set-associative caches perform better.
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Cache design

Caches that load themselves with written data on cache misses are called allocate write. To save logic, you can design a nonallocate-write cache, which doesn't load written data to cache on a miss. The incremental performance improvement of an allocate-write cache may not be worth the effort.

Overemphasizing reads is an effective strategy except when the CPU contains an onboard cache. These generally small caches, called primary caches, already intercept a large percentage of read requests. A secondary cache optimized for read operations is a superset of the on-chip primary cache. As a result, a secondary cache is somewhat redundant and provides a smaller return on your memory and cash investment.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Look-aside</th>
<th>Look-through copy back</th>
<th>Look-through write through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read hit</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Write hit</td>
<td>System-memory wait states.</td>
<td>0</td>
<td>0, unless the write buffer is already full with a pending write.</td>
</tr>
<tr>
<td>Read miss (excludes line-fill cycles)</td>
<td>System-memory wait states.</td>
<td>System-memory wait states +1 due to an extra look-up cycle.</td>
<td>System-memory wait states +1 due to an extra look-up cycle.</td>
</tr>
<tr>
<td>Write miss</td>
<td>System-memory wait states.</td>
<td>0, unless the write buffer is already full with a pending write.</td>
<td>0, unless the write buffer is already full with a pending write.</td>
</tr>
</tbody>
</table>

Alternatively, a secondary cache optimized for write operations can boost performance of the portion of the cache's operation that the primary cache does little to improve. A cache technique under development by Mosel uses dual-port SRAMs and takes advantage of the burst-memory data access. The SRAMs, which will work with 80386- and 80486-based systems, facilitate building 64k-byte, 2-way set-associative caches. The memories operate by simultaneously latching all 128 bits in a 5-cycle, 16-byte burst using 7-nsec latches at

Caching branches reduces pipeline stalls

When designers at Advanced Micro Devices were designing the 29000 RISC µP family (the 29005 16-MHz device costs $50 (1000), they realized their transistor budget would allow them to implement a small cache on-chip. Because the processor has both an instruction bus and a data bus, they needed to decide whether to build an instruction or data cache.

They also realized that, because the processor uses instruction prefetching, it would perform better if they could prevent pipeline stalls. Combining the transistor budget with the need to eliminate stalls, the designers came up with a branch-target cache (BTC).

The BTC functions like a normal cache in that it stores data already in the dynamic RAM (DRAM). However, it differs by only storing the four instructions following a branch. If the branch was previously taken, the processor executes the branch in a single cycle.

When the processor executes a branch for the first time, the cache doesn't contain the succeeding instructions. It takes one cycle to execute the branch from memory and five cycles to refill the instruction pipeline. AMD claims a 60% hit rate for the 512-byte BTC on the 29000.

The BTC is organized as a 2-way set-associative cache. Each way comprises sixty-four 32-bit words divided into 16 blocks of four words each. These four words define a branch target entry. Each block is associated with one 28-bit cache tag. The tag includes 26 bits derived from the address and two bits, called the Space ID, that indicate whether the instructions were fetched from instruction/data memory or from read-only memory and whether the instructions were fetched in user or supervisor mode. Finally, each word in the cache has an associated valid bit that indicates the instruction's validity.

After a branch, the address of the fetched instruction selects a line to store the instruction sequence of the branch, if that branch instruction sequence isn't in the BTC. The processor uses a random replacement scheme based on the processor clock to choose which set to replace. The processor then sets the address tag and the space ID to properly describe the instructions being stored in the cache before loading the instructions into the cache.

BTCs are more efficient than conventional caches when the caches are smaller than about 1k byte, according Dr Mark Hill (Ref 1). Conversely, Hill says that conventional caches are preferable when larger than 8k-bytes. He further says that intermediate-sized BTCs and conventional caches offer comparable performance.
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Cache design

the input and output of the memory array. The memories will be available in the third quarter of 1991.

**Caches speed sequential writes**

The dual-port memories boost performance on a write miss. The miss causes a burst allocate-write cycle that fills the secondary cache with 16 sequential bytes of data. If the next write is to the next memory location, that data will already be in the cache. According to statistics compiled by Mosel, 70% of write operations are sequential. Further, 50% are at least three sequential writes. The company expects its technique to provide write hit rates exceeding 96% while maintaining read hit rates higher than 96%.

After designing your cache, you can evaluate its effectiveness using a trace-driven cache simulator. Two such simulators, written by Professor Mark Hill of the University of Wisconsin Computer Sciences Department, are tycho and dinero III, which are quasi-shareware packages available on the EDN bulletin-board system (BBS). Both C-based simulators use the same ASCII trace format.

After you create a list of memory references from an executing applications program, you use the list to drive the simulators. In response, the simulators report the behavior of one or more alternative cache designs.

Both simulators evaluate unprocessor caches. Tycho allows simultaneous evaluation of many alterna-

---

**Manufacturers of cache SRAMs and controllers**

For more information on the ICs and Chip sets to implement caches 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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Cache design

tive caches; dineroIII only evaluates one cache per simulation run. The simulators also differ in their capabilities. Tycho is a more restrictive simulator in that all caches in a simulation must have the same cache size, don't prefetch data, and use least-recently-used replacement. DineroIII allows you to vary more cache design options, such as write-back vs write-through, random vs least-recently-used replacement, and demand fetching vs prefetching.

The simulators have been distributed to both commercial and academic sites. You can obtain copies of either or both simulators either by contacting Mark Hill directly, or via the EDN computer bulletin-board system (BBS). (Phone (617) 558-4241 with modem settings 300/1200/2400,8,N,1. Access /freeware SIG and specify (r)ead option followed by (k)ey-word search for “SR #425”.) Professor Hill asks for, but does not require, a $500 donation to the University of Wisconsin to support his continuing research.

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Dynamic specifications describe performance of subranging ADCs

Quantization maps the analog input range into $2^N$ digital words. Because the best resolution attainable from an analog input signal is 1 LSB, an infinite number of points are identifiable between any adjacent code centers (Fig 1). As a result, quantization causes an error of $\pm 0.5$ LSB max.

Quantization is an irreversible process. Once an ADC quantizes a signal, the signal’s original analog information is lost forever—an occurrence comparable to what happens to an analog signal in the presence of white noise. Because of this similarity, many engineers refer to quantization error as quantization noise.

Ray K Ushani, Datel Inc

In the world of high-speed data-acquisition components, the conventional dc parameters are not sufficient to specify the performance of A/D converters. Under dynamic conditions, an ADC’s transfer function may exhibit large errors even though the dc test results appear close to the ideal limits. This disparity is especially common in digital-signal-processing applications.

In practice, no single specification or test can completely characterize a high-speed A/D converter’s performance under dynamic conditions. Therefore, ADC users and designers should comprehend the significance of every dynamic specification. In all, there are nine dynamic parameters you should understand before attempting any test techniques. These parameters include quantization error, the signal-to-noise ratio, harmonic and intermodulation distortion, and the differential phase and gain.

Fig 1—Quantization maps the analog input range into $2^N$ digital words. This process results in a quantization error of $\pm 0.5$ LSB max.
In applications such as high-speed data-acquisition systems, the dc parameters of an A/D converter are not sufficient to specify the device's performance.

Because the quantization error (QE) is as often positive as negative, its average value is precisely zero, which gives no information about the size of the error. A more meaningful measure is the quantization error's root-mean-square value. The following relationships let you calculate the maximum rms quantization noise ($V_{\text{NOISE (RMS)}}$):

$$QE = \frac{V_{\text{IN(I)}} - IQ}{Q}$$

$$QE_{\text{RMS}} = \sqrt{\frac{1}{Q} \int_{-\frac{1}{2}}^{\frac{1}{2}} \left( \frac{V_{\text{IN(I)}} - IQ}{Q} \right)^2 dV_{\text{IN}}}$$

$$= \frac{Q^2}{12}$$

$$V_{\text{NOISE (RMS)}} = \frac{Q}{\sqrt{12}}$$

where $Q$ = LSB weight, $QE(I) = I$th code quantization error, and $V_{\text{IN(I)}} = \text{input range that produces code I}$.

In an actual A/D converter, the quantization band for certain codes can be significantly larger or smaller than ideal. Nonideal quantization bands represent differential nonlinearity errors.

For a signal with a peak amplitude of $Q(2^N)$ that an N-bit ideal converter quantizes, the maximum rms sine-wave value is

$$V_{\text{SIGNAL (RMS)}} = \frac{Q(2^{N-1})}{\sqrt{12}}.$$  

The rms signal-to-noise ratio (SNR) is then

$$\frac{V_{\text{SIGNAL (RMS)}}}{V_{\text{NOISE (RMS)}}} = \frac{Q(2^{N-1})/\sqrt{2}}{Q/\sqrt{12}} = 2^{N-1}(\sqrt{6}).$$

The rms SNR for an ideal N-bit A/D converter is

$$\text{SNR} = 20\log(\sqrt{6}(2^{N-1})) = 6.02N + 1.76 \text{ dB}.$$  

However, for an actual A/D converter, calculate the SNR as follows:

$$\text{SNR} = -20\log \sqrt{10^{-\text{SNRWD}+10} + 10^{-\text{THD}+10}},$$  

where SNRWD is the SNR without distortion and THD is the total harmonic distortion, both in decibels.

Because most of the noise in an A/D converter appears at the harmonic frequencies, the SNR plus distortion is a good estimate of the total harmonic distortion. Furthermore, SNR is the cumulative effect of many error sources such as quantization error, missing codes, integral and differential nonlinearities, total harmonic distortion, aperture uncertainty, and noise. Because of these myriad contributions, SNR is the primary figure of merit in applications such as radar and signal-detecting systems.

The effective-bits (EB) value is the number of bits an ideal A/D converter requires to yield the SNR previously calculated for an ideal N-bit converter:

$$\text{EB} = \frac{\text{SNR} - 1.76}{6.02}.$$  

The effective-bits value is a global description of the ADC's dynamic performance. It provides a general measure of how much the ADC's nonlinearity impairs its overall usefulness at a given input condition. If the quantization noise is uniformly distributed and the quantization errors from sample to sample are statistically independent, the expression for effective bits is

$$\text{EB} = \log_{10} \left( \frac{\text{full-scale volts}}{\sqrt{2} E_{\text{RMS}}} \right).$$  

where $E_{\text{RMS}}$ is the error of the digitized signal.

**Harmonic and intermodulation distortion**

The output signal of a linear device differs from its input signal only in amplitude when you measure the signals in either the time or frequency domain. Any nonlinearity a device introduces will manifest itself as a deviation from the sinusoidal response in the time domain or as new frequencies in the frequency domain. This nonlinearity is distortion.

When an ideal A/D converter with infinite resolution digitizes an ideal sine wave, the digital output fully represents the original sine wave with no distortion at any frequencies. Looking at the discrete-Fourier-transform (DFT) amplitude spectrum of such an output, you can observe a sharp peak at the input frequency. At any other frequency the amplitude will be zero. However, in the case of an actual A/D converter, the amplitude spectrum also contains peaks at integer multiples of the fundamental frequencies. These peaks
represent harmonic distortion (Fig 2). From these peaks, you can calculate the percentage of total harmonic distortion (THD) using the following relationships:

$$\text{THD} = \sqrt{\sum_{n=2}^{N} (\text{HD}_n)^2} \times 100\%$$

$$\text{HD}_N = 10^{-\left(\text{PEAK N} \times 20\right)},$$

where peak N is the Nth-harmonic distortion peak, and the harmonic distortion (HD_n) is equal to the amplitude of the signal at the Nth harmonic divided by the amplitude of the signal at the input frequency.

For an A/D converter, you can calculate THD in decibels as follows:

$$\text{THD} = 20\log \sqrt{\sum_{n=2}^{N} (\text{HD}_n)^2}.$$  

The integral nonlinearity of the A/D converter's transfer function can also cause intermodulation distortion (IMD). IMD is the change in one sinusoidal input that the presence of another sinusoidal input at a different frequency causes. For example, let the input of the A/D converter be the sum of two sinusoids with equal amplitudes but different frequencies: $\sin\omega_1 \pm \sin\omega_2$. Not only will harmonic distortion occur at $N\omega_1$ and $N\omega_2$, but harmonics will also appear at $N\omega_1 \pm K\omega_2$, where N and K are any integers (Fig 3).

This IMD interaction between input sinusoids is significant in both audio and RF-communications applications. The value, in decibels, for the intermodulation distortion when $N = 1$ and $K = 1$ is

$$\text{IMD} (\omega_1 \pm \omega_2) = 20\log \frac{\text{amplitude at } \omega_1 \pm \omega_2}{\text{amplitude at } \omega_1 (\text{or } \omega_2)}.$$  

When the input sinusoids are not of the same amplitude, $\text{IMD} = 20\log (\text{rms value of the sum and difference distortion products + rms value of the fundamental frequencies}).$

**Spurious-free dynamic range**

The spurious-free dynamic range (SFDR) is analogous to the dynamic range for slow, high-resolution A/D converters. As the name implies, SFDR is the range in the amplitude spectrum where no frequency components other than the fundamental exist (Fig 4). SFDR expresses the peak distortion of an A/D converter and is a measure of the device's dynamic range under different input conditions. Mathematically, $\text{SFDR} = \text{the amplitude of the fundamental} - \text{the next highest frequency component, with all values in decibels}.$

The SFDR parameter is of primary importance for A/D converters in noisy receiver environments where the converter must digitize a small-amplitude signal.
Once an A/D converter quantizes a signal, the signal's original analog information is lost forever.

Noise/power ratio (NPR) is another indicator of an A/D converter's dynamic performance. NPR expresses the quality of an A/D converter in broadband frequency-domain applications, such as a multiplexed system. NPR is the ratio of the power of the reconstructed output at two different conditions for a particular frequency (f). The first condition is the full-scale input containing white noise. The second condition is the same input using a notch filter with a center frequency of f. The expression for NPR in decibels is

\[
NPR = 10 \log \left( \frac{\text{1st condition power}}{\text{2nd condition power}} \right)
\]

The NPR caused by quantization noise for an ideal A/D converter is

\[
NPR = \frac{\text{full-scale volts of the ADC}}{K \text{ (quantization noise)}} = \frac{Q \left(2^N\right)}{KQ\sqrt{12}} = \frac{2^N \left(\sqrt{12}\right)}{K},
\]

where Q is the quantization level, \(Q\sqrt{12}\) is quantization noise, N is the number of bits, and K is a loading factor equal to the full-scale volts divided by the rms noise level.

The NPR in decibels is

\[
NPR = 6.02N + 20 \log (\sqrt{3}/K).
\]

For example, a 12-bit ideal A/D converter with a loading factor (K) of 5, has a NPR of 62.7 dB.

Fig 5 helps explain the loading factor. The peak-to-peak noise is a function of \(\sigma\) (\(\sigma\)=rms noise level). If K is 2, for example, 68% of the signal will be within the full-scale value of the converter (32% will exceed full scale). In this case, clipping will result, producing additional distortion. For this reason, you should select a loading factor that will keep the clipping to a small percentage and the signal at a maximum. For a 12-bit A/D converter, the LSB is 0.0248% of full scale, so a loading factor of 8 would be appropriate.

Differential phase (DP) and differential gain (DG) are relevant specifications for video applications. They express the quality of the A/D converter under two different input levels (usually one near zero and the other near full scale).

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DIALIGHT
Nonlinearity in the A/D converter's transfer function can cause both harmonic and intermodulation distortion.

Phase of an A/D converter when a small, high-frequency sine-wave signal is superimposed on a low-frequency signal at two predescribed amplitudes. Differential gain is the ratio of the output amplitudes of an A/D converter with this small, high-frequency sine-wave superimposed on the low-frequency signal at the two predescribed amplitudes.

The theoretical differential phase and differential gain for an N-bit ideal A/D converter is

\[ DP = \frac{Q}{A} \cdot \frac{2}{3} \]

\[ DG = 100\% \cdot \frac{Q}{A} \cdot \frac{2}{3} \]

\[ Q = \frac{\text{full-scale volts}}{2^N} \]

DP is the differential phase in radians (1 rad = 57°), Q is the LSB size in IRE (Institute of Radio Engineers) units, A is the amplitude of the subcarrier in IRE units, and DG is the differential gain in percent. For example, consider an 8-bit system converting a signal having a peak-to-peak value of 140 IRE units (1 V):

\[ Q = 0.546 \text{ IRE units} \]

Suppose a test signal consists of a subcarrier having a peak value of 10 IRE units (20 IRE units p-p), then

\[ DP = \frac{0.546}{10} \cdot \frac{2}{3} = 0.0364 \text{ rad} = 2.07° \]

\[ DG = 100\% \left( \frac{0.546}{10} \right) \cdot \frac{2}{3} = 3.64\% \]

These two parameters directly affect the performance of any color-graphic system, such as a high-resolution optical reader or a conventional TV. Differential gain will distort the degree of color saturation. This distortion occurs because the amplitude of a small signal superimposed on another signal represents the saturation of the color. This distortion also affects the brightness of the color. Differential phase will cause incorrect hues in the reproduced picture. In an ADC, the analog section of the converter is the primary generator of these distortions.

The analog input circuitry determines the bandwidth, which tells you at what input frequency you can expect amplitude attenuation to begin. The bandwidth is normally defined as the maximum sinusoidal input frequency at which the amplitude of the output signal, derived from the digital data, decreases by 3 dB with respect to the amplitude of the output for a low-frequency sinusoidal input. A more appropriate parameter for an A/D converter is its full-power bandwidth. This parameter specifies the maximum frequency at which the converter can accurately quantize a full-scale-input sine wave without generating any spurious or missing codes.

Engineers often overlook full-power bandwidth when evaluating a high-speed A/D converter. A wide bandwidth results in reduced amplitude roll-off and less time-delay distortion. It also minimizes the interaction between the poles of the ADC's input and the poles of any antialiasing filter before the input. A narrow bandwidth could cause time-delay distortion due to nonlinear phase response, amplitude error, or rise-time error.

To illustrate the effects of the A/D converter's bandwidth, consider the amplitude attenuation and time-delay distortion when a full-scale 5-MHz sine wave is applied to the input of an equivalent A/D converter that has a 20-MHz bandwidth (Fig 6). Assuming a single-pole model, the equivalent RC network will attenuate the input by 3% of its original value and shift the input's phase by \(-14.05°\). The result of this action is a time delay of 7.8 nsec. The following formulas express the amplitude (A), the phase (\(\phi\)), and the time delay (\(\tau\))

\[ \tau = \frac{R}{2\pi f} \]

\[ A = \frac{1}{\sqrt{1 + (2\pi f RC)^2}} \]

\[ \phi = -\tan^{-1} \left( \frac{2\pi f RC}{1} \right) \]

**Fig 6—This equivalent circuit illustrates the effects of a band-limited A/D converter compared with an ideal infinite-bandwidth converter.**
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delay (ΔT) of the output of an A/D converter with a bandwidth of Δf, where f is the frequency of the input signal:

\[ A = \sqrt{\frac{1}{1 + (f/Δf)^2}} \]

\[ \phi = -\tan^{-1}(f/Δf) \]

\[ ΔT = \frac{\phi}{360f}. \]

The transient-response time is the time the A/D converter requires to settle to its final accuracy when the input changes from negative full scale to positive full scale or the other way around. This response time depends primarily on the sample-and-hold acquisition time. Transient-response time is important in transient analysis and in applications in which the input of the A/D converter is multiplexed to increase the number of channels, as in data-acquisition systems.

When the input of an A/D converter exceeds the full-scale range, the analog section of the converter saturates. Because the error amplifier usually has a high gain, saturation is particularly significant for a subranging ADC. If the operating conditions do not let the ADC fully recover from saturation, the converter might produce an erroneous code for a valid input. The time the ADC requires to recover from saturation is called the overvoltage recovery time. The recovery time is measured from the time the input returns to the ADC’s operating range until the time that the ADC can make a proper conversion. The recovery time increases as the overrange voltage increases.

Part 3 will conclude this subranging-ADC series with a discussion of test methods for evaluating these dynamic parameters and specifications.

**Author’s biography**

Ray Ushani is the manager of the Advanced Development Group at Datel Inc (Mansfield, MA). He has been with the company for six years and has been instrumental in the development of several A/D converters, multiplexers, and S/H circuits. Ray has an MSEE from Northeastern University (Boston, MA) and is a PhD candidate at Tufts University (Medford, MA). Not one to stray far from his vocation, Ray’s hobbies include RF and microwave design.

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Design a digital synchronizer with a low metastable-failure rate

When you're attempting to synchronize asynchronous data to a system clock, don't let metastability ruin your design. Carefully considering this problem during the design phase can save you headaches down the line.

Steven R Masteller, Allied-Signal Aerospace, Bendix Engine Controls Div

Metastability is a type of failure that can occur when digital circuits attempt to synchronize asynchronous digital data. The failure is more prevalent at fast asynchronous data rates and, thus, fast synchronizing clock frequencies. If you don't consider metastability during the design phase, this monster can bite you later by producing intermittent failures that are extremely difficult to diagnose.

Although metastability is theoretically unavoidable in synchronizers, you can reduce the probability that a failure will occur during a specified time period. The common response for combating metastability failures is to use multistage synchronizers, which can reduce the number of failures to an arbitrarily small value. Understanding the various factors that influence metastability leads to a qualitative design procedure for multistage synchronizers that effectively makes the problem negligible.

Digital designers often overlook metastability and its effects because traditional textbooks don't address this type of failure. To understand the problem better, consider the simple SR flip-flop in Fig 1. A conventional digital analysis of this circuit gives rise to only two possible logic states for the inputs and outputs: logical 1 and logical 0. However, all digital circuits must pass through an active region when transitioning from one state to another. Fig 2a shows a typical transfer function, $H$, for a NAND gate having one input at a logical 1 while the other input undergoes a transition from a logical 0 to a logical 1. The following equation represents the transfer function:

$$V_{OUT} = H(V_{IN}).$$

Fig 1—The cross-coupled NAND gates of an SR flip-flop can reach a metastable condition because the output of one gate is an input to the other.
Although metastability is theoretically unavoidable in synchronizers, you can reduce the probability of a failure within a specified time period.

When you cross-couple two NAND gates to create the SR flip-flop in Fig 1, the output of one of the gates becomes one of the inputs to the other gate. The following equations define this feedback arrangement:

\[ V_{IN1} = V_{OUT2} \]
\[ V_{IN2} = V_{OUT1}. \]

You can superimpose the transfer functions for both NAND gates on a single graph to find the points of equilibrium (Fig 2b). Because the previous three equations make the following relationships true:

\[ V_{IN1} = H(V_{IN2}) \]
\[ V_{IN1} = H(V_{OUT1}) \]

the circuit reaches equilibrium at any point where

\[ V_{IN1} = H(H(V_{IN1})). \]

The points where the two superimposed transfer-function curves in Fig 2b intersect are the equilibrium points. The equilibrium points labeled "stable" are the logic states conventional analysis predicts. However, the superimposed curves identify an additional equilibrium point labeled "metastable." The logic level for the metastable point is halfway between a stable logical 1 and a stable logical 0. Theoretically, the SR flip-flop can stay in the metastable condition indefinitely if noise or some other disturbance doesn't dislodge the circuit from this state.

It's just like rolling downhill

You can make an analogy between the metastable state and a ball resting precariously at the top of a smooth hill (Fig 3). If you carefully balance the ball at the top of the hill, the ball will sit quietly until disturbed. When you disturb the ball slightly, which is analogous to a noise disturbance in a metastable circuit, the ball will roll to one side or the other and come to rest at the bottom of the hill, which is analogous to the circuit arriving at one of the two stable points. Which point the ball will arrive at is indeterminate. A ball at the bottom of the hill, which is analogous to an SR flip-flop in a stable state, will remain there barring any large disturbances.

Metastability occurs when a circuit violates the timing restrictions that the specification data impose on a flip-flop. Such restrictions include minimum pulse widths and minimum setup and hold times. If you main-
tain adequate timing margins in a synchronous circuit, metastability will never occur. However, in the many applications in which you must synchronize asynchronous data to a system clock, eliminating the synchronizing circuit's potential for becoming metastable is impossible.

Metastability causes the propagation delay of an SR flip-flop to be greater than its specified value. The metastable state is evidenced by a plateau in the output of the SR flip-flop (Fig 4a). The likelihood that an SR flip-flop will remain in a metastable state decreases exponentially with time. Metastability also increases the propagation delay of a D flip-flop from its specified value even though a metastable plateau is not evident on the output of the device (Fig 4b). The internal steering latches, which a D flip-flop employs to direct signals to its master SR flip-flop, smooth out the plateau region. Metastability can cause both types of flip-flops to generate a runt pulse. The runt pulse occurs when the flip-flop returns to the original stable state from the metastable state instead of making a transition to a new stable state.

Metastability in D flip-flops can cause two types of failures. One type occurs when a metastable condition prevents a D flip-flop from changing to a different state. In this case, an entire event can be lost. Timing failures can be even more insidious. The worst case occurs when the output of a flip-flop drives several destination flip-flops via circuit paths that have different propagation delays. A delayed output signal caused by a metastable condition may reach some of the destination flip-flops before the next clock occurs; the same output signal would arrive at other destination flip-flops after the next clock. This condition can cause some circuitry to recognize an event, such as an interrupt, one clock cycle late.

A simple equation predicts the MTBF

You can estimate a synchronizing flip-flop's mean time between failures (MTBF) due to metastability if you know the asynchronous data rate, \( F_n \); the synchronizing clock frequency, \( F_c \); the synchronizing flip-flop's propagation delay, \( T_p \); the synchronizing flip-flop's inverse gain-bandwidth product, \( G \); and the total gate delay between the synchronizing clock edge and any destination flip-flops that receive the synchronized data, \( T_D \). The equation is as follows (Ref 1):

\[
MTBF = \frac{e^{\left(F_n/F_c - T_D/G\right)}}{2F_cF_nT_p}
\]

Theoretically, you should include the circuit’s rise and fall times as well as the average time for the circuit’s noise to dislodge the flip-flop from the metastable state in the \( T_p \) term. However, the exponential factor dominates the MTBF equation for MTBFs greater than a few years. Therefore, the propagation delay of the synchronizing flip-flop is an adequate approximation.
Metastability occurs when a circuit violates the timing restrictions that a flip-flop's specification data impose.

for $T_p$. An increase in the circuit noise or the rise and fall times only marginally improves the MTBF.

The $G$ term is in the exponential factor of the MTBF equation and thus has a large effect on the resulting MTBF. Essentially, you'll produce more-reliable synchronizers by using flip-flops with large inverse gain-bandwidth products. $G$ depends on both the internal design of the flip-flop and the process technology used to construct the device. As a general rule, fast technologies result in large $G$ values and, consequently, synchronizers with high MTBFs for a specific clock frequency. Ref 2 describes a method for measuring $G$ for a flip-flop.

The $T_0$ term is the sum of all the time delays between the synchronizing clock edge and a destination flip-flop. The sum includes not only the propagation delay of the synchronizing flip-flop but also any intervening-gate propagation delays as well as the setup and hold times of the destination flip-flop. The $T_0$ term is in the exponential factor of the MTBF equation and has its most pronounced effect on the MTBF at high clock frequencies. Minimizing $T_0$ can be an effective way of increasing the MTBF but is usually difficult.

To illustrate the effects of the circuit parameters on a synchronizer’s MTBF, consider the following typical time delays and a worst-case inverse gain-bandwidth product for a single-stage D flip-flop built using a 2-µm process (Fig 5):

- Propagation delay = 7.0 nsec typ
- Setup time = 1.5 nsec typ
- Hold time = 2.5 nsec typ
- Inverse gain-bandwidth product ($G$) = 2.1 nsec max.

Using these time delays,

$$T_p = 7.0 \text{ nsec}$$

$$T_0 = 7.0 + 2.5 + 1.5 = 11.0 \text{ nsec}.$$ 

When the clock frequency ($F_C$) is 8 MHz and the asynchronous data rate ($F_I$) is 4 MHz, the synchronizer's MTBF calculates to be

$$MTBF = \frac{e^{(8 \text{ MHz}) - 11 \text{ nsec}/2.1 \text{ nsec}}}{2(8 \text{ MHz})(4 \text{ MHz})(7 \text{ nsec})}$$

$$= 27,000,000,000 \text{ years.}$$

Clearly, an MTBF of 27 billion years doesn't pose a significant risk of metastable operation in this synchronizer at these frequencies. However, when you double the clock frequency and the asynchronous data rate to 16 MHz and 8 MHz, respectively, the same synchronizer's MTBF calculates to be

$$MTBF = \frac{e^{(16 \text{ MHz}) - 11 \text{ nsec}/2.1 \text{ nsec}}}{2(16 \text{ MHz})(8 \text{ MHz})(7 \text{ nsec})}$$

$$= 6.9 \text{ hours.}$$

Simply doubling the operating frequency causes the synchronizer's MTBF to plummet from billions of years to approximately seven hours. And any synchronizer—no matter how well behaved at a particular operating frequency—will produce unacceptable failure rates at some higher frequency. You should always examine the circuit parameters for potential metastability problems whenever you upgrade a system to a higher data rate.

Changing the inverse gain-bandwidth product, $G$, also has a dramatic effect on the synchronizer’s MTBF. Changing $G$ from a worst case of 2.1 nsec to a best case of 1.2 nsec, while maintaining the clock frequency at 16 MHz and the asynchronous data rate at 8 MHz, increases the MTBF to

$$MTBF = \frac{e^{(16 \text{ MHz}) - 11 \text{ nsec}/1.2 \text{ nsec}}}{2(16 \text{ MHz})(8 \text{ MHz})(7 \text{ nsec})}$$

$$= 77,000 \text{ years.}$$

Both the process technology and the flip-flop design determine the value of $G$, so small process variations can have a large effect on $G$. Therefore, be sure to measure $G$ for flip-flops from different batches of chips to establish a worst-case value. Process variations and, therefore, $G$ tend to be constant for all chips from the
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Small changes in a circuit parameter can drastically change the calculated MTBF.

Fig 6—You can build a 2-stage synchronizer by cascading two D flip-flops that have a common clock. Continue adding D flip-flops to build a multistage synchronizer.

same batch. Obtaining one batch of chips that doesn’t exhibit metastable operation for a given set of conditions and another batch of chips that exhibits frequent metastability failures under the same conditions is indeed possible.

Although the clock rate, synchronous time delay, and process technology have pronounced effects on the MTBF due to metastability, you’ll often have no control over these variables. In these cases, you should consider a multistage synchronizer to reduce metastable failures. You can construct a multistage synchronizer by cascading stages of multiple D flip-flops and providing a clock frequency that is common to all stages.

To illustrate the effectiveness of a 2-stage synchronizer (Fig 6), consider the same circuit parameters that produced the previous MTBF of 6.9 hours, or 24,958 sec, in a single-stage D flip-flop synchronizer. Only unsynchronized data caused by metastable operation in the first stage can cause a potential metastable failure in the second stage of a 2-stage synchronizer. Therefore, you can use the MTBF of the first stage to calculate the asynchronous data rate of the second stage. Using the following circuit parameters:

\[
\begin{align*}
T_D &= 7.0 \text{ nsec} \\
T_{PD} &= 7.0 + 2.5 + 1.5 = 11.0 \text{ nsec} \\
G &= 2.1 \text{ nsec} \\
F_c &= 16 \text{ MHz} \\
F_P &= 1/24,958 = 40.1 \text{ µHz},
\end{align*}
\]

1. the MTBF of the 2-stage synchronizer is

\[
\text{MTBF} = \frac{e^{(1/16 \text{ MHz} - 11 \text{ nsec}/2.1 \text{ nsec})}}{2(16 \text{ MHz})(40.1 \text{ µHz})(7 \text{ nsec})} = 16,000,000 \text{ years}.
\]

Adding one more stage to the synchronizer increased the MTBF from 6.9 hours to 16 million years. Although this failure rate is comfortably large, adding a third stage would effectively eliminate metastability as a problem.

These examples show that a small change in a circuit parameter can cause a drastic change in the MTBF. Small variations in the data can cause large variations between the calculated MTBF and the actual MTBF. A rule of thumb for designing a highly reliable synchronizer is to achieve a calculated MTBF of at least 10,000 years. This large MTBF figure should provide an adequate safety margin against small parameter variations causing excessive field failures.

Another suggestion is to multiply the 10,000-year MTBF times the number of units you expect to sell to arrive at a calculated MTBF for a single unit. For example, if you expect to sell 100 synchronizers, the calculated MTBF of a single synchronizer should be at least 1,000,000 years. This extra margin guards against field failures that you can’t repeat in the laboratory.

References


Author’s biography

Steven R Masteller has been a design engineer with the Bendix Engine Controls Div of the Allied-Signal Aerospace Co (South Bend, IN) for the past three years. He currently specifies and develops standard-cell AS/Cs for high-reliability, high-performance electronic engine-control circuits. Steven has a BSEE from Purdue University and enjoys travel, sky diving, and science fiction in his spare time.

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Regulator accepts high or low input

Brian Huffman
Linear Technology Corp, Milpitas, CA

The switching regulator in Fig 1 produces a constant 12V dc output from inputs ranging from 8 to 20V dc, a typical requirement for battery-powered applications. The circuit uses a simple inductor, L1, instead of the more common, and more expensive, transformer.

The circuit is a buck-boost switching regulator. Its switches (D1, D2, Q1, and IC1's internal switch (VSW)) alternately connect the inductor L1 across the input and then the output.

IC1 has a high-side switch, which connects one end of the inductor to the positive rail (-1.5V). Q1 connects the other end of the inductor to ground. IC1's VSW pin provides enough drive to turn on Q1. During Q1's on period, the inductor accumulates energy. D1 blocks the output capacitor from discharging through Q1.

When IC1's power switch turns off, the voltage on IC1's VSW pin decreases until the clamp diode, D2, is forward-biased. At the same time, the falling voltage on the VSW pin turns off Q1, causing Q1's drain voltage to rise until D1 clamps it. D1 and D2 then provide a current path for the inductor to transfer its energy to the output. If you need to handle a higher input voltage, be sure to clamp the gate of Q1 below its 20V-max rating.

IC1's internal pulse-width modulator controls the energy transfer. IC1's feedback pin, VFB, samples the output from the 11.0-kΩ/2.49-kΩ divider. IC1's error amplifier compares the feedback pin's voltage to its internal 2.21V reference and controls the duty cycle, completing a control loop. You can change the output voltage by varying the resistor-divider ratio. The RC damper on IC1's VC pin provides loop-frequency compensation.

The inductor supplies output current in pulses. The output capacitor, C2, smoothes the current pulses. During the time IC1's switch is on, the output capacitor delivers current to the load. The input capacitor, C1, provides a low-resistance ac path for the inductor's current during this period. The input capacitor reduces the ripple seen on the VIN pin.

The circuit's efficiency can exceed 70% for output currents greater than 0.5A. Also, for input voltages above 15V, it can supply more than 2A of output current. (EDN BBS/DL.SIG #943)

To Vote For This Design, Circle No. 746

Fig 1—This switching regulator is suitable for battery-powered applications because it produces a 12V dc output from inputs ranging from 8 to 20V dc.

= 1% FIlM RESISTORS
D1 = MOTOROLA - MBR745
C1 = NICHICON - UPL1E102MRH6
C2 = NICHICON - UPL1C472MRH6
L1 = COILTRONICS - CTX25-5-52

EDN April 25, 1991 179
Transistor sensor needs no compensation

Jim Williams
Linear Technology Corp, Milpitas, CA

The thermometer circuit in Fig 1 uses an inexpensive transistor to accurately measure temperature without compensation or calibration. Almost all transistor sensors use the base-emitter diode's voltage-shift with temperature as their sensing mechanism. Unfortunately, the absolute diode voltage is unpredictable, necessitating circuit calibration each time you fit a new transistor sensor.

The circuit in Fig 1 overcomes this limitation. The circuit provides a 0-to-10V output corresponding to a 0-to-100°C input. Unadjusted error is <±1%.

The basis for the circuit is the predictable relationship between current and voltage in a transistor's $V_{BE}$ junction. At room temperature, the $V_{BE}$ junction diode shifts 59.16 mV per decade of current. The temperature dependence of this constant is 0.33%/°C, or 198 µV/°C. The $\Delta V_{BE}$-vs-current relationship holds, regardless of the $V_{BE}$ diode's absolute value.

An internal oscillator controls the state of the switches in IC1, the LTC1043. The 0.01-µF capacitor at pin 16 sets the IC's oscillator frequency at about 500 Hz. Q1 operates as a switched-value current source, alternating between about 10 and 100 µA as IC1 commutes switch pins 12 and 14. The two currents' exact values are unimportant, so long as their ratio remains constant.

Because of this constant ratio, Q1 requires no reference, although its emitter resistor's ratio must be precise. The alternating 10/100-µA stepped current drive

![Diagram](image-url)

**Fig 1**—The transistor $Q_2$ senses temperature. This circuit requires no compensation, even if you change transistors.
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CIRCLE NO. 111
to the sensor transistor, \( Q_2 \), causes the theoretical 59.16-mV excursion at 25°C to appear across the \( V_{BE} \) junction.

\( C_1 \) couples this signal to a switched demodulator that strips off \( Q_2 \)'s dc bias. Thus IC\(_1\)'s pin 2 sees only the 59-mV waveform, which the demodulator action at pins 5 and 6 references to ground. Pin 5, connected to capacitor \( C_2 \), sits at pin 2's peak dc value. IC\(_2\) amplifies this dc signal, with VR\(_1\) providing offset so that 0°C equals 0V output. The optional 10-k\( \Omega \) resistor protects against ESD (electrostatic discharge) events, which may occur if \( Q_2 \) is at the end of a cable.

Using the components in Fig 1, the circuit achieves \( \pm 1\% \) error over a sensed 0-to-100°C range. Substituting randomly selected 2N3904s and 2N2222s for \( Q_2 \) showed less than 0.4°C spread over 25 devices from various manufacturers. (EDN BBS/DL.SIG #945)

Reference(s)

To Vote For This Design, Circle No. 747

Feedback tames detector overshoot

Jerald Graeme
Burr-Brown Corp, Tucson, AZ

The peak detector in Fig 1 employs positive feedback, rather than using phase compensation or reducing the circuit's feedback factor (increasing gain), to control overshoot. A peak detector must control overshoot because uncontrolled overshoot leads to errors of 30% or more. Using positive feedback for control expands your choice of op amps beyond those that allow only external compensation.

Resistors \( R_1 \) and \( R_2 \) provide the necessary positive feedback. Op amp IC\(_1\) buffers and charges the holding capacitor, \( C_H \). Voltage follower IC\(_2\) isolates the hold capacitor from the load. A feedback loop removes IC\(_2\)'s errors from the output.

Diode D\(_1\) switches the feedback loop to control peak detecting. As long as the voltage on \( C_H \) is higher than the input, D\(_1\) is reverse-biased, and the feedback loop is open. When the input rises above the voltage on \( C_H \), IC\(_1\) charges the holding capacitor to this new value and D\(_1\) switches on the feedback loop, ensuring an accurate stored voltage on \( C_H \).

Without overshoot, the circuit's error is just the input error of IC\(_1\) (\( \sim V_{os} + V_{IN}/A \)). But three factors make peak detectors prone to overshoot: normal op-amp overshoot, capacitive output loading, and having two amplifiers in a feedback loop.

Most op amps have 50 to 60° of phase margin. This compensation offers the best settling time and best real-time accuracy for most applications. However, for peak detectors, this phase margin causes 10 to 15% overshoot. The inherent capacitive loading and the 2-op-amp design result in even greater overshoot.

The positive feedback via \( R_2 \) and \( R_1 \) has a positive feedback factor \( \beta \) equal to \( R_2/(R_1+R_2) \). This positive feedback combines with the unity negative feedback from the output of IC\(_2\) to the negative input of IC\(_1\).
THE MULTIPLE CHOICE ANSWER FOR SMD TRIMMERS

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4mm Sealed Multiturn

The only way to get multiturn trimming precision in a 4mm surface mount environment is with sealed trimmers. Bourne's new Bourns® Model 3934 features a rugged, 11-turn, sealed trimmer. Dynamic specifications: Rugged construction, with 200 cycles and 4mm Open-Frame Single-Turn

With a cost-effective chip style design, the model 3934 features a cross-slot rotor that is ideal for automatic assembly and adjustment techniques.

<table>
<thead>
<tr>
<th>Size</th>
<th>4.8mm x 1.8mm x 2.4mm</th>
<th>200 cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Resistance Variation</td>
<td>5% max.</td>
<td></td>
</tr>
<tr>
<td>Insulation Resistance Range</td>
<td>10 ohms - 2 megohms</td>
<td>5% max.</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>250ppm/°C</td>
<td>10 ohms - 2 megohms</td>
</tr>
<tr>
<td>Rotational Life</td>
<td>200 cycles</td>
<td>200 cycles</td>
</tr>
</tbody>
</table>

CIRCLE 44 CALL ME  CIRCLE 49 SEND LITERATURE

3mm Open-Frame Single-Turn

With a thin-film resistor, it can be either wave or reflow soldered.

<table>
<thead>
<tr>
<th>Size</th>
<th>3.6mm x 1.3mm x 1.3mm</th>
<th>70 cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Resistance Variation</td>
<td>5% max.</td>
<td></td>
</tr>
<tr>
<td>Insulation Resistance Range</td>
<td>100 ohms - 2 megohms</td>
<td>5% max.</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>200ppm/°C</td>
<td>100 ohms - 2 megohms</td>
</tr>
<tr>
<td>Rotational Life</td>
<td>100 cycles</td>
<td></td>
</tr>
</tbody>
</table>

CIRCLE 46 CALL ME  CIRCLE 49 SEND LITERATURE

4mm Sealed Single-Turn

The rugged Model 3314 trimmer is ideal for reliable performance in harsh environments. Top and side adjust styles provide excellent comparability with pick-and-place assembly techniques.

<table>
<thead>
<tr>
<th>Size</th>
<th>4.8mm x 1.8mm x 2.5mm</th>
<th>100 cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Resistance Variation</td>
<td>1% max.</td>
<td></td>
</tr>
<tr>
<td>Insulation Resistance Range</td>
<td>10 ohms - 2 megohms</td>
<td>20% max.</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>100ppm/°C</td>
<td></td>
</tr>
<tr>
<td>Rotational Life</td>
<td>100 cycles</td>
<td></td>
</tr>
</tbody>
</table>

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CIRCLE 42 CALL ME  CIRCLE 43 SEND LITERATURE

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Send Literature Circle No. 53

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Thus the circuit has a reduced feedback factor without resorting to increasing its gain.

For the components in the figure, the overall feedback factor $\beta$ is 0.09, which has the same stabilizing effect as raising the circuit's gain to 11. Overshoot is now a residual 0.2% resulting from feedback-delay oscillations.

Adding $R_1$ and $R_2$ does not alter the circuit's gain because the input signal does not appear across these resistors. For unity gain, the voltage across $R_2$ must, after all, be only the error signal. This error voltage injects a small current into $R_1$. The resulting voltage differences on $R_1$ and $R_2$ define an input-to-output voltage difference equal to $(V_{IN} + V_{OUT}/\beta)$. This difference is small because $V_{OUT} = V_{IN}$ during continued operation.

This analysis also demonstrates two other effects of the positive feedback. First, the circuit amplifies the input-error signal of IC$_1$ by $1/\beta = 11$ rather than by unity. Second, the circuit’s input resistance is much higher than you would expect. An input signal driving a feedback network normally suggests a low input resistance for an op-amp circuit. However, the positive feedback bootstraps the circuit’s resistance in the critical sample interval. The current $R_1$ draws from the input equals $V_{OUT}/A \cdot R_2 = V_{IN}/A \cdot R_2$. Thus, the circuit’s input resistance is $A \cdot R_2$ during the sample interval.

---

8051 program converts BCD to binary

John T Hannon  
Stewart Warner Alemite, Charlotte, NC

The assembly language program in Listing 1 for 8051-family single-chip µPs converts a BCD number to binary. Unlike other special-purpose, BCD-to-binary routines, you can easily extend this program to convert numbers larger than the 5-byte BCD numbers allowed here.

Before kicking off the program, you must store the 5-byte BCD number in a 5-byte register and allocate a 2-byte register for the binary result. During initialization, the program sets up pointers to these two registers and clears the binary register. Then the program stores the first BCD digit in the result register.

The program has two routines. After initialization, the first routine sets up the conversion factor for the first bit of each BCD digit. The initial value for the
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Europe (Amsterdam) 31-3403-51347

CIRCLE NO. 112
Listing 1—8051 BCD-to-binary conversion program (continued)

```
MOV R5,#03H ; OF FOURTH BCD DIGIT (1000)
CALL BCDCON
MOV R4,#10H ; CONVERSION NUMBER FOR FIRST BIT
MOV R5,#27H ; OF FIFTH BCD DIGIT (10000)
MOV R2,#03H ; CHECK ONLY 3 BITS OF FIFTH DIGIT
CALL BCDON
RET

BCDON: MOV R2,#04H ; CONVERSIONS PER BCD DIGIT
INC R0 ; INCREMENT BCD REGISTER TO NEXT DIGIT
MOV A,#RO ; GET BCD DIGIT
ANL A,#0FH ; MASK OFF UPPER FOUR BITS
MOV R3,A ; AND STORE IN TEMPORARY REGISTER
CALL BCDON1 ; GET BCD DIGIT
INC R0 ; SHIFT DIGIT ONE BIT RIGHT
MDV A,R3 ; STORE SHIFTED DIGIT AGAIN
JNC BCDON2 ; IF NO CARRY, DO NOT ADD FACTOR
MDV A,@R0 ; GET FIRST BYTE OF BINARY RESULT
ADD A,R4 ; ADD FIRST BYTE OF CONVERSION FACTOR
MDV @R0,A ; STORE FIRST BYTE OF BINARY RESULT
INC R0 ; INCREMENT TO 2ND BYTE OF BINARY REG
MDV A,R5 ; ADD (WITH CARRY) 2ND BYTE OF FACTOR
DEC R0 ; STORE SECOND BYTE OF BINARY RESULT
MDV A,R5 ; DECREMENT POINTER TO FIRST BYTE OF
BCDCON1: MDV R2,#04H ; BINARY REGISTER
INC R0 ; DOUBLE VALUE OF CONVERSION NUMBER
MDV R3,A ; FOR EACH BCD DIGIT BY SHIFTING R4
JNC BCDON2 ; AND R5 ONE BIT TO THE LEFT.
MDV A,R3 ;
RRC A ;
MDV A,R3 ;
JNC BCDON2 ;
MDV A,R3 ;
INC R0 ;
MDV A,R3 ;
ADD A,R4 ;
MDV A,R3 ;
DEC R0 ;
DEC R0 ;
MOVC A,R5 ;
DJNZ FC:, BCDON2
RET ; DECREMENT CONVERSION COUNTER
; REPEAT UNTIL ALL BITS CHECKED
```

The conversion factor is $10_{10}$ ($000A_{HEX}$). Then the first routine calls the second routine as a subroutine to do the actual conversion. If the BCD digit's bit is a one, the subroutine adds the conversion factor for that bit to the partial binary result. Then the program adjusts the conversion factor to correspond to the next bit in the selected BCD digit. The program checks each bit in a similar fashion.

The program uses a loop counter to check all four bits of each BCD digit. When the loop counter reaches zero, the program increments the BCD-register pointer, gets the next BCD digit, and masks off the digit's upper four bits in case the number is in ASCII. The program then shifts one bit to the right through the carry bit and stores the shifted number.

Checking the carry bit determines if the conversion factor gets added to the binary result or not. If the bit is a zero, the conversion factor does not get added; if the bit is a one, the conversion factor does get added.

To repeat the bit-conversion loop, the program shifts the conversion factor one bit to the left, doubling its value. The result of decrementing the bit counter determines if the loop needs to be repeated or not. This test allows the conversion routine to test each bit in a BCD digit and add $10_{10}$, $20_{10}$, $40_{10}$, and $80_{10}$ for each bit, respectively, that is a one.

After converting the first digit, the program returns to the initialization section, adding $100_{10}$ ($00064_{HEX}$) to the conversion factor. The program then repeats, converting the second, third, and fourth BCD digits. For the fifth—or ten-thousands—digit, the bit counter's value is only 3 instead of 4 because a 5-digit BCD number cannot be greater than 65,535.

You can easily extend this program by expanding the registers and extending the counters. You can obtain the listing from the EDN BBS (617) 558-4241, 300/1200/2400, 8, N, 1—from main menu, enter (s)ig, <s/di_sig>, rk941), (EDN BBS /DL_SIG #941)
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- Adjustable turn-on times
- Low profile 6-pin mini-DIP
- Cost efficiency

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**INPUT ELECTRICAL CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Part Current</th>
<th>FB00CD</th>
<th>FB00FC</th>
<th>FB00KB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Continuous Input Current (I_{IN})</td>
<td>10</td>
<td>50</td>
<td>mA_{DC}</td>
</tr>
<tr>
<td>Input Current (Guaranteed On)</td>
<td>10</td>
<td>mA_{DC}</td>
<td></td>
</tr>
<tr>
<td>Input Current (Guaranteed Off)</td>
<td>100</td>
<td>µA_{DC}</td>
<td></td>
</tr>
<tr>
<td>Input Voltage Drop at (I_{IN}) = 25mA</td>
<td>3.25</td>
<td>V_{DC}</td>
<td></td>
</tr>
</tbody>
</table>

**OUTPUT ELECTRICAL CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Part Number</th>
<th>FB00CD</th>
<th>FB00FC</th>
<th>FB00KB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bidirectional Load Current (I_{LOAD})</td>
<td>±1.0</td>
<td>±0.50</td>
<td>±0.25</td>
</tr>
<tr>
<td>DC Load Current (I_{LOAD})</td>
<td>2.0</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Bidirectional Load Voltage (V_{LOAD})</td>
<td>±80</td>
<td>±180</td>
<td>±350</td>
</tr>
<tr>
<td>DC Load Voltage (V_{LOAD})</td>
<td>80</td>
<td>180</td>
<td>350</td>
</tr>
<tr>
<td>ON-Resistance (R_{ON}) at (I_{LOAD}) max.</td>
<td>0.72</td>
<td>1.8</td>
<td>12.9</td>
</tr>
<tr>
<td>Turn-On Time (T_{ON})</td>
<td>800</td>
<td>800</td>
<td>500</td>
</tr>
<tr>
<td>Turn-Off Time (T_{OFF})</td>
<td>300</td>
<td>600</td>
<td>500</td>
</tr>
</tbody>
</table>

Notes:
1. A series resistor is required to limit continuous input current to 50mA (peak current can be higher).
2. Rated input current is 25mA for all tests.
3. Loads may be connected to any output terminal.
4. ON resistance shown is for the bidirectional configuration. The DC ON resistance is 1/4 of these values.

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EDN April 25, 1991
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Relay guarantees polarity protection

N Kannan
Centre for Development of Imaging Technology, Thiruvananthapuram, India

The two most common methods of reverse-polarity protection for dc circuits do not absolutely guarantee that the "protected" circuit will always be safe and operate properly. Using a series diode in the power line wastes power, causes a voltage drop, and impairs regulation. The combination of a series fuse and a reversed shunt diode will clear the fuse if you apply reverse-polarity power. But the diode and the fuse take a finite time to open the power lines. During this interval, damage can occur.

Fig 1—This simple relay circuit provides absolute reverse-polarity protection because it will not apply power to the load unless the power's polarity is correct.

The simple circuit in Fig 1 will not apply power to the load unless the power's polarity is correct to begin with. The circuit consumes little power, causes no voltage drop, and does not impair regulation. Switch S is an optional on/off switch. (EDN BBS /DL_SIG #942)

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Omron Electronics Inc, 1 E Commerce Dr, Schaumburg, IL 60173. Phone (708) 843-7900. FAX (708) 843-7787. Circle No. 357

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AT&T Microelectronics, Dept 52AL040420, 555 Union Blvd, Allentown, PA 18103. Phone (800) 372-2447; in Canada, (800) 553-2448; in PA, (201) 771-2826. Circle No. 359

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HOLDUP TIME
20 milliseconds from loss of nominal AC power.

OUTPUTS
See model selection table.

ADJUSTABILITY
±5% trim adjustment. All 5VDC outputs are adjustable up to 5.2VDC @ full output.

OUTPUT POLARITY
All outputs are floating from chassis and each other and can be referenced to each other or ground as required.

LINE REGULATION
Less than ±0.1% or ±5mV for input changes from nominal to min. or max. rated values.

LOAD REGULATION
±0.2% or ±10mV for load changes from 50% to 0% or 100% of max. rated values.

MINIMUM LOAD
Main output requires a 10% minimum load for full output from auxiliaries.

REMOTE SENSING
On all outputs except those less than 100 watts and less than 20 Amps.

RIPPLE & NOISE
1% or 100mV pk-pk, 20 MHz bandwidth.

OPERATING TEMPERATURE
0-70°C. Derate 2.5%/°C above 50°C.

COOLING
A min. of 10 LFS cooling air directed over the units for full rating. Two test locations on chassis rated for max. temperature of 90°C. 1000 and 1500 watt units have built-in fan.

TEMPERATURE COEFFICIENT
±0.02%/°C.

EFFICIENCY
80% typical.

SAFETY
Units meet UL 1950, CSA 22.2 No. 220, CSA bulletin 1402C, EN 60 950, DIN VDE 0805/05.90. Certifications in process.

DIELECTRIC WITHSTAND
3750 VRMS input to ground. 3750 VRMS input to output. 700 VDC output to ground.

SPACING
8 mm primary to secondary. 4 mm to grounded circuits.

LEAKAGE CURRENT
0.75 mA at 115 VAC 60Hz. input. 1.5 mA for 1000 watt and 1500 watt models.

EMISSIONS
Units meet FCC 20780 Part 15 Class A and VDE 0871/6.78 Class A for conducted emissions. Compliance with Class B limits by use of additional external filter. 1000 watt and 1500 watt models require optional filter for Class A.

DYNAMIC RESPONSE
Peak transient less than ±2% or ±200mV for step load change from 75% to 50% or 100% max. ratings.

RECOVERY TIME
Recovery within 1%. Main output – 200 microseconds. Auxiliary outputs – 500 microseconds.

AC UNDERSURGE
Protects against damage for undervoltage operation.

OVERVOLTAGE PROTECTION
Standard on main output.

REVERSE VOLTAGE PROTECTION
All outputs are protected up to load ratings.

OVERLOAD & SHORT CIRCUIT
Outputs protected by duty cycle current foldback circuit with automatic recovery. Auxiliaries have additional backup fuse protection.

THERMAL SHUTDOWN
Circuit cuts off supply in case of local over temperature. Units reset automatically when temperature returns to normal.

SOFT START
Units have soft start feature to protect critical components.

LOAD REGULATION
±0.2% or ±10mV for load changes from 50% to 0% or 100% of max. rated values.

FAN OUTPUT
Nominal 12 VDC @ 12 watts maximum.

INHIBIT
TTL compatible system inhibit provided.

SHOCK
MIL-STD 810-D Method 516.3, Procedure III.

VIBRATION
MIL-STD 810-D Method 514.3, Category 1, Procedure I.

MECHANICAL

<table>
<thead>
<tr>
<th>CASE</th>
<th>WATTS</th>
<th>H</th>
<th>x</th>
<th>W</th>
<th>x</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400 W/500 W</td>
<td>2.5&quot;</td>
<td>x</td>
<td>5.05&quot;</td>
<td>x</td>
<td>9.0&quot;</td>
</tr>
<tr>
<td>2</td>
<td>750 W</td>
<td>2.5&quot;</td>
<td>x</td>
<td>5.20&quot;</td>
<td>x</td>
<td>9.63&quot;</td>
</tr>
<tr>
<td>3</td>
<td>1000 W</td>
<td>5.0&quot;</td>
<td>x</td>
<td>5.05&quot;</td>
<td>x</td>
<td>10.4&quot;</td>
</tr>
<tr>
<td>4</td>
<td>1500 W</td>
<td>5.0&quot;</td>
<td>x</td>
<td>5.20&quot;</td>
<td>x</td>
<td>11.0&quot;</td>
</tr>
<tr>
<td>5</td>
<td>860W</td>
<td>2.5&quot;</td>
<td>x</td>
<td>5.0&quot;</td>
<td>x</td>
<td>6.85&quot;</td>
</tr>
</tbody>
</table>

POWER FAIL MONITOR
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. Available on units with a high current 5 volt output.

AUTO RANGER
Optional circuit provides automatic operation at specified input ranges without strapping. Not available on single output units.

PILOT BIAS
Optional circuit provides SELV output of 5 volts at 1 Amp independent of the main power converter. Output isolation compliant to safety specifications referenced above. Not available on single output units.

EMI FILTER
For Class A on 1000 and 1500 watt units.

COVER
Optional flat cover recommended when customer supplied fan cooling is directed through the length of the unit.

FAN COVER
Optional cover with brushless DC fan which provides the required air flow for full rating of VM power supplies.

POWER FACTOR CORRECTION
Refer to Bulletin FM-101 for FM Series units with 0.99 power factor and harmonic currents compliant to IEC 555-2.
DESCRIPTION

VM Series switchers comprise a line of open frame power supplies with output combinations that are required for a large variety of bus systems such as VME, VXI, and FUTUREBUS. Units in this fully modular family offer power density up to 10 watts per cubic inch. The small size and high power available permits more system hardware to be packaged in a given enclosure. The extended function without additional cabinet overhead will give your product a competitive edge in the marketplace.

VM Series feature outstanding quality, insuring full compliance to specifications, reliable field operation and long service life. This exceptional quality is a result of three major efforts.

- Meticulous innovative engineering design.
- Total modular mechanical design.
- Excellent thermal management.

VM Series are available in power ratings from 400 to 1500 watts and with 1 to 7 outputs in a single package.

FEATURES

- TUV, UL, CSA.
- 10 watts per cubic inch.
- 120 kilohertz MOSFET design.
- Current mode control.
- System inhibit.
- Load proportional DC fan output.
- Options include: Auto ranger for continuous input operation. Power fail monitor. Pilot bias. EMI filter for 1000 and 1500 watt units. Cover. Fan cover – 1000 and 1500 watt units have fan built in.

SINGLE OUTPUT MODELS

<table>
<thead>
<tr>
<th>Model</th>
<th>VDC</th>
<th>Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM12D0-YY</td>
<td>2VDC</td>
<td>150A</td>
</tr>
<tr>
<td>VM12D1-YY</td>
<td>3.3VDC</td>
<td>150A</td>
</tr>
<tr>
<td>VM12D2-YY</td>
<td>5VDC</td>
<td>150A</td>
</tr>
<tr>
<td>VM12D3-YY</td>
<td>12VDC</td>
<td>72A</td>
</tr>
<tr>
<td>VM12D4-YY</td>
<td>15VDC</td>
<td>57A</td>
</tr>
<tr>
<td>VM12D6-YY</td>
<td>24VDC</td>
<td>36A</td>
</tr>
<tr>
<td>VM12D9-YY</td>
<td>48VDC</td>
<td>18A</td>
</tr>
</tbody>
</table>

MULTIPLE OUTPUT MODELS

<table>
<thead>
<tr>
<th>Model</th>
<th>Total Power</th>
<th>Case</th>
<th>Ratings:</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM1A-YY</td>
<td>400 Watts</td>
<td>1</td>
<td>5VDC @ 50A, 12VDC @ 12A, 24VDC @ 6A</td>
</tr>
<tr>
<td>VM2A-YY</td>
<td>400 Watts</td>
<td>1</td>
<td>5VDC @ 50A, 12VDC @ 12A, 24VDC @ 6A</td>
</tr>
<tr>
<td>VM1B-YY</td>
<td>500 Watts</td>
<td>1</td>
<td>5VDC @ 80A, 12VDC @ 12A, 24VDC @ 6A</td>
</tr>
<tr>
<td>VM2B-YY</td>
<td>500 Watts</td>
<td>1</td>
<td>5VDC @ 80A, 12VDC @ 12A, 24VDC @ 6A</td>
</tr>
<tr>
<td>VM3B-YY</td>
<td>500 Watts</td>
<td>1</td>
<td>5VDC @ 80A, 12VDC @ 12A, 24VDC @ 6A</td>
</tr>
<tr>
<td>VM1D-YY</td>
<td>750 Watts</td>
<td>2</td>
<td>5VDC @ 120A, 12VDC @ 12A, 24VDC @ 4A</td>
</tr>
<tr>
<td>VM2D-YY</td>
<td>750 Watts</td>
<td>2</td>
<td>5VDC @ 120A, 12VDC @ 12A, 24VDC @ 4A</td>
</tr>
<tr>
<td>VX1B-YY</td>
<td>1000 Watts</td>
<td>3</td>
<td>5VDC @ 30A, 12VDC @ 12A, 24VDC @ 5A</td>
</tr>
<tr>
<td>VX1D-YY</td>
<td>1500 Watts</td>
<td>4</td>
<td>5VDC @ 120A, 12VDC @ 15A, 24VDC @ 8A</td>
</tr>
<tr>
<td>VX1E-YY</td>
<td>1000 Watts</td>
<td>3</td>
<td>5VDC @ 30A, 12VDC @ 12A, 24VDC @ 5A</td>
</tr>
<tr>
<td>VX1F-YY</td>
<td>1500 Watts</td>
<td>4</td>
<td>5VDC @ 120A, 12VDC @ 15A, 24VDC @ 8A</td>
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</tbody>
</table>

OPTIONS

<table>
<thead>
<tr>
<th>Code</th>
<th>Function</th>
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</thead>
<tbody>
<tr>
<td>00</td>
<td>None</td>
</tr>
<tr>
<td>01</td>
<td>Power Fail</td>
</tr>
<tr>
<td>02</td>
<td>Auto Ranger</td>
</tr>
<tr>
<td>04</td>
<td>EMI Filter</td>
</tr>
<tr>
<td>32</td>
<td>Cover</td>
</tr>
<tr>
<td>64</td>
<td>Fan Cover</td>
</tr>
</tbody>
</table>

Notes:
1. All 5VDC outputs adjustable to 5.2VDC. Others trim adjustable ±5%.
2. On models VX1E-YY and VX1F-YY the max. total power for the sum of outputs #1 to #3 must not exceed 500 watts and 750 watts respectively.
3. Models VX1E-YY and VX1F-YY include built-in fan.
4. Models VX1E and VX1F require EMI Filter option to meet FCC and VDE Class A for conducted emissions.

7 output unit with fan cover
DIMENSIONS

CASE 1 & 2

NOTES:
(1) WITH COVER (#6-32), W/O COVER (.150 DIA.)
(2) W/FAN COVER UNIT HEIGHT (4.100)
(3) TERMINAL BLOCKS (#6-32)
(4) STUDS (1/4-20)

CASE 3 & 4

CASE 5

DELTRON, inc.
290 WISSAHICKON AVENUE, P.O. BOX 1369, NORTH WALES, PA 19454

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NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

Enhanced Real-Time OS For 68000 Family

- Provides SCSI support for hard-and floppy-disk drives
- Lets you install boot files on magnetic tape

OS-9 version 2.4 is an enhanced version of the real-time operating system for Motorola's 68000 family of µPs. You can perform all software-development tasks either on a PC or Unix host computer, or on the target 680X0 system; the compilers (C, Fortran, Pascal, or Basic) produce position-independent, re-entrant, ROMable code. New communications facilities support the 68332 communications controller, as well as evaluation boards that use this chip. Other new features include the SCSI common-command set, as well as SCSI connect/disconnect and device-installation commands. A random block-file manager supports write-through caching; you can set the cache size and enable or disable the cache, and you can get a report on usage statistics. The random block-file manager also supports variable sector sizes, which can be any integral power of 2—from 256 to 32,768 bytes. The file manager supports noncontiguous boot files whose size is limited only by the hardware device. Professional OS-9 includes the OS, a compiler, a screen editor, a debugger, file managers, and utility programs. 32-bit 680X0 CPUs, $1150; 16-bit CPUs, $800; industrial OS-9, including OS, a sequential-character file manager, and interprocess-communications manager, 32-bit CPUs, $425; 16-bit CPUs, $275.

Microware Systems Corp, 1900 NW 114th St, Des Moines, IA 50325. Phone (515) 224-1929. FAX (515) 224-1352. Circle No. 351

Spice Postprocessor

- Provides custom windowing interface
- Lets you view and compare waveforms from several output files

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EDN April 25, 1991

CIRCLE NO. 17
grade of postprocessor and graphical data-analysis package. Version 3.1 provides a custom windowing interface that allows you to select, view, and compare waveforms from several Spice output files simultaneously. Special program options let you display data from ac, de, transient, and distortion analyses without having to manipulate the net list. The waveform calculator lets you perform cursor-based measurement, waveform arithmetic, and engineering functions, such as waveform construction, polynomial regression, smoothing, convolution, or filtering. You can direct report-quality graphics to laser or dot-matrix printers, or to pen plotters. The program works with data produced by any Berkeley Spice-compatible simulator, including the vendor's IssSpice. The program runs on IBM PCs that have at least 640k bytes of RAM, a math coprocessor, an EGA, VGA, or Super VGA monitor, and a DOS 3.1 or later version. Version 3.1, $325. Current users can upgrade for $100.

Intusoft, Box 710, San Pedro, CA 90733. Phone (213) 833-0710. FAX (213) 833-9658.

Circle No. 352

Process-Control Library Of PID Functions
- Routines keep track of a loop's setpoints and coefficients
- Triggers alarms when outputs exceed a specified threshold

The PID Blok library contains routines for creating, tuning, and executing feedback control loops that use PID (proportional, integral, derivative) algorithms. These routines calculate the difference (error) between the current value of a process variable and the desired setpoint, as well as the values that control hardware should receive in order to bring the variable back to the setpoint. Using the PID routines in combination with the vendor's multitasking library, Divvy, you can update as many as 16 PID loops in real time. The PID routines can set alarms whenever control outputs fall outside a preset range applicable to the controlled device; they can also set independent high

SPOTLIGHT: DESIGN & DEVELOPMENT

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A full spectrum of choices.

<table>
<thead>
<tr>
<th>Device</th>
<th>Organization</th>
<th>Speed (ns)</th>
<th>Package</th>
<th>Micron Part #</th>
<th>Availability</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Meg DRAM</td>
<td>x4*</td>
<td>70 – 100</td>
<td>DIP, ZIP, SOJ</td>
<td>MT4C4256</td>
<td>Now</td>
<td>VGA, 8514, 340*, XGA, MAC*, Workstation, Multimedia</td>
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<tr>
<td></td>
<td>x16*</td>
<td>80 – 100</td>
<td>ZIP, SOJ</td>
<td>MT4C1666/65/70</td>
<td>Now</td>
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<tr>
<td>4 Meg DRAM</td>
<td>x16*</td>
<td>60 – 100</td>
<td>SOJ, TSOP</td>
<td>MT4C16256/7</td>
<td>Samp. Q4 '91; Prod. 1H '92</td>
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<tr>
<td>256K VRAM</td>
<td>x4</td>
<td>100 – 120</td>
<td>DIP, ZIP</td>
<td>MT42C4064</td>
<td>Now</td>
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<tr>
<td>1 Meg VRAM</td>
<td>x4</td>
<td>80 – 120</td>
<td>ZIP, SOJ</td>
<td>MT42C4255/6</td>
<td>4255 Now; 4256 Q4 '91</td>
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<td></td>
<td>x8</td>
<td>80 – 120</td>
<td>ZIP, SOJ</td>
<td>MT42C8127/8</td>
<td>8127 Now; 8128 Q4 '91</td>
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<tr>
<td>2 Meg VRAM</td>
<td>x8</td>
<td>70 – 100</td>
<td>SOJ</td>
<td>MT42C8256</td>
<td>Samp. Q4 '91; Prod. 1H '92</td>
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<tr>
<td>1 Meg Triple-Port DRAM</td>
<td>x4</td>
<td>80 – 120</td>
<td>SOJ</td>
<td>MT43C4257/8</td>
<td>Now</td>
<td></td>
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<tr>
<td></td>
<td>x8</td>
<td>80 – 120</td>
<td>PLCC</td>
<td>MT43C8128/9</td>
<td>Now</td>
<td></td>
</tr>
</tbody>
</table>

*Also in low power versions.

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and low alarms. The PID Blok library is supplied in C source code that you can compile with Microsoft C or Turbo C compilers. PID Blok, $149; Divvy, $229.

Drumlin, 1011 Grand Central Ave, Glendale, CA 91201. Phone (818) 244-4600. FAX (818) 244-4246.

Circle No. 353

Reverse Engineering Tool For VMS Languages
• Analyzes source code to generate program structure charts
• Works with any of the languages supported by VAX/VMS
Teamwork/C Rev is available to VAX/VMS users and extends the tool's reverse-engineering capabilities to programs written in Fortran, Pascal, Basic, PL/1, Macro, and Bliss, as well as C. The program interfaces to the VAX source-code analyzer (SCA), which creates libraries that include structural information about programs. Teamwork/C Rev extracts this structural information and produces structure charts within the Teamwork project environment. If you need to modify a module, the software lets you use your preferred editor or the appropriate VAX language sensitive editor from the VAX tool set. You need the VAX/VMS operating-system version 5.2 or later, and VAX SCA version 3.1 or later. Teamwork/C Rev processor, $7500; browsing capability, $100/seat.

Cadre Technologies Inc, 222 Richmond St, Providence, RI 02903. Phone (401) 351-5950.

Circle No. 354

File-Transfer And Flash-EPROM Programming Tool
• Lets you remotely update solid-state disk emulators
• Hosted on half-sized PC expansion board
Flashlink, a high-speed file-transfer and flash-EPROM programming software package works with the vendor's PROMdisk III disk-emu­lator board. The disk emulator can emulate either a 1M-byte floppy-disk drive or as many as three floppy-disk drives, using both flash-EPROM and RAM solid-state memory. A common arrangement is to put the operating system in standard EPROM that emulates a bootable drive (A); the application program (which may change) in flash-EPROM that emulates drive B; and read/write files in nonvolatile static RAM that emulates drive C. The program lets the host send new application files to remote em­bedded systems via modem or di­rect connection between RS-232C ports, at data rates as high as 115k bits/sec; automatic error detection maintains the integrity of the data. PROMdisk III disk emulator board, including Flashlink software and 1M byte of flash-EPROM memory, $495.


Circle No. 355

Upgraded Schematic-Capture Software
• Provides improved user interface
• Net-highlighting feature includes pads and connections
Version 4 of Schema-PCB provides an improved user interface and user-defined keyboard macros. A new net-highlighting feature indicates both the pads and the connections that you're currently routing interactively. Version 4 comes with printer drivers for both HP Laserjet and Postscript printers as well as facilities for generating editable CAM output. Options include auto-routing, autoplacement, AutoCAD DXF interface, and CAM output. $975.

Omation Inc, 801 Presidential Dr, Richardson, TX 75081. Phone (800) 553-9119; in TX, (214) 231-5167.

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Circle No. 29
If you had this...
and we gave you this...
think what you could do!

Introducing the Logic Switch™
Imagine! Noise-free, logic-level switching from an electromechanical package! We're calling it the Logic Switch because this alternative to mechanical contact switches gives you discrete, noise-free signal through optoelectronics. Solid-state and designed for long life and reliability. Think of the possibilities!

Here's How It Works.
The Logic Switch uses an infrared emitter and phototransistor sensor combination. An internal "flag" interrupts a beam of infrared light from emitter to sensor, thus changing the switch's output when activated.

The infrared light transmission reduces dust problems associated with visible light transmission, and the solid-state life-span is estimated at 50 million cycles.

What Can You Do With It?
The Logic Switch is so new, we wouldn't presume to guess at all its uses. Instead, we invite you to examine it firsthand and try it out on your ideas. Call Cherry at 708-360-3500, and we'll send qualified engineers a free Logic Switch and a specifications sheet.

The Logic Switch is ideal for any application in which logic-level switching is necessary and traditional snap-action switches are problematic.

But perhaps you have some different ideas.

Why not call us today and put those ideas to the test right in your own laboratory—for FREE. All you've got to lose is signal noise.

The Logic Switch: an electronic device in an electrical package.
NEW PRODUCTS
INTEGRATED CIRCUITS

High-Performance Voice-Coil Drivers
- For 5 or 12V disk drives
- Provide 0.5 to 1.0A drive
The ML4406, ML4407, and ML4408 provide a voice-coil drive for either a 5 or a 12V hard-disk servo drive. The devices integrate power amplifiers, head-retract circuitry, gain switching, and power-fail detection on a single chip. The ML4406 and ML4407 can drive coils requiring 0.5A of peak current in 12V systems. The ML4408, which is targeted for smaller disk drives such as those used in laptop computers, can provide 1.0A of peak current in either 5 or 12V systems. The ML4406 and ML4407, which include on-chip power transistors, have a voltage drop of <1.5V at rated current. The ML4408 uses external pnp transistors to reduce the voltage drop to <0.8V. ML4406 and ML4407 in a 20-pin plastic leaded chip carrier, $3.50 (1000); ML4408 in a 24-pin SOIC, $3.65 (100).
Micro Linear Corp, 2092 Concourse Dr, San Jose, CA 95131. Phone (408) 433-5200.
Circle No. 363

Low-Voltage Quad Op Amp
- Operates down to 1.8V
- Needs only 700-µA/amplifier
The NE/SA5234 matched quad op amp operates as low as 1.8V and features rail-to-rail operation for both its input and output. The device can accept common-mode inputs as much as 250 mV greater than the supply rails, optimizing the dynamic range and helping to prevent distortion of input signals. The output swings to within 50 mV of the supply rails. The op amp has a unity-gain bandwidth of 2.5 MHz and consumes only 700 µA/amplifier, an important feature in battery-powered applications. The op amp is available in 14-pin DIPs and SOICs. From $1.56 (100).
Signetics Co, Box 3409, Sunnyvale, CA 94088. Phone (408) 991-2000.
Circle No. 365

BiCMOS Quad 12-Bit DAC
- Has four 12-bit voltage outputs
- Settling time is 15 µsec
The BiCMOS SP9345 integrates four low-power CMOS DACs with bipolar output stages to provide four 12-bit, voltage-output DACs on a single monolithic chip. The device accepts input data in either 8-bit- or 12-bit-wide words, and you can use the separately addressable double latches in front of each DAC in either conventional, semitransparent, or fully transparent modes. The DACs provide a ±10V output range with offset binary coding. Other key specifications include full-scale settling time of 15 µsec, integral and differential non-linearity of ±½ LSB, and 12-bit monotonicity. The quad DAC, which operates from ±15V supplies, is available in 28-pin ceramic packages and 44-pin plastic leaded chip carriers. From $65 (100).
SiPex Corp, 6 Fortune Dr, Billerica, MA 01821. Phone (508) 663-9691. FAX (508) 670-9001.
Circle No. 364

Modem IC
- Has 2400-bps speed
- Compliant with CCITT standards
The SSI 73K324L 2400-bps modem conforms to CCITT V.21, V.22, V.23, and V.22 bis standards. The quad-mode IC interfaces with standard microprocessors for control of modem functions through its 8-bit multiplexed bus. An optional serial controller bus is also available. In addition to the basic FSK modulation and demodulation sections, the modem includes synchronous/asyn-
chronous buffering, DTMF, guard, and calling-tone generator capabilities. Handshake pattern detectors simplify control of connect sequences, and tone detectors allow accurate detection of call-progress, answer-back, and calling tones. The modem also provides diagnostic test modes. Samples of the 73K324L, which comes in DIPs and plastic leaded chip carriers, will be available in the second quarter of 1991. Approximately $20 to $25 (10,000).

**Silicon Systems**, 14351 Myford Rd, Tustin, CA 92680. Phone (800) 624-8999; in CA, (714) 731-7110. FAX (714) 669-8814. Circle No. 366

---

**High-CURRENT Op Amp**
- **200-mA output capability**
- **700-MHz bandwidth**

Offering a combination of high output current and high speed, the OPA654 op amp can deliver 200 mA into a 50Ω load (±10V), and can slew to 750 V/µsec. The op amp also features a gain-bandwidth product to 700 MHz, a maximum settling time of 150 nsec to 0.1%, and an input bias current of 50 pA. The device, which operates from ±5 to ±18V supplies, uses external compensation. This feature lets the user optimize the device’s open-loop gain and phase characteristics to the desired closed-loop gain, load, and dynamic characteristics. OPA654, in 8-pin metal TO-3 package, $22.95; in 11-pin plastic SIP, $14.30 (100).

**Burr-Brown Corp**, Box 11400, Tucson, AZ 85734. Phone (800) 548-6132; in AZ, (602) 746-1111. BBS (602) 741-3978 (300/1200/2400 8,N,1). Circle No. 367

---

**Caller-Identification IC**
- **Identifies incoming phone numbers**
- **Decodes FSK modem signals**

The SC11210 caller-identification IC supports the caller-number-delivery feature in the switched telephone network. The chip receives and decodes FSK modem signals sent through telephone lines between the first and second rings. These signals transmit the caller’s number to a user’s premises while the phone is on hook. The CMOS device integrates a differential-input buffer, a 4-pole bandpass fil-
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term, an FSK demodulator, a user-selectable energy-detect circuit, and a clock generator. Depending on the setting of the energy-detect circuit, the IC will either pass or block the data from the FSK modem. The IC accepts a 3.57-MHz clock and uses it to generate the internal timing. The IC comes in an 8-pin package. The 14-pin device provides support for power-down and call-progress detect functions and has four energy-detect levels. Approximately $2 (10,000).

Sierra Semiconductor, 2075 N Capitol Ave, San Jose, CA 95132. Phone (408) 263-9300. FAX (408) 263-3337. Circle No. 368

Pro-Logic Dolby Surround-Sound Decoder

• Features autobalance function
• Includes center-mode control
The SSM-2125 combines all the core functions of a complete Dolby Pro-Logic surround-sound decoder on a single chip. The first to integrate an autobalance function, the device also includes an active decoding matrix, center-mode control, and a noise generator. Autobalance provides dynamic correction of left-right input signal-level imbalance, eliminating the need for manual adjustments. According to the company, the on-chip autobalance function replaces as many as 24 active and passive components. In all, the decoder integrates 30 op amps, 10 voltage-controlled amplifiers, a converter amplifier, two dual-output rectifiers, two log-difference amplifiers, comparators, random logic, and a digital noise source. A user-selectable bypass mode provides a 2-channel signal path without the need for external relays. Thin-film resistors and laser trimming eliminate the need for external gain and offset trimming. The decoder's 100-dB dynamic range and 0.015% THD provide an 18-bit equivalent performance. The decoder comes in a 48-pin plastic DIP. From $15 (100).

Analog Devices Inc, Precision Monolithics Div, 1500 Space Park Dr, Santa Clara, CA 95052. Phone (408) 562-7513. Circle No. 369

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TEST & MEASUREMENT INSTRUMENTS

Analog I/O Subsystem For Workstations
- Records, replays, and allows graphical editing of data
- Handles two 14-bit inputs and 14-bit output at once

Desklab, a 14-bit analog input/output subsystem (two inputs, one output) connects to Unix- and VMS-based workstations via a SCSI interface. To the workstation, the subsystem appears to be a disk drive. The system records, replays, and permits editing and analysis of real-time data. You can access application-development tools from the command line, from shell scripts, or via program calls to a C-language function library. Application programs (for example those for speech recognition) can also access the subsystem. The system includes a microphone input, 16 digital I/O lines, and two RS-232C ports that operate to 38.4k bps. The system can include an optional 1.44M-byte MS-DOS-compatible floppy-disk drive and 45M-byte hard disk. $5500.

Gradient Technology Inc, 95B Connecticut Dr, Burlington, NJ 08016. Phone (609) 387-8688. FAX (609) 387-5001. Circle No. 374

Development-Tool Set For Am29000
- Has debugger interface, compiler, and downloader
- Execution board can include 32M bytes of memory

The Nice-29K is a set of software and hardware development and debugging tools for code written to run on Advanced Micro Devices' AM29000 RISC µP. The tools work with IBM PC/ATs and compatible machines. Included in the tool set are a native compiler, an interface to Microtec Research's Xray29K debugger, and a high-speed download facility. The hardware portion of the tool set is a 33-MHz execution board that can contain as much as 32M bytes of RAM. With these tools, the typical duration of a compile/download cycle for a moderately large C program is 21/2 minutes. Tool set, $11,600; evaluation board, $4995.

Step Engineering, Box 3166, Sunnyvale, CA 94088. Phone (800) 538-1750; in CA, (408) 733-7837. FAX (408) 773-1073. Circle No. 375

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C-Size VXIbus I/O Modules
- 16-bit ADC takes 200k samples/sec
- Simultaneous S/H circuit has 16 channels

The DBS 8700 is an 8-channel, 16-bit A/D conversion module that takes 200,000 samples/sec. The DBS 8710 is a 16-channel simultane-
ous sample/hold board compatible with the ADC. It maintains time correlation between channels to ±200 psec. The DBS 8720 is a 32-channel multiplexer also compatible with the ADC. Each of the three modules is a C-size plug-in for the VXI bus. The ADC board includes an instrumentation amplifier whose software-programmable gain can be changed on a channel-by-channel basis. The board also incorporates a sequence controller that permits continuous data acquisition without host intervention. Onboard RAM stores scan sequences that include gain and sample rate for each channel. DBS 8700, $4000; DBS 8710, $3900; DBS 8720, $1295. Delivery, six to eight weeks ARO.

Analogic Corp, 8 Centennial Dr, Peabody, MA 01961. Phone (508) 977-3000. FAX (508) 532-6097. TLX 6817144. Circle No. 376

Icon-Based Test-Development Software
- Provides graphical prompts to operators
- Includes Dispatch and Execute icons

Wavetest, an icon-based software package, facilitates development of programs for control of data acquisition and testing. Version 3.0 offers these features: The Dispatch icon performs case selection for control of program flow, and the Execute icon lets you run other programs from within Wavetest. You can create graphical prompts to aid test operators in connecting to the unit under test or to guide them through fault diagnosis. Possible graphical prompts are schematics, block diagrams, and pictures. Version 3.0 runs under MS Windows 3.0. Wavetest 3.0, $1495; Version 2.6 users' upgrade, $495.

Wavetek San Diego Inc, 9045 Balboa Ave, San Diego, CA 92123. Phone (800) 874-4835; in CA, (619) 279-2200. Circle No. 377

EDN April 25, 1991

TEST & MEASUREMENT INSTRUMENTS

Evaluation Board For DSP Analog I/O Components
- Includes ADC, DAC, clock, and trigger generators
- Connects to the vendor's DSP boards
The DEM-DSP102/202 evaluation board helps you evaluate and test the vendor's DSP-processor-compatible I/O components. It contains a socketed, 2-channel, 18-bit, 200k-sample/sec A/D converter (the vendor's DSP102JP); a socketed, 2-channel, 18-bit, 500k-sample/sec D/A converter (the DSP202JP); sample-rate and bit-clock generators;
digital I/O interfaces; removable 20-kHz, 6-pole, lowpass filters; and a prototyping area. The board is compatible with the vendor's ZPB34 and ZPB3212 DSP boards. $375.

Burr-Brown Corp, Box 11400, Tucson, AZ 85784. Phone (800) 548-6132; in AZ, (602) 746-1111. FAX (602) 889-1510. Circle No. 378

16-Bit Analog I/O Card
- Includes eight analog inputs and two analog outputs
- Has three timers and four digital I/O lines

The DAQ-16 1-card, 16-bit data-acquisition system runs on IBM PC/ATs and compatible computers. The board includes eight overvoltage-protected analog-input channels, two analog outputs, four digital I/O lines, and three 16-bit interval-counter/timers to control sampling of data. The ADC's maximum sampling rate is 100k samples/sec. $1395; 50k sample/sec unit, $1295.

Quatech Inc, 662 Wolf Ledges, Akron OH 44311. Phone (216) 434-3154. FAX (216) 434-1409. Circle No. 379

Logic-Analyzer Support Package For i486
- Displays disassembly in standard mnemonics
- Allows replacement of addresses with symbols

The 80486 Map (µP-analysis package) adapts the vendor's Clas 4000 logic-analysis system to work with Intel's i486 32-bit µP. The adapter will support µP operation to 50 MHz. Among the package's functions are a display of disassemblies in Intel standard mnemonics and replacement of addresses with symbols. Included in the package is a probe board that measures 1.75 x 5.3 x 0.75 in. The board fits between the µP's 179-pin package and the chip's socket in the target system. To permit use of the board where components are close to the µP socket, the package includes a zero-insertion-force socket. $2950.

Biomation Inc, 19050 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 538-9320; in CA, (408) 988-6800. FAX (408) 988-1647. Circle No. 380
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SCSI Controller Board

- Has an option for adding a disk cache
- Supports the enhanced AT-attachment protocol

The Smartcache Plus is a SCSI disk-drive controller board for ISA bus computers. It has an emulation mode for controlling one SCSI-2 or two SCSI-1 disk drives or two floppy-disk drives without the need for special-device drivers or BIOS ROMs. An optional cache module converts the board to a caching controller. The module provides from 512k to 16M bytes of cache RAM. Access time using the cache RAM is <0.5 msec. Using its enhanced AT attachment protocol, the board becomes a bus master, allowing it to overlap commands, scatter and gather data, and queue commands. Features include a 68000 µP, a 16-bit SCSI controller chip, and several ASICs. Controller board, $595; cache module with 512k bytes of RAM, $555.

Distributed Processing Technology, 140 Candace Dr, Maitland, FL 32751. Phone (407) 830-5522. FAX (407) 260-5366. Circle No. 370

EISA Bus Computer

- Has 33-MHz 80486 µP and eight 32-bit slots
- Options include SCSI-2 bus master adapter board

The Vectra 486/33T PC, an enhanced version of the company's Vectra 486 PC, is an EISA bus computer. It has a 33-MHz 80486 µP and eight 32-bit expansion slots. The computer supports more than 200 LAN users or 100 terminals on a Unix system. The unit's custom memory controller handles burst mode and a 128k-byte external-cache memory. Its 4M bytes of zero-wait-state memory is expandable to 64M bytes. Other features include a Weitek 4167 coprocessor socket; two serial ports; one parallel port; and hard- and floppy-disk controllers. Options include a 440M-, 670M-, or a 1G-byte SCSI-2 disk drive. A bus-master SCSI-2 adapter board is optional. The computer has certification to run Novell's Netware and Banyan's network software. It runs on SCO Unix, MS-DOS, and MS-OS/2 operating systems. Vectra 485/33T with 4M bytes of RAM and no hard-disk drive, $9499.

Hewlett-Packard Co, 300 Hanover St, Palo Alto, CA 94304. Phone local office. Circle No. 371

3-D Graphics Controllers

- Feature 1280 x 1024-bit resolution and a 16-bit Z buffer
- Incorporate VCAD 3-D graphics engine

The Animator and the Shader 3-D graphics controllers for IBM PCs and compatible computers have 1280 x 1024-bit resolution. They also feature the company's VCAD 3-D graphics engine, a TI graphics processor, a 25M-flops Mathbooster, and a 16-bit Z-buffer for real-time display of 3-D images. In <6 sec, the Shader draws the rotated crank, a common 3-D test file. The boards can draw more than 22,000 3-D shaded triangles/sec and can display as many as 16.7M simultaneous colors. The Animator has dual-frame buffers, allowing the board to construct an image in one buffer while displaying a completed image in the other frame. Both boards provide realistic images with color gradation and without banding. Shader, X/Series Model 3D-S, $5995; Animator, X/Series 3D-A, $6995.

Vermont Microsystems Inc, 11 Tigan St, Winooski, VT 05404. Phone (800) 354-0055; in VT, (802) 655-2860. Circle No. 372

Data-Compression Module

- Compresses data for SCSI tape drives
- Achieves compression ratios from 2:1 to 5:1

The MSB-8400 Squeezebox stand-alone data-compression module compresses data from a host computer to a SCSI tape-backup drive. It features Centronics D-type input and output connectors. A high-speed VLSI chip implements a proprietary compression algorithm. Because hardware accomplishes the data compression, the unit doesn't require any modifications to the operating system, utilities, or disk drives. The module achieves compression ratios from 2:1 to 5:1 on 8- and 4-mm tape drives. The 8-mm tape drive attains a capacity of 10G bytes. The same drive also achieves a data-transfer rate as fast as 1230k bytes/sec, which is equivalent to a throughput of 73M bytes/minute. The unit measures 8.1 x 2.5 x 6.3 in. and requires a 110 or 220V ac power source. $1750.

Megatape Corp, Box 317, Duarte, CA 91010. Phone (818) 357-9921. FAX (818) 357-2369. Circle No. 373
Brochure Features EMC Systems

The brochure, Total Solution to Your EMC Problems, discusses the R2500 Series EMC evaluation/measurement systems. It presents an evaluation of various EMC countermeasures and measurement levels. After examining various testing situations for a particular application, including counter measures, noise terminal voltage measurement, and shield-material evaluation, the publication recommends the optimal R2500 system from the company's 11 configurations. Charts and graphs complete the booklet.

Advantest America Inc, 300 Knightsbridge Pkwy, Lincolnshire, IL 60069. Circle No. 381

Catalog Presents VXI Products

Catalog 5091-0223EUS, HP 75000 Family of VXI Products, contains the manufacturer's entire line of VXI products, including the latest digitizing oscilloscope and universal counter. The text presents the system approach to VXIbus instrumentation. It also provides product descriptions, specifications, illustrations, and ordering information. The book focuses on three categories: software, an interactive test generator; firmware, standard commands for programmable instrumentation; and hardware, main-frame series B and C, DMMs, oscilloscopes, power meters, counters, sources, switches, interfaces, computers, and development tools.

Hewlett-Packard Co, Box 10301, Palo Alto, CA 94303. Circle No. 382

Study Focuses On Pick/Unix Impact

This publication is an "executive summary" of the 1991 IDBMA (International Database Management Association) Pick Industry-Impact Study. It contains information for the Pick and Unix markets and discusses the merge of the Pick business-applications software market with the Unix mainstream. The 100-pg document discusses how the mainstream has chosen Pick, and it elaborates on promises and realities of the market.

IDBMA Inc World Headquarters, 10675 Treena St, Suite 103, San Diego, CA 92131. Circle No. 383

Troubleshooting Approach To Test Sensors

This 4-color poster, Troubleshooting Electronic Components, provides a well-illustrated, troubleshooting approach for testing automotive engine sensors and actuators, using a digital multimeter. The chart presents testing of oxygen sensors, manifold absolute-pressure sensors, mass-air-flow sensors, cam and crankshaft position sensors, fuel-injection systems, the feedback carburetor, idle air-control motors, temperature sensors, and throttle-position sensors. Also included is a step-by-step diagnosis of a real-life automobile electrical problem. The poster features the 88 automotive meter as the diagnostic tool used in the examples.

John Fluke Mfg Co Inc, Box 9090, Everett, WA 98206. Circle No. 384

Publication Discusses PC Instrumentation

The 72-pg catalog, PC Instrumentation for the 90s, describes the vendor's line of PC-based data-acquisition boards, software, ADCs, DACs, and solid-state relay controllers. It provides specifications, photographs, and schematics. A selection guide and an appendix complete the publication.

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Here's where the barricades start to come down in the mixed signal revolution.

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Cleveland, OH  Westchester, NY  San Diego, CA  Santa Clara, CA  Houston, TX
March 19  April 3  April 12  May 14  May 23
Pittsburgh, PA  Smithtown, NY  McLean, VA  Pleasanton, CA  Dallas, TX
March 20  April 4  May 6  May 15  May 24
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March 25  April 5  May 7  May 16  May 28
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March 26  April 8  May 8  May 17  May 29
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EDN April 25, 1991
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QUESTION #1

Would you be willing to join an engineers’ union?

☑ YES  ☐ NO

Unions claim they have much to offer, but most engineers remain indifferent to them.

Professionals such as schoolteachers, college professors, and white-collar government workers all have large and long-established unions to represent them. For example, there are approximately 2.2 million elementary and secondary schoolteachers in America today, and more than 1.8 million of them—82%—belong to the NEA.

Very few engineers, on the other hand, are members of unions. The Council of Engineers and Scientists Organizations (CESO) is an umbrella group representing 10 small and widely scattered unions (or professional associations as most of them prefer to be called) that include engineers as members (see box, “The members of CESO”). CESO represents about 70,000 people—less than 3% of the estimated 2.3 million engineers in this country. Although CESO is not a union itself, it lobbies for its member organizations.

Many engineers have legitimate complaints about their salaries, benefits, and working conditions. And those are exactly the sort of concerns that unions or professional associations are supposed to deal with. Yet most engineers are reluctant to join them.

“I think it has to do with the way engineers are educated,” says Edward Olson, president of the Southern California Professional Engineering Association (SCPEA). “College professors teach this idea of professionalism, that you negotiate for yourself. Students also have a tendency to believe that engineers are a part of management. Early on, the thinking is that it’s unprofessional to belong to a labor union.

“As a result, when a young engineer first gets out into the workplace, he feels that he can negotiate his own wages, hours, and benefits. It takes a while before he realizes it’s very difficult to negotiate those things when you’re working for a large company.”

Daniel Mahoney, general counsel for the Seattle Professional Engineering Employees Association (SPEEA), shares Olson’s views. “Perhaps it’s the indoctrination they get in engineering schools that they are professionals,” he says. “They believe that it’s somehow demeaning to be categorized with what they perceive to be the traditional American labor-union member.”

Engineers’ image of themselves

Many engineers see themselves as rugged individualists, working on projects that are almost personal, which makes them unwilling to join any organization. “The analogy I use is they come out of school and they hit a strainer,” says Harold Ammond, executive director of the Association of Scientists and Professional Engineering Personnel (ASPEP). “They go off into computers, physics, all the gradations of electrical engineering, and the result is that there’s nothing that makes them homogeneous.”

Jay Fraser,
Associate Editor
This idea of independence that so many engineers hold dear also leads some of them to change jobs frequently. They don't join unions because they don't expect to stay very long with any firm. Ammond explains, "When he goes to work for a company, the average young person says, 'Well, I'll stay here for two years, then I'll go to another company for two years, then I'll go to a third company for two years, and every time I change jobs I'll pick up a 10% wage increase.' They think of themselves as individual entrepreneurs."

Engineers have other doubts about unions. Some are afraid that if they joined a union and weren't happy with it, they'd find it very difficult to get out and would be obligated to continue paying dues. Union dues can run into hundreds of dollars per year. Some engineers think the dues are too high. And many engineers simply aren't convinced that a union can do anything for them.

In addition, membership in most professional organizations is voluntary. Yet the National Labor Relations Act (NLRA) requires that a union negotiate a contract for all the employees in its collective bargaining unit, whether or not they are members of the union. Some engineers see no reason to join a union when they automatically receive exactly the same benefits as union members.

This law is a constant irritation to union officials. It hinders recruiting efforts and leaves the unions with less support than they might otherwise have. "There's no question that the nonunion people are getting a free ride," says Ammond. "They get the benefits, but they don't help us in getting the maximum. That's a burden, but that's the way the law is written."

Even though the vast majority of engineers don't belong to unions, the 10 professional associations that make up CESO have been successful. Some of them have been in existence for decades and are still growing.

SCPEA was founded more than 40 years ago and currently represents about 6000 engineers and technicians, mostly at McDonnell Douglas facilities in Long Beach and Huntington Beach, CA. SPEEA is the largest member of CESO. Its membership is made up of approximately 28,000 engineers and other professionals who work for the Boeing Co in the Puget Sound area of Washington and in five other states. ASPEP was founded in 1946. It currently represents about 2000 engineers and scientists who work for the General Electric Co in Camden and Moorestown, NJ.

In some ways these professional associations act like typical unions. They negotiate the standard articles of contracts—salaries, benefits, working conditions, vacations, holidays, cost-of-living raises, and overtime compensation—and they try to protect their members' job security.

"Our contract contains the clause that nobody can be disciplined or discharged without just cause," Mahoney explains. "If someone does get disciplined or discharged, we can challenge it in arbitration and get it turned around. We provide a lot of job security for our people that wouldn't necessarily exist in a company that operated under the employment-at-will doctrine."

Professional associations also point to the protection that an established grievance procedure offers employees. "It's a very valuable thing for a professional to have that protection in regards to termination," says Olson. "The company must show just cause before they can terminate you. If you're not protected by a contract, they can let you go any time they want."

Mahoney adds, "From our observation, when they work in a collective bargaining environment, our engineers and scientists are able to act in a more professional manner. They can challenge supervision and say, 'Look, you're doing it wrong. Try it this way.' In other words, they have a forum to articulate their professional analysis of problems without fear of being disciplined. It's a win-win situation."

**Different approaches to problems**

These professional associations also differ significantly from ordinary unions. "We are a union within the meaning of the NLRA, but we're not a typical trade union," says Ammond. "Our problem-solving approaches aren't standard."

ASPEP developed a complex method for evaluating an employee's performance called the retention credit system. It's based on a formal review where the employee is given a numerical score. It also takes into account factors such as the type of degree an employee has, how long it has been since that degree was earned, and how long the employee has worked for the company. The retention credit system allows for more flexibility than a straight seniority system.

"I'm sure if I submitted that contract to some of the AFL-CIO unions they'd look at me and say,
What are you, crazy? Whoever heard of a solution to a seniority problem being this complex? But that's a reflection of the unique community we represent,” says Ammond.

Some of the large national unions that belong to the AFL-CIO are staffed by full-time, salaried administrators who sometimes have no hands-on experience doing the work the average union member does. The small professional associations, by contrast, are mostly run by and for working engineers. About 85% of the members of ASPEP are electrical engineers, and there's nobody involved in the decision-making process who is not an engineer. In addition, the work that they do is mostly on a volunteer basis.

Officials of professional associations have noticed that as engineers become older and more concerned with job security they are more likely to become members. Economic hard times and the layoffs that come with them also increase interest in unions. The recession in the mid 1970s gave a big boost to union membership. But what spurs most engineers to join professional associations is what they consider to be mistreatment by their employers. “The best union organizer is bad management,” says Ammond.

Of the 10 professional associations, only ASPEP has ever gone out on strike. In 1967 the members went on a 30-day strike for a new layoff policy. Before that, in 1958 and 1960, they walked out for three days each time in order to establish a merit rating system. Ammond points out that a typical trade union might strike to eliminate a merit system because management could use it to discriminate against some employees. The fact that engineers went on strike to establish one, he feels, is more proof of the special quality of their professional organization.

Although CESO has been successful, its officials see no large-scale expansion of the union movement among engineers in the near future. This is partly due to the reasons—good and bad—many engineers can give for not joining unions, but it is also partly due to the nature of the unions themselves and the limited resources they have to make their case.

“We have no budget to go out and put on a PR campaign to educate people, so what we do is not perceived by many individuals,” says Ammond. “We are very introspective by nature. We work with the problems of our community and ASPEP. We really don't have the capability or the wherewithal of going out and proselytizing, or, to use the trade union term, organizing. We're just not made that way.”

The members of CESO

The Council of Engineers and Scientists Organizations (CESO) is an umbrella organization of 10 unions and professional associations that include engineers. Contact the following for more information on CESO and the 10 member organizations.

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Association of Scientists and Professional Engineering Personnel (ASPEP)
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If you possess the qualifications for any of these positions and want to join a winning team, please FAX your resume and salary history to: BROOKTREE CORPORATION, Professional Staffing, 619/597-0675. Or send to: 9950 Barnes Canyon Road, San Diego, CA 92121-2790. We are an Equal Opportunity Employer. M/F/H/V. Principals only, please.
ENGINEERING CAREER OPPORTUNITIES

Join an expanding high tech R&D/product engineering firm specializing in State-of-the-Art microprocessor based designs. We encourage employee initiative and creativity and offer opportunities for continued development of analytical and technical ability.

ANALOG DESIGN ENGINEER
Requires BS/BSEE and 3+ years experience in analog design.
- Semi Custom Analog Chip Design
- PSPICE Simulation
- DC to 50 MHz Analog Design

DIGITAL DESIGN ENGINEER
Requires BS/BSEE and 1+ years experience in digital design.
- ASIC Chip Design
- Xilinx FPGA Design
- Embedded Controller Application Design

SOFTWARE ENGINEER
Requires BS/BSEE/CS and 2+ years experience.
- OS/2 and Presentation Manager
- Intel Microprocessors
- C, C++ Programming

PCB DESIGNER
Requires 2+ years CAD experience.
- SMT Layout Experience
- Low Level Analog Circuit Design

Qualified applicants should forward a resume and salary history to:
Annapolis Micro Systems, Inc.
190 Admiral Cochrane Drive, Suite 130
Annapolis, Maryland 21401
(301) 841-2514 (301) 970-2672
FAX: (301) 841-2518
- Principals Only -

ENGINNEERING OPPORTUNITIES

At COULTER®, we set standards — in what we do and how we do it. As the internationally acclaimed world leader in the field of biomedical instrumentation and automated hematology, we attribute much of our success to our commitment to quality, reliability and teamwork.

The following Engineering opportunities are currently available:

Software Engineers
Mechanical Engineers
Quality/Reliability Engineers
Manufacturing/Producibility Engineers
Senior CAD Designers

All positions require a minimum of 5 years experience. Only seasoned professionals need apply.

If you are interested in a career with stability and growth potential, consider the Company with a commitment. Consider Coulter.

We offer excellent salaries and benefits including negotiable relocation. Please send your resume to: Employment Manager, Coulter Corporation, Dept. EDN, 650 West 20th Street, Hialeah, FL 33010. Principals only — no agencies please. An Equal Opportunity Employer.

If You're Looking For a Job, You've Come to The Right Place.
DELL IS TO COMPUTER DESIGN AS AUSTIN IS TO LIVING

At Dell, we believe in letting the imagination of our engineers shape the design of our award-winning products.

From the desktop-class power of our sleek 80386SX-based 316LT laptop, to the integrated math coprocessor and built-in UNIX compatibility of our new 80486-based 425E. Dell engineers enjoy a technical environment virtually free from the bureaucratic hassles of most large corporations.

So you get to focus on the things that really matter - designing better computers. And beyond our unique engineering environment we also offer a truly unique living environment in Austin. With scenic foothills, a relaxed culture, lower cost of living and a variety of beautiful neighborhoods, the lifestyle in Austin beautifully complements the engineering lifestyle at Dell.

ENGINEERING

- Personal Computer Motherboard Design
- Laptop Display Systems
- UNIX Development
- Personal Computer Network Development
- Design for Manufacturability
- EISA BUS Logic Design
- Mechanical Engineers
- Failure Analysis Engineers

If you're an engineer with a minimum of 2 years of computer industry experience and a related degree, learn more about the advantages of Dell in Austin.

Please fax or mail your resume with a cover letter to: 512/343-3330, Dell Computer Corporation, Jerry Holt, Human Resources, Professional Employment, Department EDN42591SG, 9505 Arboretum Boulevard, Austin, Texas 78759.

Dell is proud to be an equal opportunity employer.
RESPONSIBILITY • RESULTS • RECOGNITION

SANTA CLARA POSITIONS

SUBSYSTEM ENGINEER
Begin with creative designs & see them through the entire product cycle: BSEE/MSEE & 4+ yrs experience in board & systems design.

SOFTWARE ENGINEER
Develop UNIX OS software, write peripheral drivers for the R3000 32-bit µP. BS/MS in CS & 5+ yrs exp. Req. C familiarity essential.

PRODUCT ENGINEERS
Conduct performance/failure analysis, device characterization, & provide mgmt/customer support.

Sr. Product Engineer—RISC
Requires BSEE/MSEE & 5+ yrs’ µP product design, & process experience.

Sr. Product Engineer/Group Leader
Support development & production release of complex digital products for Memory Support & RISC/Embedded Controller Support. Lead a group of Product Engineers & Technicians. MSEE & 5+ yrs experience in CMOS digital ICs required. Supervisory experience preferred.

TEST ENGINEERS
Design & conduct tests on our new & existing products using the latest techniques & equipment.

Sr. or Staff Test Engineer
Write & debug ECL SRAM tests on Advantest & Sentry memory testers. Requires BS/MS in EE/ME & 5+ yrs experience.

Test Engineer
Generate test programs for memory test systems & design related hardware. Requires BSEE & 2+ yrs testing experience using 5-90.

QUALITY ENGINEERS
Sr. Reliability Engineer/Supervisor
Requires Engineering BS, 2+ yrs reliability experience & 5+ yrs semiconductor electronics experience.

DESIGN ENGINEERS
Design & develop complex digital/mixed-signal products for Graphs/Imaging, Memory Support, RISC/EC Support, & Logic using IDT’s CEMOS®/HICEMOS™ technology.

APPLICATIONS ENGINEERS
Sr. Product Definition / Application Engineers
Requires MSEE/MScS & 5+ yrs experience in the design of embedded controllers & other new products using DISC or RISC µP & peripheral devices.

MARKETING ENGINEERS
Oversee & implement tactical product marketing strategies, incl. forecasts, information support, pricing, & introduction/distribution.

Marketing Manager—SRAM
Requires 1+ yrs semiconductor marketing experience & knowledge of SRAM products & markets.

Marketing Manager—Logic
Requires BSEE, 6+ yrs mkgl & distribution experience & working knowledge of logic design.

For Santa Clara positions, call Jeff Scheels at (408) 944-2129. Or send your resume indicating position of interest to: Integrated Device Technology, Inc.

MONTEREY COUNTY POSITIONS

PRODUCT ENGINEERS
Conduct performance/failure analysis, device characterization, & provide yield improvement & manufacturing/customer support.

Product Engineers—Memory
Openings in our Specialty Memory and CMOS SRAM groups. BS & prior experience with MOS memories required. MS preferred.

MARKETING ENGINEERS
Perform pricing & forecasting & develop custom/product strategies. Prior technical marketing or engineering experience in the semiconductor industry required.

PRODUCTION SUPERVISORS
Positions available in both Fab and Test areas. Ensure production schedules & effective operations/ equipment management. Requires BS/BA, manufacturing experience & willingness to work off-shift schedules.

LINES MAINTENANCE TECHNICIANS
Openings available in all shifts in etch, diffusion, thin films, & other photo areas. Positions require technical AS degree.

PROCESS ENGINEERS
Multiple openings in our diffusion, thin films, & plasma etch areas. Work with state-of-the-art equipment. Requires BS & 5+ yrs experience in CMOS processes in a Class 3 clean room. Openings on all shifts, including weekends. BS required, MS preferred.

EDN Databank
Professional Profile

Announcing a new placement service for professional engineers!

To help you advance your career. Placement Services, Ltd. has formed the EDN Databank. What is the Databank? It is a computerized system of matching qualified candidates with positions that meet the applicant's professional needs and desires. What are the advantages of this new service?

• The computer never forgets. When your type of job comes up, it remembers you're qualified.

• Your background and career objective will periodically be reviewed with you by a PSL professional placement person.

We hope you're happy in your current position. At the same time, chances are there is an ideal job you'd prefer if you knew about it. That's why it makes sense for you to register with the EDN Databank. To do so, just mail the completed form below, along with a copy of your resume, to: Placement Services, Ltd., Inc.

EDN Databank
A DIVISION OF PLACEMENT SERVICES LTD., INC.
265 S. Main Street, Akron, OH 44308 216/762-0927

EDN April 25, 1991
The IBM RISC System/6000 family keeps delivering performance that's positively hyperactive.

Talk about precocious. Just a little over one year ago, when we proudly announced the arrival of the RISC System/6000™ POWERstations and POWERservers, they were already way ahead of the other kids in their class, delivering amazingly high performance for their diminutive price range.

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Now, we're introducing the new RISC System/6000 POWERstation 320H. It runs 11.7 MFLOPS™ and 32.4 SPECmarks.* If you already have the original POWERstation 320, you can upgrade it now to the even more spectacular performance of the 320H.

**YET ANOTHER NEW ADDITION TO THE FAMILY.**

Our POWERserver 950 is also brand spanking new. It gives you the performance of the POWERserver 550—25.2 MFLOPS and a SPECmark of 56.3—but in a rack-mounted system, to share more disk storage, power and expandability with others. And all the models in the UNIX®-based RISC System/6000 family can now add disk expansion units for up to quadruple their previous maximum fixed disk storage. This yields up to 22.2GB on the POWERserver 950.

**A NEW BOX OF CRAYONS.**

Then there's the POWERgraphics GTO graphics subsystem. It can attach to any model in the RISC System/6000 family, to deliver super graphics performance previously available only in the POWERstation 730—990,000 3D vectors/second and 120,000 shaded polygons/second.

**MEMORY AT PRICES THAT WON'T CAUSE TANTRUMS.**

And now you can get more memory for less. The more memory you buy, and the bigger the increments, the less you pay per MB. After all, just because we're a year old doesn't mean we don't know the value of money. Especially yours.

To find out more about the RISC System/6000 family, call 1 800 IBM-6676, ext. 878. And if you think this one-year-old is a handful now, just wait until the terrible twos.

For the Power Seeker.

*SPECmark is a geometric mean of the ten SPECmark tests. MFLOPS are UNPACK double precision where n=100. AIX XL FORTRAN Version 2.1 and AIX XL C Version 11 compilers were used for these tests.

IBM and AIX are registered trademarks and RISC System/6000 is a trademark of International Business Machines Corporation. UNIX is a registered trademark of UNIX Systems Laboratories, Inc. SPECmark is a trademark of Standard Performance Evaluation Corporation. HUGAR THE HORRIBLE Character© 1991 King Features Syndicate, Inc. © 1991 IBM Corp.
The power of dual platforms – more than a promise.
The leading electronics design automation solutions are available today on two industry-leading platforms.

Now DAZIX customers will benefit from products that reside on both Sun and Intergraph workstations. Robust solutions for the entire design process. Plus, an open-system framework that integrates Intergraph, DAZIX, and Sun products – as well as other leading EDA tools – in a simultaneous engineering environment.

Billion-dollar backing.
Intergraph's financial strength gives DAZIX customers an added benefit – confidence. The confidence that comes from a partnership with the only EDA company that is part of a billion-dollar computer graphics corporation. Ranked No. 3 in worldwide EDA sales. With an installed base of 13,000-plus EDA seats and capabilities developed over more than 22 years of providing integrated graphics solutions around the globe.

DAZIX customers are assured of continued product development and excellent support. Not just today and tomorrow, but into the future.

To learn more about our numbers, call us. In the United States, 800-239-4111. In Europe, 33-1-4537-7100. In the Asia-Pacific area, 852-8661966.
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