NEW! Foldout table of contents. See reader-service card at end of issue.

EDN®

A CAHNERS PUBLICATION
March 30, 1992

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS WORLDWIDE

Special Report: RISC processors establish new performance plateaus pg 96

SPDT & SP4T SWITCHES

WITH BUILT-IN DRIVERS

10 to 3000MHz from $39.95

Now, high-speed, high-isolation switches with built-in drivers, tough enough to pass stringent MIL-STD-202 tests. There's no longer any need to hassle with the complexities of designing a TTL driver interface and then adding yet another component to your subsystem…it's already included in a rugged, low-cost, compact assembly.

Available in the popular hermetically-sealed TO-8 package or a small EMI-shielded metal connectorized case, these tiny PIN-diode reflective switches, complete with driver, can operate over a 10 to 3000MHz span with a fast 2μsec switching speed.

Despite their small size, these units offer isolation as high as 40dB(typ), insertion loss of only 1.1dB(typ), and a 1dB compression point of +27dBm over most of the frequency range. All models are TTL-compatible and operate from a dc supply voltage of 4.5 to 5.5 V with 1.8mA quiescent current.

Switch to Mini-Circuits for highest quality innovative products…and leave the driving to us.

SPECIFICATIONS

	TOSW-230 ZSDR-230		TOSW-425 ZSDR-425	
Freq. Range(MHz)	10-3000		10-2500	
Insert. Loss (dB)	typ.	max.	typ.	max.
10-100MHz	1.3	1.9	1.3	1.7
100-1500MHz	1.1	1.9	1.1	1.7
1500-3000MHz	1.8	2.7	1.8	2.5
Isolation(dB)	typ.	min.	typ.	min.
10-100MHz	60	40	60	40
100-1500MHz	40	28	40	30
1500-3000MHz	35	22	35	22
1dB Compression(dBm)	typ.	min.	typ.	min.
10-100MHz	17	6	17	6
100-1500MHz	27	19	27	19
1500-3000MHz	30	28	30	28
VSWR(ON)	typ. 1.3	max. 1.6	typ. 1.3	max. 1.6
Switching Time (μsec) (from 50% TTL to 90% RF)	typ. 2.0	max. 4.0	typ. 2.0	max. 4.0
Oper. Temp.(°C)	-55 to +100		-55 to +100	
Stor. Temp.(°C)	-55 to +100		-55 to +100	
Price (10-24) (1-9)	$39.95 $89.95		$59.95 $109.95	

finding new ways…
setting higher standards

Mini-Circuits

A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

WE ACCEPT AMERICAN EXPRESS

CIRCLE NO. 4

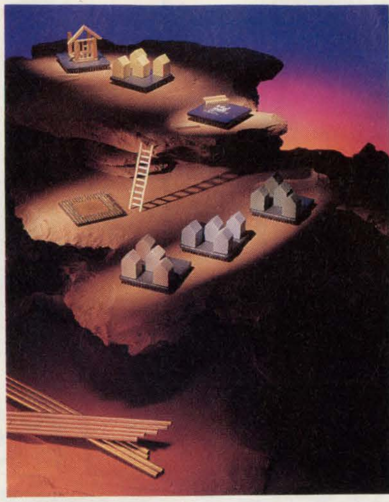
F126 REV.A

EDN

MAGAZINE EDITION

MARCH 30, 1992 VOLUME 37, NUMBER 7

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS WORLDWIDE



On the cover: The first and second generation of RISC microprocessors laid the groundwork for the increased performance of the current collection. (Photo courtesy Intel, Chandler Div; concept, design, sets, and photography by Imagination) . . . . **PAGE 96**

Continued on page 7

EDN®(ISSN 0012-7515, GST Reg. #123397457) is published 48 times a year (twice monthly with 2 additional issues a month, except for March and October, which have 3 additional issues and July and December which have 1 additional issue) by Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158-1630. Terrence M McDermott, President/Chief Operating Officer; Frank Sibley, Executive Vice President; Jerry D Neth, Senior Vice President/Publishing Operations; J J Walsh, Senior Vice President/Finance; Thomas J Dellamaria, Senior Vice President/Production and Manufacturing; Ralph Knupp, Vice President/Human Resources. EDN®is a registered trademark of Reed Properties Inc., used under license. Circulation records are maintained at Cahners Publishing Company, 44 Cook Street, Denver, CO 80206-5800. Telephone: (303) 388-4511. Second-class postage paid at Denver, CO 80206-5800 and additional mailing offices. **POSTMASTER: Send address corrections to EDN®, PO Box 173377, Denver, CO 80217-3377.** EDN® copyright 1992 by Reed Publishing USA; Robert L Krakoff, President and Chief Executive Officer. Annual subscription rates for nonqualified people: USA, $119.95/year; Mexico, $169.95/year; Canada, $181.85/year; all other nations, $207.95/year for surface mail and $329.95/year for air mail. Single copies are available for $20 USA and $25 foreign. Please address all subscription mail to Ellen Porter, 44 Cook Street, Denver, CO 80206-5800.

EDN
MAGAZINE EDITION

MARCH 30, 1992

Continued from page 5

PRODUCT UPDATES

PROCESSOR UPDATES

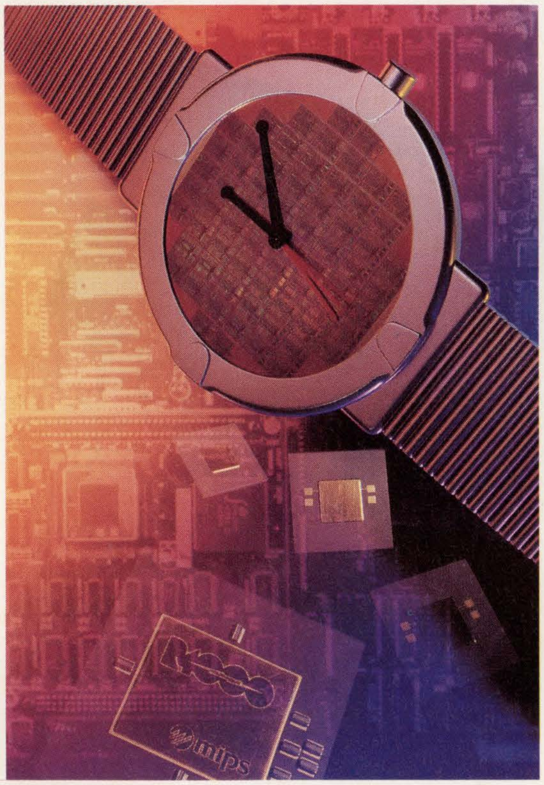
NEW PRODUCTS

DEPARTMENTS

Cahners Publishing Company, A Division of Reed Publishing USA □ Specialized Business Magazines for Building & Construction □ Research □ Technology □ Electronics □ Computing □ Printing □ Publishing □ Health Care □ Foodservice □ Packaging □ Environmental Engineering □ Manufacturing □ Entertainment □ Media □ Home Furnishings □ Interior Design □ and Lodging. Specialized Consumer Magazines for Child Care □ Boating □ and Wedding Planning.

A summary and analysis of articles in this issue

Third-generation RISC processors are just starting to appear. Some of these μPs represent the latest evolutionary step for an existing processor family, whereas others skipped the first and second generations entirely. Technical Editor Ray Weiss rounds up both the available and soon-to-be available RISC devices and architectures in this issue's Special Report. If you're not yet comfortable with the brave new world of superlative adjectives ("superscalar" and "superpipelined") used to describe these high-powered computing engines, this article will bring you up to speed.



Although a few of these processors are already available in sample quantities, many have not yet been realized in working silicon. Generally, EDN's articles present products with both price and availability data because our reader surveys tell us that you want it that way. The price and date of availability serve as reality checks; if a vendor can tell you when a product will be available and how much it will cost, the product is probably real. However, for critical products with long evaluation or design-in times, such as 32-bit μPs, we make an exception to this policy. Even when the products are not yet available, we will still supply the best availability information we can get. Such is the case with this issue's Special Report on RISC μPs.

Technical Editor Brian Kerridge's Technology Update on micropower voltage references jumps from high-power μP systems into the world of low-power analog design. Micropower voltage references are all based on bandgap devices instead of zeners. Kerridge's story tells you why and also gives you several application pointers to help you avoid noise and stability problems.

You'll most likely find one or more of these micropower voltage references in the battery-powered digital sampling oscilloscopes (DSOs) covered in Technical Editor Dan Strassberg's Technology Update. You might think of these instruments as field-service tools, but Strassberg shows that they pack enough punch for general design use. Some even have enough extra functions to replace a rack of equipment with one handheld instrument. The article's sidebar discussing batteries for DSOs should interest designers of any battery-powered equipment.

Steven H Leibson
Executive Editor

No Delays.

tributor, too. So you can get the quantity and speed you need, whenever you need them.

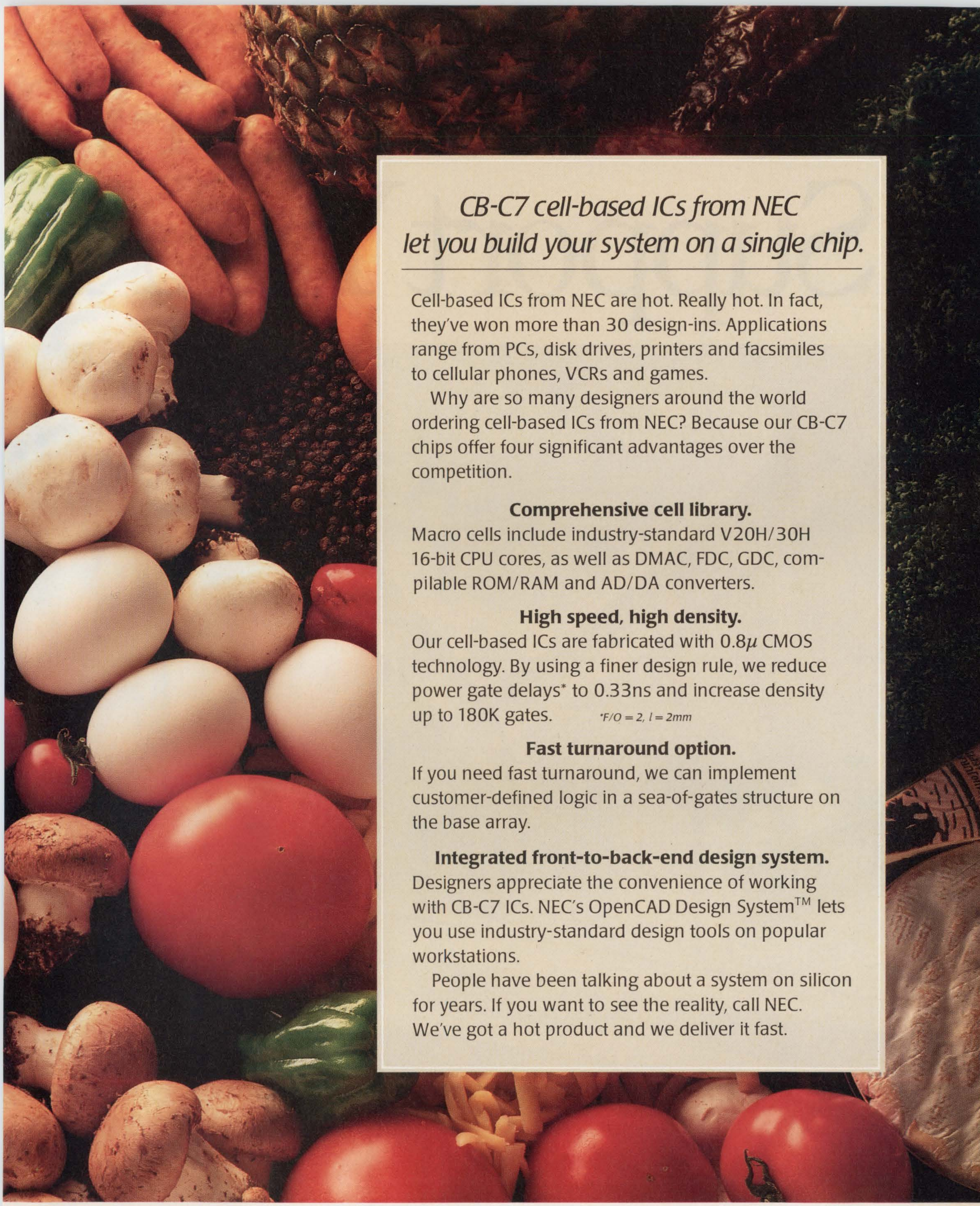
What more can you expect from the company that sells more programmable logic than all of its competitors combined?

So pick up the phone and place your order today, or call **1-800-222-9323** for more information.

Because at AMD, we don't believe in long delays either.

Advanced Micro Devices


C&C Computers and Communications
A hot product,
made to order, delivered fast,
with everything on it.



CB-C7 cell-based ICs from NEC let you build your system on a single chip.

Cell-based ICs from NEC are hot. Really hot. In fact, they've won more than 30 design-ins. Applications range from PCs, disk drives, printers and facsimiles to cellular phones, VCRs and games.

Why are so many designers around the world ordering cell-based ICs from NEC? Because our CB-C7 chips offer four significant advantages over the competition.

Comprehensive cell library.

Macro cells include industry-standard V20H/30H 16-bit CPU cores, as well as DMAC, FDC, GDC, compilable ROM/RAM and AD/DA converters.

High speed, high density.

Our cell-based ICs are fabricated with 0.8μ CMOS technology. By using a finer design rule, we reduce power gate delays* to 0.33ns and increase density up to 180K gates. *F/O = 2, l = 2mm

Fast turnaround option.

If you need fast turnaround, we can implement customer-defined logic in a sea-of-gates structure on the base array.

Integrated front-to-back-end design system.

Designers appreciate the convenience of working with CB-C7 ICs. NEC's OpenCAD Design System™ lets you use industry-standard design tools on popular workstations.

People have been talking about a system on silicon for years. If you want to see the reality, call NEC. We've got a hot product and we deliver it fast.

CIRCLE NO. 9

NEC

Toshiba Non-Vo
Support You At

latile Memories Every Level.

Toshiba EPROM, OTP and MROM: pick your part according to design code maturity and reprogrammability issues.

Toshiba: the surest path to quality EPROM, OTP and MROM. If you entered the CMOST Expressway with Toshiba memory, get ready to broaden your perspective. We've mapped out a three-ramp approach to non-volatile memory that'll get you where you're going in no time.

At the first stages of prototype, or for reprogrammable designs, Toshiba supports your brainchild with x8 and x16 varieties of 4 megabit (Mb) EPROM. As the design matures, we'll show the way with the only byte-selectable 4Mb OTPs in the industry. Then, once the code is fully proven, we'll gear up for your high-production run with reliable, 16Mb, 150ns MROMs.

Not only will the performance and cost-per-bit benefits of Toshiba MROMs impress you, you'll also be amazed at the time you'll save by using Toshiba's new MROM code transmission system. It's like knowing a shortcut through the most congested part of town.

It should come as no surprise that we're leading the non-volatile technology race. Our success is based on our proven CMOS process and backed by our high-volume production capability. No matter where your design is headed, we'll accompany you from beginning to end.

For technical literature, call 1-800-321-1718.

All roads to a successful design process emanate from Toshiba's proven CMOS process.

In Touch with Tomorrow

TOSHIBA

TOSHIBA AMERICA ELECTRONIC COMPONENTS, INC.

MST-91-052

CIRCLE NO. 16

EDITED BY SUSAN ROSE

FPGA delivers 10,000+ gate densities

With its XC4010, Xilinx increased its FPGA (field programmable gate array) densities to 10,000 usable gates. The FPGA is the next step in the XC4000 FPGA chip family. The RAM-based-array usable-gate density increases with the availability of a programmable RAM, which you can use as a RAM block. XCA4010 register clock rates can hit 45 MHz, according to Xilinx.

Register-intensive designs can use the programmable RAM look-up table instead of the block logic it controls. You can address the RAM as a 2×16- or 1×32-register array with a 4.5-nsec access time. You can configure multiple logic blocks to build wide, deep register sets. The FPGA is made up of a 20×20 matrix of 400 of these configurable logic blocks (CLBs). Each CLB has two 4-input functional logic units and two D flip-flops. Fast-carry logic supplements the CLBs for adder and addressing functions. The FPGA suits 32-bit processing. The chip provides 40-chip-wide, 3-state bit buses, which can handle a 32-bit word with additional control or parity byte. You can route the CLBs to pick up or put data values on any bit bus. The FPGA family includes 16 11-nsec, 60-input decoders.

Designers can change the FPGA designs on the board as well as FPGA functionality, depending on board or system conditions. However, the company's FPGAs require programming on power up, requiring special logic and system memory or an EPROM to hold FPGA programming data. The chip costs $737 (1000). Xilinx Inc, San Jose, CA, (408) 559-7778, FAX (408) 559-7114.—Ray Weiss

VHDL package integrates multiple tools

Vantage Analysis Systems Vantage Spreadsheet version 4.0 lets engineers compile, debug, and analyze their VHDL (VHSIC Hardware Description Language) designs. The software's compilation and simulation speeds are an order of magnitude faster than previous versions. The software also speeds testing with a tool that grades test stimulus by counting up the number of times a VHDL source-code line executes, as well as tracking the number of events for each signal. The Concurrent Compiler, a parallel version of the VHDL compiler that automatically partitions and distributes compilation tasks across a Sun or HP processor network, speeds compilation. Finally, a generic loader lets you load as many as 100,000 parameters per minute, without stopping the compiler. The software pricing starts at $44,000. Vantage Analysis Systems Inc, Fremont, CA, (510) 659-0901.—Ray Weiss

Ethernet and Token Ring on one chip

Texas Instruments' TMS380C26 chip handles both Ethernet and Token-Ring communications protocols. With this chip on a mother board, users can connect their system to either network—they do not have to choose a desktop protocol when buying the system. The chip supports Ethernet standards and remains pin and software compatible with TI's TMS380C16, an IBM-verified 4- or 16-Mbit/sec Token-Ring coprocessor.

To make reconfiguration (shifting from one to the other on site) easier, the company is also releasing the C26 Selectable Physical Layer Interface Transceivers to ease reconfiguration. These transceivers let you interface a mother board to either Token-Ring or Ethernet wiring media. Configuration is at the cable level. The TMS380-C26 will be available in a 132-pin plastic quad flatpack. $58.80 (10,000). Texas Instruments Inc, Dallas, TX, (800) 336-5236, ext 3990.

—Ray Weiss

Cache-tag RAM offers 12-nsec validated match

The CY7B180 and CY7B181 are 4k×18-bit cache-tag RAMs with extra logic to simplify your cache designs. Both devices offer a 16-bit tag field with a 2-bit status field at each location. You can read and write the two fields independently. The 180 lets you use the status bits to code the tag data for multiprocessing systems. The 181 uses these status bits to denote valid and "dirty" data. It automatically sets the "dirty" bit on a write hit and uses the valid bit to gate the match signal so that only valid matches are signaled to the cache. The validated match takes 12 nsec.

To further simplify designs, the devices automatically generate a write output signal to the cache RAM when they detect a write hit. The devices also offer an additional data port, letting you read tag data immediately when you find a match. The instant availability of the tag data helps speed copy-back cache schemes. The devices come in a 68-pin plastic leaded chip carrier and cost $72.05 (100). Cypress Semiconductor, San Jose, CA, (408) 943-2600, FAX (408) 943-2741.

—Richard A Quinnell

Scope offers record lengths to 8 Mbytes

The Systemware digital oscilloscope is available with as much as 8 Mbytes of memory words, letting the instrument record exceptionally long waveforms. The PC-based oscilloscope runs under Microsoft Windows 3.0 with a software control panel. The instrument has a 40-MHz bandwidth and digitizes 8 bits at 100 Msamples/sec. Prices range from $10,000 for an instrument with 256 kbytes of memory, to $18,825 for a system with 8 Mbytes of memory. Systemware, Westlake Village, CA, (805) 497-9603, FAX (805) 494-9719.

—Doug Conner

Conditions relax as Europe's EMC Law comes into force

Although Europe's EMC law theoretically came into force on January 1 of this year, clarifications of its implementation continue to appear. Since EDN first reported details of this law (September 16, 1991, pg 57), later statements from the Commission of European Communities have defined more clearly what products the law applies to and over what time scale the law will be introduced.

Generally, there is an overall relaxation in the scope of products that must comply with the law. Broadly, the law classifies products into one of four categories: components, apparatus, systems, and installations. Components and installations do not have to comply with the law, but apparatus and systems must. The terms are thus defined:

- Components: Any element likely to be part of an apparatus, and not intended for use by an end user. This category includes passive components, ICs, and pc-board subassemblies.
- Apparatus: A finished product with an intrinsic function intended for an end user that will be placed on the market as a single commercial unit. The law squarely applies to products in this category.
- Systems: Several pieces of apparatus designed and intended to work together. A typical example is a PC, and such products must comply.
- Installations: Several pieces of apparatus put into service in a given place for a specific task but not intended to be placed on the market as a single commercial unit. On the understanding that an installation consists of already-compliant apparatus and systems, the overall installation needs no further approval.

The Commission of European Communities has also made clear that the end-date of the transition period is December 31, 1995. During the transition period you can opt to comply with the EMC law or continue to observe prevailing national EMC regulations. At present, only Denmark has incorporated the EMC law into its national legislation. Other countries will follow suit later this year.

The arrangement for competent bodies and notified bodies to perform approval work in the EC stands. In the UK, the Department of Trade and Industry has issued a provisional list of companies to perform this service.

—Brian Kerridge

Mixed-signal IC tester gets smaller and faster

As mixed-signal ICs grow in digital complexity, the distinction between testers for mixed analog/digital chips and those for high-pin-count digital devices is becoming less clear. Teradyne Inc's mixed-signal-IC tester, the A580, has many of the attributes of testers for purely digital ICs. The system has 280 channels—of which 192 are digital—and a 200-MHz maximum clock rate for digital testing. The mixed-signal-chip tester can handle the majority of testing performed on high-pin-count digital ICs, so many companies that make both digital and mixed-signal parts should be able to use a single type of tester.

In addition to offering 2.5× as many channels and 4× the digital-test speed of its most nearly equivalent predecessor, the tester is considerably smaller (about one-half the floor space), and at $1 to $2 million, slightly less expensive. The unit also uses so much less power that it has no need for a separate power-conditioning "vault." The lower power dissipation means users won't have to install as much air conditioning. For analog applications, the highest signal frequency is 4 GHz vs 10 MHz for the earlier system; the highest voltage is 1 kV vs 60V; and the largest source current is 100A vs 1A. Teradyne Inc, Boston, MA, (617) 422-2567.

—Dan Strassberg

VGA chips attack PC-video performance problems

Now that PC processor speeds have jumped into the 33- to 50-MHz range, IC vendors are attacking the next major performance bottleneck—video display speeds—with chips that off-load graphics operations from the main CPU. AT&T's ATT20C101 super-VGA controller incorporates several features that boost display performance, including a 16-bit bus interface that can keep pace with 80386 and 80486 µPs, a write buffer that reduces wait times (at least during write operations), and a 32-bit interface to page-mode dynamic RAMs for the bit-map memory. The $14 (1000) chip has nine display modes that range from 640×480 to 1024×768 pixels and display 256- to 16.8-million colors.

The company is also offering three companion color-palette DACs: the 110-MHz, triple 8-bit ATT20C491; the 110-MHz, triple 6-bit ATT20C492; and the 200-MHz, triple 8-bit ATT20C458. These DACs cost $13, $11, and $45, respectively, (1000).

ATI Technologies' 68800 super-VGA coprocessor

uses many of the same graphics-acceleration techniques and adds a few of its own. The $79 (1000) IC has a configurable bus interface with a FIFO buffer that will transfer 8-, 16-, or 32-bit words and is fast enough to operate on the host CPU's local bus at clock speeds to 40 MHz. The controller chip communicates with video memory over a 64-bit bus and can accommodate 4M bytes of video RAM, producing a maximum display resolution of 1280×1024 24-bit pixels. An on-chip drawing coprocessor can perform bitblts, point-to-point line drawing, pattern filling, and clipping with little or no host CPU intervention. The chip also provides hardware-based assistance for antialiased character fonts. A less-expensive version of the device, the $49 (1000) 68800SX, will be available later this year. It will only accommodate 2M bytes of video memory and 1024×768-pixel displays. AT&T Microelectronics, Allentown, PA, (800) 372-2446, FAX (215) 778-4106. ATI Technologies, Inc, Scarborough, ON, Canada, (416) 756-0718, FAX (416) 756-0720.
—Steven H Leibson

High-density PLD allows in-system programming

Lattice Semiconductor's PLSI 1032 and ISPLSI 1032 are the first members of a high-density PLD family that are based on EEPROM technology. Both devices have 64 I/O pins, 8 dedicated input pins, and 196 registers. The devices' basic logic block lets you create 20 AND-product terms from a selection of 18 complementary signal pairs, 2 of which come from the dedicated input pins and 16 from any of the logic blocks. Propagation delay through the device is 15 nsec; delay for internal feedback is as low as 3 nsec.

Both the PLSI and ISPLSI devices are pin- and parameter compatible, but the ISPLSI device has an additional feature: You can program the device in-system. The ISPLSI device multiplexes four I/O pins and uses one dedicated pin (no-connect on the PLSI parts) to provide a serial access port for programming. The device has an on-chip programming voltage, so you don't need any additional voltages in your system.

Lattice supports the family with development software and engineering kits. The software runs under Windows, offers a library of macro functions, and lets you design with Boolean equations. The software costs $995; the engineering kit costs $395. The parts' cost varies with speed grade. The PLSI 1032 costs from $49 to $81 (1000). The ISPLSI 1032 costs $142 (100) in sample qty. Lattice Semiconductor, Hillsboro, OR, (503) 681-0118, FAX (503) 681-0347.—Richard A Quinnell

Voltage regulator models thin package

The TL-SCSI285 fixed-voltage regulator from Texas Instruments implements a new method for terminating SCSI lines, called active termination, which reduces power consumption by as much as 30×, thereby increasing the possibilities for SCSI portable systems. The regulator lets input voltages drop as low as 3.45V and still maintain an output voltage of 2.85V. With this dropout voltage of 0.6V, the regulator meets demands of both desktop computer systems and laptop and portable systems. Total tolerance in the 2.85V output is ±2% overtemperature, including variations caused by line voltage and load changes. The device's 110Ω, ±2% series resistors match the typical transmission-line characteristic impedance.

The device comes in a thin-scaled small-outline package (TSSOP). The 20-pin package has lead spacings of 0.025 in. and is 0.040 in. thick, which is half the height of the standard small-outline package. At 25°C, the package's power-dissipation rating is 0.775W compared with 1W for a standard DIP. The TSSOP-packaged regulator costs $1.70; DIP and TO-200 versions are also available. A second regulator with a 1V dropout voltage, the TL2217-285, costs from $1.39. These regulators are the first devices available in the thin package, but the company will also offer the package for existing and new standard linear devices. Texas Instruments Inc, Dallas, TX, (800) 336-5236, ext 3990, (214) 995-6611, ext 3990.
—Anne Watson Swager

Microsoft introduces C++

Microsoft Corp has introduced C/C++ v 7.0 Development System for Windows. The system is an ANSI C and C++ v3.1 development environment. The system's compilers use precompiled header and C++ files for increased speed.

The package includes the Microsoft Foundation Classes and an Application Framework. These classes are available in source form for use as program examples. The framework is a platform for multiple tools, including third-party development packages. Among the debug tools are a new version of Codeview for C++ and a C++ Object Browser. Other optimizations include "Packed P code" object format (interpreted P-code for 40 to 60% size reductions), programmer-directed function in-lining (saving call overhead by expanding function calls with the actual code), automatic function in-lining (compiler directed), and a virtual overlay manager. Also provided is a set of Windows documentation and basic C++ class libraries. The software costs $499. Microsoft Corp, Redmond, WA, (206) 882-8080.—Ray Weiss

The Highest, Single-Chip SPECmark in Production Now!

Performance's PR3400 Monolithic MIPS CPU/FPA/MMU

175-pin PGA
Actual size

Combined Int./F.P.
SPECmark
of 32.4
at 40MHz

Never Before in the History of Man Has Floating Point Been So Cheap!

PR3400 MIPS RISC Processor

This new monolithic VLSI component contains the PR3000A, PR3010A and more! When used with the PACEWRAP™ PR3100A, (Performance's single-chip write, read and parity buffer), it makes possible a single-board MIPS computer at 25, 33 and 40MHz.

- ☐ **32-bit MIPS RISC Processor (PR3000A)** Thirty-two general-purpose 32-bit registers; all instructions & addresses are 32 bits.
- ☐ **On-Chip MMU** Provides fast address translation for virtual-to-physical memory mapping of the 4 GByte virtual address space.
- ☐ **On-Chip Cache Control** For separate external instruction & data caches of up to 256KBytes each.
- ☐ **Five-stage pipeline** Closely approaches execution rate of one machine cycle per instruction.
- ☐ **Floating Point Accelerator (PR3010A)** Contains sixteen 64-bit registers to support single or double precision arithmetic; fully conforms to ANSI/IEEE Standard 754-1985 "IEEE Standard for Binary Floating Point Arithmetic."
- ☐ **Single 1X-Clock Pin** No external delay line required.
- ☐ **System Performance at 40MHz** SPECmark Rating = 32.4, 33 VAX MIPS; 11.6 MFLOPS, Single-Precision LINPACK; 6.7 MFLOPS Double-Precision LINPACK.
- ☐ **Available Speeds** 25, 33 and 40MHz.
- ☐ **Packages** 175-pin PGA, 25, 33 & 40MHz, 160-pin surface mount.

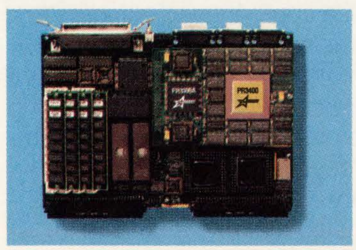
PACEWRAP PR3100A Write/Read & Parity Buffer

This new component provides a full-featured interface between the high-speed processor-cache bus and lower-speed I/O & main-memory bus resulting in outstanding performance and board density at lowest cost.

- ☐ Eight-word-deep write buffer with read-back.
- ☐ 32-word programmable read buffer.
- ☐ Parity generation & detection on reads from main memory.
- ☐ Static column DRAM support.
- ☐ Bus snooper for cache coherency in multiprocessor systems.
- ☐ Available in 160-pin PQFP @ 25, 33 & 40MHz.

PaceRunner/3400 VME SBC in a 6U Form Factor

Features high performance (28VUPS at 33MHz) based on the PR3400 and the PR3100A. Includes 64 KBytes cache, 4/16 MBytes DRAM, watchdog timer, 256/512 KBytes EPROM, SCSI/Ethernet/Duart, and master/slave VME interface. The PaceRunner/3400 VME SBC can be used in workstations, servers, industrial and process control, imaging, communications, simulation, and software development platforms.



For more information call the leading volume and speed supplier of MIPS RISC components

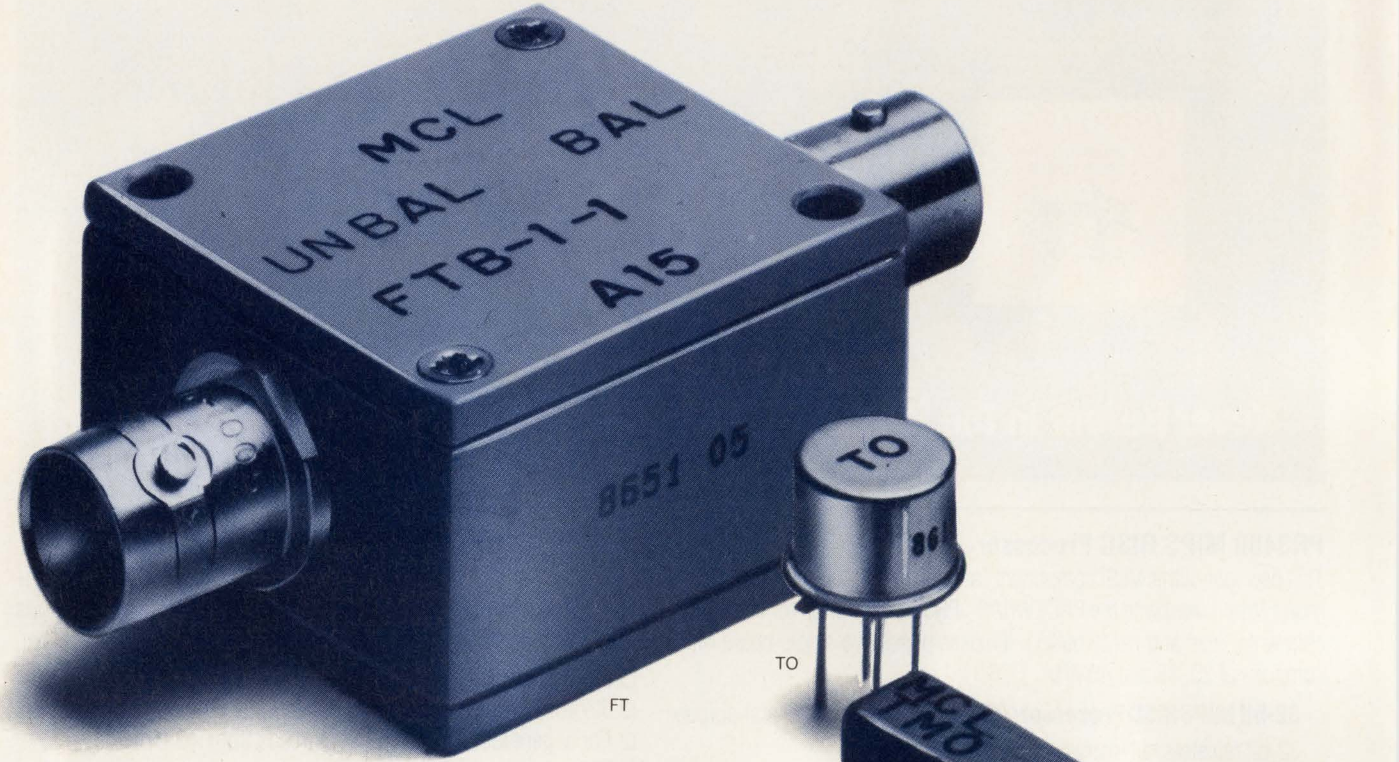
(408) 734-9000

PERFORMANCE
SEMICONDUCTOR CORPORATION
610 East Weddell Drive, Sunnyvale, California 94089

CIRCLE NO. 19

RF TRANS

Over 50 off-the-shelf models...

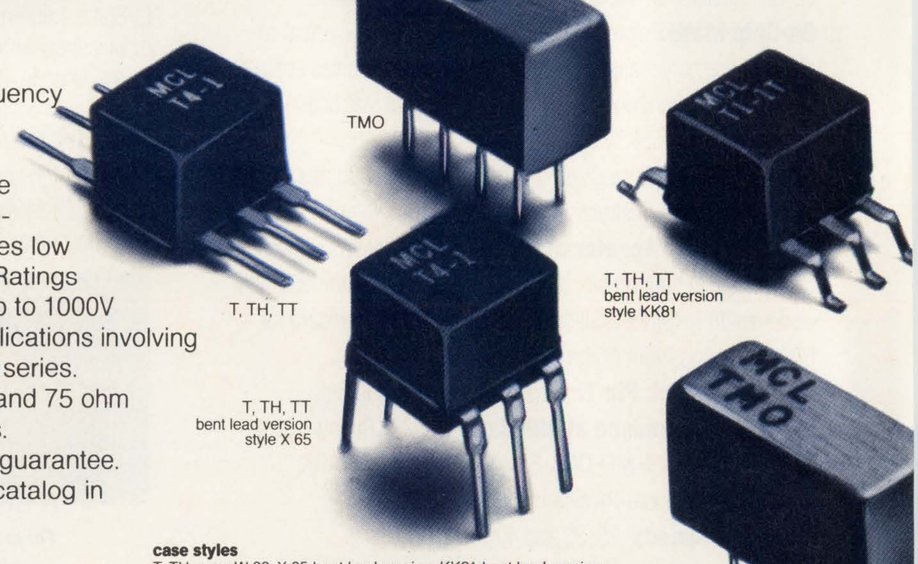


Having difficulty locating RF or pulse transformers with low droop, fast risetime or a particular impedance ratio over a specific frequency range?... Mini-Circuits offers a solution.

Choose impedance ratios from 1:1 to 36:1, connector or pin versions (plastic or metal case built to meet MIL-T-21038 and MIL-T-55831 requirements*). Ultra-wideband response achieves low droop and fast risetime for pulse applications. Ratings up to 1000M ohms insulation resistance and up to 1000V dielectric voltage. For wide dynamic range applications involving up to 100 mA DC primary current, use the T-H series. Coaxial connector models are offered with 50 and 75 ohm impedance; BNC standard; request other types. Available for immediate delivery with one-year guarantee.

Call or write for 68-page catalog or see our catalog in EEM, or Microwaves Product Data Directory.

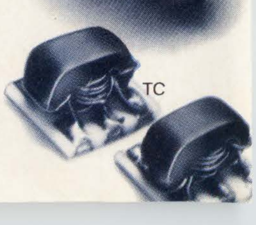
*units are not QPL listed



case styles
T, TH, case W 38, X 65 bent lead version, KK81 bent lead version
TMO, case A 11, † case B 13 FT, FTB, case H 16
NEW TC SURFACE MOUNT MODELS from 1MHz to 1500 MHz

NSN GUIDE

MCL NO.	NSN	MCL NO.	NSN
FTB1-1-75	5950-01-132-8034	TMO2-1	5950-01-183-6414
FTB1-6	5950-01-225-8773	TMO2.5-6	5950-01-215-4038
T1-1	5950-10-128-3745	TMO2.5-6T	5950-01-215-8697
T1-1T	5950-01-153-0668	TMO3-1T	5950-01-168-7512
T2-1	5950-01-106-1218	TMO4-1	5950-01-067-1012
T3-1T	5950-01-153-0298	TMO4-2	5950-01-091-3553
T4-1	5950-01-024-7626	TMO4-6	5950-01-132-8102
T9-1	5950-01-105-8153	TMO5-1T	5950-01-183-0779
T16-1	5950-01-094-7439	TMO9-1	5950-01-141-0174
TMO1-1	5950-01-178-2612	TMO16-1	5950-01-138-4593



finding new ways ...
setting higher standards

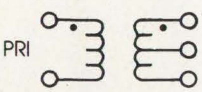
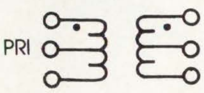
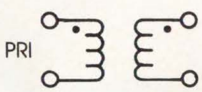
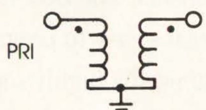
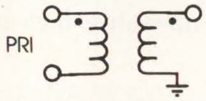
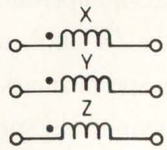
Mini-Circuits

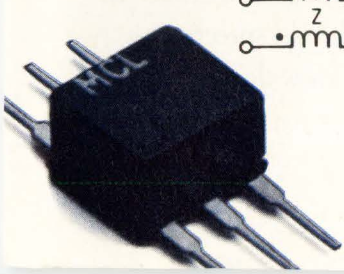
A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

C72-1 REV. B

FORMERS

3KHz-800MHz from $3^{25}

case style number see opposite page		MODEL NO.	Ω RATIO	FREQUENCY MHz	INSERTION LOSS 3dB MHz	2dB MHz	1dB MHz	PRICE $ Qty. (1-9)
A* 	T	T1-1T	1	.05-200	.05-200	.08-150	.2-80	4.45
		T1-6T	1	.003-300	.003-300	.01-150	.02-50	6.95
		T2-1T	2	.07-200	.07-200	.1-100	.5-50	4.95
		T2.5-6T	2.5	.01-100	.01-100	.02-50	.50-20	4.95
		T3-1T	3	.05-250	.05-200	.1-200	.5-70	4.95
		T4-1	4	.2-350	.2-350	.35-300	2-100	3.25
		T4-6T	4	.02-250	.02-250	.05-150	0.1-100	4.45
		T5-1T	5	.3-300	.3-300	.6-200	.5-100	4.95
		T8-1T	8	.03-140	.03-140	.10-90	1-60	7.95
		T13-1T	13	.3-120	.3-120	.7-80	5-20	4.95
		T16-6T	16	.03-75	.03-75	.06-30	.1-20	5.65
	TH	T4-1H	4	10-350	10-350	15-300	25-200	5.95
	TMO	TMO1-1T	1	05-200	.05-200	.08-150	.2-80	7.95
		TMO2-1T	2	.07-200	.07-200	.1-100	.5-50	8.45
		†TMO2.5-6T	2.5	.01-100	.01-100	.02-50	.05-20	8.45
		†TMO3-1T	3	.05-250	.05-250	.1-200	.5-70	7.95
		TMO4-1	4	.2-350	.2-350	.35-300	2-100	6.25
		TMO5-1T	5	.3-300	.3-300	.6-200	5-100	8.45
		TMO13-1T	13	.3-120	.3-120	.7-80	5-20	8.45
B* 	TT	TT1-6	1	.004-500	.004-500	.02-200	.1-50	6.95
		TT1.5-1	1.5	.075-500	.075-500	.2-100	1-50	5.95
		TT2.5-6	2.5	.01-50	.01-50	.025-25	.05-10	6.45
		TT4-1	3	.05-200	.2-50	.2-50	1-30	5.95
		TT4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	6.95
		TT25-1	25	.02-30	.02-30	.05-20	.1-10	9.95
	TTMO	TTMO25-1	25	.02-30	.02-30	.05-20	.1-10	11.95
		TTMO1-1	1	.005-100	.005-100	.01-75	.05-40	11.45
		TTMO4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	13.95
C 	T	T1-1	1	.15-400	.15-400	.35-200	2-50	3.25
		T1.18-3	1.18	0.01-250	0.01-250	0.02-200	0.03-50	5.65
		T1-6	1	.01-150	.01-150	.02-100	.05-50	5.65
		T1.5-1	1.5	.1-300	.1-300	.2-150	.5-80	4.45
		T1.5-6	1.5	.02-100	.02-100	.05-50	0.1-25	5.65
		T2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	4.45
		T4-6	4	.02-200	.02-200	.05-150	.1-100	4.45
		T9-1	9	.15-200	.15-200	.3-150	2-40	3.95
		T16-1	16	.3-120	.3-120	.7-80	5-20	4.45
		T36-1	36	.03-20	.03-20	.05-10	.1-5	6.95
	TO	TO-75	1	10-500	—	10-500	40-250	6.95
	TH	T1-1H	1	8-300	8-300	10-200	25-100	5.95
		T9-1H	9	2-90	2-90	3-75	6-50	6.45
		T16-H	16	7-85	7-85	10-65	15-40	6.45
	TMO	TMO1-02	1	1-800	1-800	2-500	—	9.45
		TMO1-1	1	.15-400	.15-400	.35-200	2-50	6.25
		TMO1.5-1	1.5	.1-300	.1-300	.2-150	.5-8	8.45
		†TMO2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	7.95
		†TMO4-6	4	.02-200	.02-200	.05-150	.1-100	7.95
		TMO6-1	6	.3-200	.3-200	.5-150	5-50	7.95
		TMO9-1	9	.15-200	.15-200	.3-150	2-40	7.95
		TMO16-1	16	.3-120	.3-120	.7-80	5-20	7.95
D 	T	T2-1	2	.050-600	.050-600	.1-400	.5-200	3.95
		T3-1	3	.5-800	.5-800	2-400	—	4.45
		T4-2	4	.2-600	.2-600	.5-500	2-250	3.95
		T8-1	8	.15-250	.15-250	.25-200	2-100	3.95
		T14-1	14	.2-150	.2-150	.5-100	2-50	4.95
	TMO	TMO2-1	2	.050-600	.050-600	.1-400	.5-200	7.95
		TMO3-1	3	.5-800	.5-800	2-400	—	8.45
		TMO4-2	4	.2-600	.2-600	.5-500	2-250	7.95
		TMO8-1	8	.15-250	.15-250	.25-200	2-100	7.95
		TMO14-1	14	.2-150	.2-150	.5-100	2-50	8.45
	FT	FT1.22-1	1.22	.005-100	.005-100	.01-50	.05-25	35.95
		FT1.5-1	1.5	.1-400	.1-400	5-200	1-100	35.95
E 	FTB	FTB-1	1	.2-500	.2-500	.5-300	1-100	36.95
		FTB1-6	1	.01-125	.01-125	.05-50	.1-25	36.95
		■FTB-1-75	1	.5-500	.5-500	5-300	10-100	36.95
F 	T	T-622	1	0.1-200	0.1-200	0.5-100	5-80	3.25
		T626	1	0.01-10	0.01-10	0.2-5	.04-2	3.95



■ Denotes 75 ohm models

* FOR A AND B CONFIGURATIONS

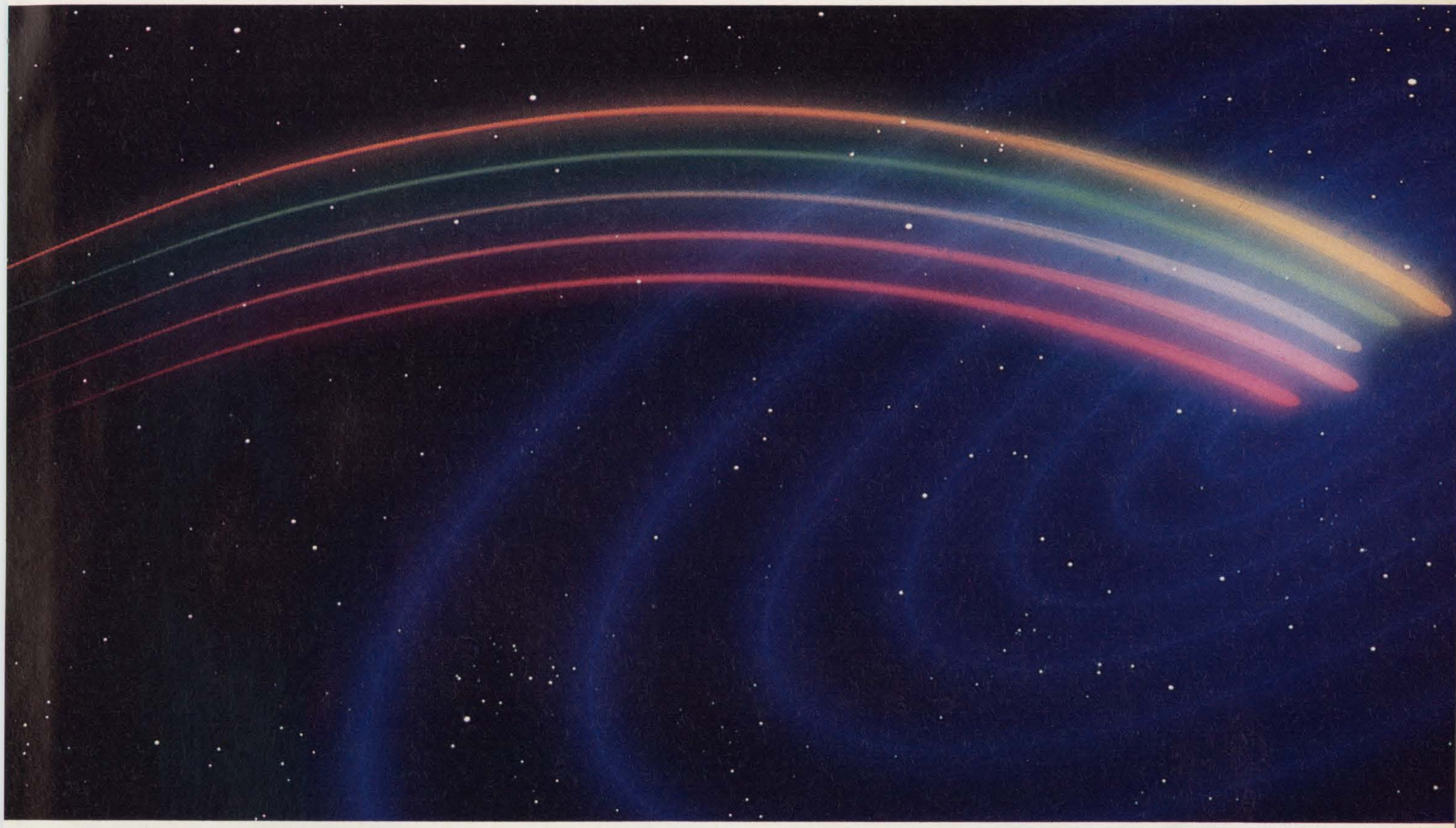
Maximum Amplitude Unbalance
0.1 dB over 1 dB frequency range
0.5 dB over entire frequency range

Maximum Phase Unbalance
1.0° over 1 dB frequency range
5.0° over entire frequency range

C72-2 REV. B

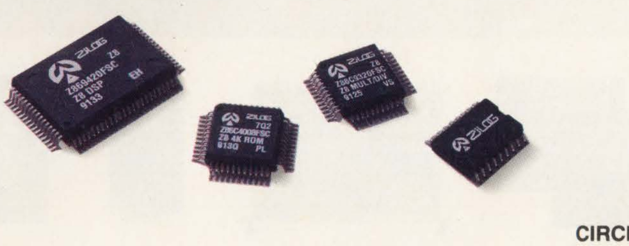
CIRCLE NO. 20

On Target.



ASSPs are clearly the best choice for a fast growing number of today's designs. At Zilog, we've been producing ASSPs and refining the technology longer and better than anyone. So we offer the largest library of familiar cores and cells in the industry and an easy, code-compatible migration path. Since we have our own fabrication facilities, we can maintain the high standards of quality and reliability for which Zilog has always been known. As we continue to develop new members of the Z8 family, you know they'll be right on target.

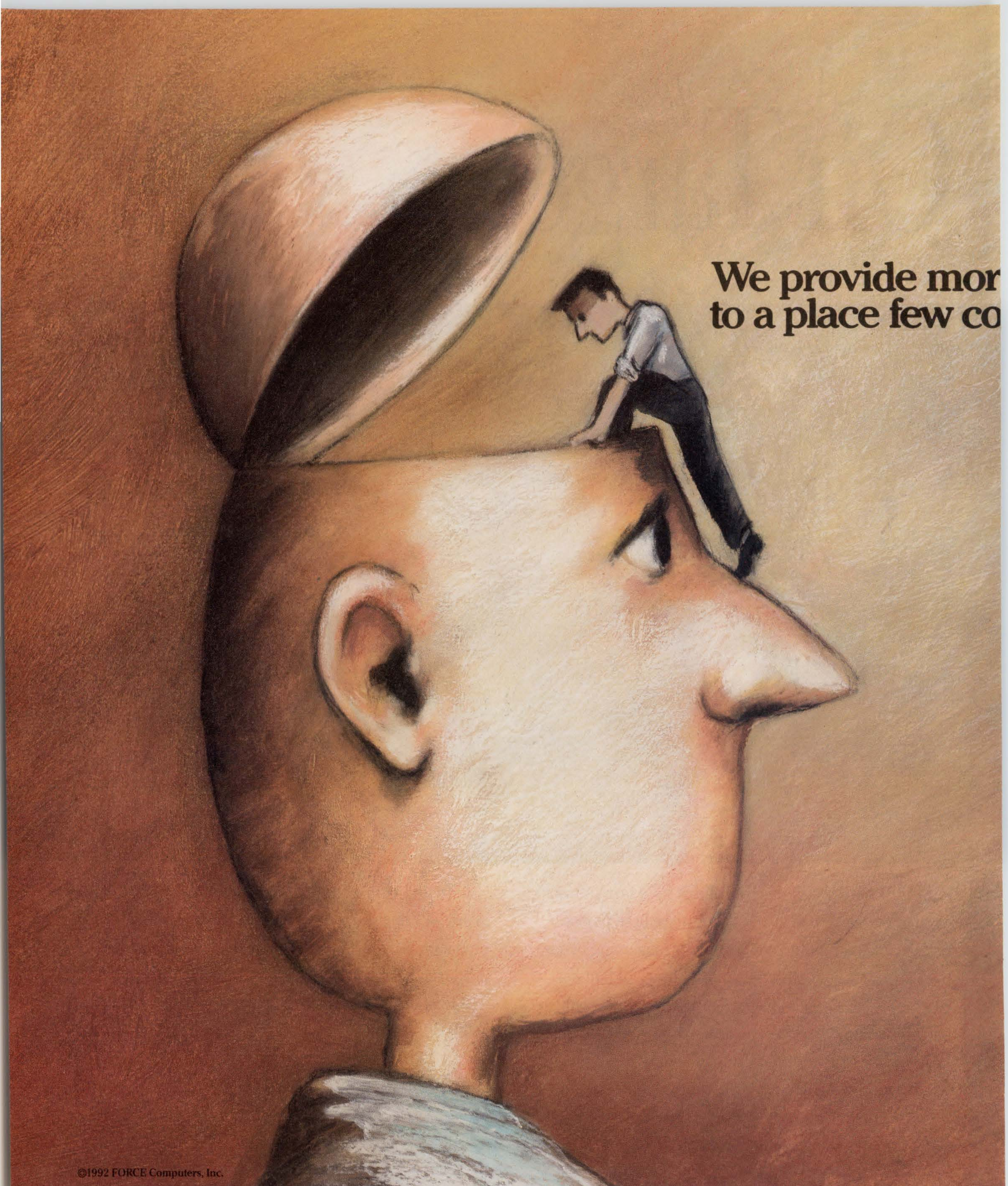
To find out more about the Z8 Microcontroller family, or any of Zilog's rapidly growing Superintegration product families, contact your local Zilog sales office or your authorized distributor today. Zilog, Inc., 210 East Hacienda Ave., Campbell, CA 95008-6600, (408) 370-8000.



ZILOG

Doing It Right

CIRCLE NO. 21


We provide mor
to a place few co

Criteria for manufacturable IC

Concerning Charles Small's editorial, "Make FPGA design easier" (EDN, October 10, 1991, pg 49), I'd like to add my perspective. I'm an engineer at a manufacturing plant where I'm the process owner for IC programming.

FPGA manufacturers, in addition to lacking the vision that they are in the IC manufacturing business, not the software business, haven't even made their devices fully manufacturable. Instead of using the JEDEC format for programming files, some use binary or POF formats. (For those who use Data I/O equipment, these formats correspond to Translation Formats 10 and 14, respectively.) These formats wreaked havoc with my programming system because of their non-ASCII nature. FPGA manufacturers also seem to prefer that I use their development systems rather than my industry-standard equipment to do my production programming.

A fully programmable IC must meet these criteria:

1. The programming file must be ASCII readable. Not only does this allow easy, reliable transmission from my design group in New Jersey, but it also allows me to write software to check its integrity.

2. All manufacturing functions must be supported by industry-standard, production-grade equipment. These include, but may not be limited to

- Reading a master device into the programmer's RAM.
- Uploading the programmer's RAM to a host computer.
- Verifying the device from RAM. This presupposes that test vectors can be generated and added to the (ASCII) programming file.
- IC handling machines connected to the programmer can be used. (The interface I have between programmer and handler doesn't support certain FPGAs.)
- Gang programming should be supported for those limited to manual operations.
- Downloading of programming files from a host computer into the programmer's RAM.
- Blank-device check.

I'm currently stuck programming FPGAs one at a time, taking 5 or 10 minutes for each.

Not only have FPGA vendors locked up the design of these wondrous devices, but they have also locked up the mass programming, too. These vendors would stand to gain a fortune if these two areas were freed up so that their devices could be put into widespread use.

Bill Fox
AT&T, Network Systems
The Columbus Works
Columbus, OH

Need of harmonizing European partners in trade

I've just read the article, "The economic challenge of a united Europe" by Jay Fraser, on the consequences of the Single European Market (EDN, November 7, 1991, pg 355), and I felt compelled to put pen to paper. Then I remembered that, despite living in "low-tech" Europe, I do have access to word-processing and fax facilities so I threw away the quill pen and shot the carrier pigeon—this is the result.

Europe is not quite as weak on high-tech as the article implies. We may not have put a man on the moon, but we are more than capable of producing high-tech products. A major problem facing Europe as a single market is the harmonization of standards that have followed separate evolutionary paths for hundreds of years.

[The differences] obviously cannot change overnight, if at all. Neither will I be running out to change all the main sockets in my house so I can buy a CD player in Dusseldorf. What Europe means is that there will be no difference between the cost of that CD player and the one on sale down the road due to some artificial tariff.

Eventually, when our politicians finish their posturings about national identities and other primitive tribalism, we may end up with a single currency. Perhaps it should be called the "Youess dollar," which would make it difficult for those who gamble on foreign exchanges at the expense of real wealth creation—but that's another issue!

Peter J Osborn
Product Manager
Newport Components Ltd
Blakelands North
Milton Keynes, UK

Changed phone number

The phone number listed for inquiries about Intel's iRMX for Windows in EDN's November 21, 1991, issue (pg 47) should be changed to (800) 438-4769.

Calling all pizzas

If you want information about Motorola's MC-145191 frequency synthesizer, don't call the number we listed on pg 118 in the February 3 issue—you'll get information about Domino's pizza instead. Try the correct number: (800) 521-6274.

HAVE YOUR SAY

EDN's Signals & Noise column provides a forum for readers to express their opinions on issues raised in the magazine's articles or on any topic that affects the engineering industry. Send your letters to Signals & Noise Editor, EDN Magazine, 275 Washington St, Newton, MA 02158. You can also send a note via MCI mail at EDNBOS or use EDN's bulletin-board system at (617) 558-4241: From the Main System Menu, enter SS/SOAPBOX, then W to write us a letter. You'll need a 2400-bps (or less) modem and a communications program set for 8,N,1.

ULTRA•REL™

*** ULTRA•REL™ MIXERS 5 yr. Guarantee**
with extra long life due to unique HP monolithic diode construction, 300°C high temp. storage, 1000 cycles thermal shock, vibration, acceleration, and mechanical shock exceeding MIL requirements.

the world's largest selection
500Hz to 5GHz from $2.49

Over 200 off-the-shelf models, from low-cost rugged industrial to Hi-Rel military/space approved types, with LO power level requirements from -4dBm to +27dBm. We offer this wide variety of models, up to 5GHz, to allow you to select exactly what you need...
pin, surface-mount, TO-8, flatpack, and connector package types, the specific frequency range your design involves, the optimum LO drive level, and a host of special types.
And, exclusively from Mini-Circuits, ULTRA-REL™ mixers with a five-year guarantee and specification limits held to 4.5 sigma for unprecedented unit-to-unit repeatability.

Choose mixers with low LO drive, low noise, load insensitive, quadrature mixer/modulators, plus a large number of MIL-mixer types tested to MIL-M-28837/A, and TX screened.

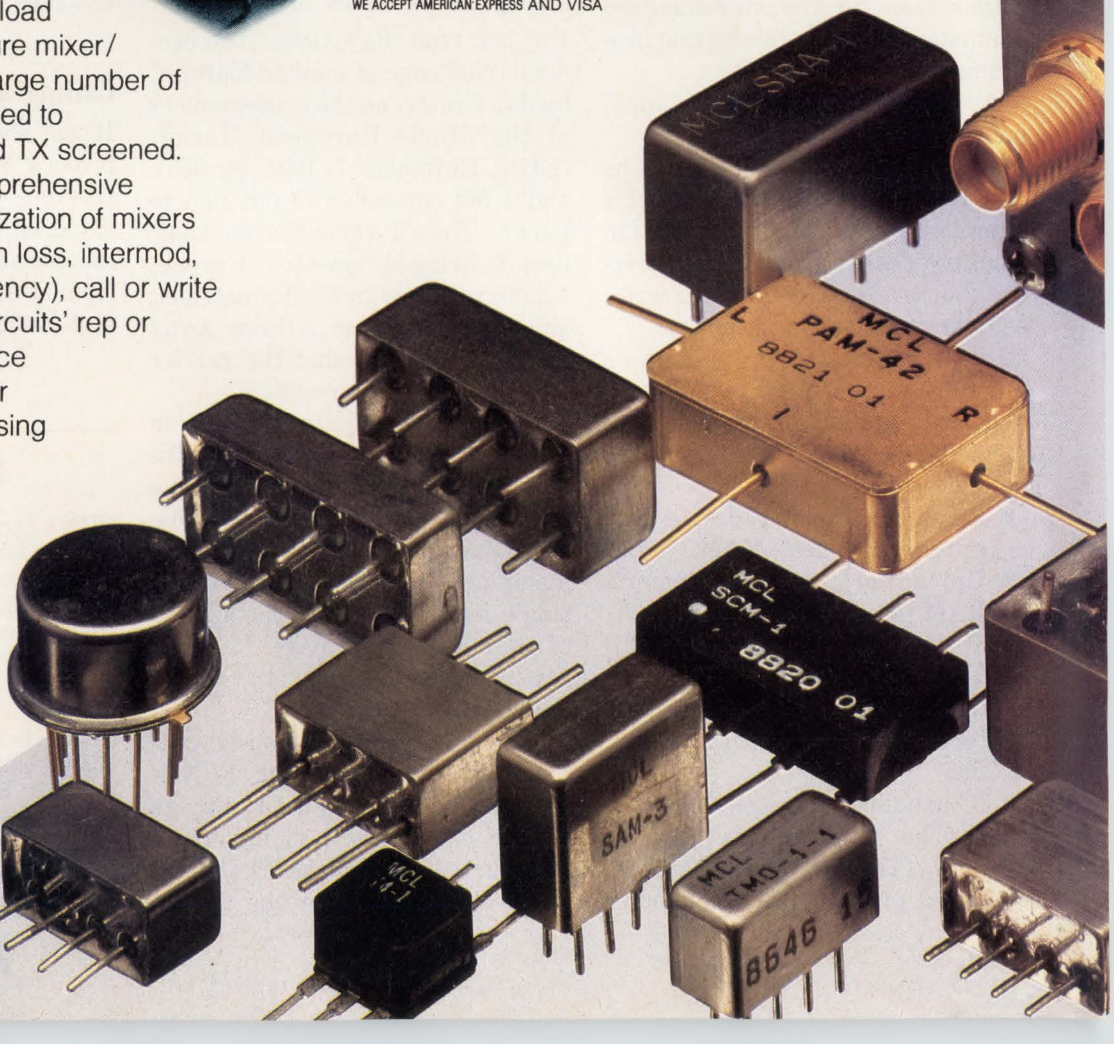
For the most comprehensive computer characterization of mixers (isolation, conversion loss, intermod, and VSWR vs frequency), call or write your closest Mini-Circuits' rep or distributor or our office for a free copy of our RF-IF Signal Processing Handbook, Vol. 1/2.

CIRCLE NO. 24

finding new ways...
setting higher standards

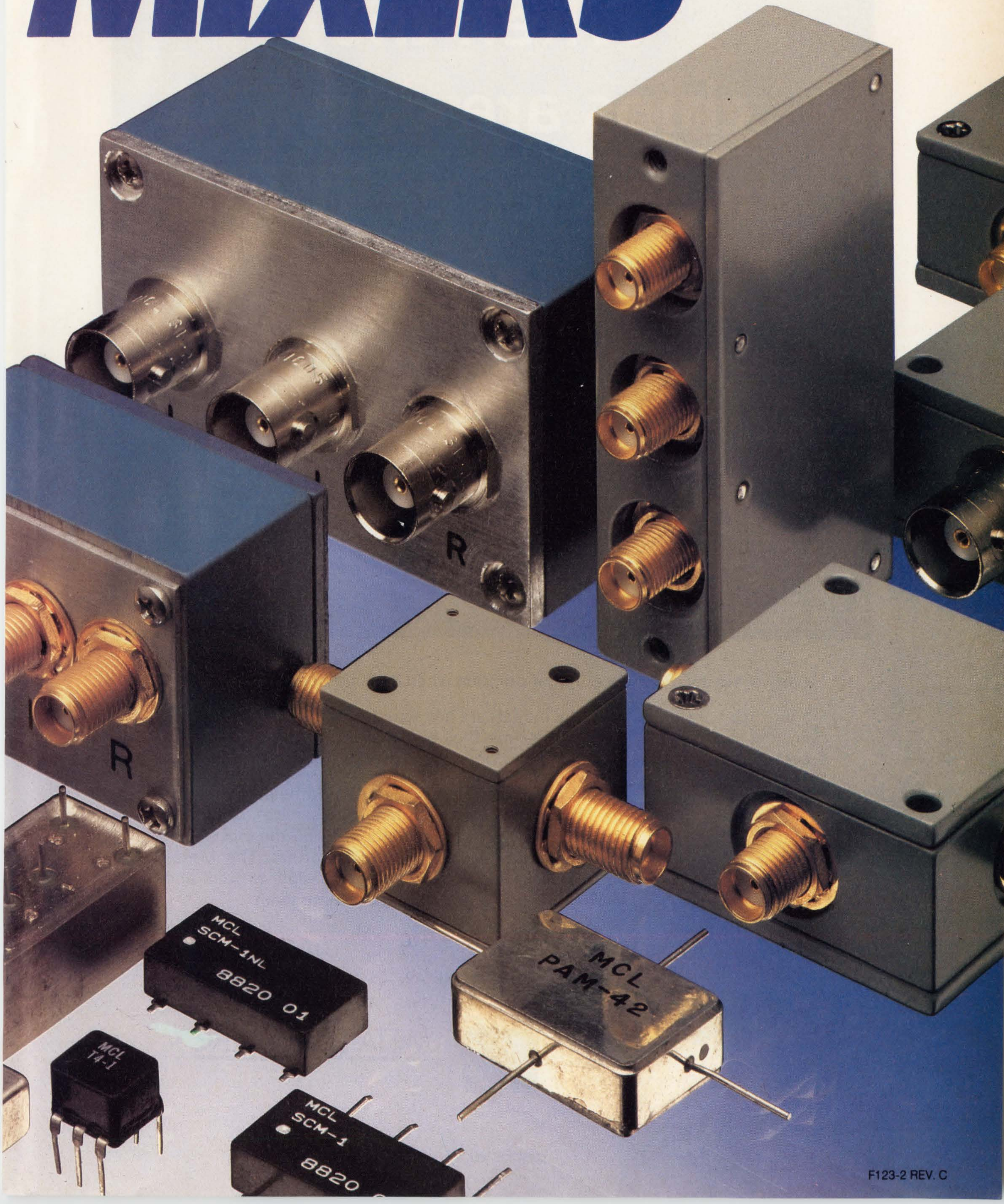
Mini-Circuits

A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156
WE ACCEPT AMERICAN EXPRESS AND VISA

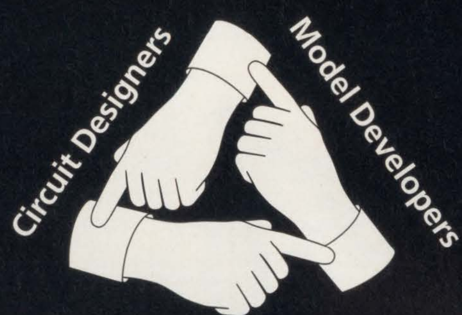


F123-1 REV. C

MIXERS



When the chips are down, the finger pointing starts.



Process Engineers

Every company experiences finger pointing when a design doesn't work.

Your circuit designers claim the models are not accurate. The model developers claim the process shifted since the time they began work on the models. The process engineers claim the model developers aren't tracking the process.

Meta eliminates finger pointing and helps you get it *right first time*™. Meta-Labs modeling services, combined with the HSPICE circuit simulator, provide the crucial link between your fab and circuit designers. The Meta-Software methodology helps your design, process and modeling groups work together as one team.

Get back in the chips with Meta-Software. For a *right first time* information package, call toll free (800) 442-3200, ext. A2.

META-SOFTWARE

right first time™

CIRCLE NO. 25

EDITED BY JULIE ANNE SCHOFIELD

Getting small quantities is tough all over

After printing Peter Gottlieb's letter about the difficulties he experiences getting small quantities of state-of-the-art parts for making prototypes, Ask EDN has received dozens of replies. All of the replies reinforced Mr Gottlieb's complaint. Here's a sampling of the letters:

Industry ignores the independent engineer

I believe Peter Gottlieb has understated the problem. I am an electrical engineer running my own business with two part-time engineers and one part-time secretary. I work on the design and prototyping of computer/microcontroller-based process controllers and custom computer bus interfaces. I generally do three or four complete designs a year. Not only do I have a difficult time obtaining small quantities of parts, but I have difficulty getting manufacturers' data books or even return phone calls from distributors of manufacturers' sales offices. I have even been turned down as a qualified subscriber to EDN. It is nearly impossible to be an independent engineer and stay afloat with the industry ignoring me.
Joe Heck
Owner
Joe Heck Enterprises
Wrentham, MA

Lack of custom parts for repair results in landfill

The letter from Mr Gottlieb hit a nerve with me. At least he has the option of ordering "production quantities" of some items—in my case, five may be a year's supply. If I had to order 1000, I'd have to find a way to resell them.

A related problem: Our company is primarily in the repair business, although we do build one-offs and short runs. Question: What happens when some of these wonderful new designs made with gate arrays, PLDs, and other such custom parts go wrong? (Notice I said "when," not "if.") Chances are the manufacturer won't have any of the gate arrays left, and of course the design will be proprietary, so telling anyone else about it is out of the question. Result: landfill. And that's regardless of whether the product is otherwise any good or not. In a way, this is a "green" issue. What happens when all this wonderful stuff starts being tossed out because one flip-flop in a 3000-gate array went out, rendering half a ton of equipment useless?
Ric Locke
E Coyote Enterprises Inc
Mineral Wells, TX

Seed small companies with state-of-the-art parts

In reference to the problem expressed by Peter Gottlieb in the December 5, 1991, issue of EDN, I too have experienced continuing frustration with the difficulty of obtaining small numbers of state-of-the-art components for constructing prototypes.

Manufacturers of ICs and other components fail to realize the importance of seeding small corporations with components that they can use to design new products. Like Mr Gottlieb, I too would be all too happy to pay full price for the privilege of getting a small quantity of state-of-the-art components. This would be preferable to jumping through manufacturers' hoops trying to get "freebie" samples.

Please listen, you big IC guys. Sell some of your best stuff to distributors like Allied Electronics or Newark Electronics, charge full price, and let us buy a few to make prototypes. You'll be doubly rewarded. Not only will you get paid for your samples, but some of those samples will turn into products that result in big orders. The most innovative companies are the small ones; that's where the least amount of seed will yield the most product.
Mark Wilson, MD
President
Enkef Instruments Inc
Boulder, CO

Turn problem into business opportunity

Regarding Peter Gottlieb's complaint in the December 5, 1991, issue: If it's not too late, I'd like to add my name to the amen column. Not only is finding prototype quantities of parts time consuming for a lot of people—with the commensurate lack of productivity—you sometimes settle for a little less than your best in a design just to get it moving. The problem is serious enough that I don't know why someone hasn't turned it into a business opportunity, something like a specialized Digi-Key, if you will. There should be a way to have some kind of shared service.
Jim Pierce
JN Designs Inc
Kansas City, MO

Try Dallas Semiconductor

Amen to Peter Gottlieb's observations about obtaining prototype quantities of electronic parts. Yes, Mr Gottlieb's experiences are typical.

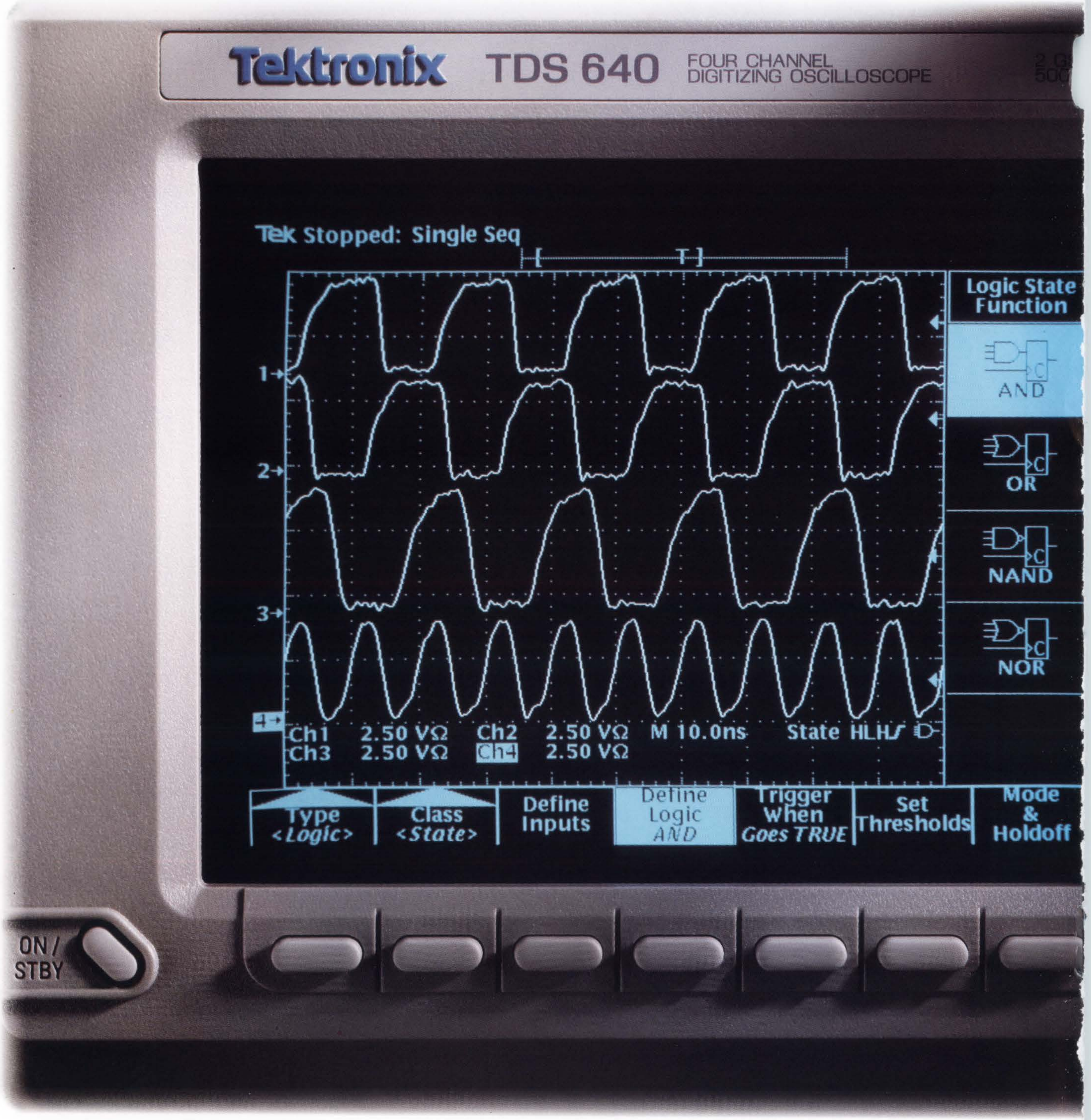
Dallas Semiconductor (Dallas, TX) has a simple method of making very small volumes of their products readily available: You call (800) 336-6933 and use a personal or corporate credit-card number, just as if you were ordering from a consumer catalog. If the company has stock, you will get what you want with little fuss or bother.

Too bad most companies don't do this.
Walt Henry
Fort Worth, TX

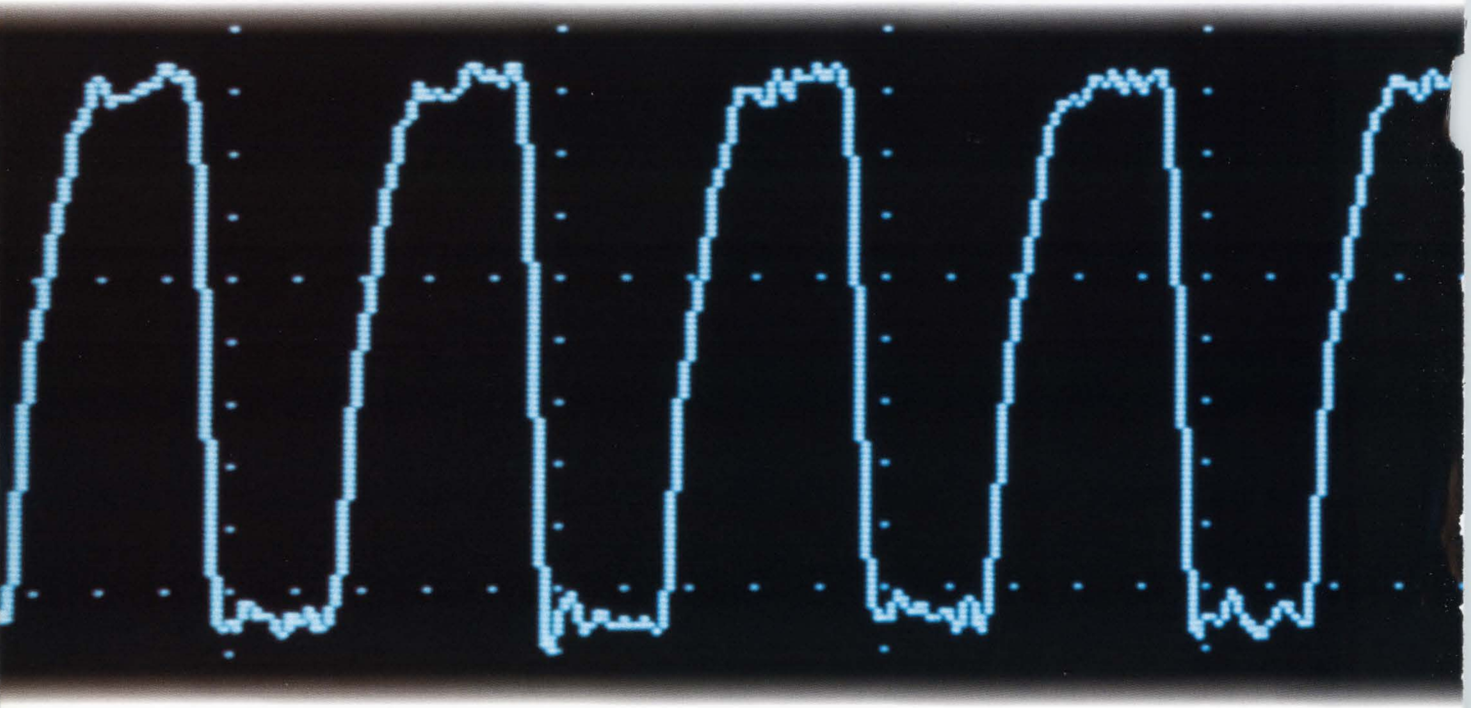
Ask EDN solves nagging design problems and answers difficult questions. Address your letters to Ask EDN, 275 Washington St, Newton, MA 02158. FAX (617) 558-4470; MCI: EDNBOS. Or send us a letter on EDN's bulletin-board system at (617) 558-4241: From the Main System Menu, enter SS/ASK_EDN and select W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

There's One Sure Way To Make The Power Of Digitizing Oscilloscopes More Accessible.

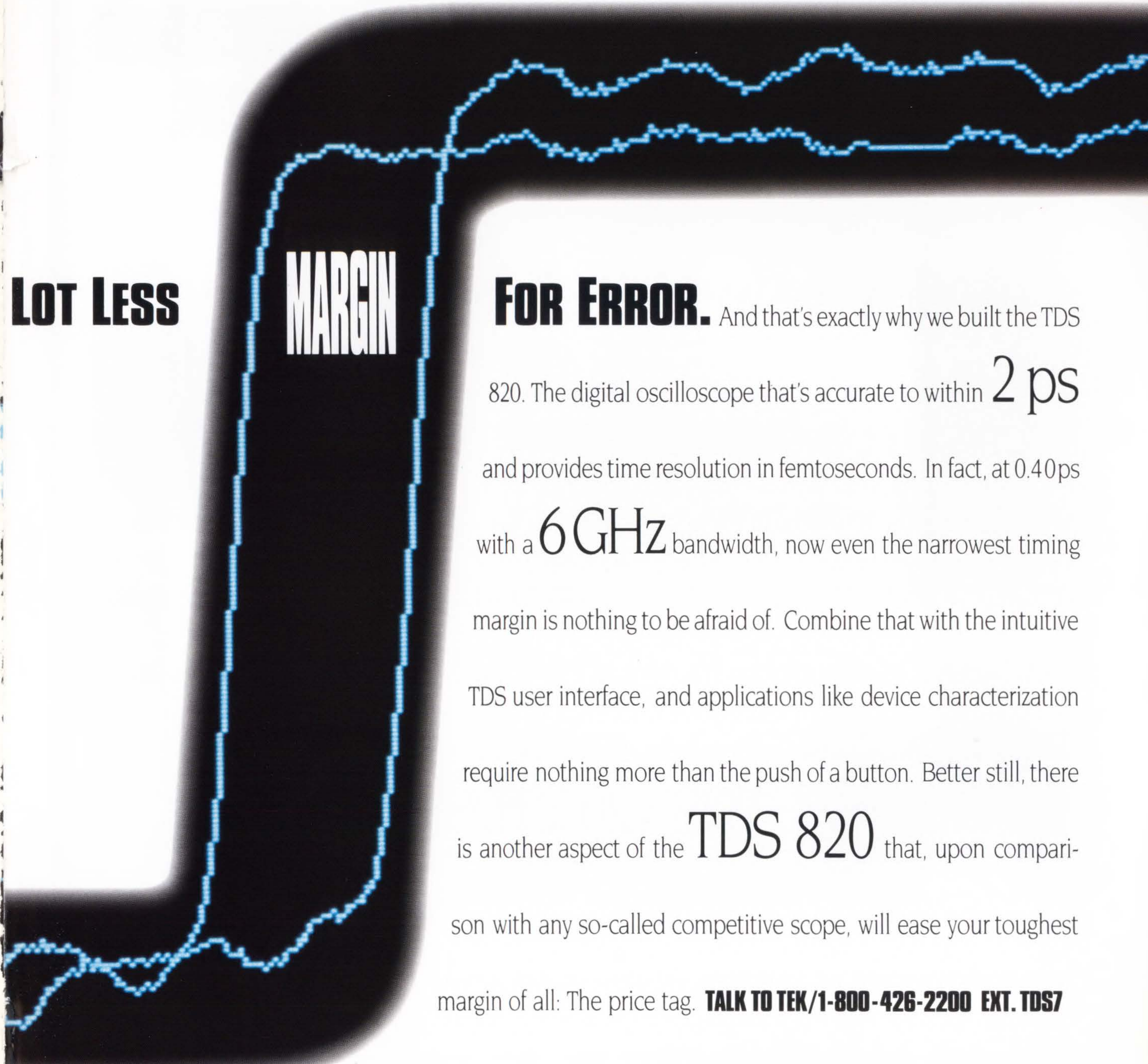
GET IN OUR

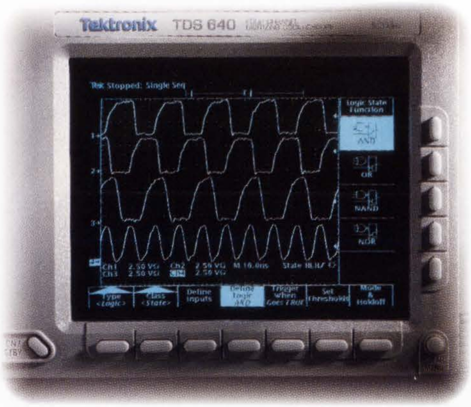

Tektronix TDS 640 FOUR CHANNEL DIGITIZING OSCILLOSCOPE
Tek Stopped: Single Seq
Logic State Function
AND
OR
NAND
NOR
Ch1 2.50 VΩ Ch2 2.50 VΩ M 10.0ns State HLHL
Ch3 2.50 VΩ Ch4 2.50 VΩ
Type <Logic>
Class <State>
Define Inputs
Define Logic AND
Trigger When Goes TRUE
Set Thresholds
Mode & Holdoff
ON/STBY

Go Ahead. Pull The Trigger On



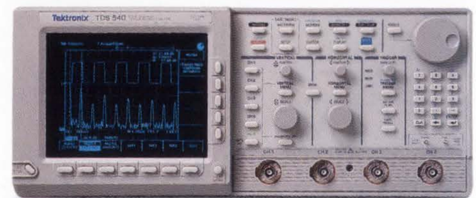
FACE IT. WITH TODAY'S FASTER SYSTEMS, YOU'VE GOT A



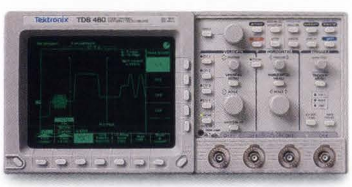


BESIDES EASE OF USE, WE ALSO CONSIDERED SUITABLE FRAMING.

At Tektronix, we designed our TDS Series user interface to be the picture of simplicity. Then, because everybody's needs are different, we framed it seven different ways. For instance, besides the TDS 620, 640 and 820, we also build the TDS 420, 460, 520 and 540.



On the 2 channel TDS 520 and 4 channel 540, you get 500 MHz bandwidth and up to 50k record lengths. A single-channel sampling rate of 1 GS/sec on the TDS 540 and 500 MS/sec on the 520—combined with edge, pattern, state, glitch, runt & pulse width triggering—greatly simplifies debugging and fault isolation. What's more, both feature built-in FFT analysis. Or, for a more economical solution, take a look at the TDS 420 and TDS 460. First off, they provide up to 350 MHz across 4 channels, at a cost usually found on 2 channel scopes. They provide video triggering, a 30,000 record length, and a sampling rate of 100 MS/sec. And both feature 5 different acquisition modes: sample, peak detect, high-resolution, envelope, and average. All of which you'll find amazingly accessible thanks to the ingenious TDS user interface. The TDS Series of digital oscilloscopes from Tektronix. For more information, don't hesitate. Get in our face. **TALK TO TEK/1-800-426-2200 EXT. TDS7**



Tektronix
Test and Measurement

CIRCLE NO. 35

Get real

My son Chris has a problem with most of the auto manufacturers that feature futuristic vehicles at the auto shows. He thinks that unless car manufacturers are really going to offer those cars for sale, they shouldn't show them. I've explained that the futuristic cars at the shows are only testbeds for new technologies and are proof-of-concept vehicles. In fact, many of the tested technologies and designs never make it to market. Either they turn out to be too expensive, no one wants them, or they just don't work. Chris makes a good point, though: Why whet the consumers' appetites when you don't expect to offer the product? I imagine there are others who feel the same way.

Unfortunately, the electronics industry does much the same thing. Companies often announce or demonstrate products that won't reach the market for a year or more—if ever. For example, some people in our industry take the International Solid State Circuits Conference (ISSCC) as a watershed event at which people announce new products. It isn't. The ISSCC gathering is worth attending if you're a chip designer. You'll hear what other companies are doing, and you'll have an opportunity to talk about your own development work. However, don't depend on the meeting's papers as plans for new-product introductions.

We found only a few developments at this year's ISSCC that were set for use in new products within the next quarter. Many of the developments are like the jazzy cars at the auto show. They're one-off models built to test concepts and processes. Testing new ideas is important, as is sharing ideas, and for IC designers, the ISSCC is a good forum. However, there's a big gap in time and cost between talking about ideas and demonstrating test devices, and actually delivering useful products. Some developments never make it out of the lab.

When new processes and technologies begin to show up in real products, we'll let you know. Sure, there will be times when you need to know about complex new products before they become available, but overall, readers tell us that when a product is more than six months from being available for purchase, hold off on telling them about it. After all, what's the use of knowing about a "product" that doesn't exist when you need a real product or design to solve a real problem?

Jon Titus

Jon Titus
Editor

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

American Society of
Business Press Editors Award
1991, 1990, 1988, 1983, 1981

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; on 9600-bps modems try (617) 558-4580, 4582, or 4398.

Now you can and not get

Introducing new RISC System/6000 POWERstation[s]

If you're interested in open systems but don't want to suffer the slings and arrows of outrageous prices, IBM is about to hit you where you live. The RISC System/6000™ POWERstation 220 gives you more wallop for your money, while delivering a hefty 25.9 SPECmarks.™ That's compared to the SUN IPC's™ 13.4 SPECmarks and the DEC5000's™ 17.8.

Model	Entry Grayscale Workstation**	Entry 8-bit Color Workstation†
IBM 220W	$7,185	$9,995
HP 705/710	$8,415	$14,065

Scientists see stars. CASE users can start with a grayscale workstation with a paging disk for just $7,185. If it's CAD clout you're after, you can get a workstation specially outfitted for mechanical design—with 2D color graphics and 400MB of fixed disk storage—for only $9,995. All models in the POWERstation 220 series come with two expansion

*In Canada, call 1 800 465-1234. **16MB, Paging Disk, Display, Operating System, Graphical User Interface. †16MB, 400MB Disk, Display, Operating System, Graphical User Interface.

get more clout, clobbered.

and POWERservers that pack more punch for less.

slots and upgradable components. And industry-standard memory upgrades and add-ons for both are affordable, so growing won't be a pain.

Striking a blow for business. The POWERserver 220 is great for commercial UNIX® solutions, too. You can configure it as a commercial server, to give your business the speed, muscle and openness of UNIX, for only $9,715. And the POWERserver 220 is as expandable as all our other models.

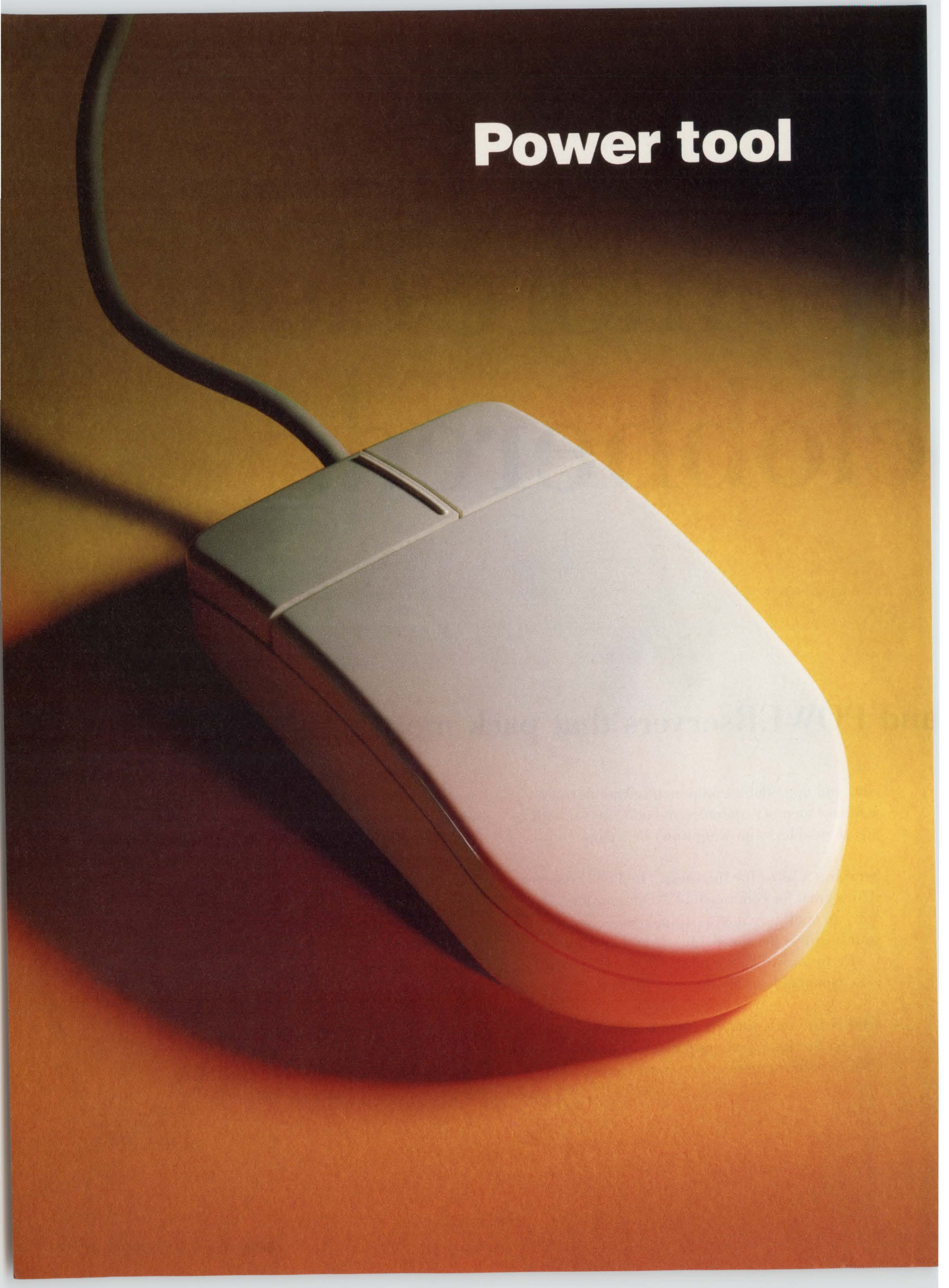
IBM is in your corner. Nobody else delivers the knockout support of IBM. An IBM customer engineer can install your machines, configure your network and integrate all your systems, whether they're made by IBM or not. And IBM Credit Corporation has flexible financing packages to meet your needs. Get hit with the details. Call your IBM marketing representative or Business Partner. For literature, call 1 800 IBM-6676, ext. 769.*

And, for those who decide to shop for UNIX solutions elsewhere, a word of advice. Duck.

The RISC System/6000
For the Power Seeker.

IBM®

CIRCLE NO. 27


Power tool

KEPCO 360~1080 WATT MAT POWER SUPPLIES ARE PROGRAMMABLE WITH YOUR MOUSE.

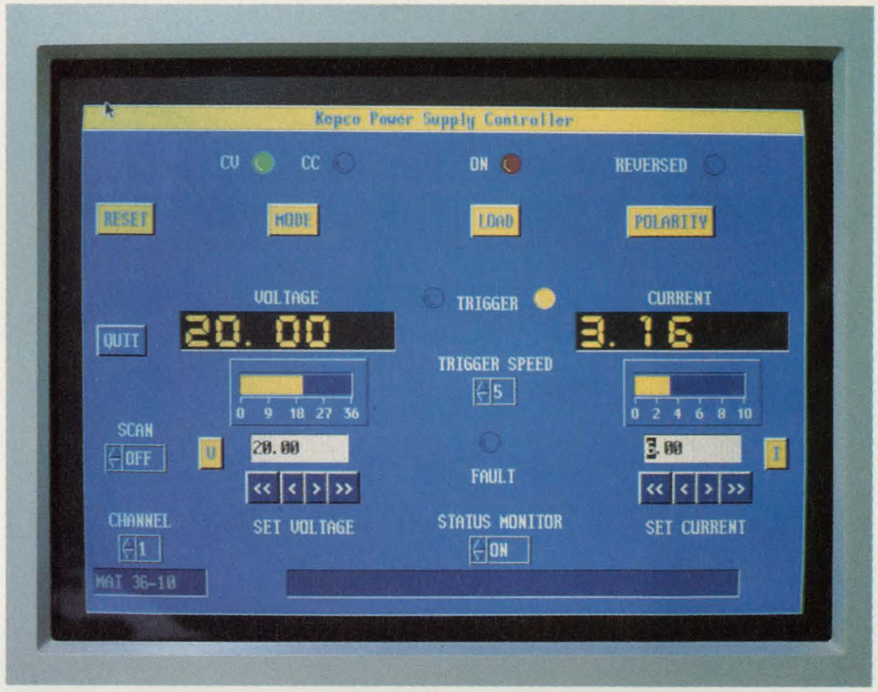
Other power supplies have knobs or keypads. Kepco's "MAT" lets you use your mouse...
POINT..CLICK..SET

Kepco's MAT power supplies implement LabWindows.(1) The interactive screen lets you use your mouse to set voltage and current and even open and close load and polarity relays. Kepco's MAT power supplies report back their actual voltage, current and status.

Use the IEEE-488 bus or communicate directly between your PC and power supply over a 2-wire telephone-like serial bus.

With Kepco's LabWindows driver, your mouse becomes a REAL power tool able to control thousands of watts with a single click.

(1) LabWindows © National Instruments



Three 360W Power Modules shown in RA 50 Housing

LabWindows runs on 386 DOS-based computers with a VGA display and, of course, a mouse. We have drivers for all of the **SN** digital interfaces, type **MAT** power supplies and the low-voltage **BOP** series bipolar power supplies. The PC can drive the power supplies via the IEEE-488 bus using Kepco's model **TMA 488-27** interface to fan out from one GPIB address to as many as 27 power supplies, or the PC can drive the power supplies directly via an internal half-card called **TMA PC-27.** The **BOP** require the plug-in interface card, **BIT TMA-27.**

Instrumentation and Bench | a-c power and d-c bipolar | Switching a-c to d-c and d-c to d-c

146-1785 146-1704 146-1760

Call/fax/write to Dept. MRM-12 for any of our three catalogs.

MasterCard VISA

SEE US AT ELECTRO/92, KEPCO BOOTH 4503, 4505

SEE OUR PAGES IN VOLUME D eem

Kepco, Inc., 131-38 Sanford Avenue, Flushing, NY 11352 USA • Tel: (718) 461-7000 • Fax: (718) 767-1102 • Easylink (TWX): 710-582-2631
Eastern Region: 131-38 Sanford Avenue, Flushing, NY 11352 USA • Tel: (718) 461-7000 • Fax: (718) 767-1102 • Easylink (TWX): 710-582-2631
Western Region: 800 West Airport Freeway, Suite 320 LB 6018, Irving, TX 75062 USA • Tel: (214) 579-7746 • Fax: (214) 579-4608
Kepco Europe, Ltd., London, England: Salamander Quay West, Park Lane, Harefield, Middlesex UB9 6NZ • Tel: +44 895 825046 • Fax: +44 895 825045

KEPCO. THE POWER SUPPLIER™ SINCE 1946

CIRCLE NO. 28

"We need you to design, compile, link, load, configure, prototype, debug

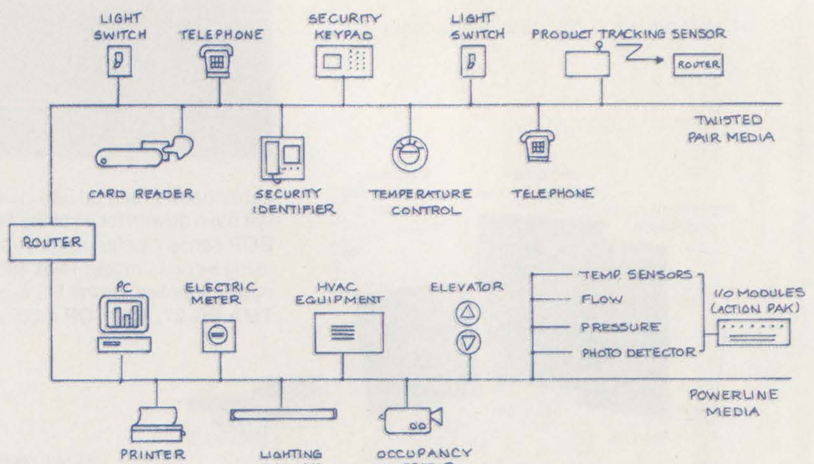
Relax. With a LONBUILDER 2 Developer's Workbench, you can do all that and more in record time.

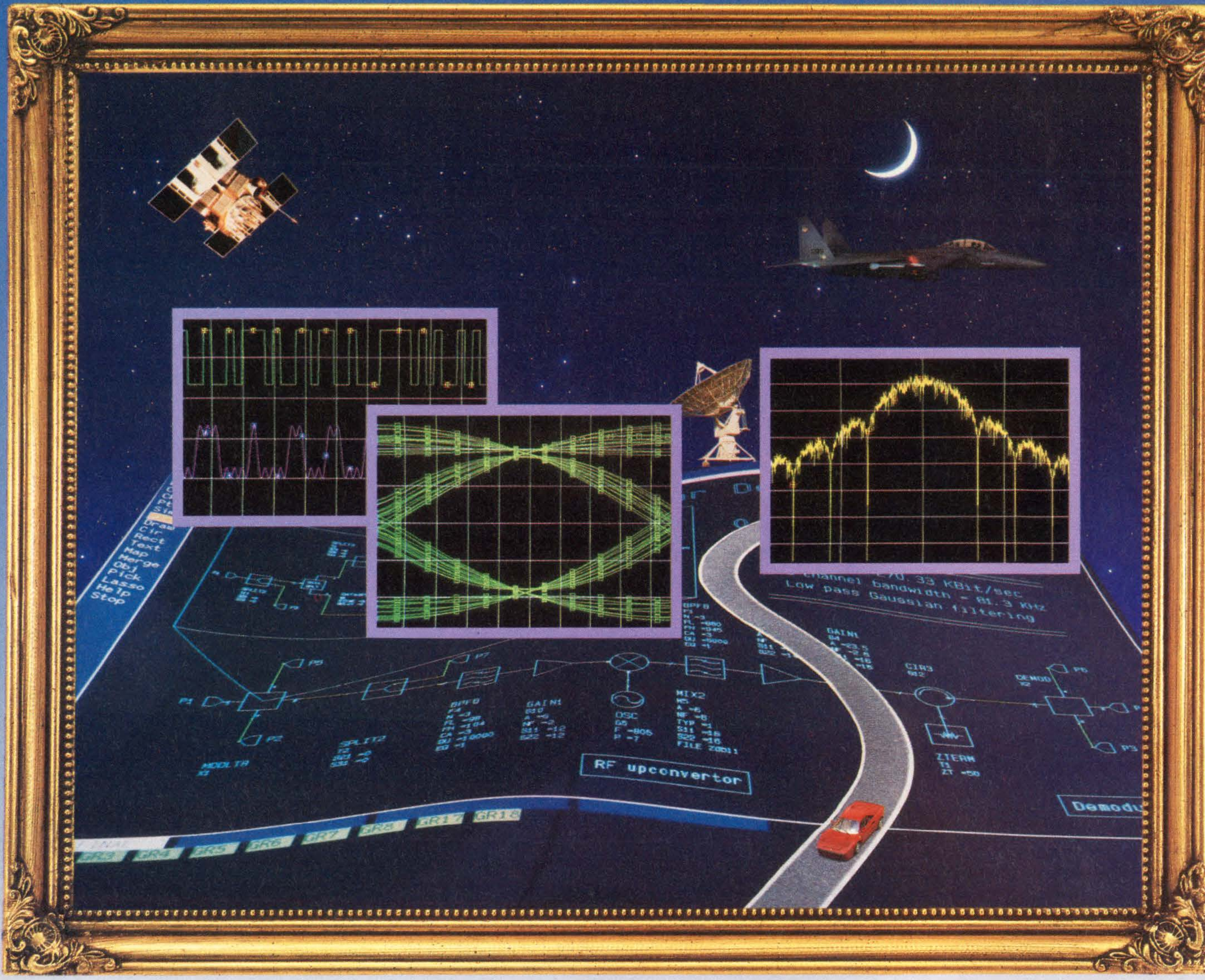
As competition becomes more intense, pressure to quickly develop new and better products increases. We can help.

With LONWORKS™ control networks for intelligent distributed control applications, and the LONBUILDER™ 2 Developer's Workbench.

LONWORKS control networks make your products "smarter," able to interoperate with and control other products. Each control network is made up of a series of "nodes" that communicate with each other. At the heart of each node is a NEURON® CHIP, available from Motorola. Nodes also contain a media interface that uses the standard LONTALK™ protocol to communicate with other nodes over a wide range of standard communication media.

And to design those LONWORKS nodes into your products quickly and inexpensively,





Modulation-Domain Simulation Gives You the Big Picture.

Introducing OmniSys Version 3.5.

Analyzing communication systems and complex modulated signals with the usual simulators? *Time-* and *frequency-*domain simulators like SPICE and harmonic balance are great, but circuit simulators don't give you the big picture. OmniSys®, EEsof's system simulator, gives you the new insight you need!

OmniSys lets you simulate system performance in the *modulation-domain* so you can see how your system will work with today's chirp, MSK, pi/4 DQPSK, and other complex modulated signals. Look at BER I-Q constellations, spectral regrowth, AM/PM distortion, and more. You'll see the effect of hardware trade-offs on your complete transmitter and receiver and you'll get your system to market faster without costly redesigns.

See the Big Picture with OmniSys.

Contact us for literature at (800) 34-EESOF...or, if you prefer, by FAX at (818) 879-6462.
In Europe, call (49) 8105-24005 or FAX (49) 8105-24000.

Breaking the Barriers...

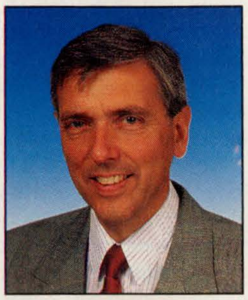
EEsof®

CIRCLE NO. 30

MICROPOWER VOLTAGE REFERENCES

Microamps sustain stable sources

BRIAN KERRIDGE, Technical Editor



Micropower bandgap references provide an attractive alternative to power-hungry zener diodes. But selection, handling, and application of these components remain decisive issues in setting overall performance.

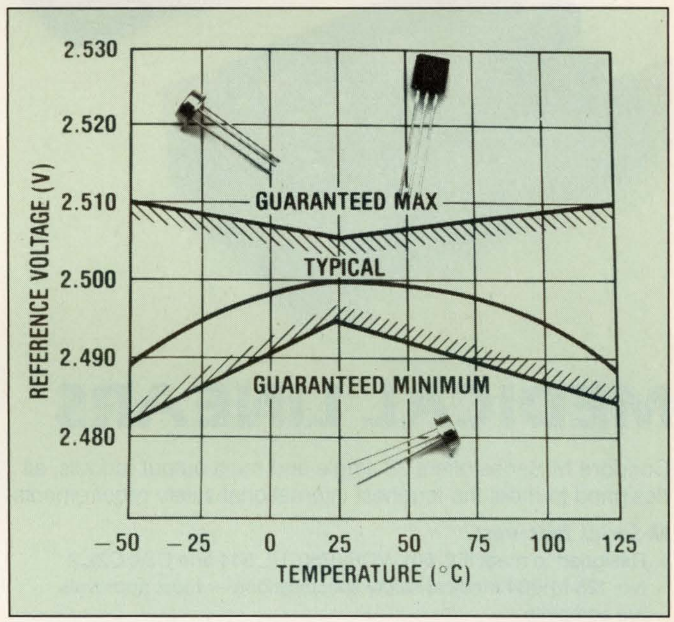
Achieving a stable voltage is possible using a micropower reference component that consumes as little as 10-μA operating current. With other key specifications, like voltage TC (temperature coefficient) of 20 ppm/°C, slope-resistance of <1Ω, and a one-dollar price tag, suddenly a 7.5-mA reference zener looks like a luxury that power-conscious designers can no longer afford.

All semiconductor references rely upon either zener diode or bandgap operation for generating a stable output voltage. All micropower examples use the bandgap reference principle, which is explained in more detail in the **box** "Generating a bandgap voltage reference."

A great attraction of bandgap devices is that the primary reference level is inherently a minimum of approximately 1.2V. (Zeners with comparable performance to bandgap devices don't exist for levels much below 6V.) In addition, vendors offer bandgap references with output levels of 2.5, 4.1, 5, and 10V, or with the facility to trim output externally to any point within this range.

By far the greatest appeal of bandgap devices is the ability to function with operating currents from milli- down to microamps. **Table 1** overviews the specifications of bandgap devices that have minimum operating currents below 100 μA, and therefore includes examples that truly qualify as micropower.

The major application for micropower references is to provide a reference source for ADCs and DACs, and increasingly in these applications manufacturers combine converters and references on-chip. Other important applications include the primary reference circuit for any battery-powered measuring instrument, battery-condition detectors, and level detecting circuits for initiating protection and control of other circuitry during power-up and power-down, or power-supply transient situations.



The curved TC-response of Linear Technology's LM185-2.5 is typical of most micropower references. Quoted TC figures assume a straight-line average from room ambient to temperature extremes.

Table 1 clearly illustrates the voltage-noise drawback associated with all bandgap devices. For example, 60-μV rms

for a 10-Hz to 10-kHz bandwidth is typical. This figure represents at least ten times the voltage noise exhibited by reference zeners, particularly buried types.

Take care when comparing noise performance in vendor's data, as it's common to find figures expressed as $\mu V/\sqrt{Hz}$, p-p, or rms, and over different bandwidths—even by the same vendor. What is more useful to know is the p-p noise in ppm over the bandwidth of interest. You can then easily translate p-p noise to digits of error on an ADC, DAC, or digital readout. For a 1.2V micropower reference, the typical figure of 60-μV rms is equivalent to 300-ppm p-p noise error. If you use such a device as the internal reference for a meter or data converter,

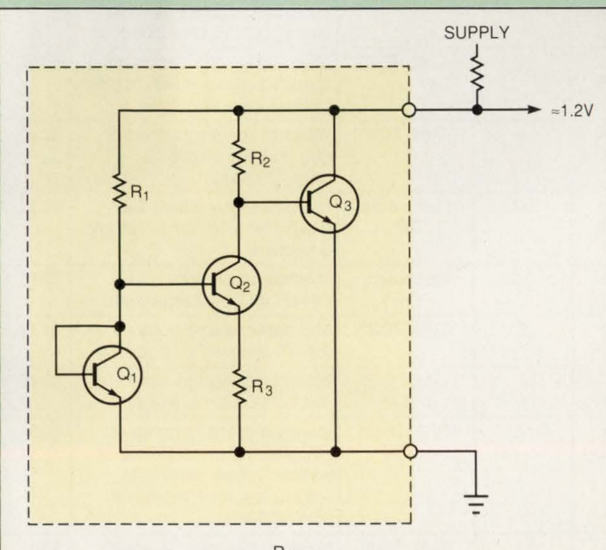
Generating a bandgap voltage reference

All micropower references rely upon the "bandgap" principle for operation. At the heart of each reference are two similar transistors operating at roughly a 10:1 current-density ratio. **Fig A** shows the essential circuit elements. If the collector current in Q_1 is approximately ten-times that in Q_2, then the V_{BE} difference for the two transistors at 25°C is around 60 mV, with a negative TC of approximately −0.2 mV/°C. These numbers result from a simple analysis using Ebers-Moll equations for a p-n junction (for more on Ebers-Moll equations, see **Ref 1**). The key factor that determines these figures is the operating current-density ratio in the two transistors. In practice, chip geometry maintains the current-density ratio, since designers can accurately lay down transistors with emitter areas of a fixed ratio. Often, an 8:1 ratio is chosen.

The negative TC V_{BE} difference across R_3 translates to a positive TC collector current in Q_2, which tends to lower Q_2's collector voltage with rising temperature. If you choose the ratio R_2:R_3 appropriately, then you can make the positive TC voltage across R_2 balance the negative TC V_{BE} of another similar transistor, in this case Q_3. Adding the two voltages produces a reference output voltage that is stable with temperature, and in practice a 1.2V output exhibits zero TC.

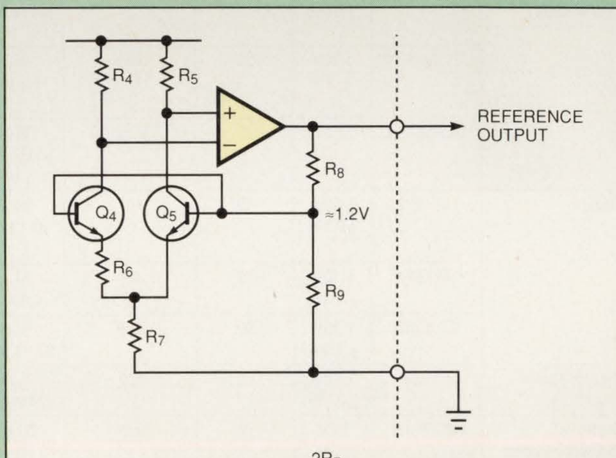
More often, you need reference levels greater than 1.2V, and it's common to find the circuit shown in **Fig B**. The circuit still uses the same bandgap difference to produce a stable 1.2V level, but additional level-shifting and amplifier circuits produce a range of other reference levels depending upon the value of R_8 and R_9.

Both circuits shown in **Figs A** and **B** are simplified versions of what you will find in the latest micropower references. Reference designers install a multiplicity of additional circuitry for compensating secondary effects on TC and to produce low slope resistance. Laser trimming resistors to produce close-tolerance output voltages adds further complexity.



$$\text{REFERENCE OUTPUT} = V_{BE3} + \frac{R_2}{R_3}(V_{BE1} - V_{BE2}) \approx 1.2\text{V}$$

Fig A—Bandgap reference circuits produce a temperature-stable output voltage by combining the +TC voltage across R_2 in series with −TC V_{BE} of Q_3.



$$\text{INTERNAL REFERENCE} = V_{BE5} + \frac{2R_7}{R_6}(V_{BE5} - V_{BE4}) \approx 1.2\text{V}$$

$$\text{REFERENCE OUTPUT} = 1.2\left(1 + \frac{R_8}{R_9}\right)$$

Fig B—Transistors Q_1 and Q_2 operate at the same I_C, but have different emitter area. Consequent current-density difference produces V_{BE} bandgap difference across R_6. Internal bandgap reference voltage (≈1.2V) appears across R_9. Reference output voltage is set by ratio R_8:R_9.

MICROPOWER VOLTAGE REFERENCES

then this error would contribute directly to approximately 1 digit of run-around on a 12-bit ADC or DAC or 2 to 3 digits of run-around on a 4.5-digit display.

In practice, applying a simple low-pass filter across the reference's output reduces noise for most applications. But to obtain appreciable noise reduction, you need to restrict bandwidth to roughly 10 Hz, and this requires large components that take up valuable pc-board space and increase component cost. You need to take care with this addition, as a reference's output is active and adding only a capacitor directly across the terminals is likely to induce oscillation.

The relatively poor characteristic noise performance of bandgap devices derives from their low operating-current design. Micropower examples suffer proportionately more, since operating currents down to 10 μA are permissible. The problem is one fundamental to any low-current IC design. By virtue of the design, internal IC resistor values need to be high, as are intrinsic transistor resistances when operating at such low currents (I_C may be <1 μA). Consequently, you cannot avoid Johnson noise in these high resistances. In fact, Johnson noise forms the dominant noise source in a micropower reference. Types with outputs boosted above 1.2V have higher noise levels still, since additional internal components make their noise contribution to the amplified inherent noise.

Selecting a micropower reference with a voltage TC anywhere from 100 down to 5 ppm/°C simply de-

Table 1—Representative micropower voltage references[1]

Manufacturer	Type	Voltage	Operating-current (min) (μA)	TC max (–40 to +85°C) (ppm/°C)	Noise (typical)	Output slope resistance (max) (Ω)	Package	Comments	Price[3] (100)
Analog Devices	REF-195	5.0V ±0.02%	30	4 ppm/°C ±1 mV	50 μV p-p, 0.1 to 10 Hz	0.01	Plastic and ceramic 8-pin DIP, SO-8	2-stage output adjust-laser trim on wafer and fuse links after packaging; output sources to 30 mA.	$1.95
GEC Plessey Semiconductors	SR12D	1.23V ±3%	90	120	10 μV rms, 1 Hz to 25 kHz	2.5	SOT-23	Other voltages 2.5 and 5V, maximum operating current 2.5 mA.	$1.10
	REF12	1.26V ±1%	60	56	1 μV/√Hz 0.1 Hz to 25 kHz	4	TO-92, MP-8	Other voltages 2.5 and 5V, maximum operating current 2.5 mA, TC in MP-8 package is 80 ppm/°C.	$1.10
Linear Technology	LT1004C-1.2	1.20V ±0.3%	10	20 typ[2]	60 μV rms 10 Hz to 10 kHz	0.6	TO-46, TO-92	Other voltage 2.5V, maximum operating current 20 mA, long-term stability 20 ppm/1000 hours.	$1.35
	LT1034C-1.2	1.20V ±1%	20	40[2]	4 μV p-p 0.1 to 10 Hz	1	TO-46, TO-92	Other voltage 2.5V, maximum operating current 20 mA, package includes 7V zener reference.	$2.85
	LM385-2.5	2.50V ±1%	20	20 typ[2]	120 μV rms 10 Hz to 10 kHz	1	TO-46, TO-92	Maximum operating current 20 mA, long-term stability 20 ppm/1000 hours.	$0.80
Maxim	MAX872	2.50V ±0.1%	10	40[2]	60 μV p-p 0.1 to 10 Hz	0.3	Plastic 8-pin DIP	Minimum supply voltage 2.6V, trim-pin for +100 mV to –25 mV adjustment.	$2.25
	MAX874	4.10V ±0.1%	15	40[2]	90 μV p-p 0.1 to 10 Hz	0.3	Plastic 8-pin DIP	Minimum supply voltage 4.2V, trim-pin for ±0.2V adjustment.	$2.25
	ICL8069	1.23V ±1.6%	50	100[2]	5 μV rms 10 Hz to 10 kHz	2	TO-52, TO-92	Maximum operating current 5 mA, TC selection to 10 ppm/°C.	$1.13
Micro Power Systems	MP5010	1.22V ±2.5%	50	100	5 μV rms 10 Hz to 10 kHz	2	TO-52, TO-92, or SO-8	Maximum operating current 5 mA, TC selection to 5 ppm/°C	$0.86
National Semiconductor	LM385-1.2	1.2V ±3%	10	150[2]	60 μV rms 10 Hz to 10 kHz	1.5	TO-46, TO-92, or SO-8	Maximum operating current 20 mA, other voltages 2.5V and adjustable, voltage selection to ±0.3%, long-term stability 20 ppm/1000 hours.	$0.94
	LM4040	2.5V ±2%	65	100	35 μV rms 10 Hz to 10 kHz	0.8	TO-92, SO-8, or SO-23	Maximum operating current 20 mA, other voltages 4.1, 5, 8.2, and 10V, voltage selection to ±0.1%.	$0.85

Notes:
1. Specifications at 25°C unless otherwise stated.
2. TC for ambient temperature range 0 to 70°C.
3. Prices shown for TO-92 where available, or plastic 8-pin DIP.

pends upon how much you are prepared to pay. For approximately $1 you get a typical 20 ppm/°C device. For a guaranteed maximum of 5 ppm/°C, you'll pay more than $10. At this level, micropower reference TC performance equates to the best specification reference zeners, such as 1N829A.

In all cases, the TC figure quoted in specifications is a straight-line average of a curved response taken from the midpoint to the extremes of the operating temperature range. The reference designers arrange that the TC approaches zero somewhere around room-ambient temperature. As the operating temperature moves off to either the maximum or minimum limit, the reference's output voltage falls more and more rapidly. Manufacturers apply various forms of compensation to iron out this basic curved response, but the TC result is never linear over the full operating temperature range.

Stress influences stability

Long-term performance of micropower references is something most vendors are reluctant to specify, since this specification is very much stress related, and therefore dependent upon application. Linear Technology quotes a figure of 20 ppm/1000 hours for all its micropower references. This figure is worst case over the first 1000 hours, because as the component ages, the voltage increasingly stabilizes. As a rule of thumb for designing-in micropower references, you can safely assume a long-term stability specification of 20 ppm/$\sqrt{1000 \text{ hours}}$ when you operate the component at room ambient.

However, if you operate references at extremes of temperature, then expect other effects to appear. For example, if you temperature cycle a reference from room ambient to its maximum or minimum operating temperature and back, you may see a hysteresis jump in output voltage as high as 100 ppm. Stress in the die and package forces changes into the reference circuit to cause this jump. The reference output voltage will eventually recover close to its original value over several days of operation.

If long-term stability is a major concern, then oven baking all your reference parts at 150°C for a couple of days before you use them generally proves beneficial. This process tends to relieve initial stress left in the die and package following component manufacture, which in turn influences stability.

This effect raises the issue of choice of packaging in general. Although most vendors don't differentiate performance relative to package style, it's well known that choice of packaging does influence reference output voltage. In a plastic package for example, the moulding presses down on the top of the die, and therefore exerts a slight force. IC legs running through plastic are not hermetically sealed, and therefore atmospheric changes can access the die. Plastic surface-mount packages introduce the additional possibility of a flexing pc-board's transmitting vibration through to the die. The net result is that your reference voltage performance is more likely to be further inside its published specification if you use a package that stands off from the pc-board, or even better has hermetically sealed legs (as in the case of ceramic or metal-can packages).

GEC Plessey Semiconductors is the only company to declare stability figures for different packages. Its REF12 1.2V references in TO-92 and 8-pin surface-mount packages have TC maximum values of 56 and 80 ppm/°C, respectively.

With a favorable mix of specifications, micropower references, in general, can supplant zeners in many applications. Future references will offer tight voltage and

For more information . . .

For more information on the micropower reference 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 read about their products in EDN.

Analog Devices Inc
1500 Space Park Dr
Santa Clara, CA 95052
(408) 562-2641
FAX (408) 727-1550
Khy Vijeh
Circle No. 706

GEC Plessey Semiconductors
Cheney Manor
Swindon SN2 2QW, UK
(793) 518136
FAX (793) 518136
Claire Smith
Circle No. 707

Linear Technology Corp
1630 McCarthy Blvd
Milpitas, CA 95035
(800) 637-5545;
(408) 432-1900
FAX (408) 434-0507
Bob Scott
Circle No. 708

Maxim Integrated Products
120 Gabriel Dr
Sunnyvale, CA 94086
(408) 737-7600
FAX (408) 737-7194
Brett Fox
Circle No. 709

Micro Power Systems
3100 Alfred St
Santa Clara, CA 95056
(408) 562-3670
FAX (408) 562-3605
Katie Meitzler
Circle No. 710

National Semiconductor
2900 Semiconductor Dr
Santa Clara, CA 95052
(408) 721-2302
FAX (408) 245-9655
Kay Hoang
Circle No. 711
In Europe:
The Maple
Kimbrey Park,
Swindon SN2 6UT UK
(793) 697617
FAX (793) 697650
Susan Cheng
Circle No. 712

VOTE . . .

Please also use the Information Retrieval Service card to rate this article (circle one):

High Interest 479
Medium Interest 480
Low Interest 481

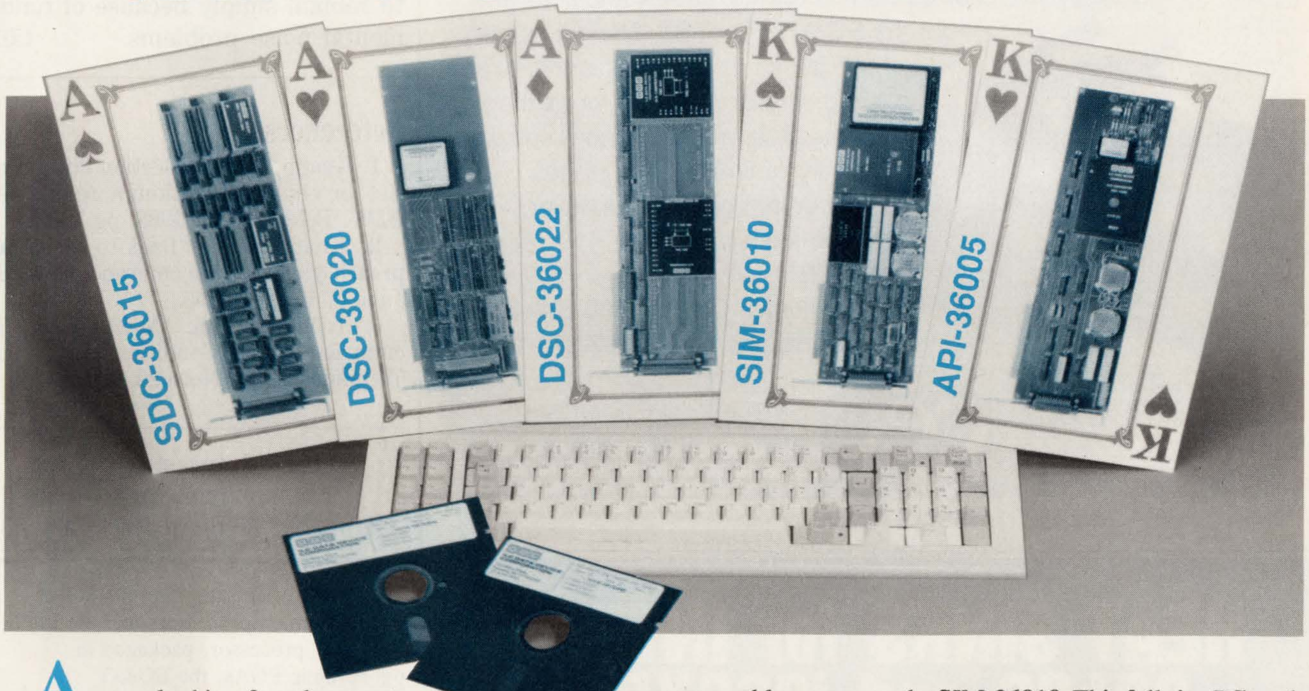
MARCH 1992

NEWS

1553 DATA BUS
SYNCHRO CONVERSION
A/D & D/A CONVERSION
POWER HYBRIDS
SOLID-STATE POWER CONTROLLERS

DDC ILC DATA DEVICE CORPORATION®

DDC's FULL HOUSE OF IBM PC® SYNCHRO CARDS



Are you looking for a low-cost method of testing synchro and resolver based designs? Are you involved with motor, antenna, robotics, or machine control? Do you need a system to simulate multiple channels of synchro or resolver signals? Do you want an accurate synchro simulator and angle position indicator? The world leader in synchro conversion has the **Hot Hand** you need. DDC is proud to offer the most complete line of Synchro/Resolver cards anywhere. The best part about these cards is they all plug into an IBM PC!

Our full house has three multichannel-socketed-cards, and two accurate-synchro/resolver-instruments.

Our SDC-36015 is a full size IBM PC card designed for one to six channels of synchro- or resolver-to-digital conversion. The card features programmable resolution and bandwidth, built-in-test, accuracy to 1 arc minute, and a quality velocity output.

The DSC-36020 is a full size IBM PC card for one to six channels of digital-to-synchro or -resolver conversion. The outputs are 11.8V synchro or resolver, 6.8V Sin/Cos, and 90V synchro with an external transformer. This medium powered card is accurate to 1 arc minute.

If you require higher power, DDC has the one to four channel DSC-36022 full size PC card. This card can drive a synchro load up to 4.5VA with accuracy to 4 arc minutes.

The API-36005 is an Angle Position Indicator in a full size IBM PC card. Its frequency range is 360 to 5000Hz with an accuracy of 18 arc seconds.

To complement the API we have the SIM-36010. This full size PC card simulator has a no-load accuracy of 25 arc seconds. The outputs are 11.8, 26, or 90V L-L synchro or resolver.

All DDC synchro cards include demo. software to start the game.

Use these cards for the best hand: to lower your instrumentation costs, or as a low-cost method of doing testing for systems development, incoming inspection, or production. Maybe you need a portable tester or a high-performance simulator; if you are at all involved with motion control or synchros and resolvers give us a call. Maybe one of the cards in our hand and an IBM PC is your solution.

For more information call Jerry Kessler at 516-567-5600 ext. 383. We are dealing with a fresh deck, no bluffing! ❑

® IBM is a registered trademark of International Business Machines.

DDC ILC DATA DEVICE CORPORATION®

HEADQUARTERS AND MAIN PLANT: ILC Data Device Corporation, 105 Wilbur Place, Bohemia, NY 11716, (516) 567-5600, TLX: 310-685-2203, FAX: (516) 567-7358, (516) 563-5208, Toll Free Outside N.Y. 1-800-DDC-1772
WEST COAST (CA): GARDEN GROVE, (714) 895-9777, FAX: (714) 895-4988;
WOODLAND HILLS, (818) 992-1772, FAX: (818) 887-1372
WASHINGTON, D.C. AREA: (703) 450-7900, FAX: (703) 450-6610
NORTHERN NEW JERSEY: (201) 785-1734, FAX: (201) 785-4132
UNITED KINGDOM: 44 (635) 40158, FAX: 44 (635) 32264; **IRELAND:** 353 (21) 341065, FAX: 353 (21) 341568
FRANCE: 33 (1) 4333-5888, FAX: 33 (1) 4334-9762; **GERMANY:** 49 (8191) 3105, FAX: 49 (8191) 47433
SWEDEN: 46 (8) 920635, FAX: 46 (8) 353181; **JAPAN:** 81 (33) 814-7688, FAX: 81 (33) 814-7689

Circle No. 60 For Sales Contact

Circle No. 61 For Literature

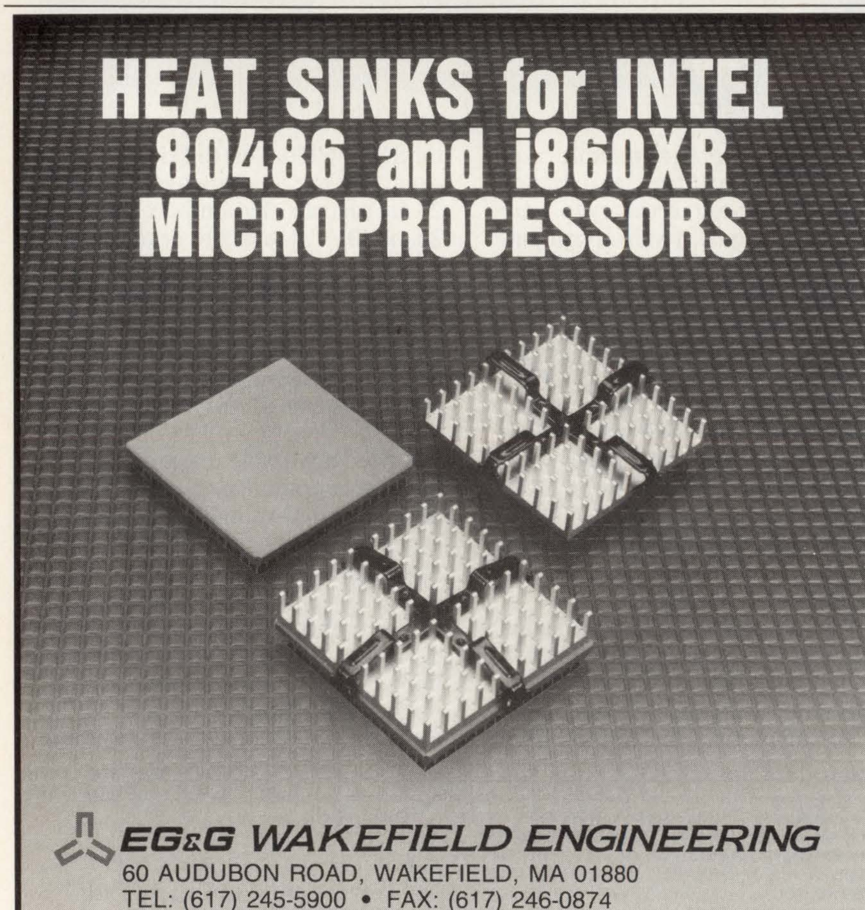
MICROPOWER VOLTAGE REFERENCES

TC specifications by design, rather than by the expensive component selection route. Analog Devices' REF-195 exemplifies this trend with its 0.02% tolerance and 4 ppm/°C as standard. However, 10 μA as a minimum operating current is likely to remain simply because of fundamental noise problems. EDN

References

1. Knapp, Ron. "Selection criteria assist in choice of optimum reference." *EDN*, February 18, 1988, pg 183.
2. Knapp, Ron. "Back-to-basics approach yields stable references." *EDN*, June 9, 1988, pg 193.
3. Williams, Jim. "Micropower Circuits for Signal Conditioning." Linear Technology App Note 23, April 1987.

Article Interest Quotient
(Circle One)
High 479 Medium 480 Low 481



Space. The Final Frontier.

Motorola's Mission: to conquer board space with our Power Surface Mount Linear DPAK low-profile package.

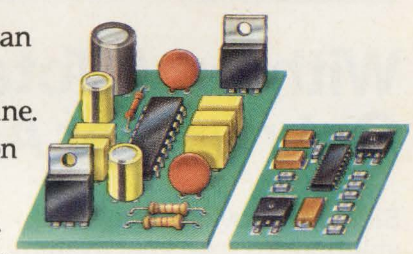
There's an infinite amount of space out there—the trick is, using as little of it as possible, as efficiently as possible. Motorola's surface mount DPAK versions of our popular voltage regulators do the trick.

Motorola offers the following regulators in DPAK:

Device	Output Current	Type	Output Voltage
MC 78MXX	500 mA	Positive Fixed	5, 8, 12, 15
MC 79MXX	500 mA	Negative Fixed	−5, −12, −15
LM 317M	500 mA	Positive Adjustable	1.2-37
LM 2931	100 mA	Positive Fixed, low V diff.	5

Planned for introduction in mid-1992:

Device	Output Current	Type	Output Voltage
MC 34268	800 mA	SCSI-2 Active Regulator	2.85



Custom devices can also be packaged in the DPAK case outline.

When mounted on a PC board with a small pad of copper, this miniature power package can dissipate the same power as a TO-220 package.

Looking for new ways to conquer space? Get more information about our low-profile Power Surface Mount Linear DPAK voltage regulators by calling us toll-free at 1-800-441-2447 or writing Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, AZ 85036.

MOTOROLA

SIEMENS

Without A Total Systems Solution, There's Only So Far An R4000 Supplier Can Take You.

Siemens provides powerful solutions to take your system performance to its highest level.
By providing the R4000 microprocessor, plus advanced DRAMs and ASIC technology, Siemens has launched a new era in systems capabilities.

R4000 Power and Performance.

The Siemens R4000—the first true 64-bit processor—provides unequaled throughput in a single chip. As a third-generation product, its scalability allows easy migration to the products of the future, and further shows our commitment to the MIPS RISC family of processors. Plus it comes in three versions, for applications ranging from PCs to sophisticated multiprocessor systems.

Siemens Total Systems Solution

With an estimated 62.5 SPEC rating and full Advanced Computing Environment (ACE) support, our R4000 also provides superior results in a wide range of off-the-shelf applications software. But what's most impressive about our R4000 is that it's only part of our total system solution.

Superior ASICs and DRAMs.

Siemens is the only European DRAM manufacturer, and one of the leading U.S. suppliers, with high-quality 1-Mb and 4-Mb DRAMs in production today, and 16-MB and 64-Mb DRAM programs for the near future.

In CMOS ASICs, we offer both Sea-of-Gates and standard-cell product families, featuring sub-micron technology which is completely compatible with Toshiba, even at the GDS2 level, for true alternate sourcing worldwide.

And they're fully supported by Siemens ADVANCAD design system, which is based on industry-standard workstations and simulators.

Complete System Solution.

Give your system the extra boost we offer with our R4000, DRAMs and ASICs. Our common processes provide you with an extra margin of compatibility, which means the most reliable, highest-quality products in the industry.

See how far Siemens can take your system performance. Call **800-456-9229,** and ask for literature package M20A013.

Siemens
World Wise, Market Smart

CIRCLE NO. 40

BATTERY-POWERED DSOs

Versatile units find more use than you might expect

DAN STRASSBERG, Technical Editor

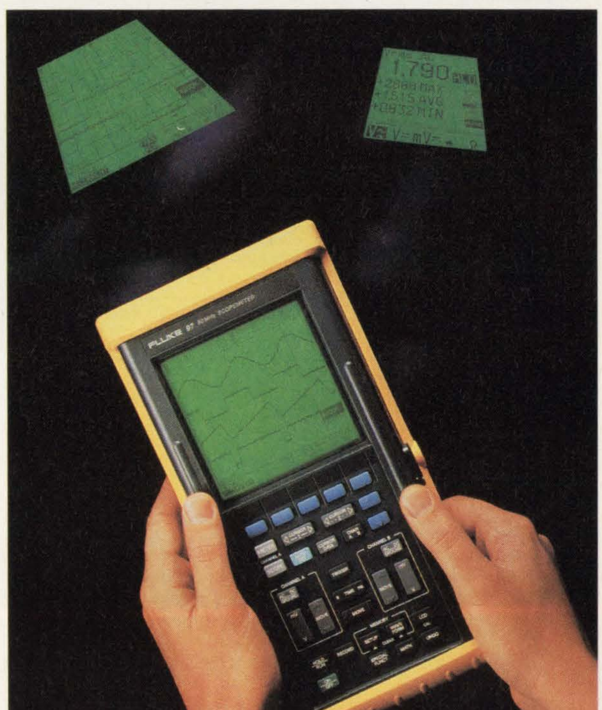
Though widely thought of as tools for field service and, at times, for test, these rugged versatile instruments offer surprisingly good performance that often is just what design engineers need.

A product designed to meet the needs of a well-defined audience can appeal to a significantly larger group. Although the designers of three and possibly four of the five battery-powered DSOs in **Table 1** clearly had field-service engineers in mind, the scopes will also be useful to many design engineers.

Four of these five battery-powered DSOs (from Fluke/Philips, Gould, Leader, and Tektronix) feature small size and light weight. Three of the units (Fluke, Leader, Tektronix) weigh less than 5 lbs and fit easily into an attache case. These three units also provide input-to-chassis ohmic isolation unavailable in ac-powered DSOs—although, in one instance (Leader), the isolation applies not to the scope but to the DMM that resides in the same enclosure. The two larger units (Hewlett-Packard (HP) and Gould) are full-featured designs that make few compromises. One of these, the HP unit, is a general-purpose DSO teamed with a package that contains a sealed lead-acid battery and an inverter.

The smallest units (Fluke, Leader) have LCDs that display both numeric information and waveforms (see **box**, "Some notable features"). The Fluke 97's LCD offers electroluminescent backlighting. (Fluke's lower-priced 95 and 93 and Leader's 300 lack backlighting; you can use their displays only where there is adequate ambient light.) The other scopes use CRTs. The Tektronix units' CRTs are small but quite readable; the HP's screen is standard scope size (7 in. diagonal); the Gould's screen size falls in between the other two.

To digitize repetitive waveforms at very high effective rates (2 to 10 GHz), all of the DSOs, except the Leader 300, use random equivalent-time sampling, which lets you view pretrigger information. The Leader unit uses sequential equivalent-time sampling to multiply its acquisition rate by 5 to 10× at the highest sweep speeds. To take full advan-



Drawing some of its design concepts from handheld DMMs, Fluke's 97, which is about 3× the size of such meters, provides 50-MHz bandwidth, a 2.5-Gsample/sec equivalent acquisition rate for repetitive signals, and a long list of features, including a built-in sine/square-wave generator.

Table 1—Representative battery-powered DSOs

Vendor and model	Fluke 97[3]	Gould 465	HP 54600A/601A scopes; 85901A inverter	Leader 300	Tektronix 222A, 224, 222PS
Base US list price	$1795	$4485	Scopes: $2495, $2895; Inverter: $1290	$1995	$2450, $2750, $2750
Size—H x W x D (in.)	10.8 x 5.5 x 2.5	7.6 x 10.7 x 15.7	6.8 x 12.7 x 12.5; 4.9 x 13.3 x 18.1	6.5 x 9.4 x 1.8	3.4 x 6.3 x 9.9
Weight (lbs)	4	14	Scopes: 14; Inverter: 31.3	2.6[9]	4.4
Battery type; size	4 NiCd; C[4]	NiCd	Sealed lead-acid	4 Alkaline; AA	Sealed lead-acid
Operating time (hours)	4	2	2 minimum, 2.5 typical	2.25	3 minimum; 4 typical
Low-battery indication	Symbol flashes	None	Flashing LED and buzzer	Display	Warning on CRT
Warning before shutoff	1 hour	NA[7]	10 minutes	10 minutes	2 to 3 minutes
Fastest recharge time	10 hours	2x discharge time	3 hours typical, 6 hours maximum	See "Battery" box	3 hours
Charge within scope?	Yes	Yes, ONLY in scope	Battery recharges within inverter	No	Yes
Use while charging?	Yes	Yes	Can use scope by disconnecting inverter	NA	Yes
Charge time (scope on)	18.5 hours	2x discharge time	NA	NA	About 6 hours
Supply needed for ac?	Yes	No	No; without inverter, scopes run on ac	Yes	Yes
Supply price	Included	NA	NA	$39	Included
External charger price	NS[5]	NA	Included in inverter	See box in story	$200 See "Battery" box
Battery price	$40	$250 (repair)	$72.50	Depends on type	$70
Channels, max traces[1]	2, 4	2, 2	54600A: 2, 4; 54601A: 4, 4	2, 4	2, 2
Bandwidth (MHz)	50	100	100	10	222A, 222PS: 10; 224: 60
Max samples/sec/ channel	See note 6	200M	20M	30M—1 shared ADC	10M
Samples/trace (stored)	512	512	4000	180; 1800 switchable	512
Bits/sample	12	8	8	7	8
Equivalent-time mode	Random	Random	Random	Sequential	Random
Effective samples/sec	2.5G	2G	10G (100-psec resolution)	150M	1G
Captured-glitch width	40 nsec	See note 8	50 nsec at all sweep speeds	No glitch capture	100 nsec at slowest sweep
Time/div (min, max)	10 nsec, 60 sec	25 nsec, 50 sec	2 nsec, 5 sec	0.1 usec, 200 sec	5 nsec (magnified), 200 sec
Volts/div (min, max)	1m, 1k (probe)	2m, 5	2m, 5 (50 with probe)	5m, 20 (2-kV probe)	222A: 5m, 50; Others: 50m, 200
Display type	EL back-lit LCD	CRT	CRT	LCD	CRT with stroke vectors
Display size	84 x 84 mm	NS	7 in. diagonal	60 x 113 mm	NS
Display resolution	240 x 240 pixels	NA	255 x 500 points	128 x 180 pixels	NA
Isolation voltage[2]	600V rms; 4 kV peak	Not isolated	Floating ground NOT recommended	See note 10	222 PS: 600V rms; Others: 400V peak
Hard-copy provisions	Isolated RS-232C	Integral plotter	RS-232C, IEEE-488, parallel modules	Accessory printer	Yes, see note 11
Affects isolation?	No	NA	NA	No	No
Extended data storage	Months	About 1 month	With optional module; duration NS	1 month	Several months
Retains panel setups?	Yes, 10	No	Yes, 16	No (has autosetup)	Yes, 4

Notes:

1. The first figure is the number of signals the unit can acquire and simultaneously display. The second figure is the largest number of traces displayed at one time. Some units can display signals acquired and stored earlier, in addition to those being acquired.
2. The highest common-mode voltage you can safely apply between the scope's chassis and its Y-axis input terminals.
3. The 90 series also includes the 93 and 95, which offer fewer features at lower prices.
4. Unit can also run from nonrechargeable Alkaline cells.
5. NS = Not specified.
6. Because of the need to sample a signal several times per cycle to reconstruct it with reasonable accuracy, the usable bandwidth for single-shot events is approximately 6 MHz.
7. NA = Not applicable.
8. 1 μsec at 100-μsec/div sweep speed.
9. Weight shown is without batteries.
10. Withstands 1.1 kV between either DMM input and scope ground and also between DMM voltage and common inputs. Withstands 250V between DMM ohms and common inputs. DMM mA input is fused. Scope Y-axis inputs withstand 400V to ground without a probe and 600V with a probe. Trigger inputs withstand 100V to ground. All withstanding voltages are dc + p-p ac for 1 minute.
11. The $295 WP200 provides a parallel interface to Epson FX-compatible printers. The $395 CAT200 allows an MS-DOS PC to control the scope. With this package, you can obtain waveform printouts on a graphics-capable printer connected to the PC.

tage of any of these scopes' vertical bandwidth, you must use their equivalent-time modes.

The Gould 465 has a real-time sampling rate of 200 Msample/sec—high enough, in theory, to let you view single-shot events whose frequencies extend over its full 100-MHz bandwidth. However, you're well advised to limit your viewing of single-shot signals to those whose frequencies don't exceed 50 MHz. Observing this precaution will provide 4 samples/cycle, the minimum most scopes need to reconstruct waveforms well enough for you to make sense of what you see. (Although 4 samples/cycle is a usable rate, several scope vendors recommend rates of at least 10 samples/cycle. Using that figure, you should limit the bandwidth of single-shot events you view with the Gould 465 to 20 MHz.)

Similarly, the Leader 300's maximum 30-Msample/sec rate (when digitizing one channel) is theoretically adequate to capture signals having components at 10 MHz (the full bandwidth). But at 3 samples/cycle, signal reconstruction would not be adequate, so the scope switches to the sequential equivalent-time mode at sweep speeds that let you observe the details of 10-MHz signals.

These units represent some of the best examples of how today's DSOs exhibit both higher performance and lower prices than were obtainable in instruments introduced only a few years ago. Still, these scopes are somewhat more expensive than analog scopes whose key electrical specifications are similar. Therefore, you have good reason to ask why you shouldn't choose a less-expensive battery-powered analog scope in place of a battery-powered DSO.

In the case of the Fluke/Philips and Leader units, no analog scopes offer equivalent performance and features in similar packages (see

Although it resembles a pint-size version of a conventional scope, the Tektronix 224 is not conventional. It offers 60-MHz bandwidth, and its two inputs are ohmically isolated—not just from the chassis but from each other.

box, "Some notable features"). Moreover, the Tektronix scopes, in addition to their small size and high performance, offer inputs that are ohmically isolated not just from the chassis but from each other. Not only is such isolation unique among the scopes in **Table 1**, if it is available at all in analog scopes, it isn't easy to find.

Isolation is particularly important when you work with high voltages. When you connect a source of high common-mode voltage to an isolated scope input, you can touch the instrument's controls without fear of receiving a shock, provided the voltage doesn't exceed the scope's breakdown rating. The only currents that flow across the isolation barrier are small leakage currents, due mostly to the barrier's nonzero isolation capacitance.

With nonisolated inputs, including differential ones, the usual way to measure signals at high common-mode voltages is to disconnect the scope's chassis from ground (for example by connecting the scope to the ac line with a "cheater" 3-prong to 2-prong adapter). With such a connection, you risk a possibly lethal shock if you touch any of the scope's metal parts. Obviously, scope manufacturers don't sanction such operation.

In some applications that require isolation, the classic reasons for choosing a DSO rather than an analog scope are particularly important. When displaying phenomena that occur infrequently, most analog scopes present dim, flickering images; observing these dim traces at best requires a viewing hood. Sometimes, the only way to see such displays is by photographing them with very fast film. Low repetition-rate signals are common in power-supply and motor-control work where high voltages often necessitate isolation. Among analog scopes, only storage scopes provide bright displays of low repetition-rate phenomena. But most storage scopes are large and costly, and few operate from batteries or offer isolation.

Isolation and battery power

One reason that isolation and battery power seem to go together is that, although you can certainly design a power supply with no resis-

BATTERY-POWERED DSOs

tive path to its output from the ac line, designing a supply with line-to-output capacitance (isolation capacitance) of only a few pF is a challenging task that usually increases its cost. By eliminating the line connection, battery operation lowers isolation capacitance and allows higher common-mode voltages than economical ac-powered instruments can withstand. Stated another way, even if your battery-powered scope works when connected to ac, when you take advantage of its isolation capability, you'll get the best results if you run it from its batteries.

If you don't need isolation but need portability and want to save captured waveforms indefinitely—say, on a floppy disk—the idea of plugging an ISA-bus DSO card into a laptop PC, thus turning the PC into a battery-powered DSO, seems an obvious solution. As far as EDN could find out, though, no such configuration operates completely from batteries. We know that notebook PCs (which are even smaller than laptops) are out of the question; they lack bus slots. On the other

Some notable features

Fluke 97—Simultaneously acts as DMM (3000 counts full-scale) and scope through same leads. Adds, subtracts, multiplies, inverts, filters, and integrates waveforms. Also functions as sine/square-wave generator.

Numeric display capabilities: Voltage differences; time differences; frequency; maximum, minimum, p-p, rms, rms+dc, and mean voltage; phase; rise time; fall time; time from trigger to cursor; ratio; dBm; dBV; dBW; resistance.

Gould 465—Any two traces can be added, subtracted, or multiplied. In persistence mode, simultaneously displays all acquisitions over a period of time. Auto-setup mode evaluates inputs, chooses appropriate ranges, and displays settings on screen. A plotter option ($600 if purchased with the scope; $695 if you add it after purchase—you can install it yourself) provides hard-copy output capability within scope. The identical scope, without battery power, costs $3490. You can later add battery power for $1275.

Numeric display capabilities: Cursor measurements of rise time, frequency, duty cycle, overshoot, p-p voltage, period, pulse width, area, and rms voltage.

Hewlett-Packard 54600A/601A, 85901A—Fast (250× per sec) updates and familiar control layout produce a DSO with "analog feel" but, when displaying low repetition-rate signals, without the faint, flickering traces of analog scopes. Autostore mode displays the average of many waveforms at full brightness and the envelope of all measurements at half brightness. Optional modules allow expanding the scopes' capabilities, for example to add an RS-232C, parallel, or IEEE-488 interface; long-term waveform storage; or limit-testing.

Numeric display capabilities: Automatic and cursor-based measurements of average, rms, peak, p-p, and minimum voltage; frequency; period; duty cycle; rise time; fall time; time a signal is positive; and time a signal is negative.

Leader 300—Incorporates 3200-count DMM whose input is separate from the scope channels, making it, in a sense, a 3-channel unit. With optional logic probe, functions as 8-channel 15-MHz logic-timing analyzer. Logic-analyzer memory depth is 180 words when sweep speed is 5 μsec/div or faster and 1.8k words at slower sweep speeds. Optional credit-card size battery-backed memory card stores 80 normal-length (180-word) DSO traces, eight 1.8k-word traces, 10 screens of 8-channel×180-word (or one screen of 8-channel×1.8k-word) logic-analyzer data. Uses sequential equivalent-time sampling to achieve a 5 to 10× improvement in sampling rate at the highest sweep speeds. Also offers a "strip-chart" or "roll" mode for low-speed signals.

Numeric display capabilities: Range and mode information appears continuously at left side of screen and on screen printouts produced by accessory printer.

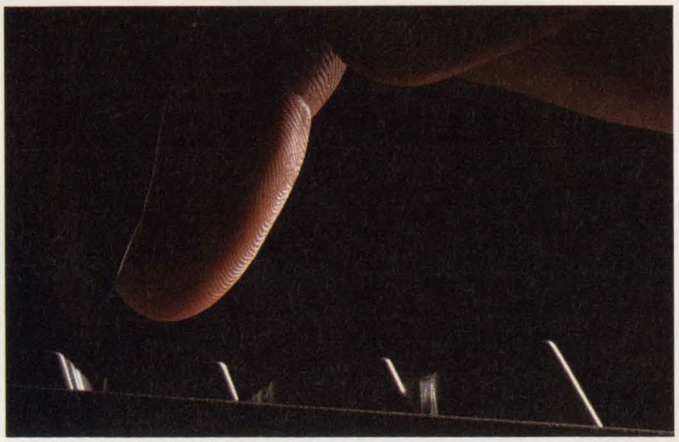
Tektronix 222A, 224, 222PS—The 222PS has a motor-control trigger feature that provides a stable display of variable-frequency waveforms that normally cause triggering problems. Because of the stroke-vector display and 1/30-sec update speed, the display resembles that of an analog scope. Channels are separately isolated from chassis and have separate ADCs. (Some competitive scopes provide isolation between the chassis and all inputs as a group. Such scopes tolerate only limited common-mode voltages between their inputs and the floating ground.) The 220-series scopes are listed by Underwriters' Laboratories (UL) and Canadian Standards Association (CSA). The 222PS withstands 6-kV common-mode transients.

Numeric display capabilities: These scopes do not provide numeric displays of measured quantities. They do display range settings on their CRTs.

IN THE TIME IT TAKES TO READ THIS AD, YOU COULD ROUTE THE WORLD'S FASTEST FPGA.

Believe it or not, it only takes about 150 seconds to place and route a Xilinx FPGA.

It will probably take you longer to read this ad.



Our new push-button software makes programming other logic devices seem positively tedious.

THE FIRST AND STILL THE FASTEST.

At Xilinx we invented the FPGA. And we've led the industry ever since.

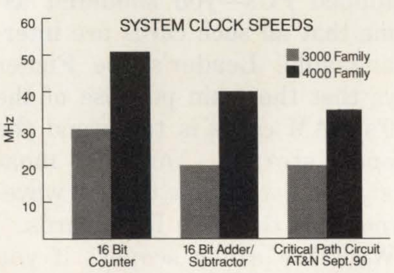
With the fastest, highest performance FPGAs available anywhere.

Today, we offer system clock speeds of 60 MHz. With on-board RAM. And on-chip wide decode.

Making our newest FPGAs ideal for everything from FIFOs to address decoding.

NEW ENHANCED SOFTWARE PROVIDES PUSH BUTTON SOLUTION.

To make Xilinx FPGAs even faster and easier to program, we've redesigned our software.



As measured by typical design benchmarks, the XC3000 family is the industry's fastest FPGA. Or at least it was until we introduced the 4000 family.

Our new version of XACT™ now comes with 200 soft macros. And fifty hard macros.

Providing automatic placing and routing for virtually all designs. With greater than 90% gate utilization.

If you've worked with Xilinx FPGAs before, you'll see improvements even before you start to place and route your design.

If you've never worked with Xilinx FPGAs before, you'll find every other logic device to be positively tedious by comparison.

WHEN IT COMES TO SYSTEM TESTING, WE PASS WITH FLYING COLORS.

Our newest FPGAs offer you the industry's first on-chip JTAG boundary scan for easy testing of PC boards and device I/Os.

This unique Xilinx offering improves overall system testability and dramatically reduces board test costs. A major boost for those designing high-density, surface mount systems or complex, multilayer PC boards.

IF AT FIRST YOU DON'T SUCCEED, IT'S EASY TO TRY AGAIN.

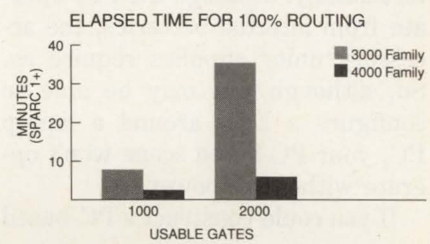
Xilinx FPGAs can be quickly reprogrammed an unlimited number of times.

Our FPGAs save you an enormous amount of time right up front. And they also save you time later when you need to make those "last minute" enhancements.

It's one more way we make it easier for you to get your product to market as fast as possible.

GETTING AN EDGE OVER YOUR COMPETITORS IS JUST A PHONE CALL AWAY.

If you've read this far, you could have already placed and routed one of our FPGAs.



New algorithms have reduced place and route times by a factor of four.

So don't delay. No other programmable logic company offers you the many exclusive features of Xilinx FPGAs.

Call 1-800-255-7778. Or in California, 408-559-7778. And we'll send you more information on how our FPGAs can give you the competitive edge.

But you better hurry.

Some of your competitors have already finished reading this ad.

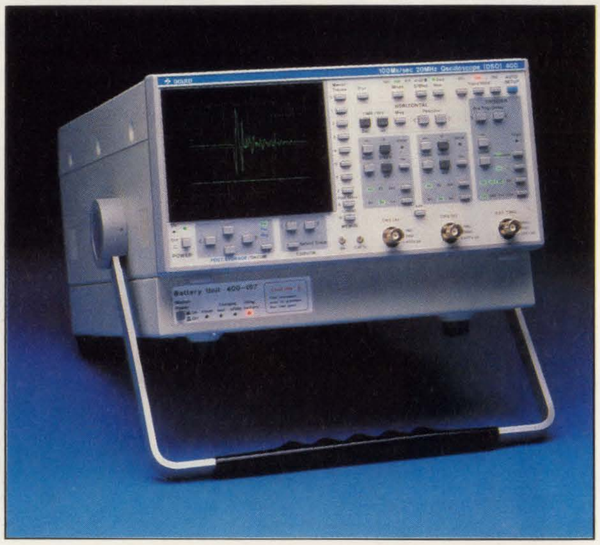
XILINX

The Programmable Gate Array Company.℠

BATTERY-POWERED DSOs

hand, some laptops do have slots (usually a single slot). We inquired of two vendors of PC-based scope hardware—Rapid Systems (Seattle, WA) and Gage Applied Sciences (Montreal, PQ, Canada)—to see if they knew of a laptop PC and a scope card or scope accessory that would work together under battery power.

The few laptops that have slots seem not to have the full-length slots needed to accommodate DSO cards. Moreover, the bus connectors of some of these laptops don't deliver the normal supply voltages that DSO cards need. The laptops that allow you to use a full-length ISA-bus board require you to bolt an accessory unit to their lower surfaces. Such combinations are still quite small and light and provide large high-resolution screens. Unfortunately, although the PCs operate from internal batteries, the accessory units' supplies require ac. So, although you may be able to configure a DSO around a laptop PC, your PC-based scope won't operate without ac power.



A different approach to battery-powered DSOs is embodied in Gould's 465. You can purchase this small scope with or without the battery pack. The vendor intends the scope primarily for operation where ac is available, but with the batteries, it will run for two hours or more away from the power line.

If you could construct a PC-based battery-powered digital scope, with appropriate software, its disk drives would provide a feature not available in any of **Table 1**'s DSOs: *truly* nonvolatile waveform storage. Although none of the scopes has a disk drive, most of the units offer fairly long-term storage, even when you have drained their batteries so much that you need fresh batteries or an ac source to continue scope operation. (See the row "Extended data storage" in **Table 1**.) In some cases though, if you retain a critical waveform, you limit the scope's ability to acquire additional signals.

Of the listed scopes, only the Leader 300 can transfer waveforms to a credit-card-size, battery-backed RAM card. Such cards store data for years. Although RAM cards sometimes can function as media for exchanging data with other units—for example, suitably equipped PCs—you shouldn't assume that all such cards are interchangeable. Leader's Joe Fisher says that the main purpose of the 300's RAM cards is to extend the scope's storage. Your PC most likely will not be able to read waveforms from the 300's RAM cards.

With the other scopes, if you want to save a waveform indefinitely, you must transfer it elsewhere, say to a desktop PC's hard disk. Several of the scopes provide ports through which you can transfer the data. In some cases, you have a choice of the type of port—RS-232C, parallel, or IEEE-488. The Fluke and Tektronix scopes allow you to use the serial port without affecting the scope's input-to-output isolation.

However, using an RS-232C port to save a waveform is not an ideal

For more information . . .

For more information on the battery-powered DSOs 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 read about their products in EDN.

John Fluke Mfg Co Inc
Box 9090
Everett, WA 98206
(800) 443-5853;
(206) 347-6100
Circle No. 700
In Europe:
Philips Test & Measurement
Bldg TQIII
5600MD, Eindhoven
The Netherlands
Phone local office
Circle No. 701

Gould Inc
Test & Measurement Group
8333 Rockside Rd
Valley View, OH 44125
(216) 328-7000
FAX (216) 328-7400
Doug MacLennan
Circle No. 702

Hewlett-Packard Co
19043 Pruneridge Ave
Cupertino, CA 95014
(800) 752-0900
Circle No. 703

Leader Instruments Corp
380 Oser Ave
Hauppauge, NY 11788
(800) 645-5104;
(516) 231-6900
FAX (516) 231-5295
Joe Fisher
Circle No. 704

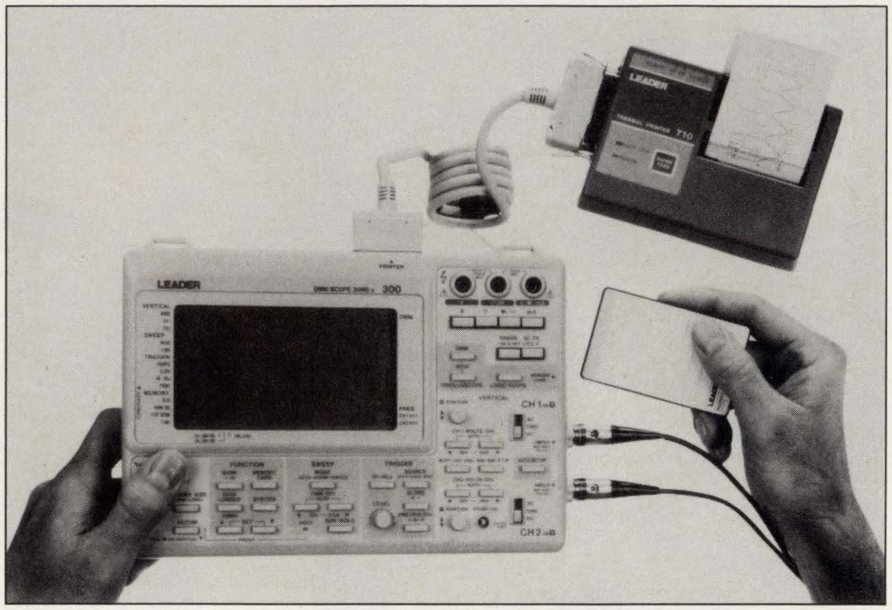
Tektronix Inc
Box 1520
Pittsfield, MA 01202
(800) 426-2200
Circle No. 705

VOTE . . .

Please also use the Information Retrieval Service card to rate this article (circle one):
High Interest 476   Medium Interest 477   Low Interest 478

solution. Usually, this approach requires you to be near the computer to which you will transfer the data. Connecting a small modem to the scope's serial port might save the day when the computer is some distance away, but remember, the scope is not a PC. The scope won't run your favorite telecommunications software package. On the PC, a package designed to download waveforms from your scope may not work with a modem.

If you can't save waveforms as files on a disk, perhaps the best alternative is printing them out. Your computer may not be able to read the printouts, but you will be able to, and the printouts will last a while. Mostly, if you want a printout, you must rely on communicating via a serial, parallel, or IEEE-488 port. The Leader 300 offers a



Extended data storage in credit-card-size, battery-backed RAM cards and the ability to print out waveforms on a dedicated accessory printer are just two of the Leader 300's features. The unit also includes a 3000-count DMM and, with an accessory probe, converts to an 8-channel logic-timing analyzer.

A battery of batteries for battery-powered DSOs

Among manufacturers of battery-powered equipment, there is no unanimity on which battery chemistry system is "the best." The reason, not surprisingly, is that "best" means different things to different people. Even when the products perform similar functions and are used by people in similar jobs under similar conditions, product designers can have radically different views of the relative importance of various aspects of performance and cost. As a result, the scopes in **Table 1** use NiCd, Nickel-metal-hydride, and sealed lead-acid rechargeable batteries as well as nonrechargeable Alkaline cells. (Technically, a battery consists of several cells. Despite what people commonly call them, most cylindrical "batteries"—for example, the C and AA sizes—really are individual cells. On the other hand, a 9V "transistor-radio" battery really is a battery because it contains several cells.)

The designers of Fluke's 90 series had flexibility in mind. They chose C-size NiCd cells as the units' usual power source, but designed the scopes (or "Scopemeters," as Fluke calls them) to work from C-size Alkaline cells too. That way, if you don't spend the money for an extra set of NiCds and you exceed the four hours of operation you can expect from the rechargeable cells, you can remove the NiCds and substitute a set of Alkaline cells. C-size Alkaline cells are quite inexpensive and are available in supermarkets and variety stores. Moreover, Alkaline cells have a shelf life measured in years and will run the Scopemeters longer than the NiCd cells will—perhaps twice as long.

Fluke has not yet stated that you can substitute Nickel-metal-hydride cells for the NiCds. Nickel-metal-hydride cells are only just now starting to appear commercially. They are still quite expensive, but in applications that draw moderate discharge currents (and that includes the majority of battery-powered electronic equipment), they will usually run the equipment for a period significantly longer than NiCd cells will (that is, for nearly as long as Alkaline cells will run it). On the other hand, Nickel-metal-hydride cells discharge themselves more rapidly than NiCd cells do, and NiCds exhibit faster self-discharge than Alkaline cells. In other words, if you use rechargeable batteries, to maximize their operating time, you should, if possible, keep them "float charged" (so they don't self discharge) until just before you use them.

The designers of Leader's 300 did not give top priority to using rechargeable batteries. They built the scope to run first of all from Alkaline cells (AA size), but you can substitute NiCd or Nickel-metal-hydride cells for separate accessory printer designed for use with the scope. Its printouts show the measurement ranges in use. The larger Gould 465 provides the most convenient solution: It accommodates a color plotter, and installing the plotter doesn't increase the scope's size. You can order the scope with the plotter or easily add the plotter yourself after purchase.

No time left

If you are in the middle of taking important data when your scope's batteries are about to run down, you'd probably like some warning and maybe you'd like to replace the batteries with a freshly charged set. Most of the units provide a low-battery indication on their displays. Usually, the warning occurs when enough operating time remains for you to print out the contents of the waveform memories—if a printer is handy.

Some of the scopes use separate batteries to retain data after shutdown, so you can replace the main batteries and resume operating pretty much as if there had been no power interruption. In some cases, if you don't have more rechargeable batteries ready, you can substitute nonrechargeable ones. (See **box,** "A battery of batteries for battery-powered DSOs.")

Stacked up against larger and more expensive DSOs, these units set no performance records, but the availability of very respectable performance in small, rugged, relatively inexpensive packages is definitely noteworthy. When you consider that these instruments operate without ac power (and in some cases, provide isolated inputs) and that some of them offer useful features rarely found in scopes (full-featured DMMs in the Fluke and Leader units, a logic-timing analyzer in the Leader 300, a sine/square-wave generator in the Fluke 97), you're justified in calling them quite remarkable. EDN

Article Interest Quotient
(Circle One)
High 476 Medium 477 Low 478

the Alkaline cells. Unlike the Fluke units, which let you recharge the NiCd cells inside the scope, with the Leader unit you must remove the cells to recharge them. Although having to use an external charger may seem like a disadvantage, it does let you match the charger to the type of cells you are using. In the case of Leader, though, this flexibility means that the scope vendor doesn't supply chargers, nor did it indicate charger prices. Leader did emphasize, however, that chargers are readily available and multiply sourced. Because charging times depend on both the batteries and the charger, Leader did not provide information on charging times.

Obviously, external chargers vary in price. The $200 price of the charger for the Tektronix 220 series scopes includes—besides a charger that can charge two batteries at once—a spare battery, a viewing hood, an extra ac adapter, and an automobile cigarette-lighter adapter.

A battery of battery prices, too

The price of the batteries varies from $40 to $250, although the cost of nonrechargeable batteries—if your scope can use them—is considerably less. The Gould 465's battery is a special case. Its $250 price includes the factory's labor. The battery, which is sealed within a unit that includes the charger, is not replaceable in the field. You must return the entire unit, and perhaps the scope, to the factory for a replacement. Gould says that an EE with a soldering iron and a screwdriver should have no trouble installing the battery unit on a scope not originally equipped with it. The unit, which attaches to the bottom of the scope case, is no harder to remove than to install. Hence if the battery fails, you probably won't have to go without the scope while the factory replaces the battery.

All of the scopes operate from ac as well as from batteries. In some cases, ac operation requires an external unit, such as a transformer that plugs into a wall outlet. In **Table 1,** the row "Supply needed for ac?" tells whether an external unit is needed. The next row, "Supply price" shows the cost of the supply.

The row marked "fastest recharge time" presents the times required to recharge the units' batteries to full charge from a state of discharge that causes the unit to shut down. These times apply with the scope not in use. With the scope in use, recharging times sunder otherwise similar conditions are generally longer and appear on the row labeled "Charging time (scope on)."

LISTEN.

"P-CAD helps us transform abstract engineering concepts into sound designs."

Jeff Rowland

Jeff Rowland, President

P-CAD products, unique as your application.

P-CAD products include all the interactive and automatic tools you need to complete PCBs, from symbol creation through manufacturing.

All made possible by P-CAD's open architecture and its interfaces to a wide range of third party tools such as VIEWlogic®. P-CAD lets you easily exchange PCB files with your favorite mechanical CAD programs such as CADAM's MICRO CADAM®. And whether it's a DOS or UNIX®- based solution you're looking for, there is a P-CAD product that is engineered to meet your desktop PCB design needs.

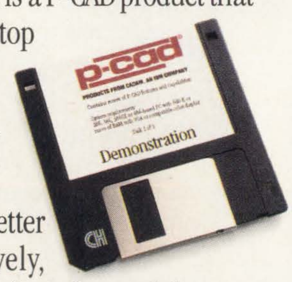
Sound PCB designs, with P-CAD® software.

Jeff Rowland Design Group creates high end audio products that are not only elegant in design, but are technically innovative as well.

The Jeff Rowland product design strategy emphasizes the control of complex field interactions and electrical geometries. And this task demands the finest PCB design software available.

P-CAD designed PCB products give Jeff Rowland engineers the speed and features they need to design minimum area layouts with custom path geometries.

P-CAD also combines an easy to use interface with end-to-end integration, so audio electronics designs can be completed and verified to support the world's most demanding product quality and performance criteria.



Now hear this. Here's how to get a free P-CAD demo.*

When it comes to designing better PCBs faster and more productively, the advantages of P-CAD are definitely worth hearing about. To take advantage of this free offer for a hands-on demonstration, just call us for the name of your nearest CADAM Value Added Reseller. If you think this offer sounds great, simply call today toll-free: **1-800-255-5710**.

CADAM®
AN IBM COMPANY

World Class PCB CAD Productivity

*Available from CADAM Value Added Resellers. Contact CADAM for details. IBM is a registered trademark of International Business Machines Corp. CADAM and MICRO CADAM are registered trademarks of CADAM INC. P-CAD is a registered trademark of Personal CAD Systems, Inc. UNIX is a registered trademark of UNIX Systems Labs, Inc. VIEWlogic is a registered trademark of Viewlogic Systems, Inc.CADAM INC, 1935 N. Buena Vista St., Burbank, CA 91504. ©1992 CADAM INC.

CIRCLE NO. 44

Coupling DRAM and bus technology yields 500-MHz burst transfers

EDITORS' CHOICE EDN

The dynamic RAM (DRAM) bottleneck in high-performance computer systems may become a thing of the past if Rambus Inc's RAMbus interface and DRAM design gains acceptance. The interface uses a 9-bit synchronous-data link between processor and DRAM memory, achieving burst data-transfer rates as great as 500 Mbytes/sec.

Physically, the interface is straightforward. It has 28 wires, of which 15 are active, 8 are ground, and 5 are power. The 15 active lines include 9 data bits, bus control and enable signals, 250-MHz transmit and receive clocks, and a voltage reference. Data transfers occur at both edges of the clock signals.

Data transfer along the interface begins with the generation of a request packet by the CPU or bus master. The packet is 6 characters long and contains a transaction code, a 36-bit memory address, and an 8-bit block length. The bus-control line serves as a start bit, signaling the other devices on the bus that a request has begun.

All memory devices on the bus monitor the bus control and data lines, but respond only if the request falls within their address space. The addressed device must respond within 36 nsec either with an acknowledge code, indicating that it can handle the request, or with a negative-acknowledge code, if it cannot handle the request. If the response is negative, the bus master will re-issue the request until it receives an acknowledge.

The timing differs for read and write data transfers. When reading, the bus master will begin receiving data 36 nsec after the request packet ends. When writing, the bus master can begin supplying data 4 nsec after the request packet ends. During a write transfer, therefore, the memory's response arrives after data transfer has begun. If the response is negative, the bus master simply aborts the transfer and reissues the request.

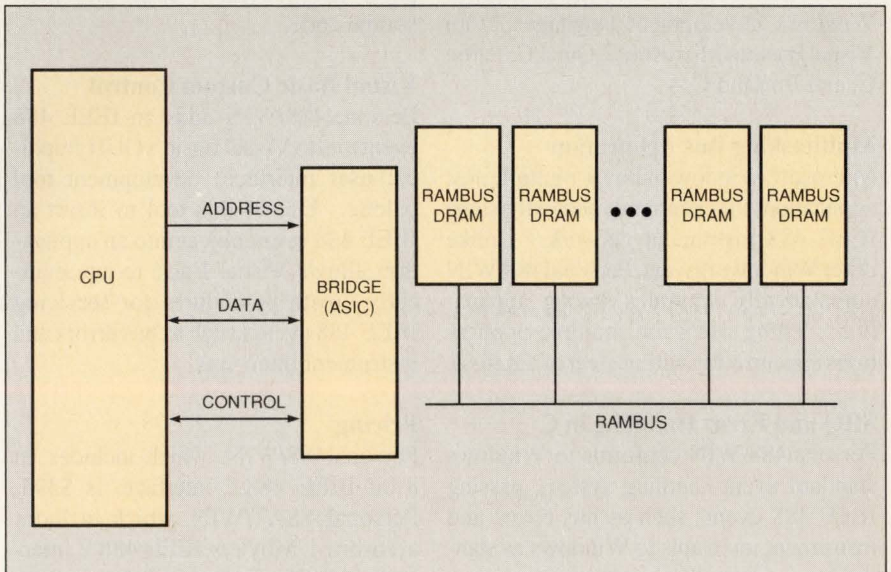
To be able to transfer data on both edges of the 250-MHz clocks, the interface must have carefully controlled electrical characteristics. The interface uses a variety of techniques so that you don't have to work too hard to use RAMbus-based devices.

To begin with, the interface's mechanical details are completely defined, including specifications for circuit-board trace widths and lengths and component layout. The interface's capacity is limited to 32 memory devices. RAMbus-based devices must connect in a straight line, with the bus master at one end of the circuit.

To minimize clock-to-data skew, the 250-MHz receive clock enters the circuit at the end away from the bus master so that it propagates toward the bus master alongside the data that it clocks. The transmit clock is simply the receive clock looped back at the bus master, so that the master's data and the transmit clock propagate together to the memory devices.

To achieve the 500-MHz data clocking rate with currently available DRAM technology, the interface's output signal swing is restricted. Signals on the interface swing ±300 mV about a nominal 2V reference voltage. That reference voltage is included in the interface's 15 active signals so that all devices on the bus work from the same standard.

A memory subsystem built on the RAMbus interface possesses a num-



By utilizing small signal swings and by having the clocks and data signals propagate together, the RAMbus interface achieves burst transfer rates of 500 MHz. The RAMbus DRAMs use their sense amplifiers to provide two 1k × 9-bit internal caches.

ber of unique characteristics. For one, the DRAMs have the same pinout and behavior regardless of their size, so you don't need to change your circuit board in order to upgrade to higher-density devices as they become available.

Another characteristic of the subsystem is the caching nature of the RAMbus DRAMs. When accessed, the RAMbus DRAM uses part of the address to activate one 1-kword row of its internal array and caches the data in its sense amplifiers. You can cache two rows simultaneously. The remainder of the address selects which words get transferred over the serial data link. The first access to a row takes between 160 and 210 nsec. If the new access uses the same row, a read hit, the RAMbus DRAM can begin sending data within 36 nsec of the request.

When not being accessed, the RAMbus DRAM retains its cached data. A memory subsystem composed of several devices, then, has multiple independent caches active. The larger your memory array becomes, the more cache lines you have active and the greater the chance for a read hit.

The company does not produce ICs itself. Instead, it licenses its technology and provides design support to semiconductor vendors and ASIC foundries. The company already has several licensees, including Fujitsu, Toshiba, and NEC. Initial products from these companies, to be released this year, will include 512k × 9-bit RAMbus DRAMs and an ASIC that connects the RAMbus to a conventional μP.—**Richard A Quinnell**

Rambus Inc, 2465 Latham St, Mountain View, CA 94040. Phone (415) 903-3800. FAX (415) 965-1528. **Circle No. 730**

Modular unit combines functions of pulse and word generators

When selecting signal sources to stimulate digital systems or ICs—to verify system design or to perform production tests—EEs have had to choose between word and pulse generators. Word generators (data generators) provide wide data from many channels, each backed with pattern memory. However, most such generators allow little, if any, control over parameters such as edge placement, transition times, and pulse width. For precise control of signal characteristics, EEs have preferred pulse generators. But most pulse generators have few channels and, at best, offer limited pattern memory. Not only do Tektronix's HFS 9000-series modular Data Time Generators eliminate the need to choose, but they also cost less and are easier to use than a set of separate word and pulse generators.

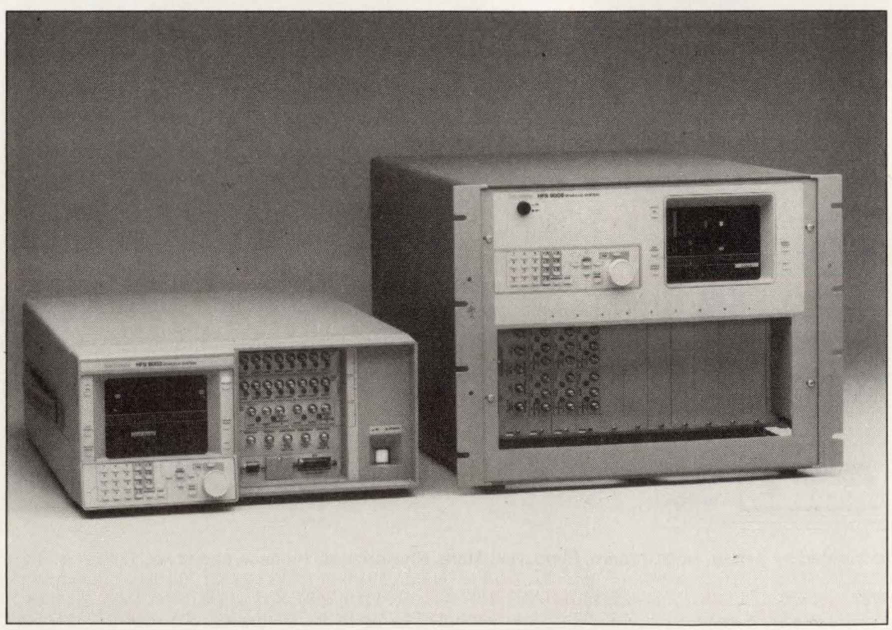
A $28,495 8-channel configuration of the Data Time Generator replaces a collection of word and pulse generators that cost three times as much and occupy many times the 7 in. of rack space used by the small Data Time Generator setup. According to the generator's manufacturer, this comparison doesn't involve choosing a particularly costly group of older instruments, and it doesn't reveal the dramatic reduction in setup time the new generators make possible (minutes vs days).

The user interface, based on a touch-sensitive monochrome CRT that displays timing diagrams and menus, is only part of the reason for the rapid setup. The major reason is a new architecture: The generators are not merely an amalgamation of classical word and pulse generators. Tektronix has replaced nearly all of the analog functions of a pulse generator with the digital equivalents. Eliminating the analog circuits reduces interactions among controls. For example, there is no baseline shift when a pulse approaches 100% duty cycle. Among the benefits of the new architecture is the generator's ability to precisely and repeatedly simulate metastable states, which is a difficult feat for most pulse generators.

The Data Time Generators produce signals at rates to 630 Mbits/sec/channel. Behind each channel is 64 kbits of pattern memory. You specify the data format, for example NRZ (non-return-to-zero), on a per-channel basis. Similarly, you specify the placement of pulse edges within a clock period on a per-channel basis, and you can specify pulses wider than one clock period. The edge-position resolution, a minuscule 5 psec, allows precise deskewing of the multiple-channel outputs without resorting to techniques such as precise matching of cables' electrical lengths.

The modular system includes two generator units. An $11,000 4-channel plug-in offers fixed rise and fall times of less than 250 psec. A $7900 4-channel plug-in provides transition times that you can vary from 800 psec to 6 nsec. Tektronix offers two mainframes: a 3-slot (12-channel) unit that costs $12,695, and a 9-slot (36-channel) unit priced at $19,995. By using several mainframes, you can put together larger configurations having 640 or more channels. Delivery is 8 to 12 weeks, ARO.—**Dan Strassberg**

Tektronix Inc, Box 1520, Pittsfield, MA 01202. Phone (800) 426-2200. **Circle No. 733**



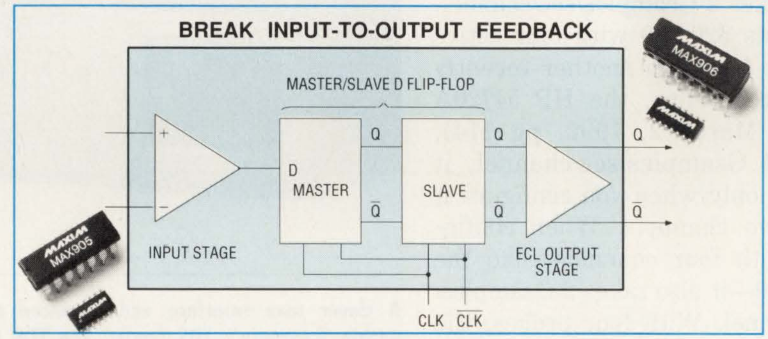
You can configure a combination word and pulse-generator from HFS 9000-series modules. Unlike systems built from classic word and pulse generators, which often provide full pulse-parameter control on only a few channels, these new instruments provide full parametric control—including 5-psec-resolution edge placement—on all channels.

2ns COMPARATORS RESOLVE 3mV SIGNALS WITH NO OSCILLATION

Propagation Delay Independent of Overdrive

Maxim's new MAX905/MAX906 are the first ultra high-speed, precision, single and dual ECL comparators to eliminate oscillation caused by unwanted parasitic feedback. Unlike other ECL comparators, the master/slave architecture resolves input voltages as small as 3mV over its common-mode range, and propagation delay is independent of input overdrive. No dispersion!* This eliminates synchronization problems common with industry standard comparators.

- ♦ **Immune to Oscillation**
- ♦ **2ns Propagation Delay**
- ♦ **Single or Dual Supply Operation**
- ♦ **7.9V Input Voltage Range Includes Negative Rail**



Master/slave D-flip/flop prevents oscillation and resolves signals as low as 3mV.

Incomparable ECL Comparators For Your Application!

	Device	Description	Comparators per Pkg.	Prop Delay (ns)	No Dispersion*	3mV Resolution	Input Range Includes Neg. Rail
NEW	**MAX905**	**Edge-triggered master/slave architecture**	**1**	**2.0**	✔	✔	✔
NEW	**MAX906**	**Dual MAX905**	**2**	**2.0**	✔	✔	✔
	MAX9685	Higher-speed Industry Standard†	1	1.3			
	MAX9687	Dual Higher-speed Industry Standard†	2	1.4			
	MAX9690	Available in 8-pin DIP/SO	1	1.3			

*Dispersion is the change in propagation delay from 3mV to 1V input overdrive. †TTL also available.

FREE Video Products Guide

Includes: Application Notes ♦ Data Sheets ♦ Cards For Free Samples

To receive your design guide, circle the response number, or contact Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086, (408) 737-7600, FAX (408) 737-7194.

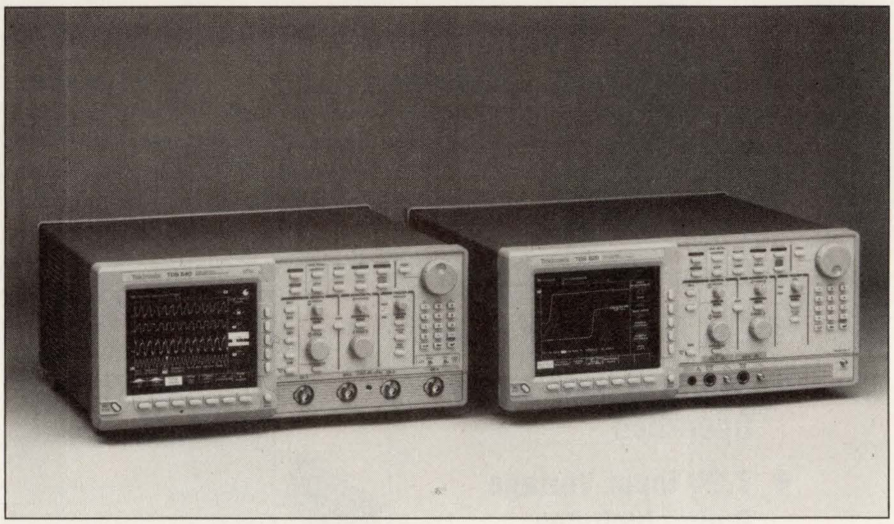
MAXIM

Distributed by Arrow, Bell/Graham, Elmo, Hall-Mark, Nu Horizons, Pioneer, and Wyle. Authorized Maxim Representatives: Alabama, (205) 830-0498; Arizona, (602) 730-8093; California, (408) 248-5300, (619) 278-8021, (714) 261-2123; (818) 704-1655; Colorado (303) 779-8060; Connecticut, (203) 384-1112; Delaware, (609) 778-5353; Florida, (305) 426-4601, (407) 830-8444; Georgia, (404) 447-6124; Idaho, (503) 292-8840; Illinois, (708) 358-6622; Indiana, (317) 844-8462; Iowa, (319) 393-2232; Kansas, (816) 436-6445; Louisiana, (214) 234-8438; Maryland, (301) 644-5700; Massachusetts, (617) 329-3454; Michigan, (313) 352-5454; Minnesota, (612) 941-9790; Mississippi, (205) 830-0498; Missouri, (314) 839-0033, (816) 436-6445; Montana, (503) 292-8840; Nebraska, (816) 436-6445; Nevada, (408) 248-5300; New Hampshire, (617) 329-3454; New Jersey, (516) 351-1000, (609) 778-5353; New Mexico, (602) 730-8093; New York, (516) 351-1000, (607) 754-2171; N. Carolina, (919) 851-0010; Ohio, (216) 659-9224, (513) 278-0714, (614) 895-1447; Oklahoma, (214) 234-8438; Oregon, (503) 292-8840; E. Pennsylvania, (609) 778-5353; W. Pennsylvania, (614) 895-1447; S. Carolina, (919) 851-0010; Tennessee, (404) 447-6124; Texas, (214) 234-8438, (713) 782-4144, (512) 346-9186; Utah, (801) 561-5099; Virginia, (301) 644-5700; Washington, (206) 823-9535; W. Virginia, (513) 278-0714; Wisconsin, (414) 476-2790; Canada, (416) 238-0366, (613) 225-5161, (604) 439-1373, (514) 337-7540.

CIRCLE NO. 71

$20,980 DSO takes 2 Gsamples/sec on four channels simultaneously

With recent introductions from several vendors, digital storage oscilloscopes (DSOs) that sample transient phenomena in real time have gotten faster than ever. Now they have also become more affordable. Tektronix's TDS 640 has four channels, takes 2 Gsamples/sec/channel, and costs $20,980 with four active probes. Although another recently announced scope, the HP 54720A (*EDN*, March 2, 1992, pg 114), takes 4 Gsamples/sec/channel, it does so only when you configure it with two channels. When configured with four channels—like the TDS 460—it also takes 2 Gsamples/sec/channel. With four probes, the HP unit's price exceeds $50,000.



A clever user interface and advanced triggering features characterize two new series within Tektronix's TDS family. The TDS 620 and 640 (left) take 2 Gsamples/sec in real time on each of two or four channels, respectively. The TDS 820 (right) is a 2-channel sequential-sampling digital scope with 6-GHz bandwidth and the ability to display pretrigger data (8-GHz bandwidth optional).

The TDS 640's display is high-resolution monochrome; the 54720A's is color. The 54720A has a plug-in architecture, a waveform memory exceeding 30 ksamples, and a built-in disk drive; the TDS 640 doesn't include a disk drive, stores 2 ksamples/channel, and comes in a fixed 4-channel configuration. (A 2-channel version, the TDS 620, costs $13,540 with two probes.) Both the TDS 620 and TDS 640 have a 0.5-GHz bandwidth for transient and repetitive phenomena. They do not use techniques to enhance their effective sampling rate when they acquire high-speed repetitive waveforms; the HP scope does use such techniques, and its repetitive-signal bandwidth is 1.5 GHz.

Only you can decide whether, for your application, the difference in features justifies the 54720A's higher price. Of course, if you require single-shot bandwidth of "only" 250-MHz (with simultaneous 1 Gsample/sec real-time acquisition on four channels), you can find at least one other DSO at a price somewhat lower than that of the TDS 640. (Both the TDS 620 and 640 offer the option of deleting the active probes to reduce their prices by $495 per channel in applications that don't require probes.)

Tektronix has also introduced the TDS 820, a 2-channel sequential-sampling digital scope that has 6-GHz repetitive-signal bandwidth (8 GHz optional) and 14-bit resolution. Sampling scopes, several of which offer bandwidths in the tens of gigahertz, have acquired a reputation as finicky beasts—ones you use only if you really need their exceptional bandwidth. The vendor's intent with the TDS 820 is to provide very high bandwidth and very high sensitivity (2 mV/div max; 1 mV/div in the 8-GHz version) in an attractively priced, easy-to-use scope. Like all members of the TDS series, the 820 offers a menu-driven interface based on both words and icons and extremely flexible triggering.

A TDS 820 feature that is unusual in sequential-sampling scopes is a delay line (not available in the 8-GHz-bandwidth version) that lets you view pretrigger information. Most sequential-sampling scopes can't display pretrigger information. In scopes that offer equivalent-time sampling, pretrigger displays are normally found only in units that use random repetitive sampling, a technique that doesn't provide the bandwidth of sequential sampling.

The TDS 820's price is $19,100; delivery is eight weeks ARO. Delivery for the TDS 620 and TDS 640 is six weeks ARO.—**Dan Strassberg**

Tektronix Inc, Box 1520, Pittsfield, MA 01202. Phone (800) 426-2200. **Circle No. 731**

Streaming-data protocol extends IEEE-488 standard to 5 Mbytes/sec

Over the past 15 years, the IEEE-488 communications protocol has become a true standard in instrumentation. Except for handheld, battery-powered units, a majority of modern instruments offer an IEEE-488 port—at least as an option. But the protocol has become a bit long in the tooth; it isn't very efficient for instruments that send or receive large blocks of data. Without obsoleting existing instruments, Capital Equipment Corp (CEC) has developed an extension to the standard, called 488SD, where SD stands for "streaming data." (Note that the IEEE has not yet made this extended protocol a standard.)

Hardware support for 488SD exists only in CEC's $495 488EX IEEE-488 interface board and in a similar board from Keithley Metrabyte (Taunton, MA). These boards, designed for the 16-bit ISA bus, also work in half-length and 8-bit slots. CEC is betting that vendors of instruments that require or produce large blocks of data, such as arbitrary-waveform generators and digitizers, will want to speed up their products' operation by implementing this protocol.

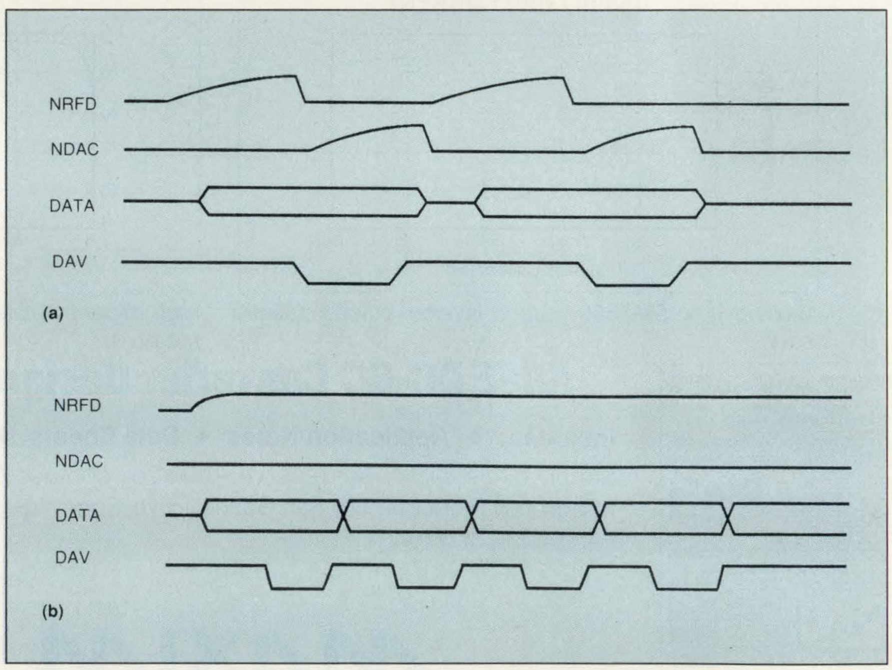
The 488SD standard actually transcends IEEE-488. One of the goals of the VXIbus modular-instrumentation standard is to achieve much faster data transfer than is possible using IEEE-488. So far, though, most users of VXI have not been able to realize that goal. Using VXI's register-based and shared-memory protocols requires tackling software issues that few users have dealt with. The alternative—treating VXI as if it were IEEE-488, that is, using VXI's message-based (word-serial) protocol—is the approach most VXI users take. Because it's compatible with VXI, 488SD could enable VXI systems to achieve their speed potential without incurring major software hassles.

Moreover, the popular method of building systems that combine VXI and IEEE-488 instruments is to make a VXI mainframe an IEEE-488 device. In such mixed systems, the streaming protocol promises faster communication with cages full of VXI modules.

Equally important is the protocol's potential to head off "destandardization" in rack-and-stack instrumentation. Because of IEEE-488's throughput limitations, some vendors of instruments that require high transfer rates offer alternative interfaces such as SCSI ports. Clearly, though, staying with a single interface for communication between computers and instruments contains system-hardware costs and simplifies software.

When an interface that supports the SD protocol tries to initiate a streaming interchange with an instrument that lacks SD support, an instrument that conforms to IEEE-488.2 will tell the interface that it doesn't support the transaction. This function even occurs with older instruments designed before this protocol existed.

You can expect that instruments offering 488SD support will continue to allow word-at-a-time trans-



Under the existing standard, (a), when a listener makes NRFD (not ready for data) false, a talker can send one byte. The listener then makes NDAC (not data accepted) false. Each time NRFD or NDAC becomes false, you must wait for the driver circuit to charge the bus capacitance. Under the streaming-data protocol, (b), after NRFD becomes false, a talker can send an unlimited number of bytes. In some circumstances, the result is a 5-fold speed increase over the best IEEE-488 data-transfer rates currently possible. (Note: DAV = data valid.)

Use our low power, low voltage memory and buy more time.

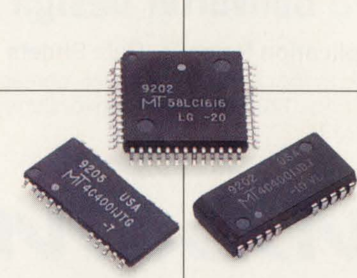
If you design battery operated systems such as laptop and notebook computers, Micron's low power, low voltage memory components can buy you more time.

Micron's extensive line of leading edge, low power, low voltage DRAMs and SRAMs are designed to give you optimum 3.3 volt operation in battery powered systems, extending battery life and system operating time. Since the parts run cooler, they also increase system reliability. And we offer the latest packaging technologies such as TSOP and PQFP.

So call Micron today at 208-368-3900. And find out how to buy more time.

Micron. Technology that works for you.

Part Number	Memory Configuration	Availability
3.3 Volt, Low Power, Extended Refresh DRAMs		
MT4C4001J VL	1 Meg x 4	3Q92
MT4LC4001 S*	1 Meg x 4	4Q92
MT4LC4001 L	1 Meg x 4	4Q92
MT4C4256 VL	256K x 4	Now
5 Volt, Low Power, Extended Refresh DRAMs		
MT4C1004J L	4 Meg x 1	Now
MT4C4001J L	1 Meg x 4	Now
MT4C8512 L	512K x 8	3Q92
MT4C16256 L	256K x 16 DW[1]	3Q92
MT4C16257 L	256K x 16 DC[2]	3Q92
MT4C1024 L	1 Meg x 1	Now
MT4C4256 L	256K x 4	Now
MT4C1664 L	64K x 16 FPM[3]	Now
MT4C1670 L	64K x 16 SC[4]	Now



Part Number		Memory Configuration	Availability
3.3 Volt, Low Power Specialty SRAMs			
MT5LC2818	Latched	16K x 18	Now
MT58LC1618	Synchronous	16K x 18	Now
MT5LC2516	Latched	16K x 16	Now
MT58LC1616	Synchronous	16K x 16	Now
5 Volt, Low Power, Low Voltage Data Retention SRAMs			
MT5C1001 LP		1 Meg x 1	Now
MT5C1005 LP		256K x 4	Now
MT5C1008 LP		128K x 8	Now
MT5C2561 LP		256K x 1	Now
MT5C2564 LP		64K x 4	Now
MT5C2565 LP		64K x 4 $\overline{OE}$[5]	Now
MT5C2568 LP		32K x 8	Now

*Self Refresh [1]DW– Dual Write Enable [2]DC– Dual $\overline{CAS}$ [3]FPM– Fast Page Mode [4]SC– Static Column [5]$\overline{OE}$– Output Enable

MICRON
TECHNOLOGY, INC.

2805 E. Columbia Rd., Boise, ID 83706 (208) 368-3900
Customer Comment Lines: U.S. 800-932-4992; Intl: 01-208-368-3410

CIRCLE NO. 51

fers. Thus there won't be compatibility problems between newer instruments and older interfaces, although achieving streaming speeds requires support by both instruments and interfaces.

The protocol's simplicity ensures freedom from constraints on the depth of a device's memory. At any time during a streaming transfer, a device can stop the transfer by asserting the NRFD (not ready for data) signal. If your test system contains a device whose output needs checking at some minimum rate, you need not worry about streaming transfers that cause you to miss critical data. You can set up the system's software to limit the duration of the streaming transfers, allowing you to check the critical device.

The best throughput will occur if you don't interrupt streaming transfers. CEC claims that with a 1m-long cable, you can achieve transfer rates of 5 Mbytes/sec, which is 5× greater than the best performance claimed by other vendors for standard IEEE-488. With a cable 10m long, the transfer rate is 2.5 Mbytes/sec.

An indexed manual describing 488SD—with state and timing diagrams and signal definitions—is free of charge. CEC will update this manual as the protocol evolves. The 488EX board includes a universal software driver for languages that support file I/O, a software analyzer that detects and suggests corrections to programming errors, a library of sample programs, and a programming and applications manual.—**Dan Strassberg**

Capital Equipment Corp, 76 Blanchard Rd, Burlington, MA 01803. Phone (617) 273-1818. FAX (617) 273-9057. **Circle No. 732**

24-bit DSP processor runs at 40 MHz

DSP processor clock rates are climbing. Motorola's 56002 is the second generation of the 24-bit, fixed-point 56001. The 56002 runs to 40 MHz, whereas the 56001 topped out at 33 MHz; this speed increase yields an improved performance of more than 20%. The 56002 peaks at 20 MIPS and 120 million operations/sec: it performs a MAC (24-bit add and multiply, result to 56-bit accumulator) with X and Y data transfers.

The 56001/2 is the only 24-bit, fixed-point DSP processor currently available. It provides higher accuracy and performance than basic 16-bit DSPs, without the larger memory of a 32-bit fixed- or floating-point DSP.

The 56002 incorporates the 56001's core and peripherals. However, the 56002 uses Motorola's universal-design-rule technology, which enables designs to move from process to process easily. The current implementation is on 1.0-μm CMOS but eventually will be moved to 0.8-μm CMOS. The design is fully static with clocks to dc frequencies. The PLL is programmable with a clock multiple to 4096.

Motorola added on-chip-emulation features of the 32-bit 96002 to the 24-bit DSP. Using on-chip emulation, designers can debug their application code, controlling the DSP processor via a 6-wire serial interface. Thus, engineers can opt to start and stop the processor, set breakpoints, and monitor and change memory and register values. Breakpoints trigger on program or data access, either addresses or address ranges. On-chip-emulation features include a breakpoint or pass counter to trigger a breakpoint on the *n*th compare iteration; the features also furnish a trace counter, specifying the number of instructions to be executed for each trace step.—**Ray Weiss**

Motorola Inc, Microprocessor and Memory Technologies Group, 6501 William Cannon Dr W, Austin, TX 78735. Phone (512) 891-2000. FAX (512) 891-2652.

Circle No. 713

56002 DSP processor

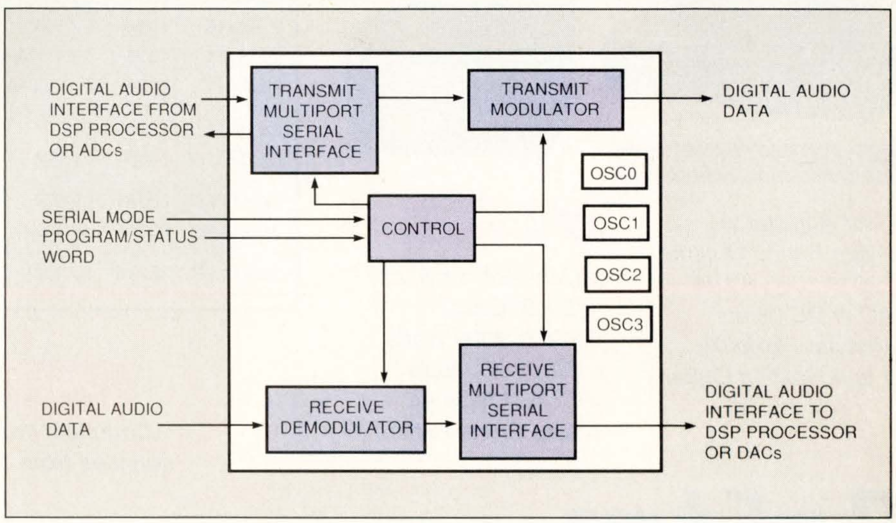
Clock	to 40 MHz internal (PLL input, to 4096×)
Instruction cycle	2 clock cycles, 50 nsec
Registers	2 24-bit; 2 56-bit accumulator
Address space	3 64-kbyte×16 bit: program, X, Y
On-chip memory	512×24-bit ROM (Instruction) 2 256×24-bit RAM 2 256×24-bit ROM
Arithmetic	56-bit ALU (24-bit logic) 48-bit multiply (24×24)
Interrupt	3 external interrupts
I/O	24 pins
Serial	asynchronous serial interface synchronous serial interface A/D, D/A, AES/EBU
Other	automatic loop control, on-chip emulation, host and DMA interfaces
Package types	132-pin pin-grid array or plastic quad flatpack
Price	\$79 (sample qty)

Chip links DAT devices and DSP μPs

Digital audio brings the ease and interchangeability of today's plug-in audio jacks. Motorola's single-chip digital audio chip, the DSP56401, links DAT (digital audio tape) devices to DSP processors. The chip acts as a transceiver to multiple digital-audio devices, linking them directly to DSP56001/2 DSP processors.

The device meets the AES/EBU and EIAJ CP-340 digital-audio standards. It takes in unidirectional, self-clocked, stereo digital-audio formats in a single serial channel. It acts as a DAT transmitter and receiver and contains a transmit serial interface, transmit demodulator, receive demodulator and a receive serial interface with a common clock generator. The transmit and receive serial interfaces can be clocked independently if needed. The hardware implements preamble detection and synchronization, parity and CRC checks, and block and frame synchronization.

A phase-locked loop (PLL) detects and recovers the bit clock from the modulated serial input. For



With this single-chip digital-audio transmitter/receiver, you can link DAT devices to DSP processors, ADCs, and DACs.

SPEC THE BEST!
LOW PROFILE / LOW COST
SWITCHING POWER SUPPLIES

- Compact: 2" to 3" High
- 250 to 1000 Watts
- 1 to 9 Outputs
- 2V to 56V Outputs
- Auto AC Line Selection
- New -- Three Year Warranty

Spec Qualidyne -- and expect to satisfy your tightest requirements. Each power supply includes a robust main and up to eight high current, floating DC outputs. Wide user-adjustable output ranges, power fail signal, auto AC line select, DC input, integral DC ball-bearing fan, margining, inhibit, and 0.99 PFC are among the features and available options.

Meets IEC 555-2

0.99 Power Factor Option

AC to DC Switchers

DC to DC Converters

BABT

Standard Models-1, 3, 4, or 5 outputs *(Partial Listing)*

Size (HxWxL)	Total Watts	Output 1	Output 2	Output 3	Output 4	Output 5
		Output Voltage Range/Max. Amps				
2x4.5x9"	250W	5V/30A	12-15V/10A	12-24V/2A	2-6V/3A	
2x4.5x9"	250W	5V/30A	12-15V/10A	12-15V/3A	5-15V/3A	
2.5x5x10"	400W	5V/50A	12-15V/15A	12-24V/3.5A	5-15V/6A	
2.5x5x10"	400W	5V/50A	12-15V/15A	12-24V/3.5A	2-6V/6A	
2.5x5x11"	400W	2-6V/60A	5-15V/12A	5-15V/12A	2-6V/12A	
2.5x5x11"	400W	5-15V/24A	5-15V/12A	5-15V/12A	2-6V/12A	
2.5x5x11.5"	500W	5V/70A	12-15V/15A	12-24V/3.5A	5-15V/6A	
2.5x5x11.5"	500W	5V/70A	12-15V/15A	12-24V/3.5A	2-6V/6A	
3x5x14.25"	600W	5V/80A	5-24V/10A	5-24V/10A	5-24V/5A	5-24V/5A
3x5x14.25"	600W	5V/100A	5-24V/10A	5-24V/5A	5-24V/5A	
3x8x14.25"	1000W	5V/150A	5-15V/20A	5-15V/10A	5-15V/10A	5-24V/10A

User Configurable

- User-Adjustable Wide Range Outputs
- 200 to 1000 Watts
- AC or DC Inputs
- Modular Flexibility
- 1 to 9 Floating Outputs

High Power

- Compact: 5 x 5" or 5 x 8" Cases
- 750 to 3000 Watts
- AC or DC Inputs
- 1 or 3-Phase AC
- Auto Current Share (N + 1)

FREE CATALOG

Complete line of quality power supplies from 100 to 3000 Watts.

Qualidyne

Lambda Group of Unitech plc

3055 Del Sol Blvd., San Diego, CA 92154
(619) 575-1100 fax: (619) 429-1011

CIRCLE NO. 88

transmission, a modulator state machine generates the preambles, parity, and CRC data incorporated in the transmitted frame with audio and nonaudio data. DAT transmission uses the LSB-first, biphase-mark Manchester decoding for transmission and receive. Multiple DAT devices interface to a single DSP56401. Combined with the DSP56001/2, it provides two chips for processing DAT applications.

In addition, the chip interfaces directly to Motorola D/A and A/D converters. The chip includes four oscillators and a jitter clock recovery system.

The DSP56401 comes in a 64-pin plastic quad flatpack and costs $25 (sample qty). An evaluation board is available from Spectrum Signal Processing Inc (Burnaby, BC, Canada). This 5×5.75-in., 4-layer board includes DAT input/output ports as well as ports to the DSP56001/2 and to audio converters such as those made by Burr-Brown. Audio connectors for AES/EBU optical lines, balanced-line XLR connectors, and unbalanced RCA connectors are also available.—**Ray Weiss**

Motorola Inc, Microprocessor and Memory Technologies Group, 6501 William Cannon Dr W, Austin, TX 78735. Phone (512) 891-2000. **Circle No. 714**

80C51 family hits 33-MHz clock rates

Memory costs—especially for high speed parts—are a major limiting factor for embedded systems. Signetics has raised 8051 clock rates to an unprecedented 33 MHz and held down memory access time, keeping memory costs down as well. Other 8051 vendors such as Matra MHS and Siemens are supplying 30-MHz parts.

Two 80C51 family members, the 80C51 and 80C52, run at rates to 33 MHz but require only a 90-nsec memory access time for external memory. As designers moved clock rates out, they recharacterized the parts, reducing interface requirements and gradually improving process upgrades.

The 8051 architecture is designed for both single-chip and external-memory applications. An 8051 supports a single 64-kbyte external address space or two 64-kbyte address spaces: one for instructions and one for data. External references are slower than referencing internal RAM; they must go through the accumulator and take extra cycles. The 80C51 and 80C52 differ in their amounts of scratchpad RAM and on-chip ROM: The 80C52 doubles 80C51 RAM and ROM to 256 bytes of RAM and 8 kbytes of ROM.

An 8051 takes 12 external clocks (6 internal clocks) for an instruction cycle, which includes an instruction and a potential data fetch. At 33 MHz, a base instruction takes 360 nsec. The instruction access time for external memory is specified at 90 nsec, which under previous specs would have been 60 nsec.

Recharacterized 80C51 timing results in memory access times that are lower across the entire line: a 24-MHz 8xC51 now uses a 120-nsec memory, compared with 90 nsec previously required.—**Ray Weiss**

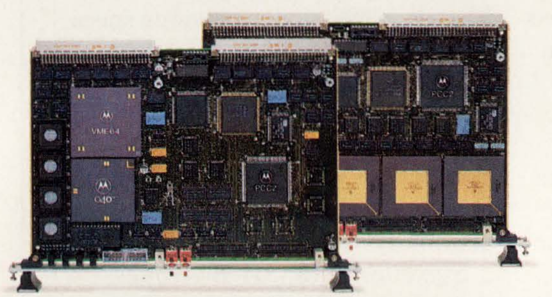
Signetics Corp, 811 E Arques Ave, Sunnyvale, CA 94088. Phone (408) 991-2000. FAX (408) 991-2311. **Circle No. 715**

The 80C51/52 family

Clock	3.5 to 33 MHz
Instruction cycle	12 clocks
Memory	128- to 256-byte scratchpad, 4- or 8-kbyte 64-kbyte instruction address space 64-kbyte data address space
Timers	2/3 16-bit timers
I/Os	Four ports: 32 lines
Interrupts	2 external
Package types	40-pin DIP, LCC, 44-pin quad flatpack
Price	$3.50 (10,000); $17.50 for one-time-programmable version (1000)

Some people think we're power crazy, obsessed with quality and downright cheap.

And it's all true.



Okay, we admit it. We're hopeless perfectionists. Driven to produce the best boards at the best price.

Take our new MVME187 and MVME167 single board computers, for instance. Best in performance at 38 MIPS* (RISC) and 26 MIPS* (CISC), respectively. Best in value at $105 (RISC) and $154 (CISC) per MIPS.

Which comes out to just $3,995 per board. And which compares rather nicely with the $8,000 to $12,000 you could pay for the competition's boards. Based on the 88100 and 68040, Motorola's highest performance 32-bit microprocessors, the MVME187 and MVME167 employ VME D64 architecture. Boosting the VMEbus bandwidth to a full 40MB/s. And both boards come with four 32-bit timers, as well as SCSI and Ethernet connections.

Naturally, since they're made by Motorola, you can expect the best in quality. The Malcolm Baldrige Award is a powerful testament to that fact.

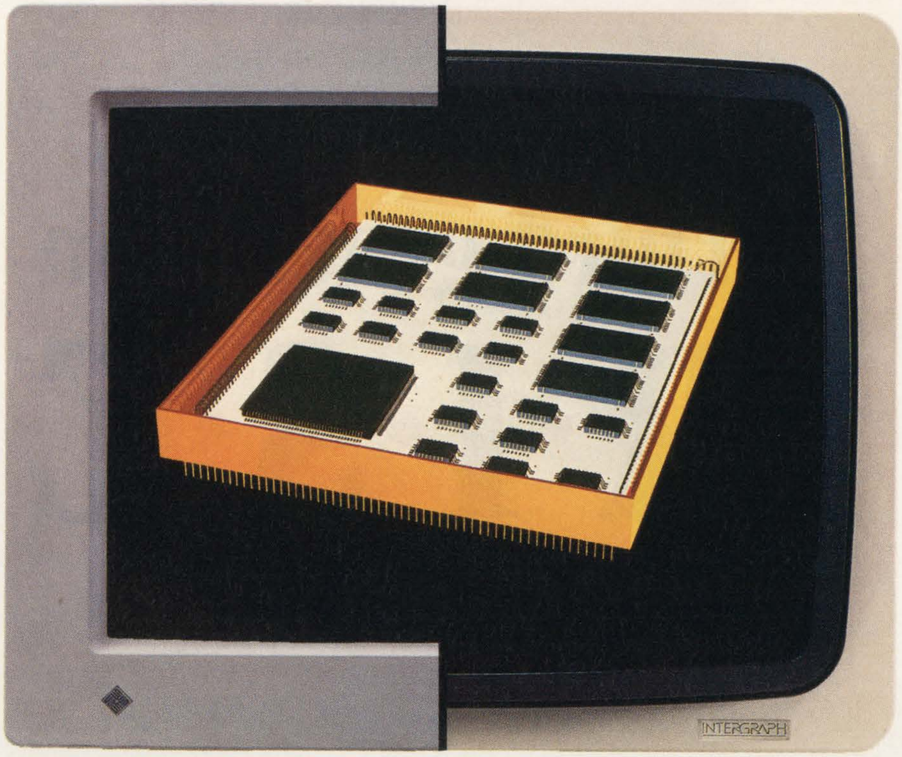
Malcolm Baldrige National Quality Award

So call 1-800-234-4VME for a free color brochure. And see why so many people are obsessed with Motorola products.

MOTOROLA

Computer Group

For a free color brochure, call 1-800-234-4VME.



INTERGRAPH

Third-generation R·I·S·C processors

Ray Weiss, Technical Editor

Third-generation RISC processors are moving into the technical world spurred by rising chip densities and higher clock rates. RISC (reduced-instruction-set computer) microprocessors delivering 50 to 100 VAX MIPS are here now; others will be available within the next six months.

Mainframe and supercomputer design techniques are pushing the performance of third-generation RISC processors to 70 VAX MIPS and beyond. These processors issue as many as three instructions per clock cycle and have clock rates ranging from 50 to 200 MHz.

First-generation RISC processors—the IBM 801, the Berkeley SPARC, and the Stanford MIPS—were research projects that laid the groundwork for the second generation. Second-generation RISC processors operate at 25 to 60 VAX MIPS. They have a single instruction pipeline, which lets them execute multiple instruction in sequence at one time. These processors issue one instruction per cycle but complete one instruction every 1.2 to 1.6 clock cycles. The problems that prevent these chips from completing the ideal of one instruction every cycle include data dependencies, register conflicts, instruction- and data-cache misses, and the occurrence of branch instructions.

Two design techniques are enabling third-generation RISC chips to crash through the performance barriers of the second generation. Superpipelining is the treating of pipeline stages as miniature pipelines. Thus, the stages can start executing a second instruction before finishing the first, which speeds the performance of the processor as a whole. Superscalar RISC processors have two or more instruction pipelines running in parallel, which quickly increases instruction throughput.

However, superpipelined and superscalar architectures have their own set of problems. For example, the branch-related problem of second-generation chips are even worse for the third generation. And, third-generation chips require more-complex control logic and wider instruction bandwidths. The superpipelined and superscalar architectures came from the world of mainframe and supercomputer designers, as do two techniques for easing third-generation chip problems: register scoreboarding and register renaming.

Every major RISC chip design is moving to either superpipelining or superscalar implementations to break out of the performance limitations of second-generation RISC processors. The Mips Computer Systems R4000, Sun SPARC, Motorola 88110, Intergraph Clipper, IBM RS/6000, Intel i960 and i860, National Semiconductor 32SF641, SGS-Thomson T9000

Manufacturers are speeding RISC microprocessors' instruction throughput by using superpipelined and superscalar architectures. (Photo courtesy Mips Computer Systems Inc)

Transputer, and Digital Equipment Corp Alpha are all part of this next-generation of processing power.

RISC processors are pipelined so multiple instructions can execute in sequence at one time. A pipeline is a series of stages; each stage performs one of the micro-operations that make up an instruction. These micro-operations include instruction fetch, instruction decode, operand fetch, operation execution, and result writeback. The ideal is to have a balanced pipeline in which all stages take the same number of clock cycles to execute. Pipelining isn't new; IBM introduced the technique in its 7030 Stretch computer in 1960.

With careful hardware design, a pipeline that has n stages can concurrently execute n sequential instructions: fetching the next instruction in the first stage, decoding the current instruction in the second stage, fetching the operands for the previous instruction in the third stage. . . A new instruction starts at each pipeline cycle, but the instruction latency (the time for an instruction to finish) would be n cycles.

The maximum instruction throughput of an ideal pipelined RISC chip would be 1 CPI (cycles per instruction). At each clock cycle, the CPU would issue a new instruction and finish a previous instruction. In practice, second-generation RISC processors deliver throughputs of 1.2 to 1.6 CPI.

Hang-ups and hurdles

Rocks and shoals limit RISC-processor performance. Data dependencies and resource conflicts can cause processing to stall or hang up. For example, a load instruction whose value is used by the following instruction can trigger an interlock. The second operation stalls until the data is available in the pipeline. Similarly, data dependencies—the result of one instruction being used by a following one—can cause a delay until the result is passed to the pipeline stage where it's needed.

Branches can cause worse problems, and most code has a lot of branches. In fact, branches often average as many as one every four to six instructions. The problem with pipelines and branches is self-evident: On each cycle the pipeline fetches a new instruction, but which instruction should it pick following a conditional branch? The logic executing a branch instruction may not know which is the next instruction address for one or more stages. And if the logic chooses the wrong path, it will have to flush the pipeline to remove intermediate results.

Another hurdle for RISC chips to overcome is load and store delays. RISC architectures tend to limit memory accesses to load and store instructions. The CPU manipulates data in loaded registers. Some RISC processors, however, do have complex instructions: IBM's RS/6000 features multiple loads or stores.

Loads cause delays of as many as three cycles in second-generation RISC processors. If an instruction following a load uses the loaded value, it stalls until that value is available to the pipeline. In some third-generation RISC chips, such as the Mips R4000, an instruction can't use a loaded value until the third or fourth pipeline stage. DEC's Alpha chip, for example, has a 3-cycle delay for loads.

Store instructions can also cause significant delays, especially if they need a new cache entry or write to memory. Many third-generation RISC chips buffer stores to decouple memory accesses from the CPU pipeline, thus minimizing stalls. Another way to lessen store delays is to forward the buffered store data to downstream loads so the loads won't stall while waiting for the data.

Pushing the clock

Probably the most obvious way to increase performance is to increase the base CPU clock rate, which is what RISC chip vendors have been doing. Second-generation RISC processor clock rates have peaked at 40 to 50 MHz.

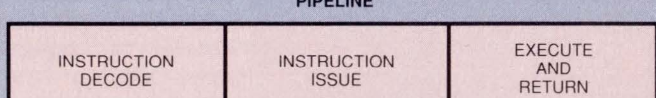
Simply pushing up the clock rates has the advantage of minimizing mi-

Intel i960CA

- 16-, 25-, 33-, 40-MHz clock
- 575,000 transistors
- 30 SPECmarks
- Superscalar, issues as many as 3 instructions per clock cycle
- 6-port 32×32-bit register file, 128/64 bit paths
- 1-kbyte 2-way set-associative instruction cache with 128-bit line size; 1.5-kbyte data/register-set cache
- 32-bit pipelined external memory interface; multiple memory regions, burst mode
- 3-stage pipeline, 2 stages for branches
- Four functional units: multiply/divide, instruction/fetch, integer, and address generation; no FPU
- Branch-prediction bit; out-of-order branch execution; speculative post-branch execution
- Pipelined store, 3-entry buffer
- Register scoreboard in scheduler
- 16-MHz version, $69.90; 33-MHz version, $107.65 (25000)

Comments: First commercial embedded RISC µP. Family targets embedded systems and data-handling chores. Military part has FPU, MMU, and 2-kbyte instruction and data caches.

PIPELINE



cro-architectural changes you'd otherwise have to make to get higher speeds. However, as internal clock rates go up, the nicely balanced, fixed-stage RISC pipeline often starts to crumble. Designers can easily speed up and even double the rate of some stages; the rates of others, such as caches, can't be increased.

One way around the speed-up difficulty is to pipeline the individual pipeline stages. Thus, a pipelined stage, such as a cache or a multiplier, could accept a new instruction

Mips Computer Systems R4000SC

- 100-MHz internal clock (50-MHz external)
- 1.1M transistors
- 70 SPECmarks
- Superpipelined architecture
- 64-bit architecture; 36-bit physical address space
- 32×64-bit integer registers, 16×64-bit floating-point registers
- Two direct-mapped 8-kbyte caches, 64-bit fetch, 16- or 32-byte line size
- PC version has 64-bit multiplexed, address/data bus; SC version has 128-bit data bus.
- Supports 128-kbyte to 4-Mbyte direct-mapped secondary cache
- Eight pipeline stages
- 3-cycle branch delay
- 2-cycle load delay
- 2-entry (64 bits each) store buffer
- Chip vendors are sampling (see manufacturers' box); prices vary from $615 to $1300, depending on version, quantity, and vendor.

Comments: Three chip versions: the low-end PC (179 pins); the SC, which supports secondary cache; and the MC, an SC that can do multiprocessing. The ISA architecture was designed by Mips; six chip vendors have signed up to produce the R4000, which is one of the ACE (Advanced Computing Environment) consortium CPUs.

PIPELINE

← CLOCK CYCLE →

INSTRUCTION FETCH	INSTRUCTION ISSUE	REGISTER FETCH	EXECUTE	DATA FETCH*	DATA STORE*	TAG CHECK	RESULT WRITEBACK	
	INSTRUCTION FETCH	INSTRUCTION ISSUE	REGISTER FETCH	EXECUTE	DATA FETCH*	DATA STORE*	TAG CHECK	RESULT WRITEBACK

*ONLY FOR LOAD OR STORE INSTRUCTIONS

RISC references

Here are five technical references to help you get up to speed on third-generation RISC microprocessor architectures:

- *Microprocessor Report* (triweekly newsletter, $445/year), 874 Gravenstein Hwy S, Suite 14, Sebastopol, CA 95472. (707) 823-4004. FAX (707) 823-0504.

Edited by Michael Slater, this periodical is an excellent source for evaluating µP and µC chips. The newsletter provides in-depth analysis for new chips and architectures. The same organization also holds the annual Microprocessor Forum, which is where most companies present their major chip designs.

- *Superscalar Microprocessor Design*, by Mike Johnson, Prentice-Hall Inc, Englewood Cliffs, NJ, 1991, $48. ISBN 0-13-875634-1.

This resource is the only technical book that completely addresses superscalar processor design. It provides a good, clear set of definitions and in-depth analysis of superscalar design techniques.

- *Computer Architectures: A Quantative Approach*, by John L Hennessy and David A Patterson, Morgan Kaufmann Publishers Inc, Palo Alto, CA, 1990, $64.95. ISBN 1-55880-069-8.

This book is rapidly becoming the computer designer's bible. Written by RISC pioneers Hennessy and Patterson, it is a textbook, a collection of design lore, and a RISC-based design example to study. This massive book contains some 700 pages of tutorial and design techniques and is an easy read as well.

- *Cache and Memory Hierarchy Design: A Performance Directed Approach*, by Steven A Przybylski, Morgan Kaufmann Publishers Inc, Palo Alto, CA, 1990, $43.95. ISBN 1-55860-136-8.

If you need the numbers to evaluate cache designs, this book is for you. It provides detailed models of cache designs that are based on actual simulation and trace data. The book breaks down memory-level design and includes models for varying cache and lines sizes, memory speed, and set size.

- *IBM Journal of Research and Development*, Vol 34, Number 1, January, 1990. IBM Corp, Armonk, NY.

This volume is a complete set of papers defining the IBM RS/6000 superscalar architecture. It provides a comprehensive system, hardware, and software view of superscalar design and implementations.

each clock cycle, even if the stage had not finished executing the current instruction. This technique is called superpipelining.

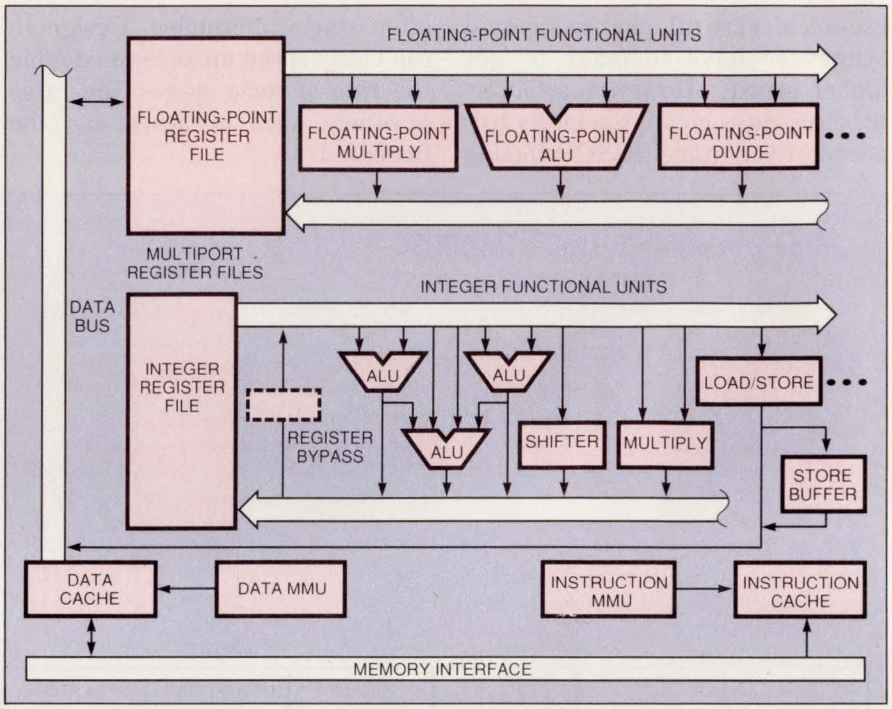
Superpipelining enables RISC designers to take advantage of higher clock speeds and still keep their basic pipeline stages. However, the technique only makes sense if the designer can raise clock rates dramatically, which is not possible every year.

Mips Computer Systems used superpipelining for its R4000. The R4000's base clock is 50 MHz, but the chip actually uses a 100-MHz internal clock. The Mips R3000's 5-stage pipeline grew to eight stages for the superpipelined R4000.

Superpipelining has its own costs. Each superpipelined pipeline stage must be latched. Functional units—logic that does one or more specific function—must be partitioned to match the basic clock rate, perhaps complicating the logic. In addition, the functional units' pipelined stages need their own level of control. Most new and emerging RISC processors include pipelined functional units. Intel's i860, introduced in 1989, has pipelined floating-point add, multiply, and graphics units, as does the IBM RS/6000's FPU (floating-point unit).

Another way to increase processor performance is to do more than one operation at a time. Superscalar RISC processors can issue, and ideally execute, more than one scalar instruction per clock cycle. In effect, such processors run multiple pipelines in parallel.

One of the benefits of using superscalar techniques is that designers can increase performance without necessarily raising clock rates. Typically, higher clock rates open up new difficulties in interfacing the CPU to the lower memory levels, such as main memory and disk storage. These memory media do not move as rapidly up the speed curve as processor silicon. So the faster



One way to get superscalar performance—a processor's issuing more than one instruction per cycle—is to have multiple functional units executing in parallel. You can even cascade functional units, as shown by the two parallel adders feeding a third adder their results.

a CPU goes, the larger the speed gap between the CPU and the various memory levels.

Thus, increased delays in memory and store accesses for cache misses and page faults can nibble away performance increases realized from faster clocks. One reason for the increasing use of secondary caches is that these caches provide a buffer layer between the high-speed on-chip caches and the slower system memories.

Superscalar techniques let you have your cake and eat it, too: You get more instruction throughput without a need for faster caches. These gains aren't free. Processor control logic must, by necessity, become more complex, although this logic will still be a small portion of the total chip transistor count.

Also, superscalar processors need wider memory accesses than second-generation, single-pipeline RISC chips so they can pump through groups of multiple instructions for execution. A superscalar processor of degree n—one that issues an average of n instructions per clock cycle—requires an instruction bandwidth approaching n times the scalar instruction bandwidth. Superscalar operation does not as heavily affect the data bandwidth because loads and stores are 10% or less of a typical RISC instruction mix. Memory interfaces are moving to 64 bits in most processors; some superscalar RISC processors have a 256-bit-wide memory bus.

Evaluating the third generation

However, designing a high-performance third-generation RISC processor is more complex than just choosing between superpipelining and superscalar techniques. Implementation technology has changed the playing field. Yesteryear's world of fixed-length pipelines and stages is gone. Second-generation RISC ALUs and caches were major performance bottlenecks. But third-generation fast adders and multipliers and pipelined caches are changing that state of affairs. Today, RISC adders can do a full addition in what used to be half a stage clock. For example, the Mips R4000 does a 64-bit addition in one 50-MHz clock cycle.

Fast adders and pipelined caches have led to a confusing state of affairs. The previous way of evaluating RISC implementations by taking the functional-unit clock rate as a base won't work anymore. Many emerging RISC chips, such as the Motorola 88110 and the TI SuperSparc, no longer have functional units that all take the same number of clock cycles. Some stages take three cycles; others complete in one. The SuperSparc, for example, has three adders, two of which can feed into the third. All adds complete in one 50-MHz clock cycle; the individual adders operate in half a clock cycle. The IBM RS/6000, a multichip RISC implementation, has different-length pipelines to compensate for delays between functional units on different chips.

Thus, there's no clear dividing line between superpipelined and superscalar architectures. Superpipelining—the pipelining of functional units—is becoming universal. You can't evaluate the emerging third-generation RISC processors by looking at the basic clock frequency and calculating a CPI rating. The superscalar Mips R4000 delivers 70 Specmarks. In the old view, that performance would be considered good for a 50-MHz clock but mediocre for a 100-MHz clock. Many RISC chips always had internal clocks faster than their system clocks, but now the internal clocks are viewed as the instruction-cycle clock.

Parallel functional units

Superscalar RISC processors are following the track pioneered by mainframe and supercomputer designers. Chip designers are dividing processor operations into separate, parallel functional units. These units can execute in parallel if there are no data dependencies or resource conflicts. CDC (Minneapolis, MN) introduced this technique in its

National Semiconductor 32SF641

- 33-, 40-, 50-MHz internal clock; external bus half internal rate
- 1.1M transistors
- 100 native MIPS peak, 1024-item FFT in 1.5 μsec, single-cycle integer multiply takes 20 nsec; 2-cycle floating-point multiply
- Superscalar architecture, dual instruction fetch, dual pipelines
- 6-port register file; 32 × 32-bit general-purpose registers, 16 × 64-bit floating-point registers
- 4-kbyte, 2-way set-associative instruction cache, 64-bit line size; 1-kbyte, 2-way set-associative data cache, 128-bit line size; both are locking caches
- 64-bit external-memory interface
- Two pipelines with buses: 4-stage integer pipeline, 5-stage integer/floating-point pipeline
- Four functional units: two ALUs, DSP multiplier, FPU
- Branch-destination offset stored in cache with branch address; 2-cycle delay if wrong
- 1-cycle penalty for load that needs a store value
- Bypass register passes values between pipelines.
- Loads can bypass data cache.
- In-order execution, 1 or 2 instructions per clock cycle
- 16-bit timer, two DMA channels
- $970 with FPU, $300 (1000) without

Comments: Chip suits embedded systems and math-intensive, DSP-type processing. 64-bit memory bus is dynamically sizable and designed for interleaved memory. C-like assembly language. Dual-processor mode for fault-tolerant operation.

PIPELINE

INSTRUCTION FETCH	INSTRUCTION DECODE	EXECUTE	MEMORY ACCESS FOR LOAD	STORE RESULT

IBM RS/6000 single-chip processor (RSC)

- 33-MHz clock
- 1.2M transistors
- 25.9 SPECmarks
- Superscalar architecture, issues dual instructions
- 32 × 64-bit register file, 32 × 64-bit FPU register file
- 8-kbyte combined instruction and data cache; 2-way set-associative write-through cache
- 64-bit data and 27-bit address buses, 32-bit I/O bus; glueless SIMM connection; 8-bit error-correction codes
- 5-stage pipeline
- Three functional units: fixed point, floating point, branch
- Static branch-prediction bit; automatic in-page instruction fetch
- 4-entry store buffer
- Microcoded I/O sequencer for I/O and DMA
- In-order execution
- 3.3V, 4W
- Proprietary—used in the IBM Powerstation 220

Comments: The RSC is the single-chip version of IBM's Power architecture, the RS/6000 multichip implementation. The Power architecture will also be extended for single-chip versions in a joint development with Motorola and Apple. The series, the PowerPC, will initially use the 88110 bus interface and be built by Motorola. PowerPC will handle 32- and 64-bit operations.

PIPELINE

INSTRUCTION FETCH	INSTRUCTION DECODE	EXECUTE INSTRUCTION	EXECUTE SECOND FLOATING-POINT INSTRUCTION OR FIXED-POINT RESULT WRITEBACK	FLOATING-POINT RESULT WRITEBACK

6600 mainframe, which had 16 functional units including four FPUs and seven integer units.

Most RISC superscalar processors issue two to three instructions per clock cycle. Thus, they can make do with as few as two or three parallel functional units. The i960, 32SF641, T9000, and DEC Alpha chips have four functional units each. IBM's multichip RS/6000 and single-chip RCS each have three functional units.

All functional units, however, are not alike. IBM's RS/6000 and Intel's i960 have a few, sophisticated functional units, which include multistage control logic. An example of such a unit is the RS/6000's instruction-cache unit, which handles branches and condition-code operations internally. It dispatches instructions to the fixed-point or floating-point functional units.

The alternative approach is to have more, less-sophisticated functional units. These units are more like the execution units that run the execute stage in a second-generation CPU pipeline. The 32SF641, 88110, and SuperSparc take this more egalitarian tack.

The 88110 has 10 functional units, including two ALUs, two graphics units, a bit-field unit, a floating-point add unit, a multiply unit, and a divide unit. The two remaining units—the load/store and superscalar-instruction units—are more control oriented. The load/store functional unit helps coordinate loads and stores. Its logic can easily check for loads that are dependent on pending stores. For example, the 88110 has a separate load/store execution unit. The 88110 also has seven spare functional-unit addresses for future expansion.

Integer ALU instructions make up the largest percentage of instructions executed by RISC processors. In some studies of the Mips architecture, ALU operations were 40 to 50% of all instructions executed. Thus, multiple ALUs provide a way to speed execution. Many third-generation RISC processors have implemented multiple ALUs, including the National Semiconductor 32SF641, which has two separate pipelines each of which has an integer ALU, and Motorola's 88110, which also has two ALUs.

Problems, however, start with data dependencies between sequential instructions; for example, an add that is followed by another add that uses the results of the first add instruction. Multiple ALUs won't help in this case: The second instruction will stall until it can use the result of the first as an input. Software scheduling can make the best use of multiple parallel ALUs by sorting instructions to minimize data dependencies. The compiler can intermix instruction sequences with partial results held in registers or cache.

The Sun/TI SuperSparc design team went even further than hanging three ALU functional units on a general bus. It created an ALU hierarchy: The first two ALUs operate independently, and the resulting outputs can feed into the third ALU. Thus, the third ALU can add the results of two adds. Moreover, all three adds can be done in a single group of simultaneously issued instructions.

Intergraph C400

- 50-MHz internal clock
- C411 integer unit, 160,000 transistors; C421 FPU, 140,000 transistors
- 42 SPECmarks
- Superscalar architecture, issues as many as 2 instructions per clock cycle; superpipelined functional units; C411 integer unit
- 5-port 32×32-bit register file
- Separate FPU chip, C421, has 16×64-bit floating-point registers
- External, direct-mapped unified cache as large as 128 kbytes
- Separate input and output buses: 64-bit output bus, 32-bit address/input bus
- Variable-stage pipeline: 3 to 5 stages
- Four functional units: ALU, multiplier, divider, shifter
- Compare and branch instruction takes 2 delay-slot cycles and has no condition codes; branch-prediction bit
- Pipelined loads and stores
- Register scoreboard stalls instructions until resources are available.
- In-order execution
- 7W chip has off-chip drivers/receivers; multilayer PGA
- $1000 (1000) for C411 and C421 chip set

Comments: The C400 is the latest version of the Clipper RISC chip. Separate FPU on- and off-chip caches. Minimal RISC design suits multichip implementations. Company is working on a 64-kbyte cache/MMU chip for a multichip module.

PIPELINE

INSTRUCTION FETCH	INSTRUCTION FETCH	INSTRUCTION DECODE	INSTRUCTION DECODE	EXECUTE	RESULT WRITEBACK
INSTRUCTION-CACHE ACCESS		REGISTER FETCH	DATA-CACHE ACCESS		REGISTER FETCH

One, two, many

Legend has it that one Pacific Aborigine tribe has a limited counting system of 1, 2, and many. That system is perfect for describing superscalar CPI rates. One for the second-generation RISC limit, two for the third-generation superscalar limit, and many for future RISC processors.

It's just not that easy for a superscalar RISC chip to consistently issue multiple instructions. Dependency problems become worse than those of chips with a single pipeline because you've got more instructions to worry about at any given time. Issuing more instructions means having more-complex control logic. Techniques like register scoreboarding and register renaming help to detect and minimize data dependencies and register conflicts.

In register scoreboarding, which was pioneered by the CDC 6600 mainframe, a table or scoreboard tracks register use. A register scoreboard has a bit for each processor register. If the bit is set, the register has a pending update (a result coming). When the register is updated, the bit is cleared, opening the register up for use. Intel's i960, Motorola's 88110, and DEC's Alpha all use register scoreboarding. The Alpha also uses scoreboarding to check for resource and load/store dependencies.

Current superscalar chips issue multiple instructions, but in object-code order. The instructions issue in order, although they can finish out of order. The CPU checks for data dependencies before issuing the instructions. In-order execution minimizes control logic but limits instruction throughput. The hard-

Digital Alpha

- 200-MHz internal clock
- 1.68M transistors
- 100 SPECmarks (estimated)
- Superscalar architecture, issues as many as 2 instructions per clock cycle; pipelined functional units
- 64-bit processor
- 32×64-bit register file, 32×64-bit FPU register file
- 8-kbyte, 2-way set-associative instruction cache; 8-kbyte data cache; 32-byte line size
- Supports secondary cache
- 7-stage pipeline, 10 cycles for floating-point operations
- Four functional units: load/store, integer, FPU, branch
- Branch/data replacement operation: can load one of two values without taking a branch
- Function stack (four return addresses)
- 4-entry, 32-byte store buffer; 3-cycle load delay; store bypass
- Register scoreboard detects data dependencies and does result forwarding
- In-order execution for operations; single-cycle add, two sequential add cycles in pipeline
- Programmable modes for interfaces: ECL, TTL/CMOS; 128- or 64-bit data and secondary-cache interfaces
- 3.3V, 30W, 441-pin PGA
- Proprietary; introduced at ISSCC; hardware by end of 1992.

Comments: The Alpha RISC μP was developed by DEC as a replacement for the VAX and RISC CPUs. Designed for multiprocessing and VAX emulation.

PIPELINE

INSTRUCTION FETCH	SWAP PREDICT	INSTRUCTION DECODE	ISSUE INSTRUCTION, REGISTER READ	EXECUTE (ALU1)	EXECUTE (ALU2)	RESULT WRITEBACK

Manufacturers of RISC processors

For more information on RISC processors 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.

Digital Equipment Corp
146 Main St
Maynard, MA 01754
(508) 493-5111
Circle No. 650

IBM Corp
Old Orchard Rd
Armonk, NY 10504
(800) 426-3333
Circle No. 651

Intel Corp
Embedded Processor Group
5000 W Chandler Ave
Chandler, AZ 85226
(602) 554-2388
Circle No. 652

Intergraph Corp
Advanced Processor Div
2400 Geng Rd
Palo Alto, CA 94303
(415) 494-8800
FAX (415) 856-9224
Circle No. 653

Mips Computer Systems Inc
950 DeGuigne Dr
Sunnyvale, CA 94086
(408) 720-1700
FAX (408) 991-7777
Circle No. 654

Motorola Inc
Microprocessor and Memory Technologies Group
6501 William Cannon Dr W
Austin, TX 78735
(512) 891-2000
FAX (512) 891-2652
Circle No. 655

National Semiconductor Corp
Box 58090
Santa Clara, CA 95052
(408) 721-6816
FAX (408) 730-6241
Circle No. 656

SGS-Thomson Microelectronics
1000 E Bell Rd
Phoenix, AZ 85022
(602) 867-6100
FAX (602) 867-6102
Circle No. 657

Texas Instruments Inc
Box 809066
Dallas, TX 75380
(713) 274-2379
Circle No. 658

Mips vendors:

Integrated Device Technology
Box 58015
Santa Clara, CA 95052
(408) 727-6166
FAX (408) 988-3029
Circle No. 659

LSI Logic Inc
1551 McCarthy Blvd
Milpitas, CA 95035
(408) 433-8000
FAX (408) 434-6457
Circle No. 660

NEC Electronics
Box 7241
Mountain View, CA 94039
(415) 960-6000
Circle No. 661

Performance Semiconductor
610 E Weddell Dr
Sunnyvale, CA 94089
(408) 734-8200
FAX (408) 734-0962
Circle No. 662

Siemens Components
2191 Laurelwood Rd
Santa Clara, CA 95054
(408) 980-4500
Circle No. 663

VOTE . . .

Please also use the Information Retrieval Service card to rate this article (circle one):

High Interest 485
Medium Interest 486
Low Interest 487

ware is stuck with the instruction parallelism inherent to the instruction stream. It cannot reorder the stream for better parallelism.

Issuing instructions out of order is certainly possible, but the technique imposes a heavy hardware complexity cost because of the number of different possible instruction combinations that could occur (n fetched instructions $\times m$ issued instructions $\times p$ pipeline stages).

Register renaming is a hardware technique to minimize conflicts for register resources. The concept was introduced in the IBM 360/91 mainframe in 1967. Compilers convert high-level languages to assembly code, and in the process assign registers to hold values. In a superscalar processor, an operation may request a register before a prior instruction is finished using that register. This condition is not a data conflict. The downstream operation doesn't need the register value, just a register, and the operation will stall until a register is free.

The idea is to pick a free register, rename it to match the instruction parameter, and let the instruction use it. A fast look-up table, usually an associative memory, translates the map or renames the register.

Register renaming is not yet in general use by most third-generation RISC processors. One reason is that third-generation processors are issuing small numbers of instructions concurrently. The SGS-Thomson T9000 can issue a group of as many as eight instructions, but it is a stack-oriented machine and doesn't need register renaming. IBM's RS/6000 uses register renaming in its FPU.

Beating branches

Conventional branch-delay slots won't work well for superscalar RISC chips. A branch delay can be two cycles, but a superscalar chip that issues n instructions per clock cycle must find $2n$ instructions to plug into the empty pipeline execution slots. Using branch delays has been relatively successful for a single branch in a single-pipeline RISC chip, but the technique's effectiveness falls off rapidly as more in-

Motorola 88110

- 50-MHz clock
- 1.3M transistors
- 63.7 SPECmarks (80 with secondary cache, both figures estimated)
- Superscalar architecture, issues as many as 2 instructions per clock cycle
- 8-port 32×64-bit register file, 32×64-bit or 32×80-bit FPU register file
- 80-bit internal data paths
- 8-kbyte, 2-way set-associative instruction cache; 8-kbyte data cache with 64-bit fetch; 32-byte line size
- 32-bit address, 64-bit external interfaces; split transaction (can start new cycle while waiting for access); 8-word burst bus, bus snooping
- 88410 chip is 256-kbyte to 1-Mbyte secondary-cache controller
- 4-stage pipeline, different-length stages
- Ten functional units: 2 ALUs, bit field, floating-point add, multiply, divide, load/store, superscalar execution, and two graphic units
- Static branch prediction; taken-branch, target-instruction buffer
- Load/store reordering, 3-entry store buffer
- Register scoreboard for detecting data dependencies; history buffer holds speculative results.
- In-order, speculative execution
- In development; release in second quarter 1992

Comment: Second-generation 88000 chip. Has powerful bus interface and can run with or without secondary cache. Has two 3-D graphics functional units: a pixel-pack and a pixel-add unit.

PIPELINE

INSTRUCTION FETCH	INSTRUCTION DECODE	EXECUTE	RESULT WRITEBACK

Texas Instruments SuperSPARC

- 50-MHz base clock, 100-MHz clock cycle
- 3.1M transistors
- 75 SPECmarks (estimated)
- Issues 3 instructions per clock cycle
- 8-port 32×32-bit register file
- 20-kbyte, 5-way set-associative instruction cache; 128-bit instruction fetch; 16-kbyte, 4-way set-associative data cache; single 64-entry TLB (translation look-aside buffer) for both caches.
- 64-bit memory interface designed to Mbus-level II interface
- Cache-controller chip (2.2M transistors) handles as much as 2 Mbytes of direct-mapped secondary cache.
- 4-stage pipeline; different-length stages (2/3/2/1 clock cycles)
- Eight functional units: 3 integer ALUs, shifter, load/store, branch, floating-point multiply, floating-point divide
- Branch-prediction bit, taken branches optimized; loads branch target address on instruction fetch
- Fast load from cache, can use data in same group; 8-entry store buffer; load bypass
- Speculative execution; 2 instruction buffers: 8-word instruction prefetch, 4-word branch target prefetch; can stop and squash target instructions before writing values
- Sampling to SPARC International members

Comments: Most sophisticated, largest superscalar RISC processor to date. Joint development by Sun and TI. First superscalar SPARC chip. Both uniprocessing and multiprocessing configurations.

PIPELINE

20-nSEC CLOCK CYCLE

	INSTRUCTION FETCH	INSTRUCTION DECODE	EXECUTE	RESULT WRITEBACK
INSTRUCTION 1 INSTRUCTION 2 INSTRUCTION 3				

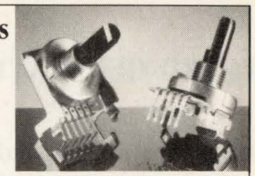
Vertical Mount Fixed Resistors

Series RSS Vertical Mount Metal Oxide Fixed Resistors feature self-standing, snap-in terminals, and they exhibit an excellent high frequency response and low inductance, making them suitable for PC board mounting in power supplies, switching regulators, monitors, printers, and color TVs.

Model RSS3FB is rated at 3W with a resistance range of 1Ω to 100KΩ. Model RSS5FB is rated at 5W with a resistance range of 1Ω to 2.4KΩ. Both are available in 15mm and 25mm heights. Free samples are available, contact Noble at 708/364-6038.

CIRCLE NO. 121

2-, 4-Bit and 5-Bit Rotary Encoders



Noble SDB161 2-, 4- and 5-bit encoders are compact (21mm ø) with a low profile (under 10mm height). Built with a sturdy diecast and steel construction, these encoders offer long life and reliability.

SDB161 encoders are for relative (2-bit) and absolute (4-bit, 5-bit) reference applications. 2-bit switches offer 36 detented positions; 4-bit switches offer 12 or 16 detented positions; 5-bit switches offer 24 or 32 detented positions. All encoders feature continuous rotation. The 2-bit is available in gray code; the 4-and 5-bit versions offer either binary or gray code. Custom designs can be accommodated. For free samples, contact Noble at 708/364-6038.

CIRCLE NO. 122

Rotary potentiometers that offer both reliability and versatility.

Here's where to turn.

Whatever size rotary potentiometer your panel design calls for, Noble can probably provide it. Our lineup has been proven in use and consists of an extremely wide variety of pots, including our smallest—the new 9mm series.

But we don't stop there. Many options are readily available to provide you with even more versatility. Or we can custom design a component that will perfectly conform to your specifications. The result is all the design freedom you need.

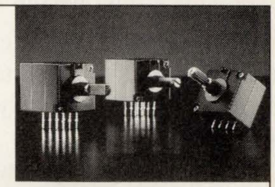
For full information, write, fax or turn to the phone and call: 708/364-6038.

NOBLE

Noble U.S.A., Inc.
5450 Meadowbrook Industrial Court
Rolling Meadows, IL 60008
Phone: 708/364-6038
FAX 708/364-6045

CIRCLE NO. 125

Hi-Grade Potentiometers



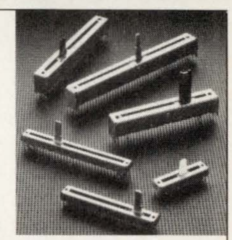
The AP25 Series of Hi-Grade Potentiometers are specifically designed to meet the performance demands of quality audio equipment.

Each element is completely shielded to make possible a tracking tolerance of ±2dB at 0 – 70dB and a maximum attenuation level of -90dB (R≥50kΩ).

Noble also offers custom design capabilities for the AP25 potentiometers. This includes shaft lengths, number of detents or taper requirements. For free samples and information, contact Noble at 708/364-6038.

CIRCLE NO. 123

Slide Potentiometers



The VJ Series High and Low Profile Slide Potentiometers are lightweight, durable, and provide smooth operation. They function as volume, balance, brightness/contrast, temperature, lighting and graphic equalizer controls.

The Low Profile Series (with single or dual elements) features a slide travel of 15, 20, 30, 45, or 60mm. The High Profile Series is available in 30, 45, 60, 80 or 100mm travel.

Custom designs can be accommodated. Contact Noble at 708/364-6038 for a free sample.

CIRCLE NO. 124

THIRD-GENERATION RISC PROCESSORS

structions are needed to fill empty slots.

The second-generation Hewlett-Packard PA chip limits branch delays by using built-in branch prediction. The CPU predicts that forward branches (tests) will not be taken and that backward branches (loops) will be taken. A 1-cycle stall results when the prediction is incorrect. SGS-Thomson takes a simpler approach for its T9000 Transputer. The processor predicts that all branches will not be taken and incurs a 5-cycle penalty for taken branches.

Other RISC processors use branch-prediction bits the compiler sets into the branch instruction word to predict taken or nontaken branches. The i960, C400, RCS, and 88110 all use branch-prediction bits.

Speculative execution takes branch prediction one step further. Not only does the processor pick a path to succeed the branch instruction, but it then begins filling the pipeline with the path's instructions and executing them. If the wrong branch path was taken, pipeline execution for the post branch instructions halts, and the processor state rolls back to the branch point.

Another way to cope with branch indeterminacy is to use branch-target caches to hold branch-target addresses. Typically, on the first pass the CPU takes the branch-delay penalty. On subsequent executions, the CPU takes the previously calculated branch address, thus eliminating any pipeline delays. This tactic is effective for loops; AMD pioneered this technique in RISC μPs with its second-generation 29000. The 88110 has an on-chip, 32-entry branch-target cache for holding target addresses. The cache holds instruction pairs for both taken and nontaken branch paths.

National Semiconductor's designers store the target address in a different place. The 32SF641 caches the branch-target address with the branch instruction in the instruction cache. Accessing the branch instruction brings up the target address. TI's SuperSparc uses branch prediction to select which branch path to execute. The CPU places branch-target instructions into a branch-target cache and then executes them. If the branch is wrong, the alternate path's set of instructions is also ready for execution,

SGS Thomson T9000 Transputer

- 50-MHz clock (external 5-MHz clock)
- 3.2M transistors
- 70 SPECmarks (estimated)
- Superscalar architecture; issues as many as 8 instructions per clock cycle (prefix bytes count as instructions)
- 8-bit instructions
- Register file: Three integer stack registers, three floating-point registers, three ports (two read, one write)
- Local cache for local variables (256 bytes or 32 words)
- 16-kbyte cache RAM in 4 banks, fully associative; 4-word (16-byte) line size
- Memory interface: 32-bit address, 64-bit data buses; four 32-bit crossbar buses (1 for each cache bank); glueless 8-Mbyte max SIMM connection
- 5-stage pipeline
- Four functional units: two address generators, ALU, FPU
- Optimizes non-taken branches; 5-cycle penalty for taken branches
- Pipeline checks for dependencies and interlocks
- In development; sampling third quarter of 1992

Comments: Four 100-Mbyte/sec link ports to CPUs. Has two control links. Companion C104 chip for dynamic routing. Has 4-region MMU and fast context switch (local cache is write-through). Built-in hardware process-scheduling kernel.

PIPELINE

INSTRUCTION FETCH	INSTRUCTION DECODE	OPERAND REAP	EXECUTE	RESULT WRITEBACK

Intel i860XP

- 25-, 40-, 50-MHz clock
- 2.55M transistors
- 42 SPECmarks
- VLIW (very-long-instruction-word) architecture: issues 2 instructions—1 scalar and 1 floating point—per clock cycle; FPU instruction can schedule 2 FPUs.
- 32×32-bit register file, 16×64-bit FPU register file
- 4-way set-associative 16-kbyte instruction and 16-kbyte data caches; 32-byte line size
- 64-bit memory interface, 2 clock cycles per transfer, burst mode; uses MESI (modified, exclusive, shared, or invalid) cache-coherency protocol
- 4-stage pipeline
- RISC core and three functional units—multiply, add, and graphics (all pipelined)—in FPU
- Compiler-filed branch-delay slots
- Pipelined floating-point load instruction bypasses cache with 128-bit load.
- Single- or dual-instruction mode
- Built-in support for PAX (parallel architecture extension) for medium grain parallelism.
- Built-in graphics functional unit for pixel and Z buffer manipulation
- $132, $327, $551 (1000) for 25-, 40-, and 50-MHz versions, respectively.

Comments: New XP version has faster clock, write-through caches, bus snooping, and built-in hooks for medium grain multiprocessing.

PIPELINE

INSTRUCTION FETCH	INSTRUCTION DECODE	EXECUTE	RESULT WRITEBACK

Are your designs limited by prehistoric technologies?

Today's engineers design for the future. They need technology which allows rapid prototyping and reduces development costs.

At Advanced Microelectronics, we can help you out of the Stone Age and into the future by reducing manufacturing costs, providing unlimited flexibility, and rapid results.

Our FPGA design methodology allows you to migrate your architecture to gate array, standard cell, or full custom implementations. In addition to FPGAs, we also offer custom mixed signal solutions using bipolar, CMOS, and BiCMOS process technologies. From IC design, to modeling, to testing, to finished goods, we have a proven track record.

We give you the future now. Call today for more information:

(601) 932-7620, Fax 932-7621.

email: design@aue.com

CIRCLE NO. 63

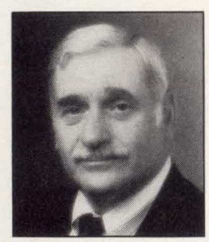
AμE Advanced Microelectronics

which minimizes the cost of the CPU's predicting wrong.

The DEC Alpha architecture has combined instructions: The processor can do a value selection—setting one value or another depending on a test—without needing to use a branch. The first instruction sets the first value. The second instruction tests another value and will load a second value if specified by the test results. This instruction sequence eliminates the need to use a branch to set alternative values, which in turn avoids pipeline interruptions.

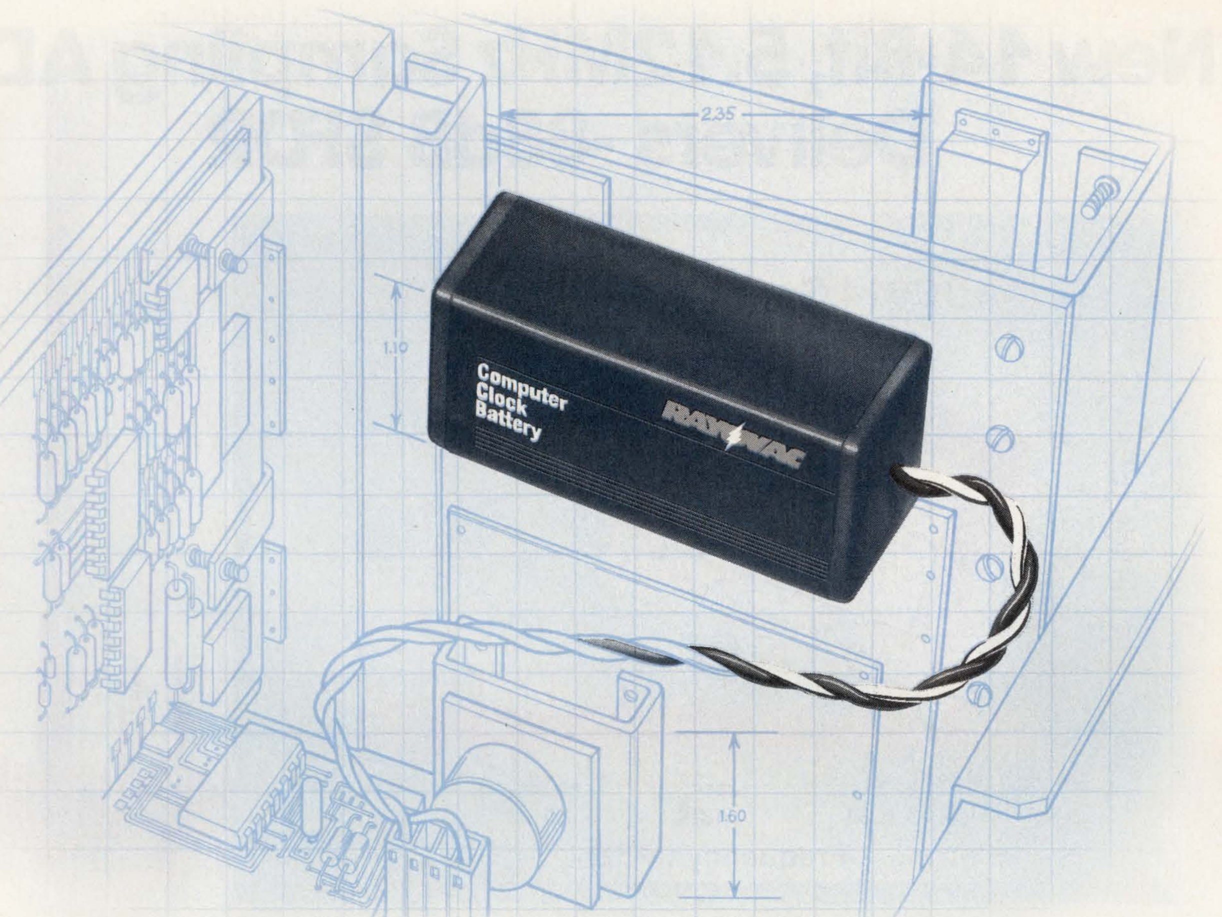
Conventional condition codes can become a real problem with superscalar execution. Multiple instructions, such as two adds, could set conflicting condition codes. Designers needed a way to handle multiple conditions without conflict. IBM took the tack of creating separate condition-code registers in its instruction-cache unit. Multiple conditions can be tested using a single branch.

Some RISC processors take a different approach to condition codes by eliminating them entirely and placing ALU and test results into an addressed register. The Mips RISC chips and the 88110 use this approach. EDN



Ray Weiss, Technical Editor, can be reached at (818) 704-9454; FAX (818) 704-7083.

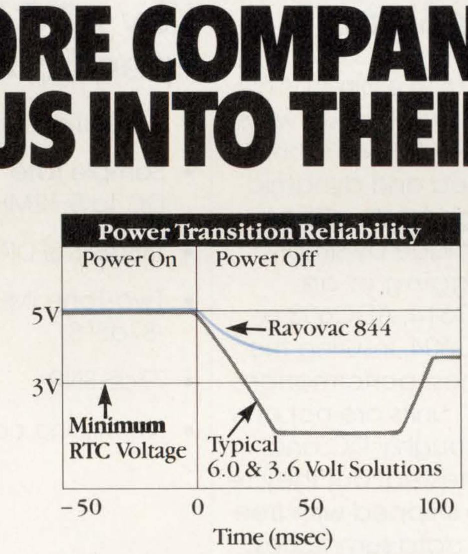
Article Interest Quotient (Circle One)
High 485 Medium 486 Low 487



WHY MORE COMPANIES ARE PLUGGING US INTO THEIR DESIGNS.

Today the Rayovac 844 computer clock battery is specified by 23 system architects worldwide. Its proven reliability safeguards the configuration file memory in 286/386/486 personal computer products, especially in power-down situations.

Maintaining voltage is just one way the Rayovac 844 delivers superior reliability. It also offers long life, a 3-5 year span, plus safety no lithium battery can match.



The 844 ensures IC voltage above the critical 3.0V level maintaining clock stability and configuration file memory.

The 844 is compatible with industry standard chip sets: Chips & Technology; VLSI Technology; Western Digital; Zymos and Intel. And it's made in the U.S.A., with on-time delivery available around the world.

So plug added reliability and service into your design. Specify a Rayovac 844. Call Rayovac's Technical Sales & Marketing Department for complete information and battery specifications at 608-275-4694. Fax: 608-275-4994.

In Europe contact:
Rayovac Europe B.V.
Tel: 31-1892-17855
Fax: 31-1892-17138

RAYOVAC®

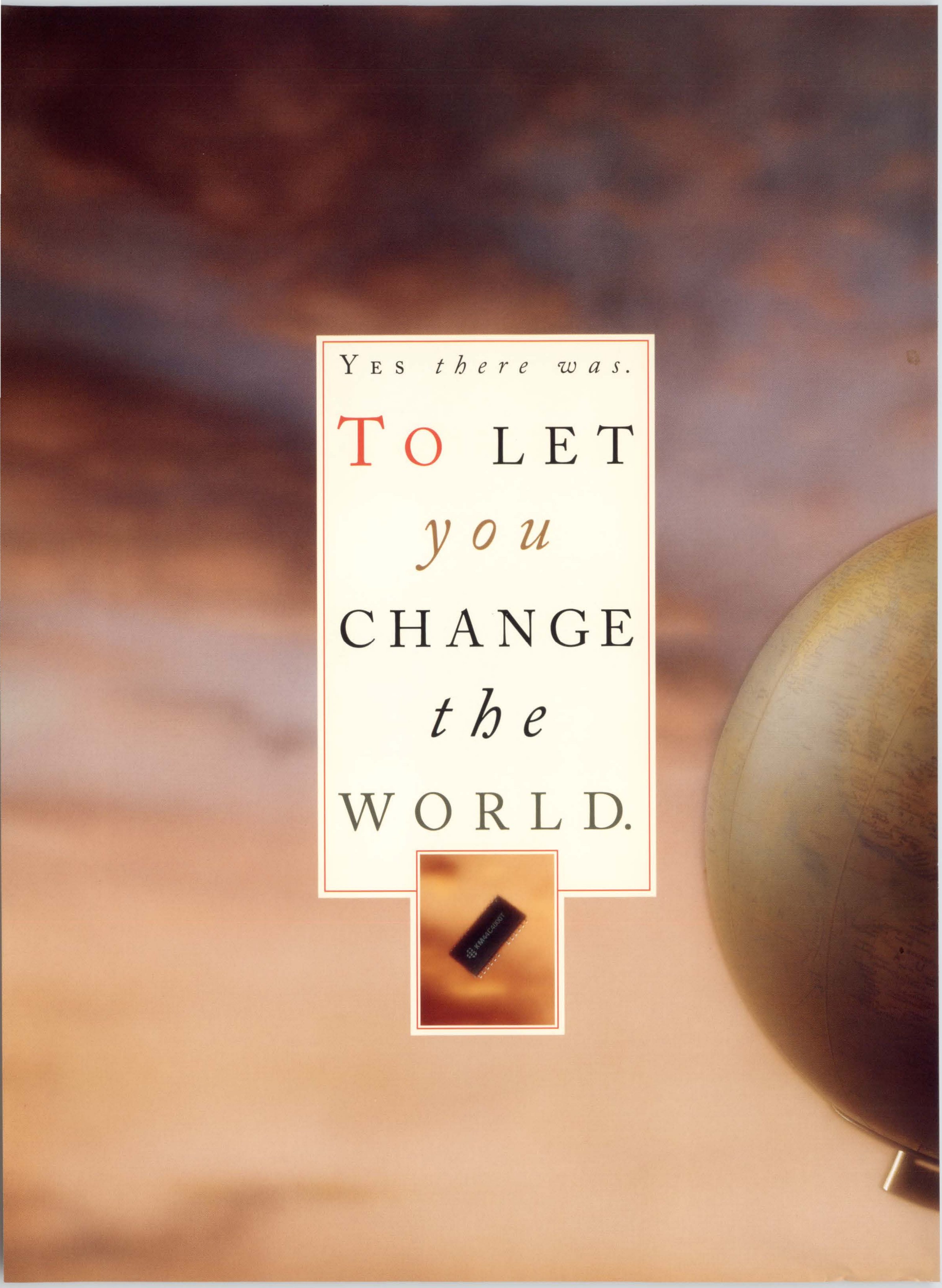
When performance really counts.

CIRCLE NO. 62

WAS THERE *some special reason we produced*

The

WORLD'S FIRST 16 *meg* DRAM?



Yes there was.
To let
you
change
the
world.

Samsung began shipping DRAM chips in the new 16M density—in production volumes—during 1991. Our customers for the product include many of the world's premiere computer and workstation makers.

They tell us we are the first supplier to complete this next generation of memory.

We, in turn, see it as a significant milestone in the global effort toward elegance and power in computing.

Of equal significance, Samsung's completion of the generation marks something of a transformation in the worldwide map of supply. And we believe consumers of electronic components will benefit from this.

Yet perhaps most important, is the fact that the 16-meg will indeed help the electronics community—in the U.S. and elsewhere—to do nothing less than change the world.

The new-generation DRAMs are a significant boon to the hugely beneficial technology of today's workstations. Machines that allow us to better comprehend the world, and to advance in areas as different as medicine and transportation, finance and filmmaking.

The new generation will also, in short order, facilitate ever-more-capable notebook and palmtop computers. Computers that will make us more productive—and will also define the workplace in a whole new way.

In the near future, more will be heard from Samsung.

We are among the major makers of DRAMs in all organizations and densities, and we are an increasingly major supplier of SRAMs. We make a wide line of fast, ultra-fast, and high-density SRAMs, up to 4M in density and 8 ns in speed. Our specialty memories include ROMs, VRAMs, pseudo and cache SRAMs, EEPROMs, and FIFOs. And we also build superior ASICs, microcontrollers, MOSFETs, and RAM DACs.

And, of course, in DRAMs, there is always the 64-meg.

About which, we hope to be writing soon.

If we may provide further information of any kind, please contact us via the coupon at left, or by telephone at 1-800-446-2760.

The world's first 16-*meg* DRAM.

Organization	*Mode*	*Speed*	*Samples*	*Production*
16M X 1	FAST PAGE	60/70/80	NOW	NOW
16M X 1	NIBBLE	60/70/80	NOW	6-92
16M X 1	STATIC COL.	60/70/80	NOW	6-92
4M X 4	FAST PAGE	60/70/80	NOW	NOW
4M X 4	STATIC COL.	60/70/80	5-92	8-92
4M X 4 (WPB)	FAST PAGE	60/70/80	5-92	8-92
4M X 4 (WPB)	STATIC COL.	60/70/80	5-92	8-92

2K and 4K refresh available.

YES. *I want to learn about the next generation of memory. Please send more information.*

Name ______ *Title* ______

Company ______

Address ______

City ______ *State* ______ *Zip* ______

Return coupon to Marketing Communications, Samsung Semiconductor, 3725 No. First St., San Jose, CA 95134. Or call:

1-800-446-2760

SAMSUNG

A *Generation* AHEAD.

Time-domain techniques enhance testing of high-speed ADCs

Michael J Demler, Micro Networks

Designers commonly use DSP techniques to characterize the dynamic performance of high-speed A/D converters, but these tests often yield an incomplete picture. Adding a sine-wave curve-fitting algorithm or beat-frequency test provides the missing description of sampling accuracy in the time domain.

The increasing availability and applications of high-speed A/D converters has led most manufacturers to include specifications for dynamic performance in their data sheets. Limiting dynamic testing to DSP techniques such as FFTs or statistical modeling such as sine-wave histograms does not portray the complete picture of a device's performance. Designers can employ a sine-wave curve-fitting algorithm or beat-frequency test techniques to add measurements in the time domain for a more comprehensive analysis. Time-domain analysis allows an engineer to evaluate test results without the limitations inherent in transforming sampled signals into other forms.

The most common DSP test uses a fast Fourier transform (FFT) to do a spectral analysis of an ADC's digital output. **Fig 1** shows the FFT obtained by testing the Micro Networks MN5902, an 8-bit CMOS flash ADC. The ADC was sampling a full-scale 828.75-kHz sine wave at 15 MHz. The test was a 4k-point FFT. The ratio of signal amplitude to noise plus distortion was 44.1 dB.

Spurious-free dynamic range (SFDR) is a measure of the usable dynamic range of an ADC. SFDR is defined as the difference, in decibels, between the amplitude of the fundamental and that of the largest spurious component in the FFT spectrum. In the example, the SFDR measured 49.6 dB between the fundamental and the second harmonic at 1.66 MHz.

An equation that expresses the signal-to-noise ratio (S/N ratio) of an ideal ADC with a resolution of n bits is S/N ratio$=6n+1.8$ dB (**Ref 1**). Because the S/N ratio of an ideal 8-bit ADC is 49.8 dB, the spurious-free range of 49.6 dB illustrated in **Fig 1** depicts an ADC that exhibits a usable dynamic range of 8 bits. A parameter called the effective number of bits (ENOB),

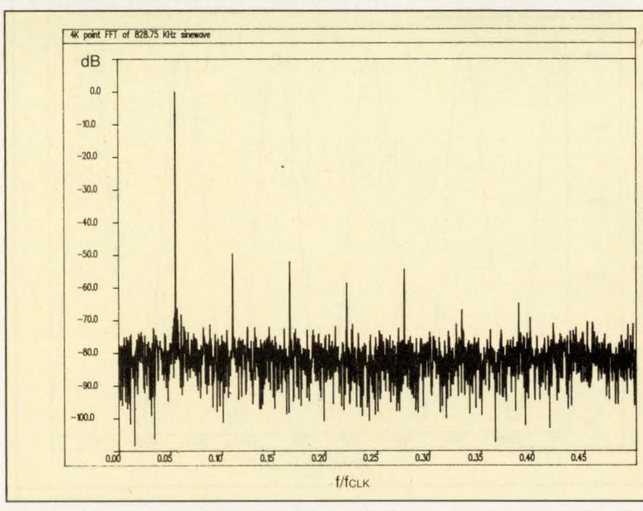


Fig 1—This plot shows the result of a 4k-point fast Fourier transform (FFT) performed on the MN5902 8-bit flash A/D converter. The ADC was sampling a full-scale 828.75-kHz sine wave at 15 MHz. FFT plots graphically illustrate parameters such as S/N ratio and spurious-free dynamic range (SFDR).

which is commonly derived from an FFT, provides a measure of dynamic resolution. To find the ENOB of an equivalent real ADC, the equation for S/N ratio is rearranged so that ENOB = (S/N ratio − 1.8)/6.

Using the data from the example FFT, with an S/N ratio of 44.1 dB, the effective number of bits would be approximately 7. One problem with this calculation is that all manufacturers do not use the same technique for measuring S/N ratio. Many measure the S/N ratio by first eliminating all harmonics and intermodulation products from the FFT. In such cases, the manufacturer should also report these distortion products separately.

In the **Fig 1** example, the S/N ratio without harmonics was 47 dB, which results in an effective bit calculation of 7.5. The problem exemplified by this erroneous 0.5-bit improvement is that the S/N ratio measurement doesn't reflect the actual resolution and accuracy of the individual samples taken by the ADC. If your interest is only in frequency-domain processing, the error may not matter; but if the accuracy of dynamic measurements is important, you'll want to include the harmonics and other spurious components in the ENOB calculation.

To show how severe the ENOB error can be when relying solely on the frequency domain, the data used to calculate the FFT in **Fig 1** was edited to create a spurious code at one of the zero crossings in the data record. **Fig 2** depicts a portion of the edited sine wave. Instead of producing the code 128, the data was changed to produce code 0. Such spurious codes often occur and are called sparkle codes. The high slew rate of the input signal near the mid-scale point of the waveform can cause problems in the encoding circuitry of some flash ADCs. These problems result in glitches in the digital output. **Fig 3** shows the result of reproducing the 4k-point FFT with the corrupted data. The spectra differ very little. The signal-to-noise measurement of the **Fig 3** spectrum indicates less than 2 dB of loss, which shows up as a slightly elevated noise floor. The SFDR did not change significantly, and the ENOB was reduced by only 0.3 bits.

Using a long data record, such as the 4k points in the example, is a common way to accurately measure an ADC's S/N ratio. An undesirable result of this method is that small numbers of large errors, such as the mid-scale glitch, are averaged out with no indication of the severity of the error in the frequency domain. Shorter FFTs can have other problems because the higher noise floor that results from taking fewer samples can mask many small coding errors. For this reason, multiple FFTs are often performed so that the spectra can be averaged together to remove random noise and clearly discriminate harmonics. Of course, this averaging further conceals information about sampling errors unless you examine the actual acquired data.

An alternative method of calculating effective bits is to use an algorithm that will find the sine wave that achieves the "best fit" to the data from the ADC (**Ref 1**). A sine-wave-fitting algorithm recursively calculates the amplitude, offset, and phase of an ideal sine wave that results in the minimum rms error when compared with the actual quantized waveform. Using the same

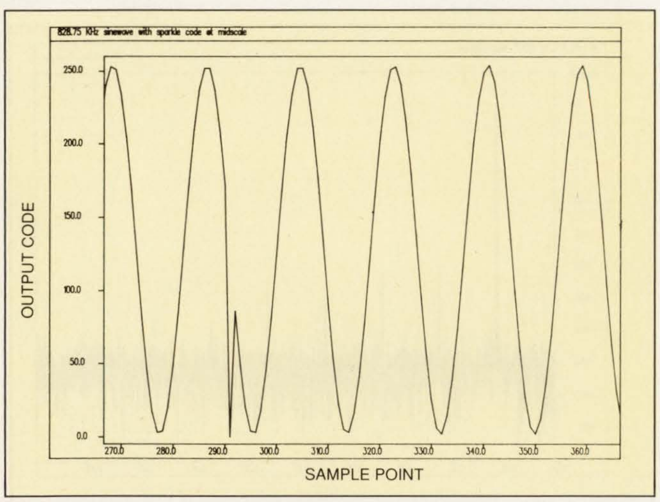


Fig 2—The data used to calculate the FFT in Fig 1 was edited to create a spurious code (code 0 instead of code 128) at one of the zero crossings in the data record. This plot depicts a portion of the edited sine wave, which exhibits corrupted data in the form of a sparkle code.

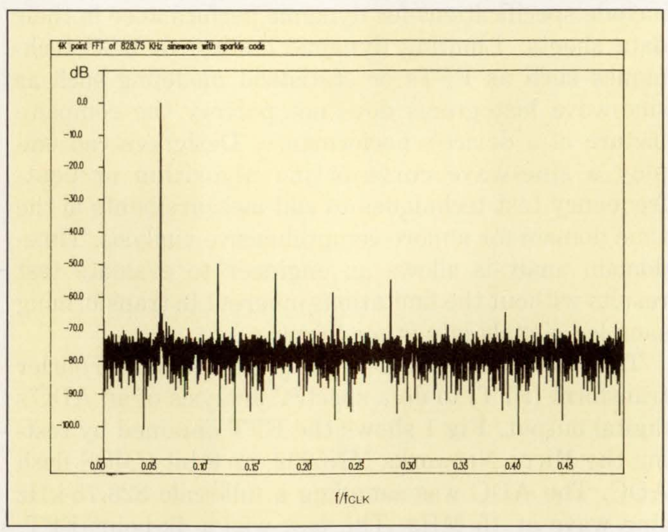


Fig 3—The result of reproducing the 4k-point FFT of Fig 1 using the corrupted data of Fig 2 shows very little difference when compared with the original. The main difference is the corrupted-data plot's slightly elevated noise floor.

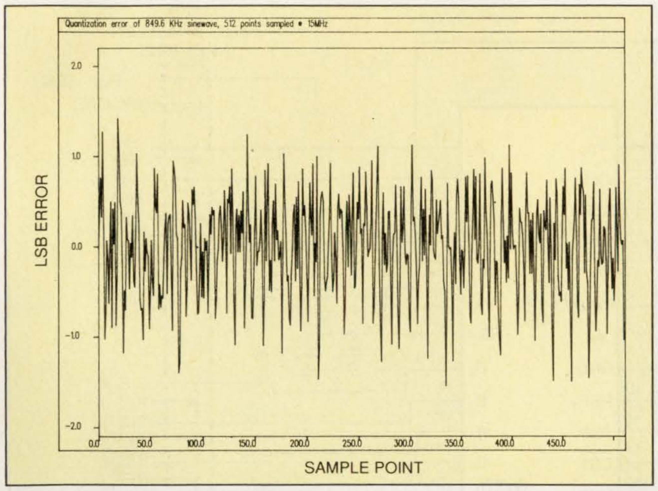


Fig 4—This quantization-error plot of the flash ADC first tested in Fig 1 provides a graphical measurement of the time-domain errors under dynamic conditions. As is evident, the samples are generally within ±1 bit of the ideal.

flash ADC tested in **Fig 1,** 512 data points were collected to produce an FFT and a best-fit sine wave. Subtracting the best-fit waveform from the original quantized data produced the dynamic-quantization-error plot of **Fig 4**. The plot provides a graphical measurement of time-domain errors under dynamic conditions.

As you can see, the samples were generally within ±1 bit of the ideal, with worst-case errors of ±1.5 bits. By including all of the nonlinearity and noise effects of the ADC, this method gives a true indication of the device's dynamic resolution. You should not confuse the dynamic-error plot with "dynamic linearity," which some manufacturers specify in their data sheets. Dynamic linearity is usually based on histogram techniques, which can hide time-domain errors. In contrast, looking directly at the quantization error plot, both large and small errors, which could be lost in an FFT or sine-wave histogram, are immediately evident.

The rms quantization error (V_e(rms)) in **Fig 4** is 0.55 bits. In an ideal ADC with a uniform distribution of all codes, the rms quantization error would be $q/\sqrt{12}$, where q is one quantization step, or LSB. This relationship leads to an alternative equation for effective bits:

$$V_e=\frac{V_{REF}}{2^{ENOB}\cdot\sqrt{12}}$$

$$ENOB=\log_2\left(\frac{V_{REF}}{\sqrt{12}\cdot V_e(\mathrm{rms})}\right),$$

where V_{REF} is the full-scale range of the ADC.

Because this method includes all harmonics and spurious components, it is better for calculating the effective number of bits than the FFT-based technique. When you analyze data digitally, as in the quantization error plot of **Fig 4,** you can convert the equation for ENOB to units of bits rather than volts:

$$ENOB=\log_2\left(\frac{\text{MAX CODE}-\text{MIN CODE}}{\sqrt{12}\cdot\text{rms BIT ERROR}}\right).$$

Converting to the more convenient base-10 logarithm yields

$$ENOB=3.32\cdot\log_{10}\left(\frac{\text{MAX CODE}-\text{MIN CODE}}{\sqrt{12}\cdot\text{rms BIT ERROR}}\right).$$

A disadvantage of sine-wave curve-fitting algorithms is that they may have long execution times and sometimes have difficulty converging to a solution. An alternative that is fast and can provide a quick graphical interpretation of performance, as well as supply data for more quantitative measurements, is the beat-frequency test. This test is the ultimate stress test of a flash A/D converter in the time domain. The beat-frequency test directly measures input signal bandwidth, reveals sampling errors that result in spurious or out-of-place codes, and provides a measure of aperture errors.

Designers familiar with sampling theory know that the Nyquist criterion requires that you sample a signal

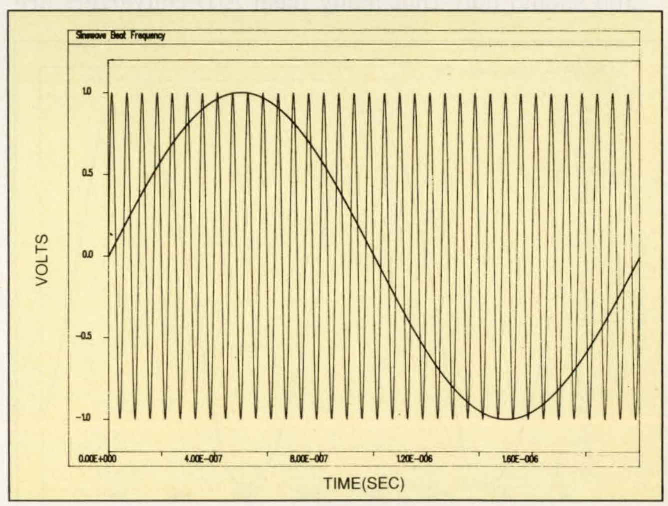


Fig 5—This single-tone beat frequency is the result of using an input sine wave slightly higher in frequency than the sampling clock, and connecting the sampled data points in a continuous time record. To guarantee that you exercise all the codes, calculate the input frequency to produce a change of less than 1 bit in the beat tone at the maximum slewing point. This point is set at the mid-scale point of unipolar ADCs.

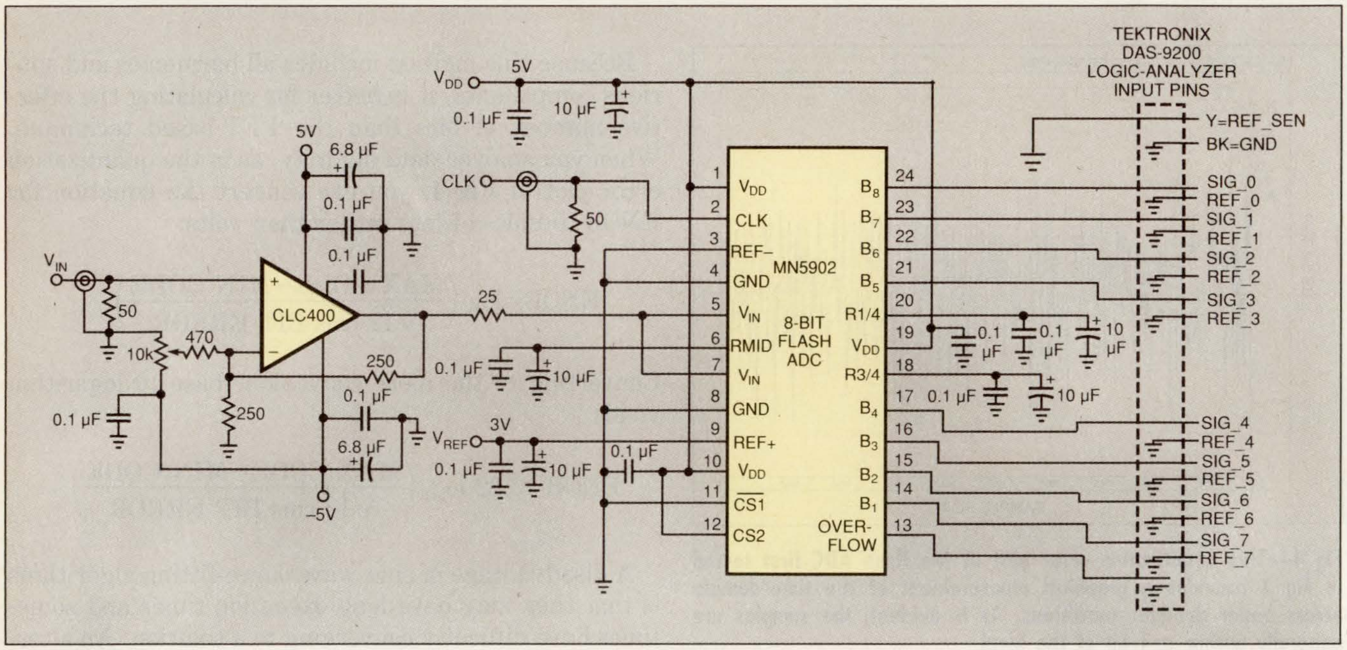


Fig 6—You can use this test circuit to demonstrate the ADC beat-frequency measurements Figs 7 through 10 show.

at a rate greater than twice the signal's highest frequency component. Signals that do not adhere to this limitation result in "aliases." Aliases are the result of high-frequency signals at an ADC's input that are transferred to lower-frequency signals within the output bandwidth of one half the sampling rate. Beat-frequency testing exploits this phenomenon by deliberately producing low-frequency representations of high-frequency signals.

You should note that many flash A/D converters are

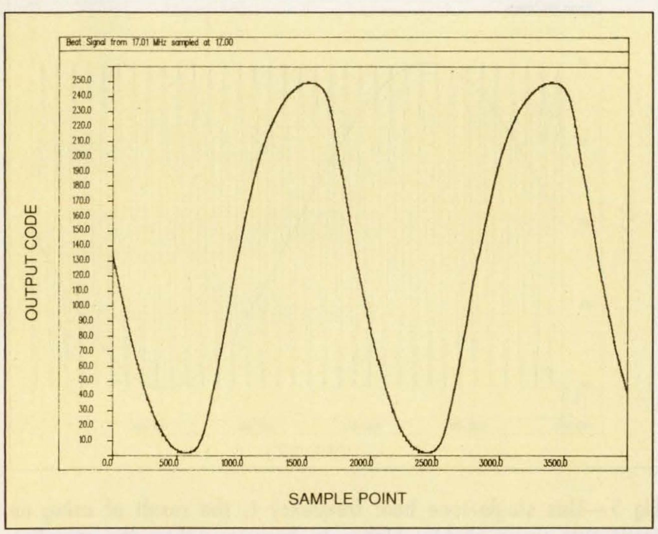


Fig 7—This plot shows the 10-kHz beat-frequency results of digitizing a full-scale input at 17.01 MHz with the ADC sampling at 17.00 MHz. The peak-to-peak amplitude of the output code is −0.275 dB relative to full scale, and the beat waveform shows no evidence of spurious codes.

specified for a "full-power bandwidth" that is less than the Nyquist rate. Often this specification describes the point where gross errors occur on the ADC's output.

During a beat-frequency test, the ADC digitizes input signals that are multiples of the sampling rate. If you use an input sine wave just slightly higher in frequency than the sampling clock, the sampling point will change in relative phase at a rate equal to the difference in frequency between the two signals. By connecting the sampled data points in a continuous time record, the single-tone beat frequency is traced out as **Fig 5** shows. To guarantee that you exercise all the codes, calculate the input frequency to produce a change of less than one bit in the beat tone at the maximum slewing point. This point is set to the mid-scale point of unipolar ADCs. The calculation is

$$\frac{dV_{IN}}{dt}(MAX)=2\pi\cdot A\cdot f_{BEAT}.$$

Set A to half the full-scale range of the ADC, which is $V_{REF}/2$ for a unipolar converter. For a change of one bit per sample at the maximum slewing point:

$$\frac{dV_{IN}}{dt}=\frac{2\pi\cdot V_{REF}\cdot f_{BEAT}}{2},$$

$$\text{and}\quad f_{IN}=\frac{f_{CLK}}{2^N\cdot\pi}+x\cdot f_{CLK},$$

where x is an integer.

To demonstrate the technique, a series of beat-

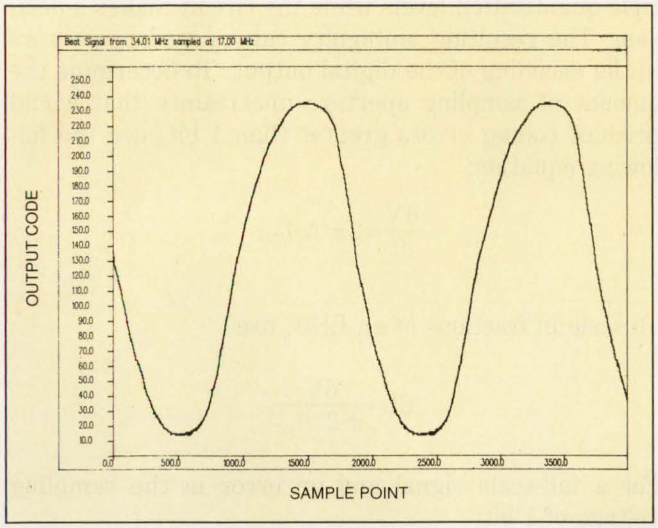


Fig 8—In this test, the input frequency was doubled to 34.01 MHz while the sampling rate was kept at 17.00 MHz. Again, the plot shows a 10-kHz beat, but with a peak-to-peak attenuation of 1.24 dB.

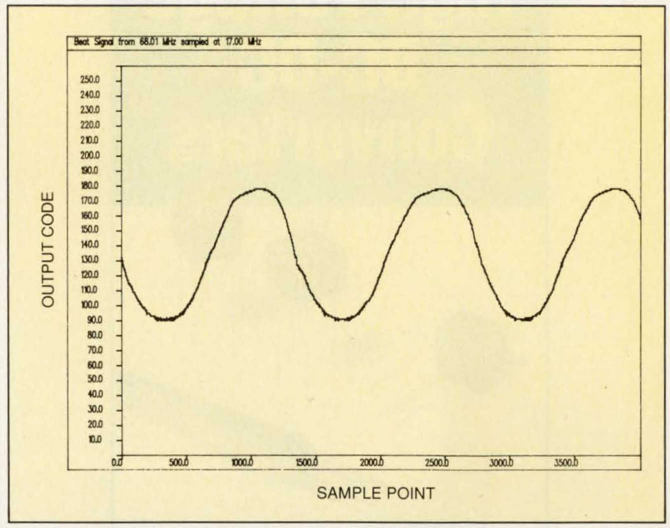


Fig 10—In this final test, the input frequency of 68.01 MHz is four times the sampling rate. The frequency increase attenuated the output amplitude by 9.28 dB but generated no sparkle codes.

frequency tests were performed using the MN5902 CMOS flash ADC in the test circuit of **Fig 6**. The beat tests started by digitizing a full-scale input (f_{IN}) of 17.01 MHz with the ADC sampling at a 17.00-MHz clock rate (f_{CLK}). This test produced the 10-kHz beat frequency evident in the **Fig 7** plot of digital output codes. In this plot, the horizontal axis represents the number of data points, and the vertical axis represents the 8-bit code. The peak-to-peak output-code amplitude was −0.275 dB relative to full scale. An examination of the beat waveform shows no evidence of spurious codes.

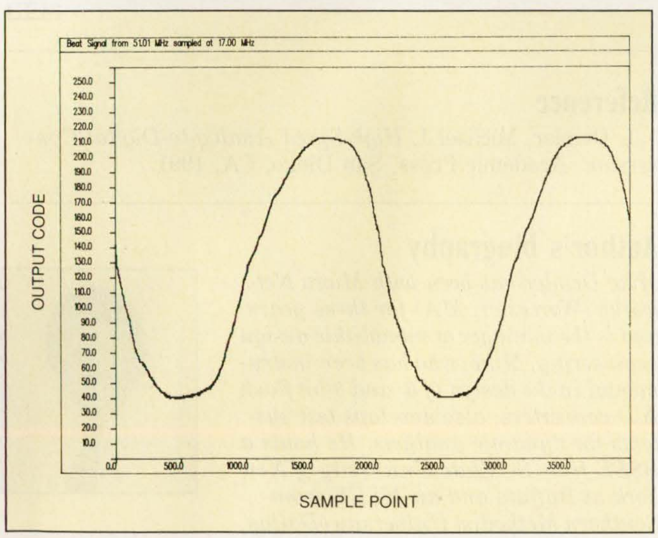


Fig 9—In this third test, the input frequency of 51.01 MHz is three times the clock rate. Under these conditions, there were still no spurious codes present, and the peak-to-peak output was attenuated by 3.4 dB. The attenuation of the beat frequency gives an accurate indication of the overall −3-dB bandwidth of the composite sampling system.

You can also derive the beat waveform from signals that are offset in frequency from harmonics of the sampling rate. In the second test, which **Fig 8** shows, the input frequency was doubled to 34.01 MHz while the sampling rate was kept the same. Once again the 10-kHz beat was obtained, with a peak-to-peak attenuation of 1.24 dB. In the third test, which **Fig 9** shows, the input frequency is increased to three times the clock rate for an input of 51.01 MHz. Under these conditions, no spurious codes were present, and the peak-to-peak output was attenuated −3.4 dB. Although these results include effects caused by the large-signal-bandwidth roll-off from the input-signal amplifier, attenuation in the beat frequency gives an accurate indication of the overall −3-dB bandwidth of the composite sampling system.

Finally, in **Fig 10,** the input frequency was increased to 68.01 MHz, or four times the sampling rate. This increase reduced the output amplitude by 9.20 dB but did not result in any sparkle codes. Although you may observe increased distortion as you approach an ADC's performance limits, it is more important to users that a device degrades gracefully and has no abrupt onset of gross sampling errors. If more accurate measurements are required under extreme undersampling conditions, you can lock the two signal sources to a common reference to reduce phase jitter, which can corrupt the low-frequency beat. No attempt to do so was made for the tests described here.

You can use the extremes of input frequency to measure the margin of aperture uncertainty a flash ADC is capable of providing. If there is a small variation in the sampling point of the ADC's adjacent comparators, high-frequency signals will slew through mul-

TESTING HIGH-SPEED A/D CONVERTERS

tiple quantization levels while the circuit makes a decision. The resulting ambiguity can cause large errors in the encoding of the digital output. To determine the amount of sampling aperture uncertainty that would produce coding errors greater than 1 bit, use the following equation:

$$\frac{dV}{dt}=2\pi\cdot A\cdot f_{IN}.$$

To scale in fractions of an LSB, use

$$dt=\frac{dV}{\pi\cdot 2^N\cdot f_{IN}}.$$

For a full-scale signal and an error in the sampling voltage of 1 bit:

$$dt(MAX)=\frac{1}{\pi\cdot 2^N\cdot f_{IN}}.$$

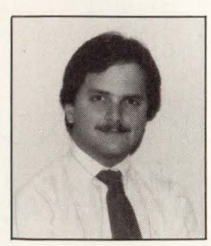
As an example, for the **Fig 9** input signal of 51.01 MHz with an effective attenuation of -3 dB, the aperture uncertainty is less than 35 psec.

In addition to providing an immediate indication of large-signal bandwidth and sparkle immunity, sine-wave beat signals can be used to perform the other dynamic tests previously described. For example, you can use sine-wave-fitting algorithms to measure the quantization error of the beat waveforms. You can perform FFTs if you take aliasing into account and provide any required bandpass filtering at the input. EDN

Reference

1. Demler, Michael J, *High-Speed Analog-to-Digital Conversion*, Academic Press, San Diego, CA, 1991.

Author's biography



Mike Demler has been with Micro Networks (Worcester, MA) for three years and is the manager of monolithic design engineering. Mike, who has been instrumental in the design of 6- and 8-bit flash A/D converters, also develops test systems for dynamic analysis. He holds a BSEE from the State University of New York at Buffalo and an MSEE from Southern Methodist University (Dallas, TX). In his leisure time, Mike enjoys home remodeling, photography, and sports.

Article Interest Quotient (Circle One)
High 473 Medium 474 Low 475

 CIRCLE NO. 66

Use the analytic approach to avoid errors when probing CMOS circuits

Art Porter, Hewlett-Packard Co

Heisenberg's uncertainty principle states that you can't measure a physical event without somehow affecting that event. This principle holds true for CMOS circuits, but armed with the right analytical techniques you can render those effects immaterial.

When you're making measurements on CMOS circuitry, you must take probe characteristics into consideration. Probe resistance and probe capacitance can affect voltage measurements as well as the accuracy of delay-time measurements. However, using the right techniques can help you overcome these problems.

To understand how a probe's characteristics can affect measurements, you must look inside the device you're measuring. The output circuitry of any CMOS device consists of one or more FETs tied to the positive supply rail and one or more FETs tied to ground (**Fig 1a.**) In the high output state, the FETs connecting the gate's output pin to the power supply are turned on hard; in the low state, the FETs between the output and ground are turned on hard.

When you consider the addition of a pull-up resistor and add the resistance of the probe, the output circuit looks like **Fig 1b.** The first thing you'll want to know is how the dc voltage levels at the output node will change due to probe resistance.

In the low output state, no current will flow through the probe resistance because there is no voltage across it. Thus, you need only consider the high state. To analyze the high-output voltage level, you need to understand the characteristics of a CMOS output. **Fig 2** reproduces published high-level voltage vs current (E/I) characteristics for various CMOS devices.

The plot in **Fig 2a** depicts the output characteristics for a family of CMOS logic from Integrated Device Technology (IDT). The output E/I slope corresponds to an equivalent resistance of approximately 25Ω as long as the current does not exceed 100 mA. This impedance is the equivalent on-resistance of the on-chip FET between the gate's output pin and the positive power-supply rail. This output impedance is much smaller than any reasonable pull-up resistor you might design into a circuit using this FET, so you only need

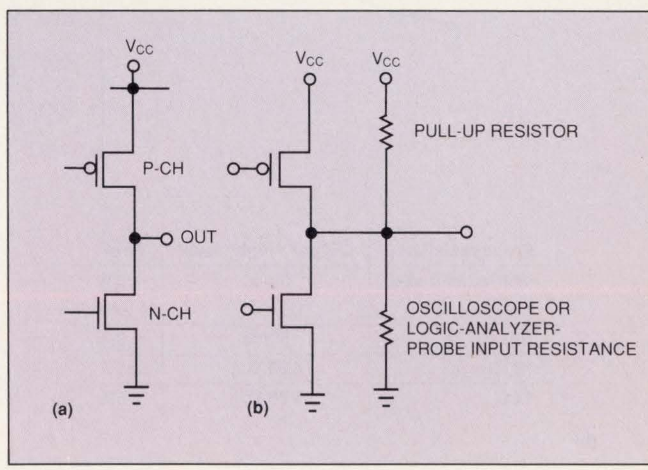


Fig 1—You can understand the effects of probe resistance on measurement accuracy best when you look at the output circuitry of CMOS devices (a). Addition of the probe resistance (b) creates a resistive divider and introduces error into level measurements.

to consider the circuit, which consists of the FET's on-channel resistance and the probe resistance.

Fig 2b illustrates how the IDT FET's output voltage will vary as a function of the probe resistance when the supply voltage equals 5V. A 1-kΩ probe represents a 5-mA load on the output.

The same concepts apply to devices with steeper E/I output curves. For example, Cypress' CY7C909/CY7C911 microprogram sequencers have an output E/I slope (**Fig 2c**) that is very nearly linear and has an equivalent resistance of approximately 100Ω. For these devices, **Fig 2d** illustrates how the high output level will react as a function of probe resistance.

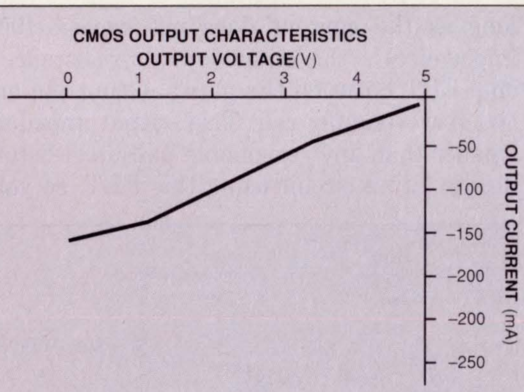
These examples make one significant point—when the gate is in the active-high state, the effect of a probe's resistive loading depends on the on-channel resistance of the output-stage FET rather than on the value of the external pull-up resistor. These examples illustrate that an understanding of an IC's high-output-state E/I characteristics can be useful when deciding what measurement probe to use. In general, a probe resistance of 100 kΩ is adequate for virtually all types of CMOS circuitry, and some circuits can tolerate 1-kΩ resistive loads.

A probe's capacitance affects the accuracy of timing measurements. To change the output level from low to high or high to low, an IC's output stage must source or sink current to charge or discharge the capacitive load. This load includes the capacitance of the probe, the input capacitance of any gates connected to the IC's output, and any parasitic capacitance associated with the pc board or other fixtures. Altering the charge on this capacitance takes a finite amount of time—it is not instantaneous.

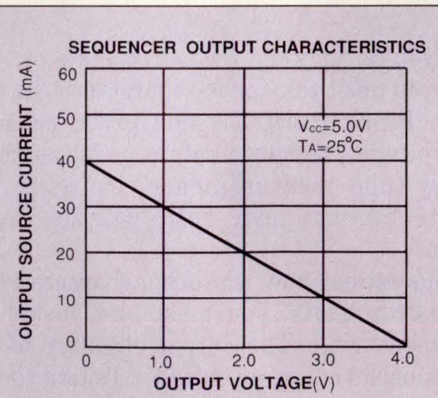
Some CMOS-device data sheets provide information on how propagation delays change with load capacitance. For example, **Fig 3** shows delay curves for the Cypress CY7C150 static RAM. For this device, a probe with a load capacitance of 8 pF will change the output-edge timing by about 0.4 nsec.

For vital timing measurements on very-high-speed CMOS circuitry (transition times of approximately 1 nsec), the probe capacitance can become critical. In these cases, choose the probe type with the lowest capacitance. A passive resistive-divider probe, designed to be terminated into 50Ω, has the lowest capacitance (see **box**, "A probing primer"). A 20:1 resistive-divider probe designed for a 50Ω termination will present an input resistance of 1 kΩ to the circuit under test. High-speed CMOS circuits are typically designed to have a relatively low on-channel resistance and can provide relatively high currents, so a 1-kΩ probe will introduce minimal voltage errors.

Probe resistance is not a significant factor in making



(a)



(c)

Probe resistance	Output "high" level	Error
Infinite (no probe)	5 Vdc	0%
1 MΩ	5 Vdc	0%
100 kΩ	5 Vdc	0%
10 kΩ	4.99 Vdc	0.25%
1 kΩ	4.88 Vdc	2.5%

(b)

Probe resistance	Output "high" level	Error
Infinite (no probe)	4 Vdc	0%
1 MΩ	4 Vdc	0%
100 kΩ	4 Vdc	0%
10 kΩ	3.96 Vdc	1%
1 kΩ	3.64 Vdc	9.1%

(d)

Fig 2—To analyze high-output voltage levels, you must look to the output characteristics of CMOS logic (a). The FET's output voltage will vary as a function of probe resistance (b). For CMOS devices with steeper I/O characteristics (c), the effects of probe loading are more pronounced (d).

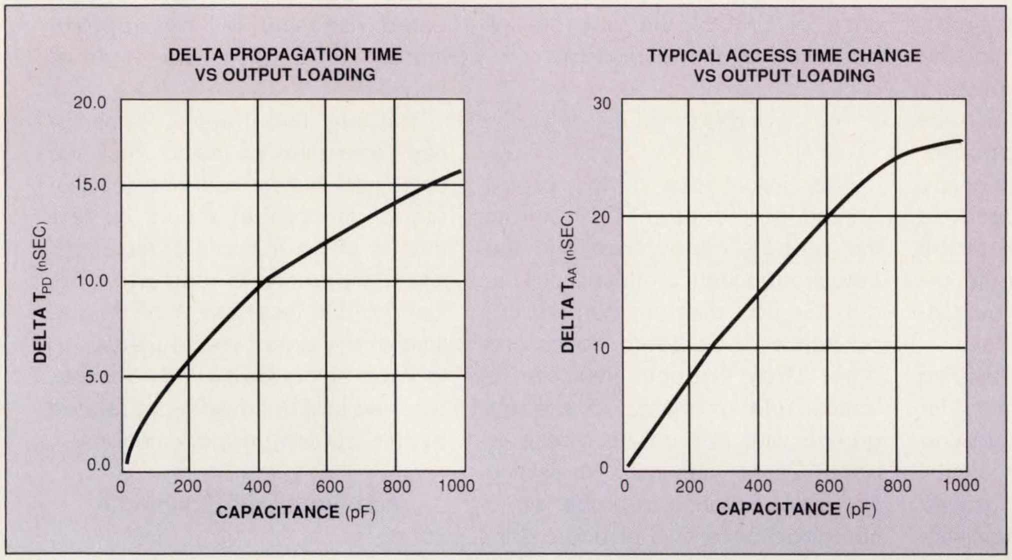


Fig 3—Propagation delay and access time both increase as the load capacitance increases. To minimize problems, always choose the probe with the lowest capacitance.

accurate voltage-level measurements on CMOS circuits as long as the outputs are in an active-high or an active-low state. However, high-Z measurements can be problematic. Measuring the time it takes for a device's output to go into the high-Z state after its output-enable pin is negated can be difficult. It's even tougher to make a measurement when you suspect that some device's output is trying to drive a bus high or low when the bus should be in the high-Z state. Having several drivers connected to a bus makes it very tough to find the culprit.

The output impedance of a device should be infinite when it is in the high-Z state, so you might guess that you need a very-high-resistance scope probe to detect this state. You might at least assume that the resistance of the scope probe should be many times larger than that of the node's pull-up resistor. Neither of these assumptions is correct.

To approach this measurement, think about what it means for an output to be in the high-Z state and how the circuit behaves. When a logic output is in the high-Z state, no current should be flowing. Other components connected to the output node will therefore determine the voltage at the device's output pin. These components include the pull-up resistor, other device inputs or active outputs connected to the same node, and the capacitances of the pc-board trace and the components attached to the circuit node.

When all outputs on a circuit node are in the high-Z state, the voltage at that node will change only if the charge on the node's load capacitance changes. With all outputs in a high-Z state, the only current source available to alter the charge on the node's load capacitance is the pull-up resistor, if one is connected. The rate of voltage change will therefore be set by the node's time constant, which equals the load capacitance value times the pull-up resistor's value. Typical CMOS devices have an input capacitance of 4 to 10 pF. Circuit-board traces can add several pF. For a bus with several devices connected to it, the total capacitive load might be on the order of 100 pF. For a 10-kΩ pull-up resistor and a 100-pF load capacitance, the time constant is 1 μsec.

Thus, when a device's output enters the high-Z state, we would not expect to see the output voltage level change significantly for tens or hundreds of nanoseconds. Of course, if the output were at a "high" level before going to the high-Z state, we would not expect the output level to change at all because the voltage is already as high as it can go. Therefore, voltage measurements will not tell you whether a device is really in the high-Z state or how long it takes to reach that state, regardless of the probe's resistance.

The best way to determine whether a particular device is trying to drive the bus either high or low is to measure the current in the device's output pin using a current probe and an oscilloscope. No current should flow through the device's output pin in either direction when the device is in the high-Z state. Make sure you select a current probe and oscilloscope with adequate bandwidth for this task (5 to 10× wider than the circuit's bandwidth).

Because the current probe introduces an unknown time delay, you should first de-skew the current probe and the voltage probe. Connect the equipment as shown in **Fig 4a.** Some digital oscilloscopes have internal de-skewing capabilities. If the scope you are using doesn't have the capability to automatically de-skew channels, record the amount of delay between the two

Text continued on pg 128

A probing primer

Any time you connect a scope or logic-analyzer probe to a circuit, the probe becomes a part of the circuit under test and the probe's transfer function affects the overall measurement system's response. These probe effects will degrade measurement accuracy because the new circuit including the probe will behave differently from the circuit without the probe. But you cannot eliminate the probe's effect.

The probe contributes resistive and capacitive loading effects. Inductance in the probe's ground lead can also affect measurements. The probe's resistance to ground forms a divider network in conjunction with the source resistance of the circuit under test **(Fig A)**, decreasing the signal amplitude and also reducing the dc offset. If the probe's resistance is nine times greater than the Thevenin-equivalent output resistance of the circuit under test, attaching the probe will reduce the output-signal amplitude by approximately 10%. In general, the frequency-independent amplitude errors and dc offset errors introduced by a probe's resistive loading are approximately proportional to the ratio of the probe's resistance to ground and the equivalent output resistance of the circuit under test.

The probe's tip capacitance (in parallel with the probe resistance) forms an RC circuit with the output resistance of the circuit under test. The RC circuit's time constant will slow the rise time of any signal transitions, increase the slew rate, and introduce delay in the actual time the transitions occur. As a rule of thumb, the rise time of a simple RC circuit is approximately 2.2 RC. Thus, for an output resistance of 100Ω and an 8-pF probe tip capacitance, the real rise time at the node under test cannot be faster than about 1.8 nsec.

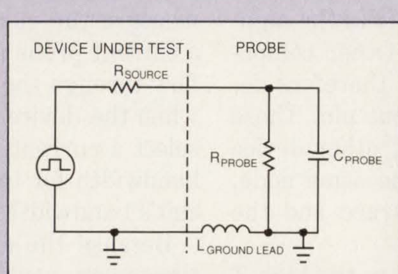
If the output of the circuit under test is current limited (as is often the case for CMOS), the slew rate will be limited by the relationship

$$dV/dt = I/C.$$

The inductance of the probe ground lead forms an LC circuit with the probe's capacitance and the output capacitance of the circuit under test, (including any parasitic capacitance of pc-board traces and other stray capacitances). As a handy rule of thumb, a probe's ground wire has an inductance of about 25 nH per inch. Neglecting circuit capacitance, a probe with a tip capacitance of 8 pF and a 4-in. ground wire will have a ringing frequency of approximately 178 MHz. Therefore, a signal with a rise time of less than 1.9 nsec may stimulate ringing.

A look at system bandwidth

To obtain error-free time-interval measurements, the bandwidth of the combined oscilloscope-and-probe system must be wide enough to accurately reproduce the circuit's signal. If you use a scope-probe combination that has a combined rise time of 1 nsec to measure a signal with a 1-nsec rise time, the approximate measured rise time will be 1.41 nsec. This answer is in error by 41%. If you use a scope-probe combination with a system rise time of 330 psec to measure the same



The amplitude of the output signal and the value of dc offset will both decrease because the probe resistance forms a divider network with the source resistance of the device under test.

1-nsec actual rise time, the indicated rise time will be approximately 1.05 nsec—an error of only 5%.

You may find it useful to memorize three rules of thumb. First, the combined system rise time (oscilloscope and probe) should be less than ⅓ of the rise time of the signal you're measuring to keep errors below 5% and less than 1/7 of the rise time of the signal you're measuring to keep errors below 1%. Second, rise time and bandwidth are related by the following approximations:

$$\text{Rise time} \approx 0.35/\text{Bandwidth}$$

and

$$\text{Bandwidth} \approx 0.35/\text{Rise time}.$$

Finally, rise times add approximately as the square root of the sum of the squares.

For example, if the oscilloscope and the probe each have a 1-GHz bandwidth, the combined bandwidth is approximately 707 MHz and the combined rise time is roughly 495 psec. Therefore this combination could be used confidently to measure actual signal rise times of 1.5 nsec with a less than 5% error or 3.5 nsec with a less than 1% error.

Oscilloscope probes are available in three common types: low-impedance resistive-divider probes; compensated, high-resistance passive-divider probes; and active probes. Resistive-divider probes are designed for scopes with a 50Ω input impedance. The probe tip consists of a 450Ω or 950Ω series resistor. The probe's cable is a 50Ω transmission line. Because the cable is terminated by 50Ω at the scope input, it appears as a purely resistive 50Ω load at the probe's tip. Therefore the resistive divider is flat over a wide range of frequencies, limited primarily by the parasitic capacitance and inductance of the 450Ω or 950Ω resistor and the fixture that holds it. The resistive-divider probe has the lowest capacitive loading. Its low capacitance and inherent wide bandwidth of several GHz make the resistive-divider probe the best choice for wide-bandwidth measurements or measurements where timing is the most critical parameter.

Relatively heavy resistive loading is a drawback of the resistive-divider probe. Not all circuits can drive 500Ω or 1 kΩ. Even for measurements in a relatively low-impedance circuit, the amplitude errors caused by a resistive-divider probe may be significant. When using this type of probe, keep in mind that the probe may cause changes in bias levels or operating currents that can cause the circuit's behavior to change.

Compensated passive-divider probes are the most common type of scope probe. Most logic analyzer probes also use this same general design. The 900-kΩ resistor in the probe tip forms a 10:1 voltage divider with a 100-kΩ resistor located at the other end of the probe cable. Some probe designs put a 9-MΩ resistor at the probe's tip, and the scope's 1-MΩ input resistance forms the other part of the voltage divider. To achieve a flat frequency response, the voltage divider must include compensation for the capacitance of the cable and for the scope (or analyzer) input capacitance. Because the input capacitance of the scope is unknown, one of the compensating capacitors should be adjustable so you can optimize the step-response flatness.

The compensated passive-divider probe has the highest input resistance of any probe type. However, it also has the highest capacitive loading and the lowest bandwidth. At 2 MHz, an 8-pF capacitance has a 10-kΩ impedance and at 100 MHz it is only 200Ω. Compensated passive-divider probes are often referred to as high-impedance probes. This is a misnomer because these probes exhibit high input impedances only at relatively low frequencies.

An active probe has a buffer amplifier at its tip. This buffer amplifier drives a 50Ω cable terminated by 50Ω at the scope's input. Active probes offer the best overall combination of resistive loading, capacitive loading, and bandwidth, even though they don't have the highest resistance, the highest bandwidth, or the lowest capacitance available. The disadvantages of active probes are relatively high cost, relatively large tip size, a somewhat limited dynamic input range, and greater susceptibility to damage. You should handle them with care.

The perfect probe doesn't exist, so you must exercise some discretion when choosing the best type for each measurement. To make this choice, you must know the equivalent circuit for the circuit you're going to test, the approximate bandwidth or spectral content of the signal you'll be measuring, and the characteristic (voltage or time) you want to measure most accurately. Logic analyzers generally don't give you a choice of probes. Logic-analyzer probes are usually designed to be used with a particular analyzer. The **table** lists some characteristics of representative oscilloscope and logic-analyzer probes.

However, you still need to understand the effect of the probes on the measurement. The examples above used a simple resistance as the equivalent circuit for the circuit under test. For actual cases, you need a more complete model to understand the probe's effects. For truly demanding measurements you may find it worthwhile to simulate the effect of the probe using SPICE.

Table A—Probe characteristics

Manufacturer	Model number	Resistance	Capacitance	Bandwidth
Resistive-divider probes				
Hewlett-Packard	54006A	1 kΩ, 500Ω	0.25 pF	6 GHz
Tektronix	P6150	500Ω	0.15 pF	9 GHz
Compensated passive-divider probes				
Hewlett-Packard	1043A 10432A	1 MΩ 10 MΩ	6.5 pF 7.5 pF	500 MHz 300 MHz
Tektronix	P6137 P6562	10 MΩ 10 MΩ	10.8 pF 10.3 pF	400 MHz 350 MHz
Fluke/Philips	PM8929/391	10 MΩ	12 pF	325 MHz
Active probes				
Hewlett-Packard	54001A 54701A	100 kΩ 100 kΩ	2 pF 0.6 pF	1 GHz 2.5 GHz
Tektronix	P6203 P6204 P6205	10 MΩ 10 MΩ 1 MΩ	2 pF 1.9 pF 2 pF	1 GHz 1 GHz 750 MHz
Fluke/Philips	PM8943Q	1 MΩ	3.5 pF	650 MHz
Logic-analyzer probes				
Hewlett-Packard	1650B,16510B 16515A,16516A	100 kΩ 10 kΩ	8 pF 3 pF	NA NA
Tektronix	1230 Prism 30HSM	1 MΩ 165 kΩ	8 pF 11 pF	NA NA
Fluke/Philips	PM3580	200 kΩ	7 pF	NA

NA=Not applicable.

PROBING CMOS CIRCUITS

channels and subtract that amount from subsequent measurements.

If you don't have a current probe, you can use an alternate method to measure the time required by a device to achieve the high-Z state after its output-enable pin is negated. Construct a relatively small-value resistive divider connected to the output as shown in **Fig 4b.** The combined parallel value of the divider resistors should be less than 1/10 of the probe's resistance. For example, for a 100-kΩ probe, the equivalent resistance of the divider should be less than 10 kΩ, so each divider resistor should be 20 kΩ or smaller. If you plan to use a 1-kΩ resistive divider probe, use the probe as one of the divider resistors (R_2 in **Fig 4b**), and a 1-kΩ resistor for the other half of the divider.

Using this resistive-divider probe, you will measure an output level of $V_{CC}/2$ when the device's output is in the high-Z state. When the output is not in the high-Z state, you will measure the normal high- or low-output levels. Using a normal probe, you can then connect another oscilloscope channel to the device's output-enable input to measure the delay between negation of the output-enable pin and the transition to the high-Z state. This technique will not identify the offending device in cases of bus contention. Any device driving the node will force the bus line to either the high or low state. You can only use the resistive-divider technique for verifying the delay between the negation of the output-enable pin and the onset of the high-Z state. You still need a current probe to trace bus-contention problems. EDN

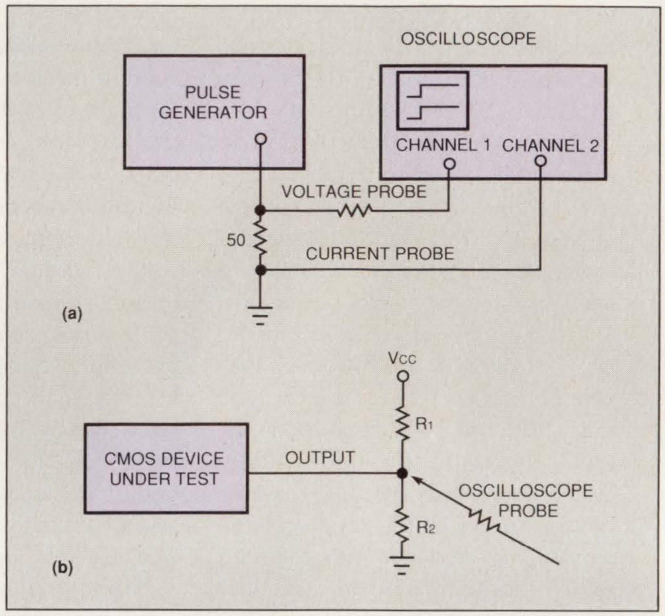
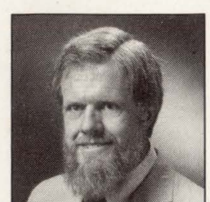


Fig 4—To account for probe time-delay characteristics when making high-Z-state measurements, you should de-skew the scope's current and voltage probes by adjusting the scope controls until the edges on channels 1 and 2 are coincident (a). When you don't have a current probe, you can use a resistive divider (b) to verify high-Z output-state conditions.

Author's biography

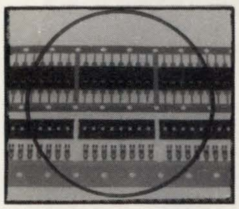


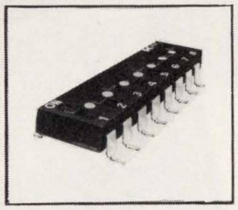
Art Porter is a product marketing engineer at Hewlett-Packard Co (Colorado Springs, CO). He is currently involved with research and development activities in the planning of new products. During his 29 years at Hewlett-Packard, Art has worked on the development of several oscilloscope product lines. In his spare time, Art enjoys photography, rock climbing, and cross-country skiing.

Article Interest Quotient (Circle One)
High 470 Medium 471 Low 472

THE WORLD'S SMALLEST SURFACE MOUNT DIP SWITCH!

American Research & Engineering's strip molding process makes for a more reliable switch





It's More Reliable

Three simple components: two composite metal/plastic strips and one plastic molded cover replaces a 25 piece assembly to make a switch that's more reliable because it's more consistent.

SAME SIZE AS AN IC!

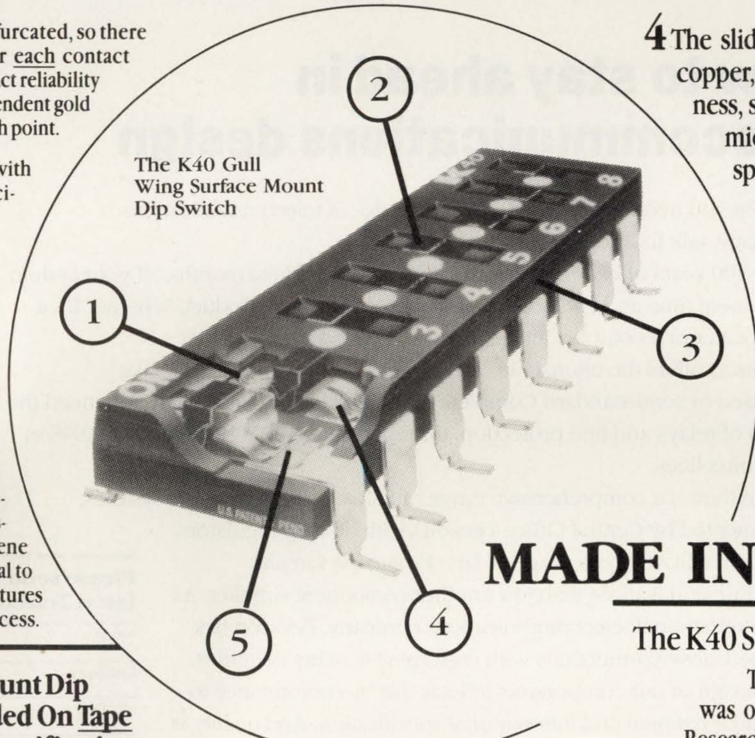
If you don't have automatic insertion equipment, we're banking that some day you will. In the meantime, your board will look neater, better and more professional. And if you have insertion equipment, you'll save the cost of hand insertion!

Three New Patent Designs That Use 40% Less Parts

1 The sides are split, or bifurcated, so there are two separate slides for each contact point. This doubles the contact reliability because you have two independent gold plated contacts at each switch point.

2 The switches are flush with the cover to eliminate accidental, on-off movement once the DIP is programmed. Simple.

3 The package is sealed. The lead frame is molded directly into the housing to provide a one piece, no leak construction. The cover is ultrasonically welded to the housing after the switch is assembled. There is no better construction. The surface mount housing is made of polyphenylene sulfide with a Kapton tape seal to withstand the high temperatures of the reflow soldering process.



4 The slides are made from beryllium copper, heat tempered to a full hardness, spring formed, plated in a 100 micro inch nickel bath and then spot gold plated 30 micro inch deep at all the contact points. This is the best proven switch contact surface that money can buy.

5 Every one of the switch contact surfaces on the main lead frame are plated with 30 micro inch of gold over 100 micro inch of nickel.

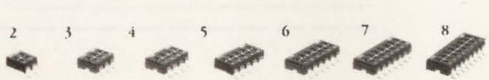
MADE IN AMERICA

The K40 Standard Pin Dip Switch

The K40 standard pin DIP Switch was originally designed by American Research & Engineering in 1982 as the world's smallest DIP Switch. It was with its incredible small size and durability that the K40 standard pin DIP Switch led to the development of the new K40 Surface Mount DIP Switch lineup. Lead time for the K40 standard pin DIP Switch is seven to fourteen days and fourteen to twenty-one days for the K40 Gullwing DIP Switch. All K40 switches are manufactured at our plant in Elgin, Illinois.

The K40 Surface Mount Dip Switches Are Provided On Tape and Reel per EIA Specifications or In Standard IC Tubes.

All K40 Dip Switches Are Available In Positions Two Thru Eight!



AMERICAN RESEARCH & ENGINEERING
1500 EXECUTIVE DRIVE ELGIN IL. 60123

FREE SAMPLE! Send Us Your Business Card Stapled To Your Letterhead

AMERICAN RESEARCH & ENGINEERING
1500 EXECUTIVE DRIVE, ELGIN, IL. 60123 1-708-888-7245
FAX [708] 888-7094

CIRCLE NO. 76

How to stay ahead in telecommunications design

When you need to keep at the leading edge of telecommunications technology, talk to Ericsson.

Our 100 years of experience in the industry could take months off your system development time and cut the cost and size of your final product. Whether it's a PCM repeater or a complete line card.

Ericsson offers the ultimate in integration for every application. Like customised or semi-standard Complete Line Interface Circuits which only need the addition of relays and line protection. Or regenerative PCM repeaters for 2.048 or 1.544 Mbit/s lines.

Then there's a comprehensive range of SLICs for PBX and DLC systems, complemented by Central Office versions with on chip regulators. In addition, a SLAC and a range of Line Protection Circuits.

But Ericsson is more than just another component supplier. As a truly international telecommunications company, Ericsson has developed close partnerships with customers in many countries. So the design of our components reflects this by conformance to every major national and international specification. And quality is assured.

The telecommunications world constantly threatens to leave you one step behind. Ericsson can help you stay ahead. Simply call us for more information.

Please send me your latest Telecom IC Shortform data EDN 3-30-92

Name

Company

Job Title

Address

Telephone

Fax

Ericsson Components Inc.
403 International Parkway Richardson TX 75081
Tel: 214-669-9900 Fax: 214-680-1059

Representatives: Alabama (205)880-8050. Arizona (602) 991-6300. California (408) 253-1960, (619) 292- 1771, (714) 891-4621. Colorado (303) 758-4884. Connecticut (203) 243-9343. Florida (407) 352-3755. Georgia (404) 448-1215. Illinois (312) 968-0118. Indiana (317) 577-9950. Iowa (319) 354-8894. Massachusetts (508) 692-2500. New Jersey (201) 525-8000. New York (516) 929-5756, (716) 586-0777, (518) 383-2239. N.Carolina (919) 847-8800. S. Carolina (803) 233-4637. Texas (214) 553-1200, (512) 834-8374, (713) 370-8177. Washington (206) 882-0962, (206) 254-4572. Wisconsin (414) 781-1730.

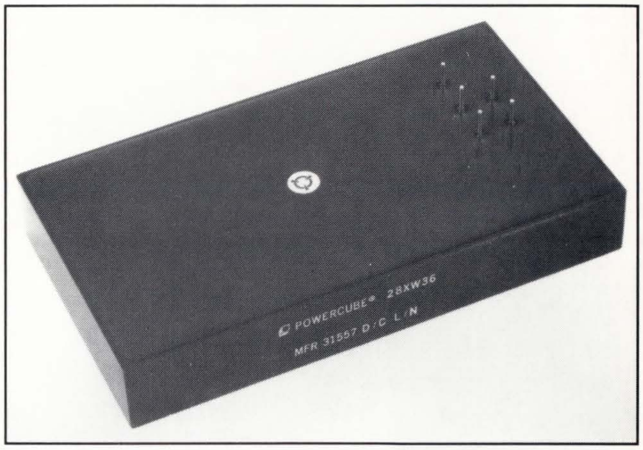
ERICSSON

CIRCLE NO. 67

6 to 60 VDC Input

12.8W/IN^3

Operates down to 6 VDC input (Steady State) allowing for droop/engine crank requirements.



XW Series
DC-DC Converters

From Powercube, the leading manufacturer of High Reliability DC to DC Converters comes an extra wide input DC to DC Converter. This converter, with 6 to 60VDC input, is designed to exceed the requirement of steady state, initial engagement and engine cranking conditions of MIL-STD-1275 at 50 watt load (10 to 60VDC at 100 watt load).

Designed to Meet or Exceed

- MIL-STD-704A through D
- MIL-STD-461B
- MIL-STD-462
- MIL-STD-1275A
- MIL-STD-810
- NAVMAT P-4855-1A
- NAVSO P-3641

Features

- Efficiency up to 72%
- Remote Sense
- Remote Shutdown
- External Trim
- Current Limit Protection
- Active OVP
- Parallelable
- MTBF > 1,000,000 Hours
- -55°C to +100°C Operation (baseplate temperature)
- Outputs 5, 12, 15, 24, & 28VDC
- Accepts 250VDC Transients
- MIL-S-19500 JANTX & 883C (consult factory)

POWERCUBE

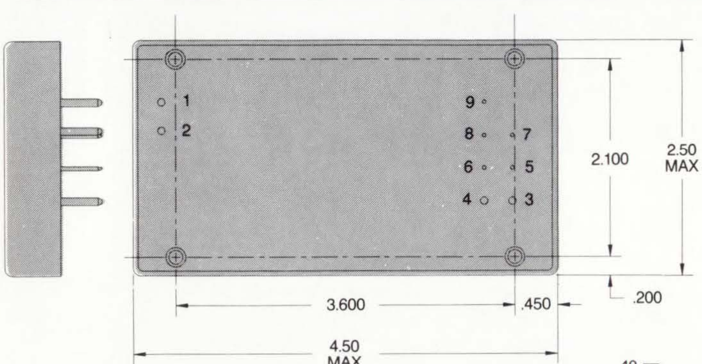
Eight Suburban Park Drive, Billerica, Massachusetts 01821
Phone: (508) 667-9500 • Fax: (508) 667-6280
Additional Facilities: Texas • Arizona • Mexico

XW Series DC to DC Converter

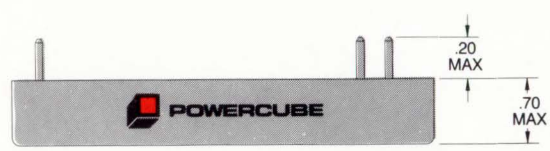
Specifications

PART NUMBER	660XW5-75	660XW12-100	660XW15-100	660XW24-100	660XW28-100
INPUT VOLTAGE	6-60VDC	6-60VDC	6-60VDC	6-60VDC	6-60VDC
NOM. INPUT VOLTAGE	28VDC	28VDC	28VDC	28VDC	28VDC
OUTPUT VOLTAGE	5VDC	12VDC	15VDC	24VDC	28VDC
OVERVOLTAGE SETTING (TYP)	7.2VDC	16VDC	19VDC	26VDC	30VDC
OUTPUT CURRENT (MAX)	15A	8.3A	6.7A	4.2A	3.6A
INITIAL SETTING (MAX)	±1%	±1%	±1%	±1%	±1%
TRIM RANGE	±10%	±10%	±10%	±10%	±10%
LINE REGULTATION (MAX)	0.3%	0.3%	0.3%	0.3%	0.3%
LOAD REGULATION (MAX)	0.3%	0.3%	0.3%	0.3%	0.3%
TEMP. STABILITY (MAX)	0.015%/°C	0.015%/°C	0.015%/°C	0.015%/°C	0.015%/°C
EFFICIENCY (28VDC IN, FL TYP)	65%	70%	72%	72%	72%
RIPPLE & NOISE (MAX) (20 MHz Bw 10% TO FL)	200mV p-p	175mV p-p	175mV p-p	175mV p-p	175mV p-p

Mechanical

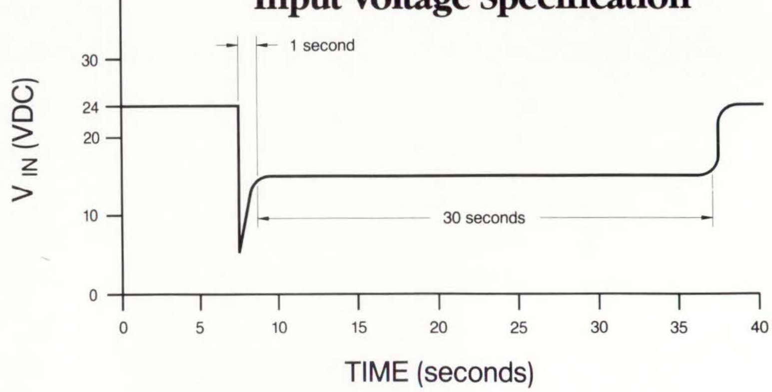


Dimensions are in inches.
Weight: 10 ozs.



PIN	FUNCTION
1	INPUT
2	INPUT RTN
3	OUTPUT
4	OUTPUT RTN
5	REM. SENSE +
6	REM. SENSE RTN
7	REM. SHUTDOWN
8	OUTPUT TRIM
9	LOAD SHARE

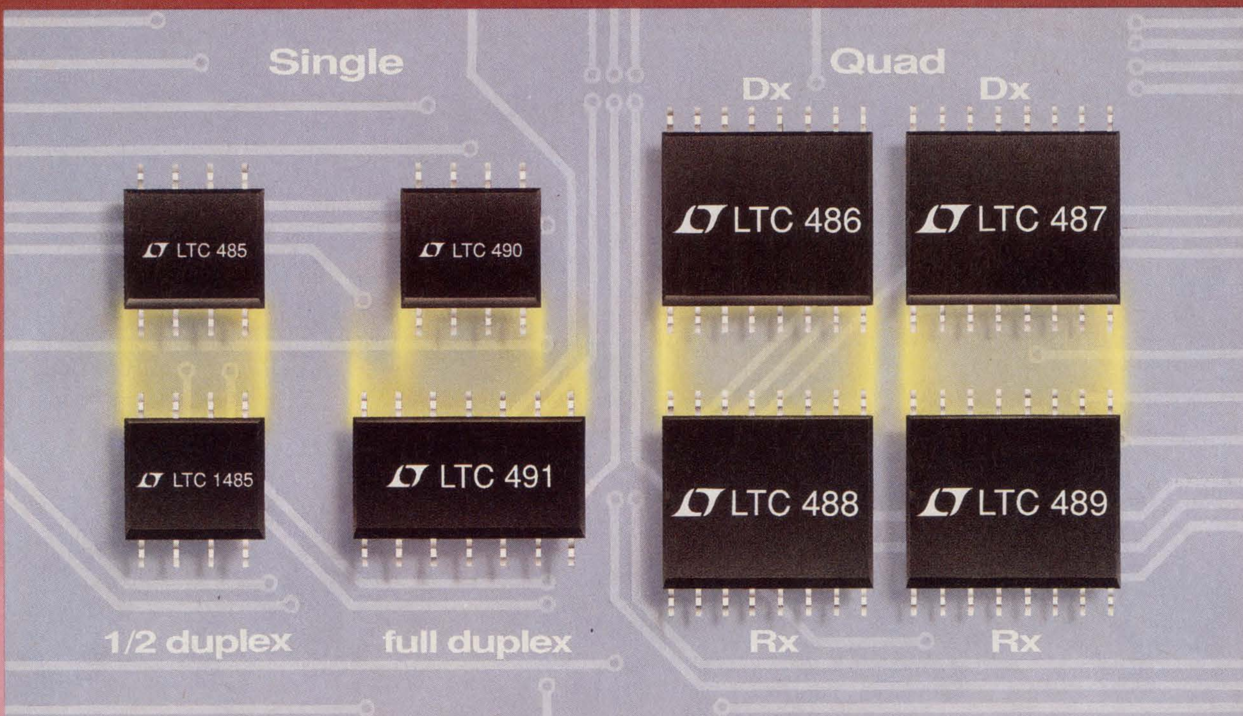
MIL-STD-1275A
Input Voltage Specification



POWERCUBE

Eight Suburban Park Drive, Billerica, Massachusetts 01821
Phone: (508) 667-9500 • Fax: (508) 667-6280
Additional Facilities: Texas • Arizona • Mexico

Lowest Power RS485 Family.



Up to 400X Less Power.

Now there are eight members of the Linear Technology ultra low power RS485/RS422 family. They're manufactured with LTC's proprietary Schottky LTCMOS™ process to achieve low power consumption without sacrificing ruggedness. The entire family is pin compatible with industry standard devices. Simply remove the old bipolar power hog from your board and plug in LTC's low power replacement for up to **400X lower power consumption!**

LTC486/487 quad line drivers are designed for data rates up to 10 Mbs, but the quiescent current is only 150 μA max. LTC488/489 quad receivers function over a −7V to +12V input common mode range at data rates up to 10Mbs and consume 8X less power than previously available parts.

LTC PART NUMBER	DESCRIPTION	LTC POWER SAVINGS	I_{CC} MAX	STD PINOUT
LTC485	Half Duplex Transceiver	60X Lower	500μA	75ALS176B
LTC486	10Mbs Quad Driver	400X Lower	150μA	75172
LTC487	10Mbs Quad Driver	400X Lower	150μA	75174
LTC488	10Mbs Quad Receiver	7X Lower	10mA	75173
LTC489	10Mbs Quad Receiver	7X Lower	10mA	75175
LTC490	Full Duplex Transceiver	140X Lower	500μA	75179B
LTC491	Full Duplex Transceiver	60X Lower	500μA	75ALS180
LTC1485	10 Mbs Half Duplex Transceiver	8X Lower	3.5mA	75ALS176B

LTC490/491 are full duplex versions of the LTC485, containing a single driver and receiver. Power dissipation is the same as the LTC485 — a mere 2.5 milliwatts. The LTC1485 is a true 10Mbs version of the LTC485 with only 17.5 milliwatts of power consumption.

All LTC RS485 parts withstand forced voltages above and below the supplies without latchup. Driver skew is less than 10ns and outputs stay glitch free during power up/down.

All parts are available in DIP and SOIC packages in commercial and industrial temperature grades. 100-up pricing in plastic DIP starts at $1.35. For more information contact Linear Technology Corporation, 1630 McCarthy Blvd., Milpitas, CA 95035. Or call **800-637-5545.**

LINEAR TECHNOLOGY

TOUGH PRODUCTS
FOR TOUGH APPLICATIONS.

CIRCLE NO. 69

CMOS logic creates precision waveforms

Michael A Wyatt, Honeywell SSO, Clearwater, FL

The circuit in **Fig 1** generates three different waveforms having frequencies less than 1 Hz: triangle waves, positive ramps, and negative ramps. At very low output frequencies, the stability of the circuit's input frequencies almost completely determines the output waveform's linearity.

XOR gate IC_3 beats input frequency f_{IN} against reference frequency f_{REF}, thus producing a train of pulses whose periods increase gradually until the frequency sources are completely out of phase. Then, the pulses' periods decrease until the sources are again in phase. Flip-flops IC_{1A} and IC_{1B} produce 50% duty-cycle inputs for XOR gate IC_3.

IC_5 and its surrounding components form a third-order, lowpass filter ($f_C=1$ kHz). The filter averages the output of pulse buffer IC_4 to produce a triangle waveform having a peak amplitude of V_{CC} and a frequency of $|f_{IN}-f_{REF}|\div 2$. Be sure to select low-dielectric-absorption capacitors for the filter circuit.

The circuit generates ramp waveforms in a similar manner except that the SR flip-flop phase comparator formed by IC_{2A} and IC_{2B} replaces the XOR gate. The phase comparator sets on every other negative transition of f_{IN} and subsequently resets on every other negative transition of f_{REF}. If f_{IN}'s frequency is greater than f_{REF}'s, then the width of IC_{2B}'s Q output pulse will gradually increase. This increase produces a positive-going ramp at the circuit's output. If f_{IN}'s frequency is less than f_{REF}'s, the output will be a negative-going ramp. Note that the filter's step response controls the ramp's reset time. Selecting a frequency greater than 100 kHz for f_{IN} and f_{REF} attenuates the pulse's ripple, which relaxes the reset-time restrictions.

EDN BBS /DI_SIG #1101 EDN

To Vote For This Design, Circle No. 746

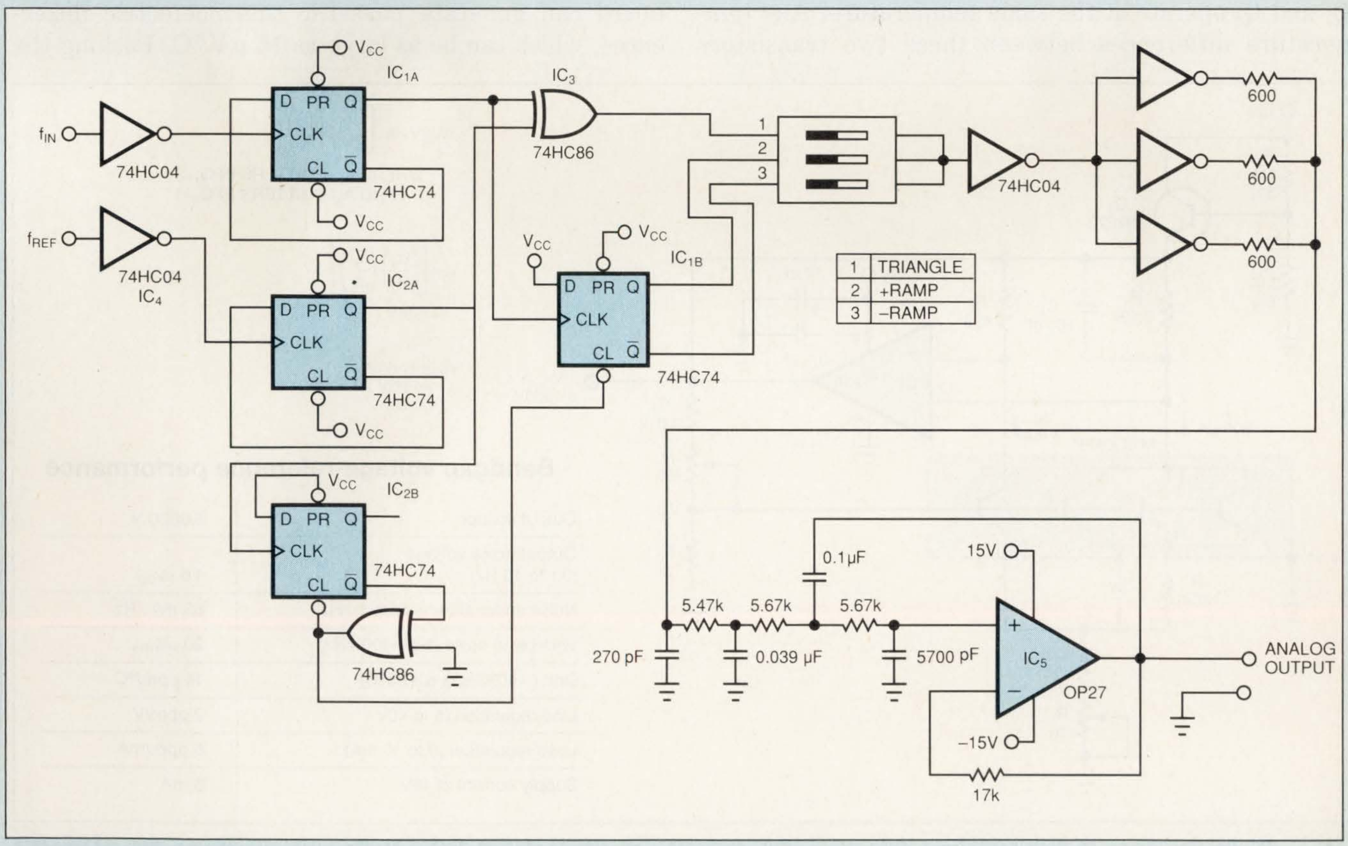


Fig 1—By beating two high-frequency input-pulse frequencies against each other and then integrating the resulting beat-frequency pulse train, this circuit produces low-frequency analog waveforms having good linearity.

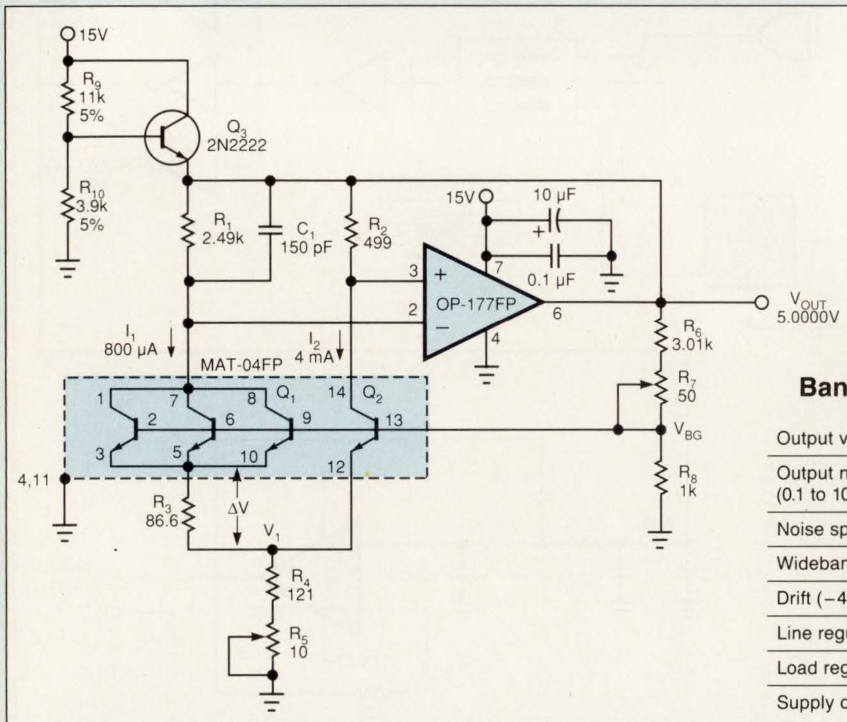
Voltage-reference circuit boasts low noise

Adolfo Garcia, Analog Devices Inc, Santa Clara, CA

Noise is of critical importance in high-resolution, 16- to 20-bit, data-acquisition systems. The voltage reference can contribute the dominant share of the system's noise floor, thereby degrading system dynamic range and S/N ratio. To maximize these parameters, all external noise contributions should be much less than 1/2 LSB. Thus, the wideband noise contribution of a voltage reference and all other sources to 5V full-scale 16- and 18-bit systems should be less than 38 μV rms and 9.5 V rms, respectively. Very few commercially available references exhibit low enough wideband noise without noise shaping or filters.

Fig 1 shows a single-supply 5V reference design whose performance is summarized in the accompanying table. This design's noise is more than a factor of 2 lower than any 5V monolithic reference. In addition, the circuit's wideband noise in a 100-kHz bandwidth is 20 μV rms, and therefore is suitable for 16-bit systems. The circuit uses very-low-noise matched transistors operating at high collector currents to keep their noise contribution low. The design also ensures that Q_1 and Q_2 operate at the same temperature. Any temperature differences between these two transistors causes V_{BE} differences that will unbalance the bandgap reference's core. The MAT-04, a quad monolithic transistor, prevents V_{BE} temperature differences because all the transistors share a common substrate. Another dominant noise source is R_3, and by operating high currents in the bandgap core, its value is kept to a minimum. In this circuit topology, the lower the value of R_3 the lower the noise. To ensure repeatable low-frequency noise measurements, take care to shield the circuit from air currents. Any air movement around the circuit can create noise because of the thermoelectric differences between the IC's package leads and the copper traces on a pc board. A Styrofoam cooler works well to keep air turbulence from polluting noise measurements.

An important parameter in any voltage reference is drift over temperature. Careful layout and selection of components account for this reference's low drift. Much in the same way air currents can generate noise in the circuit, they can be a source of drift. Junctions formed by the IC's pins and the copper traces on a pc board can generate parasitic thermoelectric differences, which can be as large as 15 μV/°C. Packing the



$$\Delta V = V_T \ln\left[\left(\frac{I_2}{I_1}\right)\left(\frac{A_1}{A_2}\right)\right]$$

WHERE A_1=EMITTERS IN Q_1=3
AND A_2=EMITTERS IN Q_2=1

$$V_1 = \left[\left(\frac{R_4}{R_3}\right)\left(\frac{I_2}{I_1}\right)\right]\Delta V$$

$$=7.0\Delta V$$

$$V_{BG} = V_1 + V_{BE}(Q_2)$$
$$\approx 1.23\text{V AT } +25°\text{C}$$

Bandgap voltage-reference performance

Output voltage	5.0000 V
Output noise voltage (0.1 to 10 Hz)	1.6 μV_{pp}
Noise spectral density at 1 kHz	63 nV/$\sqrt{Hz}$
Wideband noise (BW=100 kHz)	20 μV_{rms}
Drift ($-40°C \le T_A \le +85°C$)	14 ppm/°C
Line regulation (6 to 40V	2 ppm/V
Load regulation (0 to 10 mA)	6 ppm/mA
Supply current at 15V	8 mA

Fig 1—Minimizing noise in high-resolution data-acquisition systems—no simple design task—starts with minimizing the reference's noise contribution. This circuit uses matched transistors and carefully selected resistors to implement a bandgap reference with noise of 1.6 $\mu V_{p\text{-}p}$ in the 0.1- to 10-Hz band.

rugged plug-in amplifiers

0.5 to 2000 MHz from $13.95 (10 to 24 qty)

Tough enough to meet full MIL-specs, capable of operating over a wide -55° to +100°C temperature range, in a rugged package...that's Mini-Circuits' new MAN-amplifier series. The MAN-amplifier's tiny package (only 0.4 by 0.8 by 0.25 in.) requires about the same pc board area as a TO-8 and can take tougher punishment with leads that won't break off. Models are unconditionally stable and available covering frequency ranges 0.5 to 2000 MHz, NF as low as 2.8dB, gain to 28dB, isolation greater than 40dB, and power output as high as +15dBm. Prices start at only $13.95 *including* screening, thermal shock -55°C to +100°C, fine and gross leak, and burn-in for 96 hours at 100°C under normal operating voltage and current.

Internally the MAN amplifiers consist of two stages, including coupling capacitors. A designer's delight, with all components self-contained. Just connect to a dc supply voltage and you are ready to go.

The new MAN-amplifiers series...

• wide bandwidth • low noise • high gain
• high output power • high isolation

MODEL	FREQ. RANGE (MHz) f_L to f_U	GAIN dB min	GAIN dB flat††	MAX PWR† dBm	NF dB (typ)	ISOL. dB (typ)	DC PWR V/ma	PRICE $ ea. (10-24)
MAN-1	0.5-500	28	1.0	+8	4.5	40	12/60	13.95
MAN-2	0.5-1000	18	1.5	+7	6.0	34	12/85	15.95
MAN-1LN	0.5-500	28	1.0	+8	2.8	39	12/60	15.95
◇MAN-1HLN	10-500	10	0.8	+15	3.7	14	12/70	15.95
MAN-1AD	5-500	16	.05	+6	7.2	41	12/85	24.95
MAN-2AD	2-1000	9	0.4	-2	6.5	28	15/22	22.50
MAN-11AD	2-2000	8	0.5	-3.5	6.5	22	15/22	29.95

††Midband $10f_L$ to $f_{U/2}$, ±0.5dB † 1dB Gain Compression ◇Case Height 0.3 in.
Max input power (no damage) +15dBm; VSWR in/out 1.8:1 max.

Free...48-pg "RF/MW Amplifier Handbook" with specs, curves, handy selector chart, glossary of modern amplifier terms, and a practical Question and Answer section.

finding new ways...
setting higher standards

Mini-Circuits

A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

CIRCLE NO. 115

C118 REV. F

components tightly on the pc board minimizes this error by making sure that all the components operate at the same temperature. Enclosing the circuit in a box is a good way to shield the circuit from air currents.

Since the circuit's output voltage and drift are sensitive to resistor tolerance and temperature coefficient, all fixed resistors are type RN55C (1%, ±50 ppm/°C). Since R_1 and R_2 set the current ratio in the core, any mismatch in these components changes the current ratio, which affects ΔV and introduces drift. Second, the ratio of R_4 to R_3 amplifies ΔV with the current ratio. The result is voltage V_1, which adds to Q_2's V_{BE}, thus producing a temperature-invariant bandgap voltage of 1.23V at the bases of Q_1 and Q_2. Any mismatch in tolerance or temperature coefficient in R_3 and R_4 introduces drift by affecting V_1 and Q_2's V_{BE}. Last, R_6 and R_8 amplify the bandgap voltage of 1.23V to an output of +5.0000V. Any mismatch in these resistors changes the gain of the circuit and therefore changes the output voltage.

Another heavy contributor to the circuit's overall drift comes from the op amp's input-offset-voltage drift over temperature, which affects the bandgap core and introduces drift by changing the current ratio set by R_1 and R_2. Therefore, choose an op amp first for its low input-offset voltage drift and second for its high open-loop gain. C_1 provides compensation and stabilizes the core by rolling off the op amp's high loop gain.

Although you can use low-cost cermet trimmers for R_5 and R_7, keep in mind that these components typically have ±100 ppm/°C temperature coefficients. Therefore, use low-valued trimmers to keep the trim range narrow. Even mechanical changes that result from thermal expansion in the trimpot materials can be a large source of error. To trim the circuit, first adjust R_5 so that the bandgap voltage equals 1.23V at 25°C. Second, use R_7 to adjust the gain of the reference for +5.0000V at the output.

Bandgap references have a tendency not to start up when the power supply is turned on. You can avoid this condition by using a pair of resistors and an inexpensive npn transistor. R_9, R_{10}, and Q_3 form the start-up circuit. When the supply is turned on, there is no current in the bandgap core and the op amp's output is at 0V. Q_3 then turns on, and its emitter current flows through R_6, R_7, and R_8. When the output voltage reaches 3.2V, the op amp kicks in and stabilizes the operating point around 5V. This action shuts off Q_3 because its base is set to 3.9V. For a wider range of supply voltages, you can replace R_{10} with a 3.9V zener diode to improve the start-up circuit's supply rejection. **EDN BBS /DI_SIG #1100**

To Vote For This Design, Circle No. 749

Buffer goes solo in fast active filter

Michael Sedayao, Elantec Inc, Milpitas, CA

Active filters that drive low-impedance loads generally require a buffer with high output current at the filter output. If the filter doesn't require any gain, as in unity-gain operation, you can synthesize the filter using only the buffer. Although you give up gain adjustment, you still retain the buffer's 100-mA output driver and 180-MHz bandwidth. And, you've saved the cost of an op amp.

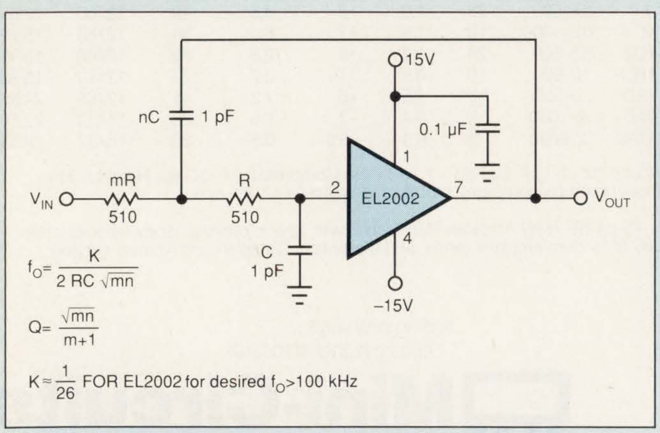


Fig 1—A single buffer implements this unity-gain Sallen-Key low-pass filter with a 12.2-MHz cutoff frequency.

Fig 1 illustrates a basic Sallen-Key low-pass filter using only one buffer. Resistor and capacitor ratios m and n and values R and C (see equations in **Fig 1**) determine the −3-dB frequency and Q of the filter. In this design, the −3-dB frequency is 12.2 MHz and the Q is 0.5. To change the low-pass filter to a high-pass filter, simply switch the resistor and capacitor locations. The resultant high-pass filter has a −3-dB frequency of 36 kHz and a Q of 0.5. This circuit will drive ±4.5V into 50 ohms and draws 5 mA of quiescent current. To achieve a Butterworth response, set Q=0.707. **EDN BBS /DI_SIG #1096**

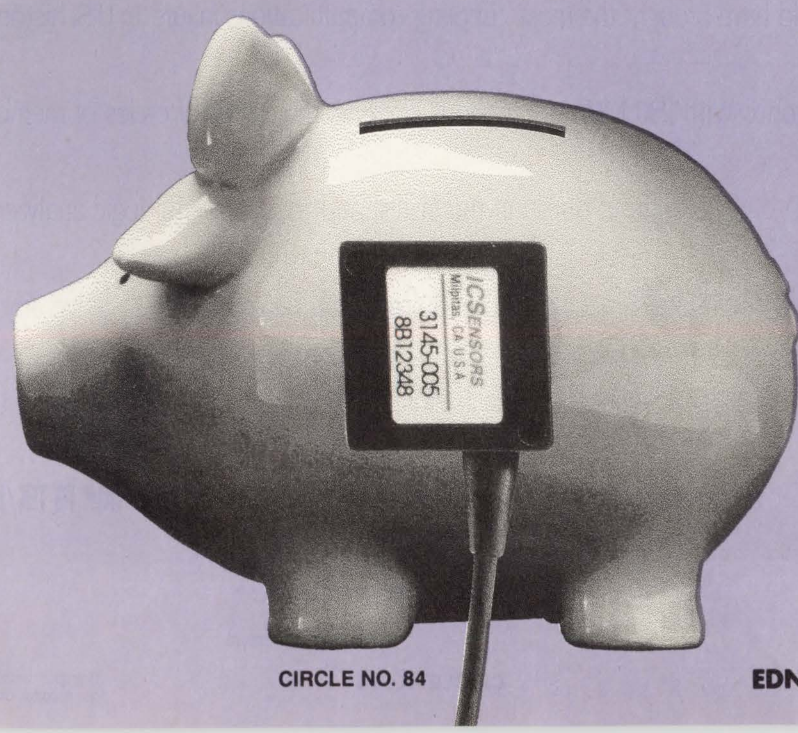
To Vote For This Design, Circle No. 750

Our new *Micromachined Accelerometers* deliver performance comparable to piezoelectric and strain gauge sensors—at a fraction of the cost. They offer built-in voltage regulation. Signal conditioning. Temperature compensation. Calibration. And they're available in a wide variety of acceleration ranges and sensitivities. Not familiar with micromachining technology? If you measure vibration, acceleration, motion or shock you should be. Circle the number below. We'll send product literature, data sheets, and a copy of *Understanding Accelerometer Technology.* Or call *800-767-1888.*

ICSENSORS

1701 McCarthy Blvd. Milpitas, CA 95035-7416

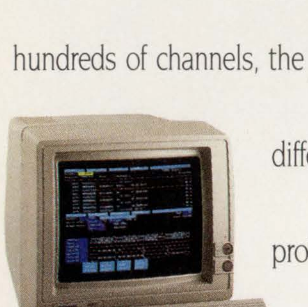
Introducing instrumentation-grade accelerometers that aren't a shock to your budget.



LAST SEPTEMBER, 85 MILLION PEOPLE DESPERATELY WANTED A DEMONSTRATION OF OUR FINEST LOGIC ANALYZER.

Only one logic analyzer could have brought the most crippling communications failure in U.S. history to a swift conclusion.

The new DAS/SE from Tektronix. With 200 MHz synchronous clocking, thousands of cycles of memory depth, and literally hundreds of channels, the DAS/SE is without question the fastest and most powerful logic analyzer around. And with 11 different stimulus & acquisition modules, it can be configured to solve any of your digital debug problems. For a personal demonstration, call Tektronix today and ask about the DAS/SE. The logic analyzer that could very well prevent another banner year. **TALK TO TEK/1-800-426-2200 EXT. 73**

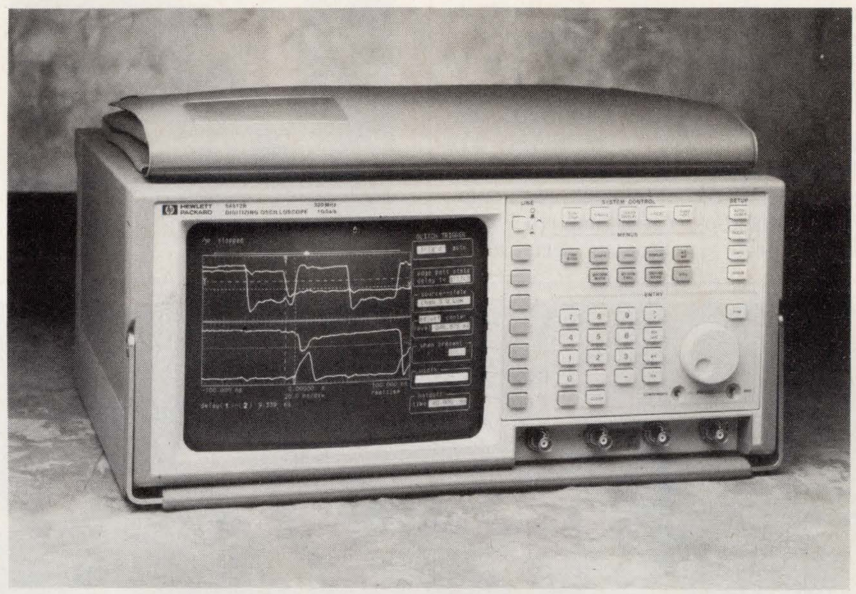


Tektronix
Test and Measurement

CIRCLE NO. 78

1-Gsample/sec 4- and 2-Channel Real-Time DSOs

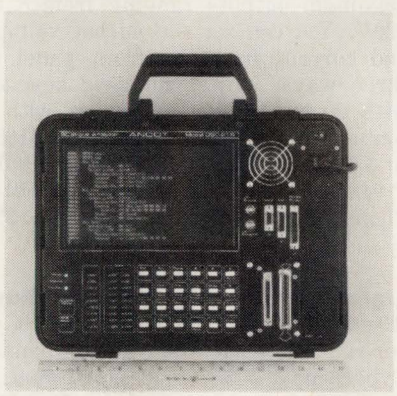
- *Have 250-MHz single-shot bandwidth on all channels*
- *Have 300-MHz repetitive-signal bandwidth*



The 54512B is a 4-channel DSO; the 54510B is the 2-channel version. Both scopes can take 1 Gsample/sec simultaneously on all channels. For transient signals, the scopes have a bandwidth of 250 MHz; for repetitive signals, where they can use random repetitive sampling, their bandwidth is 300 MHz. They use 8-bit A/D converters and have 8k-word/channel memory. The scopes also contain a long memory (more than 350k words in the 4-channel unit), which can store many waveform records. With a 512-point record, the 4-channel unit stores 723 single-shot events captured at 650 events/sec. Other capabilities include mathematical operations, such as FFTs. 4-channel scope, $17,990; 2-channel scope, $11,950. Delivery, eight weeks ARO.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900.

Circle No. 351



Attache-Case-Size Portable SCSI Bus Analyzer

- *Tests SCSI 1 and 2 Fast/Wide with 20-nsec resolution*
- *Has 32k-event trace memory (128k optional)*

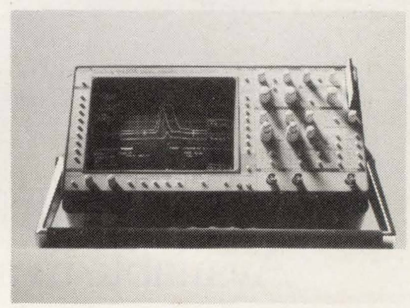
The DSC-216 is an attache-case-size tester for the SCSI bus. It handles SCSI 1 and 2 and tests fast and wide configurations of the bus. The stand-alone unit displays English-language messages on an 80-character × 24-line electroluminescent panel. It provides 20-nsec timing resolution, permits synchronous and asynchronous tracing at transfer rates above 10 MHz, and offers a 32k-event trace memory (128k optional). The tester, which performs passive synchronous/asynchronous and 4-edge request/acknowledge testing, is compatible with single-ended and optional differential versions of the SCSI bus. $8550.

Ancot Corp, 115 Constitution Dr, Menlo Park, CA 94025. Phone (415) 322-5322. FAX (415) 322-0455.

Circle No. 352

Memory Card For Telecom Testing On DSOs

- *Works with five of the vendor's scopes*
- *Includes 23 templates for testing to ANSI and CCITT specs*

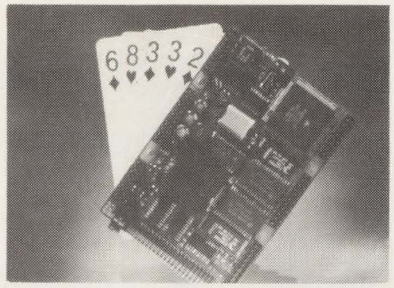


The 94XX-MC-TC1 credit-card-size memory card conforms to the PC-MCIA (Personal Computer Memory Card International Association) standard. It plugs into five of the vendor's DSOs, and the card enables those instruments to make 23 types of tests on telecommunications signals, conforming to ANSI and CCITT specifications. The card stores 512 kbytes, of which approximately 190 are occupied by the stored templates, and the rest are free. The templates are write protected. $700.

LeCroy Corp, 700 Chestnut Ridge Rd, Chestnut Ridge, NY 10977. Phone (914) 578-6097. TWX 710-577-2832.

Circle No. 353

Battery-powered data logger. The Tattletale Model 7 is a 2.75 × 4.5-in. pc board that consumes 5 mW in its low-power mode. The board includes a 68332 µP that you can operate from 160 kHz to 16 MHz (dynamically adjustable); a 12-bit ADC that takes 100 ksamples/sec; 2.2 Mbytes of RAM; 512 kbytes of flash EEPROM; 512 bytes of serial EEPROM; an RS-232C port operable to 500 kbps; a real-time clock with alarm; three synchronous serial channels; and 14 channels for time processing, auxiliary asynchronous serial I/O or digital I/O. The board works with hard disks to 500 Mbytes. From $1995. **Onset Computer Corp,** Box 1030, North Falmouth, MA 02556. Phone (508) 563-9000. FAX (508) 563-9477.
Circle No. 354



Microwave spectrum analyzer. The 2784 analyzer is a 40-GHz instrument in a coaxial-cable environment and, using external mixers, a 1.2-THz (1200-GHz) instrument for waveguide work. You can set the resolution bandwidth from 3 Hz to 10 MHz. The display has 100-dB dynamic range. The rugged, portable unit has a color display based on a monochrome CRT and a liquid-crystal color shutter. $79,500. Delivery, eight weeks ARO. **Tektronix Inc,** Test & Measurement Group, Box 1520, Pittsfield, MA 01202. Phone (800) 426-2200. **Circle No. 355**

Front-panel-programmable power supplies. The 6540A series includes five 200W dc power supplies; the 6550A series includes five 500W units; and the 6570A series includes five 2-kW supplies. In each series, units produce maximum outputs ranging from 8 to 120V. You can set the output voltage and current from the front panel in three ways: with a numeric keypad, with up and down buttons, or with a contactless digital rotary control. $1650 to $3800. **Hewlett-Packard Co,** 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900. **Circle No. 356**

Signal-conditioning and antialias-filtering system. The 2-channel CyberAmp 320 ($2400) and the 8-channel CyberAmp 380 ($5200) offer differential inputs; bandwidths of dc to 50 kHz; variable gains to 20,000; variable low-pass filtering by high-order Bessel filters; ac or dc coupling; notch filtering; and automatic baseline correction. **Axon Instruments Inc,** 1101 Chess Dr, Foster City, CA 94404. Phone (415) 571-9400. FAX (415) 571-9500. **Circle No. 357**

Simultaneous-update DAC board. The PC-422 ISA bus board contains either 8 or 16 12-bit DACs with individually selectable 5 or 10V output ranges and 3-µsec settling time. A crystal-stabilized software-programmable timer/trigger and a high-speed block-transfer DMA capability permit simul-

taneous DAC updates at 1 MHz. 8-channel board, $995; 16-channel board, $1695. **Datel Inc,** 11 Cabot Blvd, Mansfield, MA 02048. Phone (508) 339-3000. FAX (508) 339-6356. **Circle No. 358**

Variable-conversion-rate digital-audio system. Unlike the encoders and decoders in digital-audio-tape systems, which operate only at a single (or a few) fixed clock frequencies, the Multi-rate Digital-Audio System operates at seven conversion rates from 8 to 48 ksamples/sec. The system provides a digital-audio I/O interface for Sun workstations. It unloads DSP operations from the workstation and lets you use digital-audio tape decks and compact-disk players. $11,950. **Atlanta Signal Processors Inc,** 770 Spring St, Suite 208, Atlanta, GA 30308. Phone (404) 892-7256. FAX (404) 892-2512. **Circle No. 359**

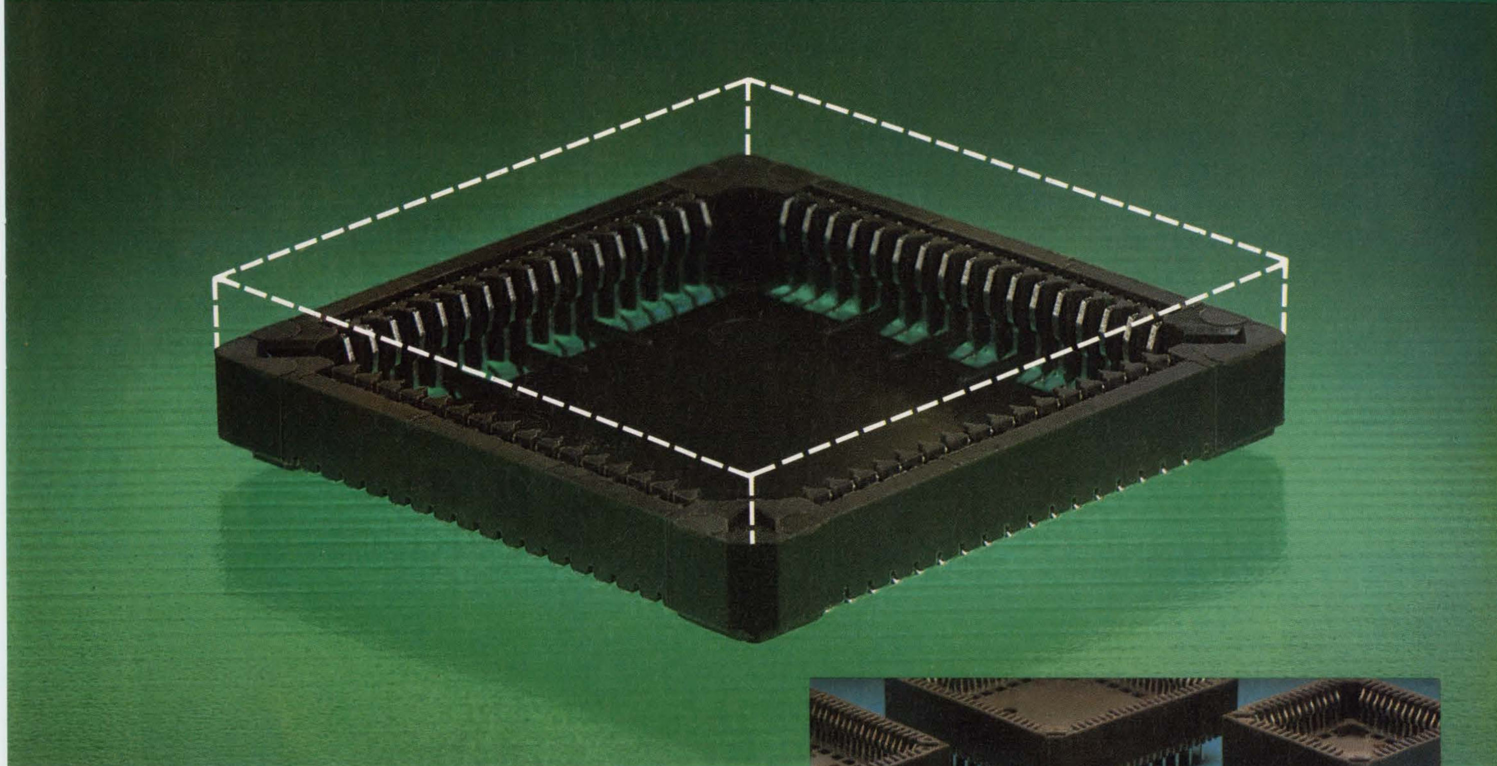
16-bit-wide SCSI 2/3 bus tester. The IPC-6020 development system uses a board that plugs into the 16-bit ISA bus and that interfaces to the SCSI bus via a 68-pin P-cable connector. The board transfers data synchronously at 20 Mbytes/sec. The system includes Borland's C + + compiler. Libraries for MS C V6.0 are available at no extra cost. $6800; IPC-4020 interactive version, $5300. **I-Tech Corp,** 6975 Washington Ave S, Suite 220, Edina, MN 55439. Phone (612) 941-5905. FAX (612) 941-2386. **Circle No. 360**

Open-architecture programmable controller. The combination of Wizdom's PLC (programmable logic controller) with the Workhorse A/D I/O system lets you control machinery and industrial processes. As higher-performance processors become available, you can upgrade the CPU without obsoleting the rest of the system. I/O system board providing interface to PLC, $700. **Keithley Metrabyte,** 440 Myles Standish Blvd, Taunton, MA 02780. Phone (508) 880-3000. FAX (508) 880-0179. **Circle No. 361**

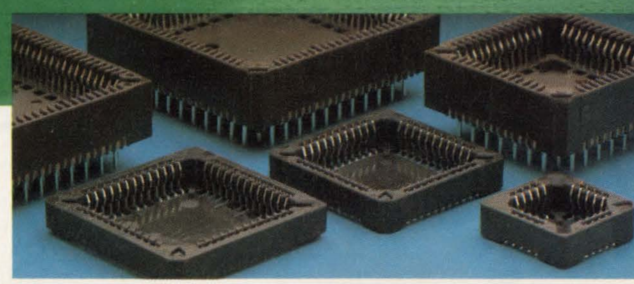
Gang programmer for MC68-HC11xx μCs. The Gangpro-SM Series II programs from 8 to 32 devices simultaneously, taking from 7 to 34 sec, depending on the memory size. The vendor can supply the stand-alone unit to program a mixture of EPROMs or EEPROMs and microcontrollers. $9995. Delivery, 8 to 12 weeks ARO. **Logical Devices Inc,** 1201 NW 65th Pl, Fort Lauderdale, FL 33309. Phone (800) 331-7766; (305) 974-0967. **Circle No. 362**

Development system for μCOM-87AD μPs. The CT-NEC87 system nonintrusively emulates all processors in the family including single-chip and ROMless units, whether in 68-pin plastic leaded chip carriers, 64-pin quad in-line packages, or shrink DIPs. The system offers a configurable, windowed interface; C and assembly-language debugging; automatic synchronization of software displays with hardware activity; real-time monitoring of variables without halting emulation; real-time tracing of address, data, and external signals; and unlimited breakpoints. $8750. **Ashling Microsystems Ltd,** Plassey Technological Park, Limerick, Ireland. Phone (61) 334466. FAX (61) 334477. **Circle No. 363**

PLCC sockets. Now half off.



THIS IS AMP TODAY.



Save big where it counts most: real estate and stack height. Our PLCC sockets address your two major concerns—the tight space requirements of today's compact designs, and the need for positive chip retention.

The newest low-profile surface-mount versions, in all popular sizes, take space savings to the max—with half the clearance of our standard types. Now you can get the advantages of socketing in barely more room than the chip itself, and hold on to the low profile you need for tight board stacking and efficient thermal management. Surface-mount styles match PLCC footprints, too, so there's no board redesign.

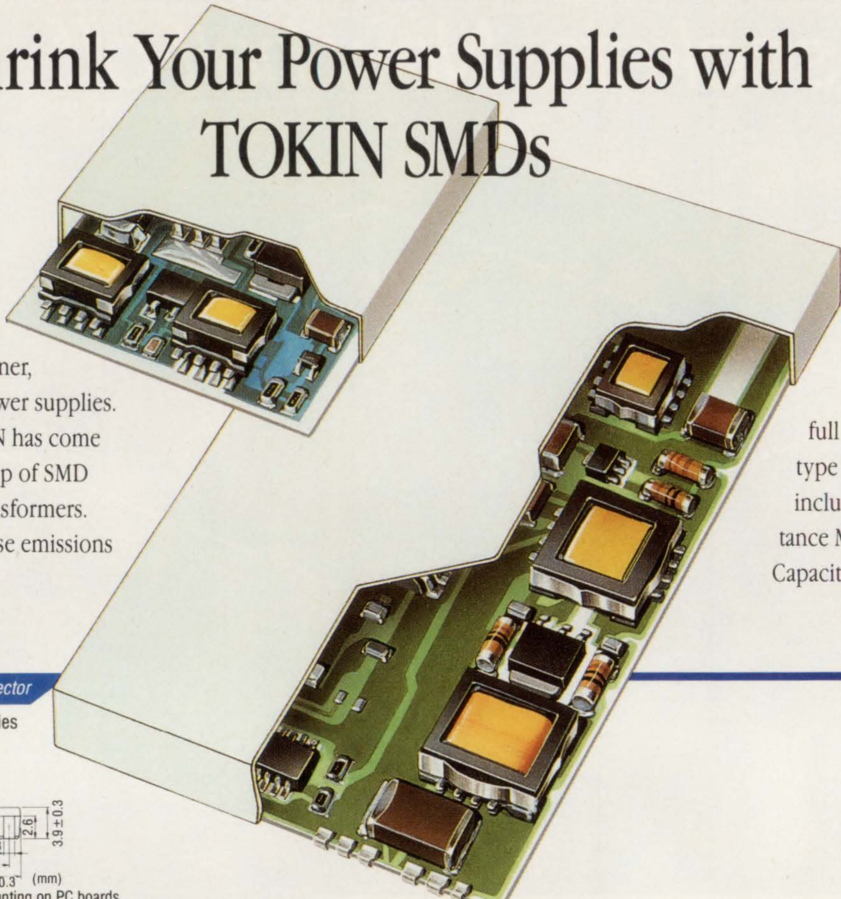
And all our PLCC sockets get solidly into contact, and stay in contact. Their proprietary, controlled-angle interface establishes very high normal forces to ensure positive retention. Short-signal-path contacts float in the housing to accommodate expansion.

Get the help you need: interconnections for your most advanced designs. And get all the advantages of better design where your PLCC meets the board. Call our Product Information Center, 1-800-522-6752 (fax 717-986-7575), for literature. In Canada call 416-475-6222. AMP Incorporated, Harrisburg, PA 17105-3608.

AMP

CIRCLE NO. 47

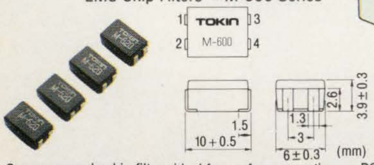
Shrink Your Power Supplies with TOKIN SMDs



The continuous integration of high-density electronic equipment has created a burgeoning demand for thinner, more compact switching power supplies. To meet this demand, TOKIN has come up with an outstanding lineup of SMD (Surface Mount Devices) transformers. And to help you counter noise emissions from compact, high-frequency power supplies, TOKIN offers a full selection of SMD-type EMC components including High-Capacitance Multilayer Ceramic Capacitors. Give us a call.

Common-mode Choke Coils at output sector

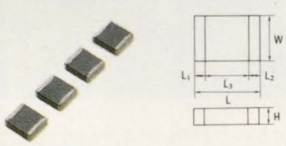
EMC Chip Filters ●M-600 Series



Common-mode chip filters ideal for surface-mounting on PC boards

Ceramic Capacitor for Converters

Multilayer Ceramic Capacitors



mm

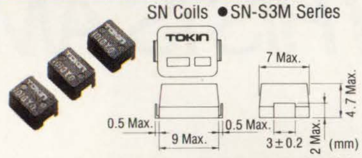
	W	L	H	L_1, L_2	L_3
C205 (SD)	2.7±0.3	5.9±0.4	2.5 max.	0.3~2.5	0.3 min.
C505 (SE)	5.0±0.4	5.6±0.5	3.0 max.	0.3~2.5	0.3 min.
C408 (SA)	4.0±0.4	8.0±0.5	3.2 max.	0.3~2.5	0.3 min.
C610 (SB)	6.3±0.4	10.0±0.5	4.5 max.	0.3~2.5	0.3 min.
C812 (SC)	8.0±0.4	12.5±0.5	4.5 max.	0.3~2.5	0.3 min.

Products above are sold only in the U.S.

Chip-type ceramic capacitor with large capacitance using Y5U materials

Normal-mode Choke Coils at input/output sector

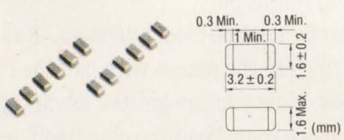
SN Coils ●SN-S3M Series



Excellent absorption characteristics for countering high impulse noise; ideal for high-density mounting

Bead Inductors for eliminating switching/spike noise

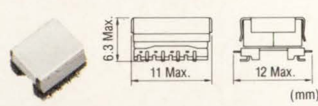
Solid Chip Inductors ●NZ Series



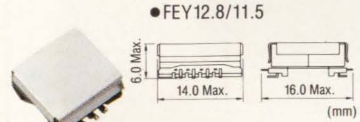
Thin, ultra-small, with monolithic structure and excellent frequency characteristics; designed for automatic mounting

Transformers for Converters

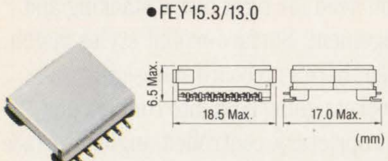
SMD Transformers ●FEY9.1/7.3



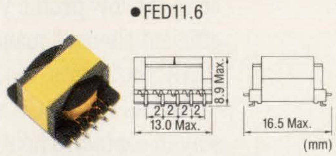
●FEY12.8/11.5



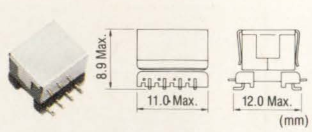
●FEY15.3/13.0



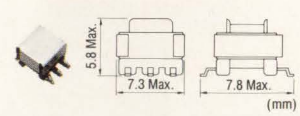
●FED11.6



●FEP7T



●FEE5



Superior magnetic circuit design technology ensures excellent frequency characteristics; compact, thin; ideal for ultra-high dennsity mounting; SMD discrete monolithic structure

TOKIN

Tokin Corporation
Hazama Bldg., 5-8, Kita-Aoyama 2-chome, Minato-ku, Tokyo 107, Japan
Phone: 03-3402-6166 Fax: 03-3497-9756

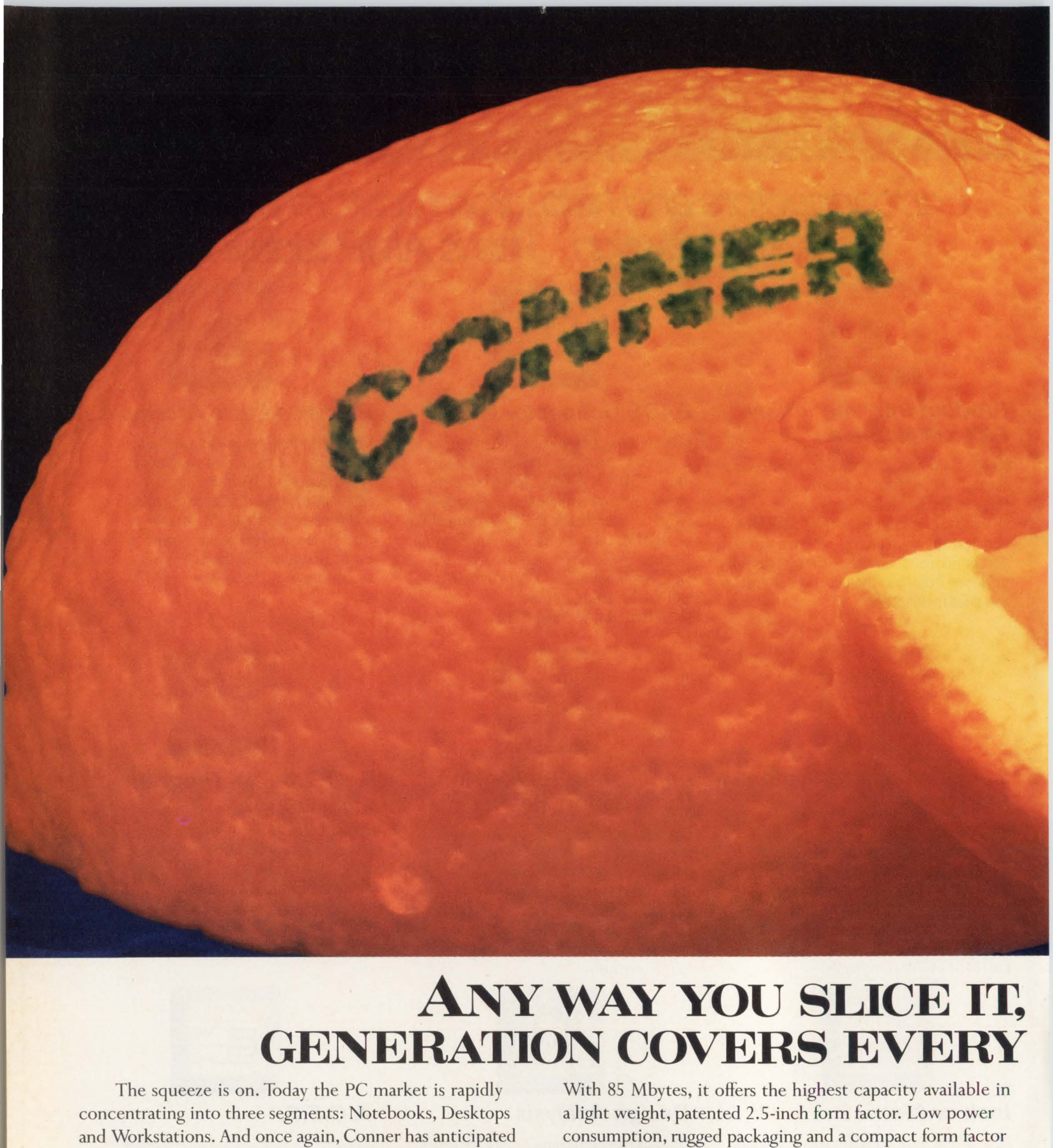
Korea Representative Office
#602, Champs-Elysees Bldg., 889-5,
Daechi-Dong, Kangnam-gu, Seoul, Korea
Phone: (2) 569-2582~5 Fax: (2) 544-7087

Tokin America Inc.
155 Nicholson Lane, San Jose, California 95134, U.S.A.
Phone: 408-432-8020 Fax: 408-434-0375
Chicago Branch
9935 Capitol Drive, Wheeling, Illinois 60090, U.S.A.
Phone: 708-215-8802 Fax: 708-215-8804
Boston Branch
945 Concord Street, Framingham, Massachusetts 01701, U.S.A.
Phone: 508-875-0389 Fax: 508-875-1479

Tokin Electronics (HK) Ltd.
Room 806 Austin Tower, 22-26A Austin Avenue,
Tsimshatsui, Kowloon, Hong Kong
Phone: 367-9157 Fax: 739-5950
Taiwan Liaison Office
3F-4, No. 57 Fu Shing N. Road, Taipei, Taiwan
Phone: (02) 7728852 Fax: (02) 7114260
Singapore Branch
140 Cecil Street, No. 13-01 PIL Bldg., Singapore
Phone: 2237076 Fax: 2236093, 2278772

Tokin Europe GmbH
Knorrstr. 142, 8000 München 45, Germany
Phone: 089-311 10 66 Fax: 089-311 35 84 Telex: 5 24 537 tokin d

CIRCLE NO. 97

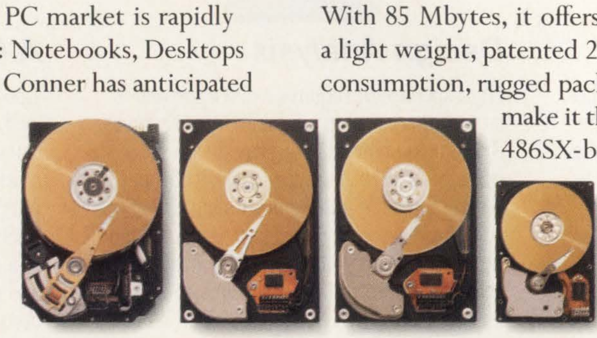


ANY WAY YOU SLICE IT, GENERATION COVERS EVERY

The squeeze is on. Today the PC market is rapidly concentrating into three segments: Notebooks, Desktops and Workstations. And once again, Conner has anticipated these changes.

Which is why we're introducing our newest wave of high-performance 2.5-inch and 3.5-inch drives to meet the needs of each of these evolving market segments.

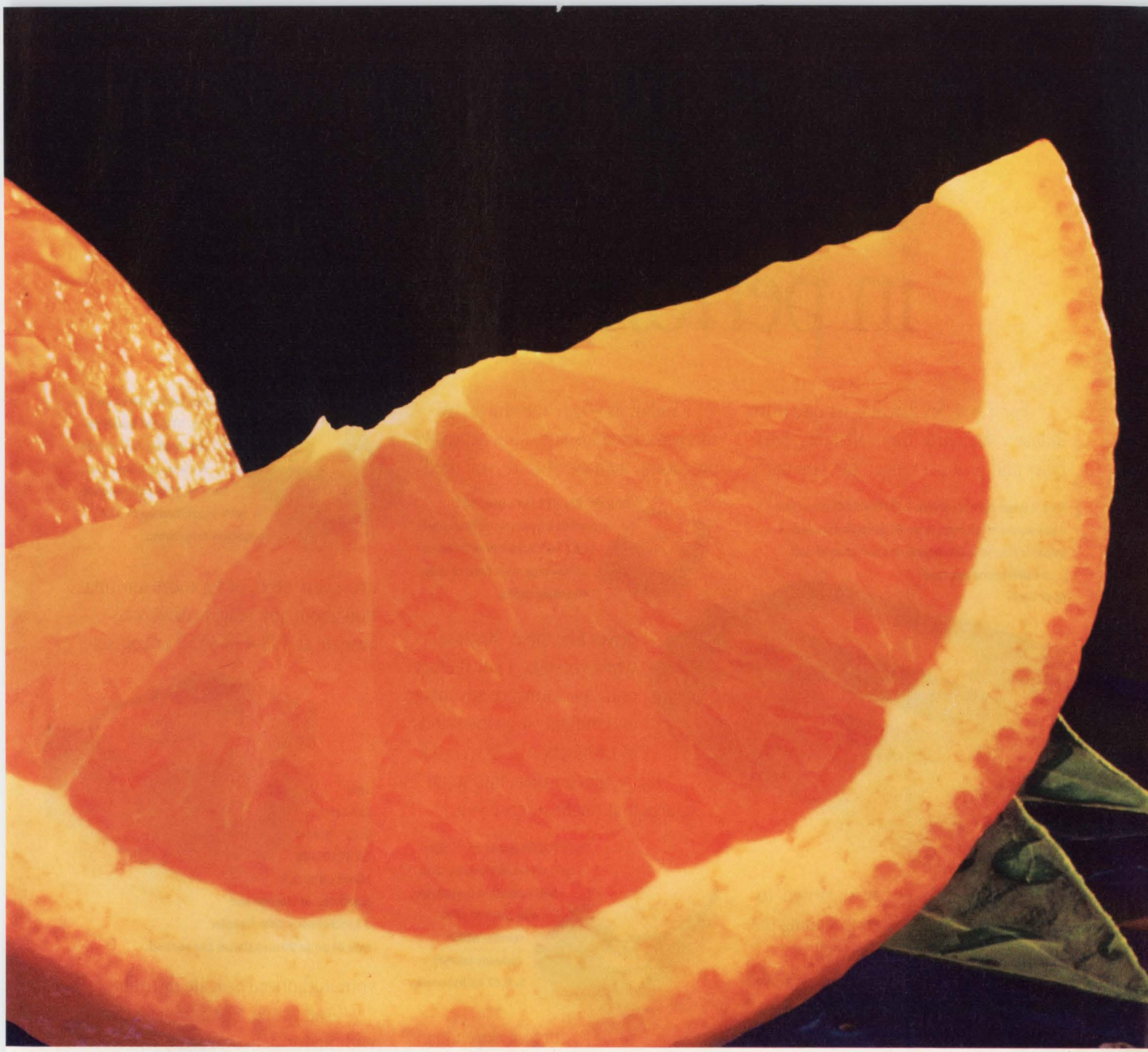
For the notebook market, take our newest Pancho drive. With 85 Mbytes, it offers the highest capacity available in a light weight, patented 2.5-inch form factor. Low power consumption, rugged packaging and a compact form factor make it the ultimate choice for 386SX and 486SX-based notebook computers.



Summit 540MB *Cougar 210MB* *Jaguar 85/170MB* *Pancho 85MB*

Then there's our new Jaguar Series for the desktop market—3.5-inch drives offering 85 and 170 Mbytes. A 17 msec. average seek time and a light weight, patented 1-inch

World Headquarters: 3081 Zanker Road, San Jose, CA 95134 Telephone: (408) 456-4500 FAX: (408) 456-4501 **Sales Offices: Asia**—Singapore: (65) 296-1992 • Taipei: (886) 2-718-9193 • Tokyo: (81) 3-3485-8901 • Seoul: (82) 2-551-0511 **Europe**



CONNER'S NEWEST SEGMENT OF THE MARKET.

high form factor make them ideal for a full range of desktop computers.

For workstations, we're introducing two new 3.5-inch drives—the 210 Mbyte Cougar and 540 Mbyte Summit. Cougar is the highest performance low-profile drive on the market today. While Summit delivers the greatest capacity and performance of any 3.5-inch drive. Both provide a fast average seek time of 12 msec., a 2.5 Mbyte per second sustained transfer rate and a SCSI-2 interface.

It's all a part of our innovative sell-design-build business philosophy. To identify our customer's needs sooner. Then fill them faster with the most advanced products. In fact, we're the technological leader with nine patents issued and 27 pending. Which is why more and more PC users are asking for systems with Conner drives.

So if the changing market segments are putting the squeeze on your systems, call us today. We'll guarantee you the most refreshing results.

CONNER

Delivering A Generation Ahead

—London: (44) 071-409-0090 • Munich: (49) 89-129-8061 • Paris: (33) 1-47-47-41-08 • Aosta: (39) 125-800260 • U.S.—Boston: (617) 449-9550 • Dallas: (214) 680-2913 • Irvine: (714) 727-2462 • Minneapolis: (612) 449-5186 • San Jose: (408) 456-4500.

CIRCLE NO. 56

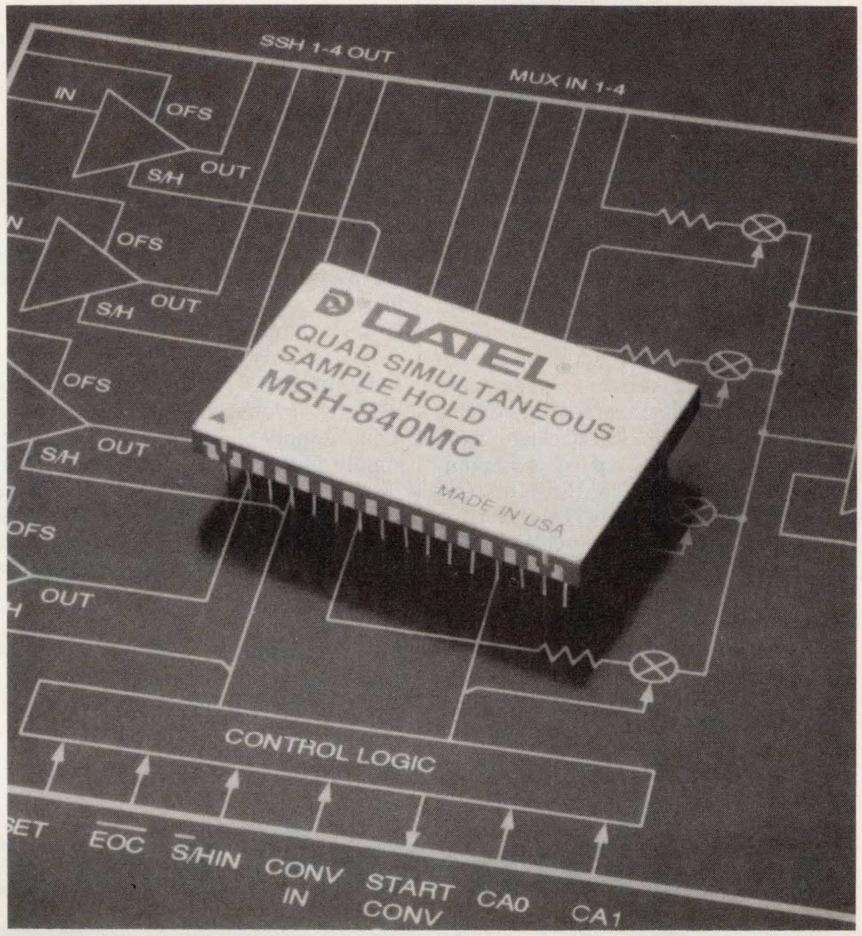
4-Channel, Simultaneous Sample/Hold Circuit

- *Includes output multiplexer*
- *Features fast acquisition*

The MSH-840 4-channel S/H circuit can acquire a 10V step to 0.01% accuracy in 775 nsec (including the settling time of the output multiplexer). The hybrid IC operates in two modes: single-channel or simultaneous sampling. In either mode, the use of the reset pin will set all the S/H circuits to the sample mode. Internal decoder circuitry allows channel selection to be digitized or the channel to be put into hold mode. The MSH-840 operates over a ±10V input range and has a maximum nonlinearity of ±0.01%. Other specifications include −70-dB harmonic distortion, a 45V/μsec slew rate, and a 13-MHz small-signal bandwidth. The MSH-840 requires 5 and ±15V supplies and comes in a 32-pin package. From $224 (OEM qty).

Datel Inc, 11 Cabot Blvd, Mansfield, MA 02048. Phone (508) 339-3000. FAX (508) 339-6356.

Circle No. 364



5V Regulator For μP Functions

- *Low dropout voltage*
- *Low quiescent current*

Combining a 5V±4% regulator with watchdog, enable, and reset functions, the CS-8140 gives the system's μP control over its own power. The low-dropout regulator (1.25V at 500 mA) has a quiescent current of 7 mA. A sleep mode reduces current drain to 250 μA. A watchdog signal from the μP to the IC's enable input controls the μP's supply voltage. When the enable pin is high, the regulator's output stage is active. When the enable pin is low, and the watchdog signal falls outside user-programmable frequency limits, the IC's output turns off, setting the IC and the μP in sleep mode. The IC generates a reset signal when the watchdog signal falls outside its frequency limits while enable is high; when the IC's output voltage drops more than 4.5%; or when the IC power is on. CS-8140, in 7-pin TO-220 or 24-pin SOIC packages, from $2.03 (1000).

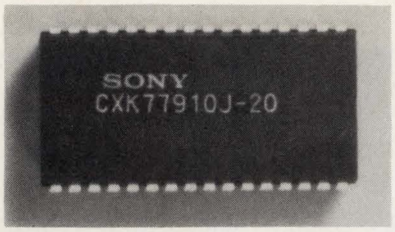
Cherry Semiconductor Corp, 2000 South County Trail, East Greenwich, RI 02818. Phone (401) 885-3600. **Circle No. 365**

High-Speed MOSFET Driver

- *Sources 6A and sinks 3A*
- *Drives high-capacitive loads*

The HV400 MOSFET driver can drive capacitive loads ranging from 5000 to 100,000 pF. With a 20,000-pF load, the monolithic IC achieves rise and fall times of 70- and 30-nsec, respectively. The driver, which does not draw any quiescent current, can source peak currents to 6A via its high-side npn switch and can sink peak currents to 30A via its low-side SCR switch. This capability lets the IC switch four parallel-connected IR452 MOSFETs in 20 nsec. In floating applications, the HV400 can operate from a small pulse transformer driven by the system's PWM circuit. Using this pulse transformer and a few low-cost components, the driver provides its own power supply, isolation, level shifting, timing, and buffering. HV400, in 8-pin DIP and SOIC packages, from $1.40 (100).

Harris Semiconductor, Box 883, Melbourne, FL 32901. Phone (800) 442-7747, ext 1047. **Circle No. 366**



Self-timed SRAM. Optimized for SPARC processors, the CXK77910J self-timed static RAM (SRAM) integrates 1 Mbit of memory with input and output registers. Organized as 128k-words × 9 bits, the SRAM comes in 16.6- and 20-nsec versions. Power consumption of the TTL-compatible device is 715 mW. In 32-pin SOJ package, from \$75 (1000). **Sony Corp of America,** Component Products Co, Box 6016, Cypress, CA 90630. Phone (714) 229-4197. FAX (714) 229-4333. **Circle No. 367**

Power-factor preregulator. The UC3852 allows 50 to 100W power supplies to operate at a 0.99 power factor. The IC regulates the output dc voltage by controlling switch on-time, and the boost inductor controls the off-time. A zero-current sensing circuit activates the switching cycle. Other features include undervoltage lockout, current limiting, and output clamping. In 8-pin DIP and SO packages, from \$1.77 (100). **Unitrode Integrated Circuits Corp,** 7 Continental Blvd, Merrimack, NH 03054. Phone (603) 424-2410. FAX (603) 424-3460. **Circle No. 368**

60-MHz op amp. The EL2044 op amp features a 325V/µsec slew rate and a 60-MHz bandwidth. Operating from a ±15V supply, the IC has an output swing of ±13.6V. Output-current capability is 75 mA. The IC operates from a dual supply of ±2 to ±18V or a single supply of 2.5 to 36V. In 8-pin DIP and SO packages, from \$1.80 (100). **Elantec Inc,** 1996 Tarob Ct, Milpitas, CA 95035. Phone (408) 945-1323. FAX (408) 945-9305. TWX 910-997-0649. **Circle No. 369**

Bus transceiver. Designed for balanced transmission lines, the SN75-LBC176 bus transceiver meets EIA RS-485 and ISO 8482:1987(E) standards. The IC has a 3-state differential line driver and a differential line receiver, both of which operate from a single 5V supply. The bus lines, which are connected internally, can send or receive data over a common-mode voltage range of −7 to +12V. In an 8-pin DIP, \$1.57 (1000). **Texas Instruments Inc,** Semiconductor Group (SC-92008), Box 809066, Dallas, TX 75380. Phone (800) 336-5236, ext 3990. Outside US and Canada, (214) 995-6611, ext 3990. **Circle No. 370**

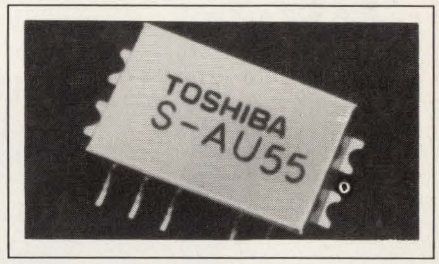
Analog filters. The MAX274 eighth-order filter has four cascadable sections, and the MAX275 fourth-order filter has two. Each second-order, state-variable section can implement bandpass or low-pass filter responses. The MAX274 programmable center frequency ranges from 100 Hz to 150 kHz; the MAX275's range is from 100 Hz to 300 kHz. Available in 24- and 20-pin packages, respectively, MAX274 and MAX275, from \$4.95 and \$3.75 (1000). **Maxim Integrated Products,** 120 San Gabriel Dr, Sunnyvale, CA 94086. Phone (408) 737-7600. **Circle No. 371**

Low drop-out regulators. Designed for automotive applications, the MIC-2950/51/54 regulators combine low drop-out voltages with load-dump and reverse-battery protection. The 2950 provides a fixed 5V/150-mA output and has a 380-mV dropout. The 2951 has the same dropout voltage and current rating but provides an adjustable 1.24 to 29V output. The 2954 provides a fixed 5V/250-mA output and has a 500-mV dropout. Depending on type and package options, from \$1.07 to \$2.53 (100). **Micrel Semiconductor,** 560 Oakmead Pkwy, Sunnyvale, CA 94086. Phone (408) 245-2500. **Circle No. 372**

10-bit A/D converter. The AD773 10-bit ADC includes an onboard T/H amplifier, a high-impedance reference input, and CMOS/TTL-compatible outputs. Optimized for video application, the ADC features a full-power bandwidth of 100 MHz, a speed of 18 Msamples/sec, and differential gain and phase specifications of 0.4% and 0.2°, respectively. The ADC can acquire full-scale voltage swings in less than 55 nsec and offers common-mode noise rejection of 75 dB. In 28-pin ceramic DIP, from \$55 (100). **Analog Devices Inc,** Applications Engineering, 181 Ballardvale St, Wilmington, MA 01887. Phone (617) 937-1428. FAX (617) 821-4273. **Circle No. 373**

Dual comparator and pin receiver. The 100-MHz EL2254 replaces the buffer, attenuator, and ECL comparators used in test equipment and data-communications line receivers. The IC provides a 4-nsec propagation delay with low dispersion of 100 psec (typ). The inhibit and latch-enable inputs are ECL-, TTL-, and CMOS-compatible differential inputs. In a 20-pin SO package, \$6.40 (100). **Elantec Inc,** 1996 Tarob Ct, Milpitas, CA 95035. Phone (408) 945-1323. **Circle No. 374**

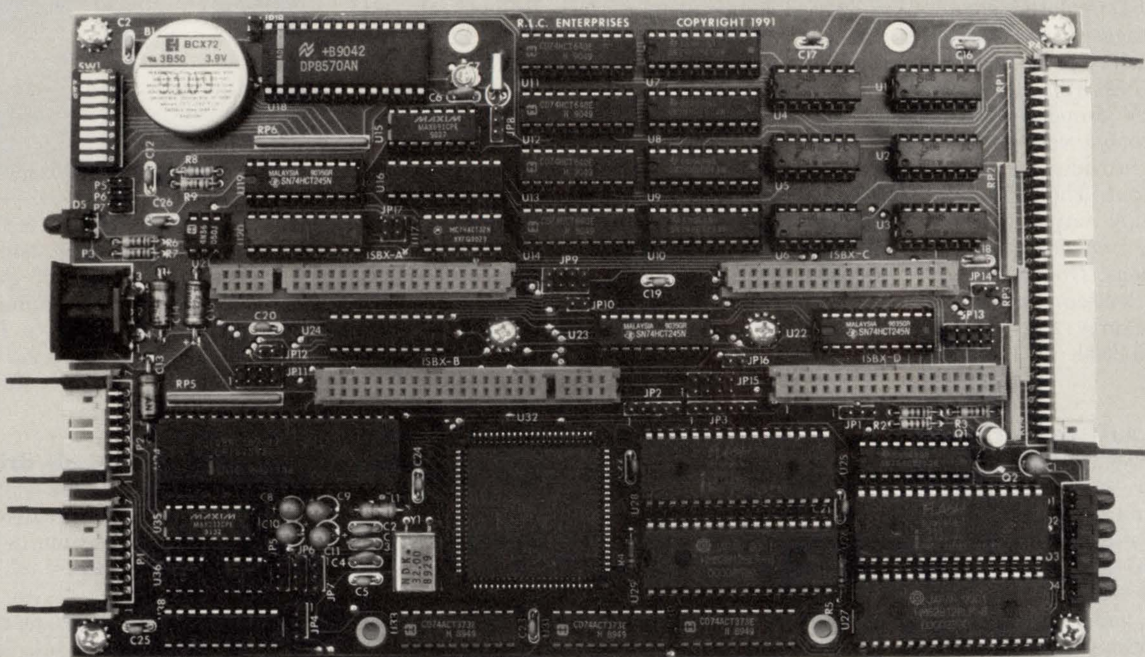
RF power amplifier. Designed for handheld cellular-phone applications, the S-AU55 RF power amplifier operates over the frequency range of 824 to 849 MHz. Input power to the GaAs FET amplifier is 4 mW, and output power is 1.12W. The 17×12×4-mm



module operates from a 5.8V supply, has an efficiency of 55%, and a gain of 24.4 dB. \$36.50 (1 to 3000 qty). Delivery, 14 weeks ARO. **Toshiba America Electronic Components Inc,** 9775 Toledo Way, Irvine, CA 92718. Phone (714) 455-2000. **Circle No. 375**

64-channel push-pull driver. The HV3225X integrates low-voltage logic with 64 push-pull output drivers rated at 250V. The logic section, which operates at 5 or 12V, comprises a 64-bit shift register and 64 latches. The programmable output stages can source or sink currents from 25 to 250 μA. In die form waffle packs, \$13.24 (1000). **Supertex Inc,** 1350 Bordeaux Dr, Sunnyvale, CA 94089. Phone (408) 744-0100. **Circle No. 376**

NO BUS! 80C186EB NO FUSS!



DARE TO COMPARE!

Compare our new **SBX-C186EB** to ANY Single Board Computer on ANY bus. Our new **Powerful, Expandable, Inexpensive, Easy to Program** Single Board Computer was designed to eliminate expensive and complicated Bus systems. All of the basic functions needed for most embedded applications are on-board . Additional I/O expansion is provided by four on-board iSBX ports which may be used to accommodate any of the iSBX modules currently available.

HARDWARE FEATURES

* 16-Bit 80C186EB Up To 16 MHz
* On-Board 80C187 Co-Processor
* 8570 Real Time Clock
* Four 8/16-Bit iSBX Expansion Ports
* Watch Dog Timer And Power Fail Detect
* Two Serial Ports (RS-232/422/485)
* 10 Year Lithium Battery For RTC And RAM
* Up To 512K Of EPROM/FLASH EPROM
* Up To 512K Of Battery Backed Static RAM
* 32 Parallel I/O Lines With Open-Collectors
* Five 16-Bit Interrupt Timers
* Program Controlled Dip-Switch And LED's
* Available In -40 to +85 C Temperature Range

TM

SOFTWARE FEATURES

* On-Board FLASH EPROM Programming
* Borland Turbo C++ Fully Supported
* Borland Turbo Debugger Supported
* I/O Driver Library Provided Free
* Demo Programs Provided Free
* No Software Royalities
* No DOS Required

QTY(1) $425
QTY (100) $319
EXCLUDING OPTIONS

Turbo C++ and Turbo Debugger may be trademarks of Borland , DOS is a trademark of IBM, iSBX is a trademark of Intel

R.L.C. Enterprises

4800 Templeton Road Atascadero, CA 93422 Phone (805) 466-9717 FAX (805) 466-9736

CIRCLE NO. 86

Searching for embedded solutions? Let us shed a little SPARClite.

VISIT BOOTH #940 AT SUNWORLD EXPO

We're blazing a trail for designers of embedded control systems. And now the unparalleled performance, innovation, simplicity and cost efficiency of RISC technology are finally in sight.

Introducing SPARClite.™ A complete family of RISC processors from the Advanced Products Division of Fujitsu Microelectronics. Designed from the ground up for high-performance embedded applications.

Our first SPARClite family member, the MB86930 processor, provides a new generation of solutions that can easily be designed into your embedded applications — for much greater performance at very competitive prices. Operating at clock speeds up to 40 MHz — and providing 40 MIPs peak and 37 MIPs sustained performance.

Software compatible with the industry-standard SPARC® architecture, our MB86930 provides the on-chip cache memory needed to meet the demands of performance-critical real-time routines. As well as a unique cache-locking mechanism and many other on-chip peripheral functions.

What's more, Fujitsu's SPARClite program is complemented by a full range of multi-platform support tools from the leading names in development systems. To help you get to market more quickly than ever before.

So why keep searching in the dark? Call us at **1-800-523-0034**. And turn on SPARClite for the best in embedded solutions.

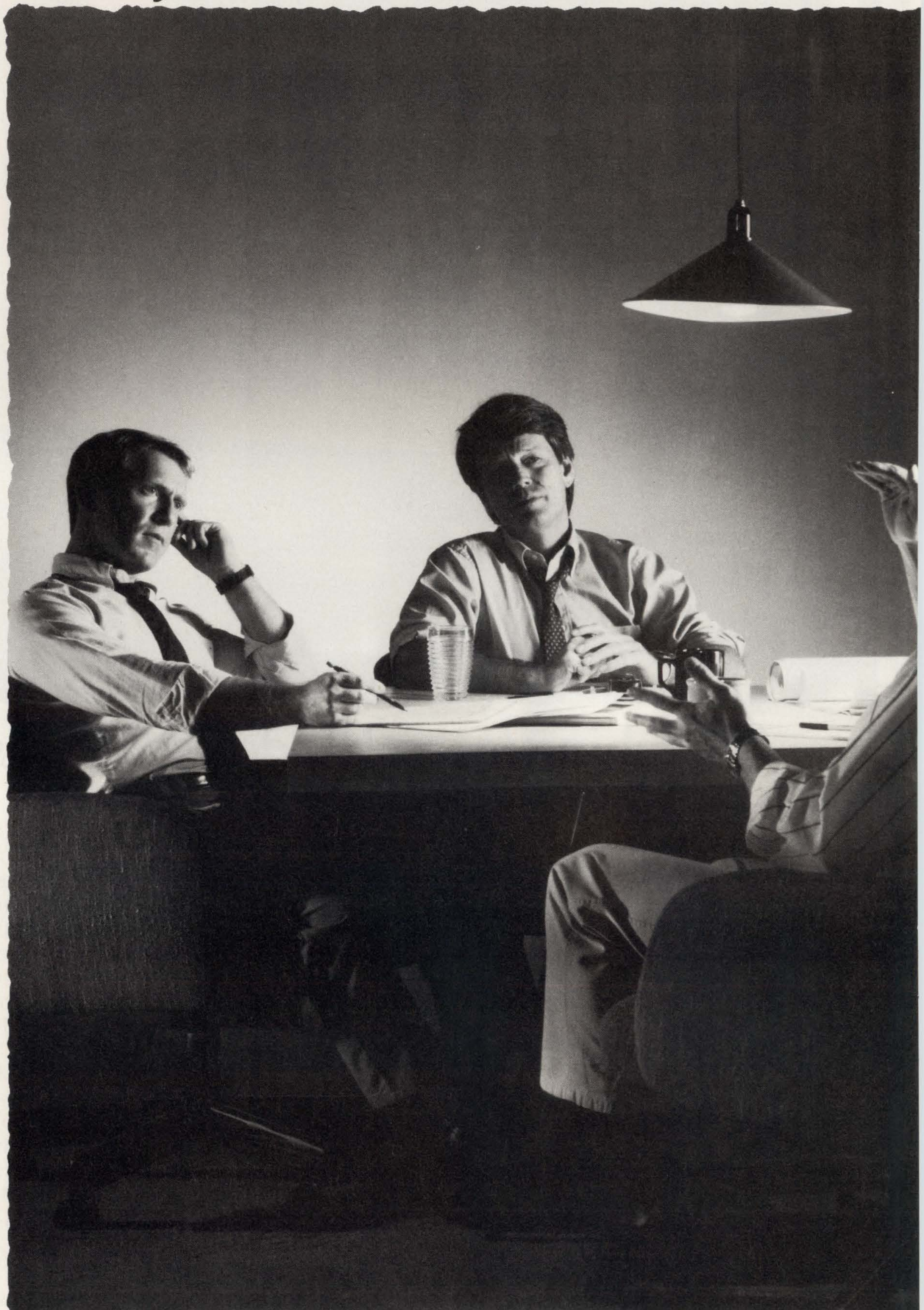
FUJITSU

Delivering the Creative Advantage.

FUJITSU MICROELECTRONICS, INC., Advanced Products Division. 77 Rio Robles, San Jose, CA 95134-1807. Ph: 408-456-1161 Fax: 408-943-9293.
FUJITSU MICROELECTRONICS ASIA PTE LTD. (Head Office, Singapore): Ph: 65-336-1600 Fax: 65-336-1609. HONG KONG SALES OFC: Ph: 852-723-0393 Fax: 852-721-6555.
TAIPEI SALES OFC: Ph: 886-2-757-6548 Fax: 886-2-757-6571. JAPAN SALES OFC: Ph: 81-3-3216-3211 Fax: 81-3-3216-9771. KML CORP. (Rep., Korea): Ph: 82-2-588-2011 Fax: 82-2-588-2017.
PACIFIC MICROELECTRONICS, PTY. LTD., (Rep., Australia): Ph: 61-2-481-0065 Fax: 61-2-484-4460.
FUJITSU MIKROELEKTRONIK GmbH (Dreieich-Buchschlag, Germany): Ph: 06103-6900 Fax: 06103-690122.

CIRCLE NO. 87

Sony Semiconductor



For fast relief from noise and space problems turn to Micro/Q® Capacitors.

Under the DIP caps – Micro/Q 1000 & 2000

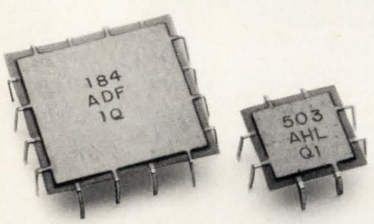
Standard Capacitors:
- Improve board performance without redesign.
- Solve noise problems by retrofitting existing boards.

Custom Capacitors:
- Special pinouts to address wide variety of specialty DIPs such as analog devices, op-amps, center pinout advanced CMOS devices.
- Applications: decoupling, EMI/RFI filtering, compensation.

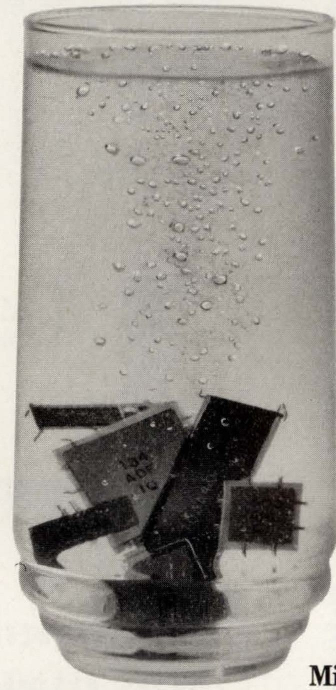
CIRCLE NO. 89

Under the PGA caps – Micro/Q 3000

- Reduce PGA and PLCC noise.
- Several part sizes address a variety of package sizes.
- Designed for all 16/32-bit MPUs, DSPs, GSPs, FPPs, gate arrays, standard cells, and fully custom ASICs.



CIRCLE NO. 90



Micro/Q® capacitors, Q/PAC® components and Mini/Bus® bars take the headache out of a host of design problems quickly and easily.

Micro/Q decoupling capacitors reduce EMI/RFI and noise voltage spikes in ICs by as much as a factor of ten. They can mount under the IC or share mounting holes to improve noise suppression where it's most effective - at the source.

Q/PAC components give two-layer boards multilayer electrical performance, eliminate discrete decoupling capacitors, and boost the reliability of the PCB assembly.

Mini/Bus bars provide high current distribution and high capacitance, eliminate up to half the decoupling capacitors, and fit between or beneath ICs to reduce required board layers.

Find out more about how we can solve your noise, EMI/RFI or space problem today. Call a Product Specialist at (602) 967-0624 (Fax 602-967-9385) and ask for more information.

Technology for tomorrow built on TQC today.

Circuit Components

2400 S. Roosevelt Street, Tempe, AZ 85282

A Division of

ROGERS

CIRCLE NO. 91

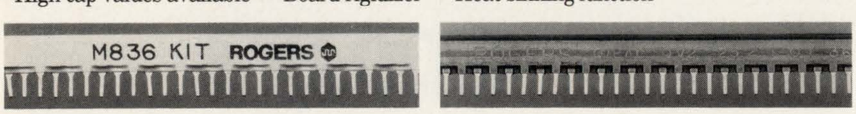
DISTRIBUTION: Europe, Japan, Taiwan, Singapore, Hong Kong, Korea, Brazil, Australia, India

Two layer PCBs power distribution and decoupling caps – Mini/Bus and Q/PAC

Mini/Bus Bars
- Distributes power to ICs • Eliminates up to half the decoupling caps
- Fits between or beneath the ICs

Q/PAC Components
- Deliver efficient power distribution • Provide built-in capacitance
- Eliminate decoupling capacitance • 2-layer economy, 4-layer low noise levels

High Current/High Capacitance Components
- High current power distribution up to 64 amps • Provide voltage equalization
- High cap values available • Board rigidizer • Heat sinking function

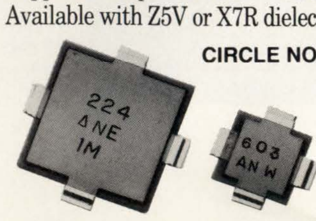


CIRCLE NO. 92

Under the PLCC - SMT caps Micro/Q 3500

- Surface mount capacitors.
- Fit under 44, 52, 68, 84/larger pin count PLCCs.
- Low inductance, 0.5 - 0.6 nanoHenries.
- Pads absorb coefficient of thermal expansion mismatch between board and device during soldering.
- Supplied in tape and reel or in bulk.
- Available with Z5V or X7R dielectrics.

CIRCLE NO. 93

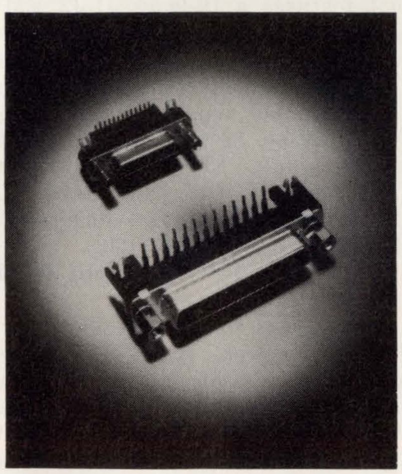


Circular Connectors

- *Weigh 70% less than standard steel devices*
- *Feature a composite shell design*

DGH123 Series circular connectors are manufactured with a metallized composite shell and panel nut. Compatible with MIL-C-29600 requirements, the units weigh 70% less than standard steel hermetic devices. Connector contacts accept wire sizes of #12 to #24 AWG. Immersible in fuels, coolants, solvents, and gases, the connectors have a leak rate of 1.04×10^{-6} cm^3/sec at 14.7 psi differential. The connectors meet all requirements in MIL-STD-1344 for immersion, and the composite materials are unaffected by MIL-C-43616, TT-M-268, MIL-H-833-06, TT-S-735, or MIL-T-81533. Operating range spans −65 to +175°C. $85 (100). Delivery, 8 to 12 weeks ARO.

Deutsch Engineered Connecting Devices, Municipal Airport, Banning, CA 92220. Phone (714) 849-7822. **Circle No. 377**



PC-Board Connectors

- *Feature a 0.05-in. pitch*
- *Comply with MIL-C-83513*

Requiring only one-third the space of conventional D subminiature connectors, the MDSM family pc-board-to-cable connectors feature a 0.05-in. contact pitch. The units are fully compatible with MIL-C-83513 and feature a contact design that makes three points of contact. A shielding system integral to the backshell provides 70-dB attenuation. The line features right-angle and cable-type connectors in 9-, 15-, and 25-position versions, as well as double-stack 9- and 15-position versions. Crimp contacts for the cable versions are available for #26 and #28 AWG wire. $7 per mated pair (1000).

ITT Cannon, 1851 E Deere Ave, Santa Ana, CA 92705. Phone (714) 261-5300. **Circle No. 378**

Rocker Switches

- *Rated for 10A loads*
- *Have a 10,000-cycle life*

D Series miniature power-rocker switches feature a right-angle terminal style that snaps into a pc board to secure switches for soldering. The switches snap into a standard panel cutout and require no tools for mounting. The line features five spst switch functions. Contacts are rated for 10A at 125V ac and 5A at 250V ac. Electrical life is specified at 10,000 cycles at full load. Dielectric strength measures 1000V rms min at sea level. Actuators and housing are available in nine colors with custom actuator markings available. The 6/6 nylon material carries a UL 94V-2 rating. Most models are UL recognized and CSA certified. From $1.11 (1000).

C&K Components Inc, 15 Riverdale Ave, Newton, MA 02158. Phone (617) 964-6400. FAX (617) 527-3062. TLX 922544.

Circle No. 379

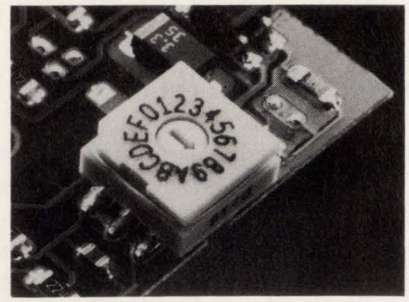
Fan trays. Designed for VME systems, these fan trays feature a 5-fan design that offers direct cooling of slots 1 through 3—the most critical in a VME system. The trays are designed for use with 160-, 220-, 280-, or 400-mm-deep chassis. Each tray includes a filter, a power-on LED, and a quick-disconnect power connector. From $300. **ACT Inc,** 1 Ivybrook Blvd, Suite 180, Ivyland, PA 18974. Phone (215) 957-9071.
Circle No. 380

Circuit breaker. The IML family of circuit breakers includes 1-, 2-, and 3-pole versions. The units are available with ratings of 0.5 to 70A at 80V dc and 0.5 to 50A at 240V ac. The breakers are UL recognized, CSA certified, and meet international spacing requirements of IEC-157-1 and VDE 0660. Models are available in screw panel-mount or snap-in styles. $14 to $16 (OEM qty). **Airpax,** Corporate Advertising, 7 McKee Pl, Cheshire, CT 06410. Phone (410) 228-4600. FAX (410) 228-8910. **Circle No. 381**

Memory-card connector. The FCN-560H series of DRAM-memory-card connectors consists of a right-angle board-mount plug and a surface-mountable card socket. The plug features 88 pins arranged in two rows with 0.05-in. contact spacing. Contact resistance equals 40 mΩ and operating range spans −55 to +105°C. $5.42 and $6.25 for plug and socket, respectively, (1000). Delivery, stock to six weeks ARO. **Fujitsu Microelectronics Inc,** 3545 N First St, San Jose, CA 95134. Phone (800) 642-7616; (408) 922-9000. FAX (408) 428-0640. **Circle No. 382**

Crystal oscillator. The HSM531/536 surface-mount oscillators are available with frequencies of 1.8432 to 70 MHz. The units are available with stabilities of ±50 or ±100 ppm over a temperature range of 0 to 70°C. The oscillators are housed in a ceramic package that has a grounded metal cover to suppress RFI. $11.25. **Connor-Winfield Corp,** 1865 Selmarten Rd, Aurora, IL 60505. Phone (708) 851-4722. FAX (708) 851-5040. **Circle No. 383**

Rotary switch. Series 94 rotary switches are available in surface-mount and through-hole versions. The units operate logic level loads, are rated for 25,000 operations, and feature octal,



BCD, hexadecimal—or their complements' coded-output choices. Octal unit, $1.69 (1000). **Grayhill Inc,** Box 10373, La Grange, IL 60525. Phone (708) 354-1040. FAX (708) 354-2820. TLX 190254.
Circle No. 384

DIN connectors. These DIN 41612 connectors come with snap-in clips that secure the units during soldering. The connectors fit into boards that are 1.6 mm thick and are available in angled male and female versions. $2.37 (1000). **Harting Elektronik Inc,** 2155 Stonington Ave, Suite 212, Hoffman Estates, IL 60195. Phone (708) 519-7700. FAX (708) 519-9771. **Circle No. 385**

Card cage. The rack-mountable Power Cage III includes a 12-slot VME (6U × 160 mm) card cage, a high efficiency 400W power supply with integral cooling, and a rugged Eurocard subrack that features a 10-layer J1-J2 VME backplane. The unit features front-panel LED voltage indicators; the hinged rear panel provides access to the fans and power supply and the rear of the backplane. $2495. Delivery, four to six weeks ARO. **Electronic Solutions,** 6790 Flanders Dr, San Diego, CA 92121. Phone (800) 854-7086; (619) 452-9333. TWX 910-335-1169.
Circle No. 386

Power supplies. The SWA series of supplies includes 15, 20, and 30W wall plug-in units and 40 and 60W cord-to-cord units. The cord-to-cord models have an input range of 90 to 264V ac; plug-in versions accept 90 to 132V and 198 to 264V. The units output from 5 to 17.5V at currents ranging to 4A. All models feature overload protection and feature 65 to 70% efficiencies. Wall plug-ins, from $39; cord-to-cord models, from $78 (100). **Tamura Corp of America,** 1150 Dominguez St, Carson, CA 90746. Phone (213) 638-1790. FAX (213) 638-9956. **Circle No. 387**

Computers & Peripherals

Portable Computer

- *Has a 50-MHz 80486 μP and 4Mbytes of RAM*
- *Optional TFT screen displays 24,389 colors*

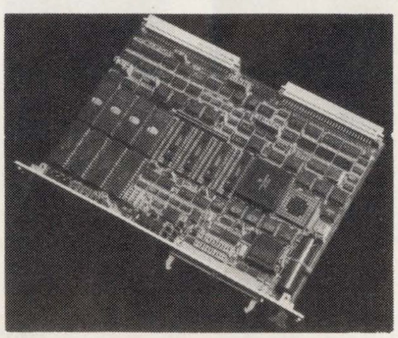
The P.A.C. 486-50E portable computer contains a 50-MHz μP. Standard features include 4 Mbytes of RAM expandable to 32 Mbytes; an 8- to 128-kbyte cache RAM; a 1.44-Mbyte floppy-disk drive; a 120- to 420-Mbyte hard-disk drive; a 64-kbyte disk buffer; and support for a WE4167 coprocessor. The unit has four internal EISA expansion slots and three external ISA expansion slots. A Gas-Plasma VGA display is standard, and you can opt for an active-matrix TFT screen that displays 24,389 colors. The unit has two serial ports, a parallel port, and a VGA port for simultaneous display on an external monitor. The computer measures 16×9.5×7.8 in. and weighs 18 lbs. 120-Mbyte hard-disk-drive version, less than $9000.

Dolch Computer Systems, 372 Turquoise St, Milpitas, CA 95035. Phone (408) 957-6575. FAX (408) 263-6305. **Circle No. 388**

VMEbus Single-Board Computer

- *Has a 25- or 40-MHz 68EC030 μP*
- *Three memory banks accept SRAM, EPROM, and dual-port RAM*

The XVME-630 VMEbus single-board computer (SBC) contains a 25- or 40-MHz 68EC030 μP. The



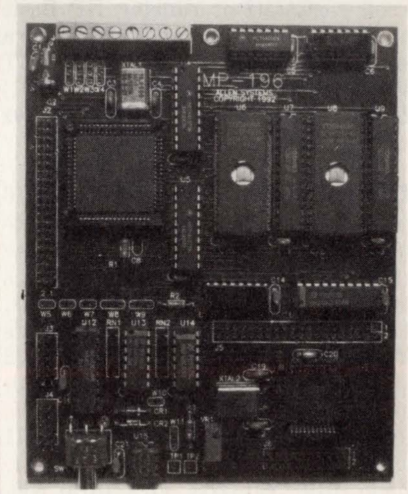
6U board contains three memory banks having four 32-pin sockets each. Bank 1 accepts static RAMs (SRAMs); bank 2 accepts EPROM; and bank 3, which has dual-port access to the VMEbus, accommodates SRAM, EPROM, or flash memory. The board has a socket for a 68882 coprocessor; two serial ports; a single-level VMEbus arbiter; and ACfail and SYSfail monitoring functions. It also has an interrupt handler and a programmable VME interrupter. The operating temperature ranges from 0 to 65°C, and board humidities are 0 to 95% noncondensing relative humidity. The board survives 30g and a vibration rate of 5 to 2000 Hz. From $1950.

Xycom Inc, 750 N Maple Rd, Saline, MI 48176. Phone (800) 367-7300; (313) 429-4971. **Circle No. 389**

Single-Board Computer

- *Has a 16-MHz 80C196KC μC*
- *Has 28 kbytes of static RAM*

The MP-196 single-board computer has a 16-MHz 80C196KC microcontroller. It measures 4.5×5.5 in. and supports 32 kbytes of EPROM and 28 kbytes of static RAM (SRAM). An optional page-mode feature supports 64 kbytes of EPROM and 56 kbytes of SRAM. The board has as many as three 8-bit parallel ports, two buffered serial ports, and one unbuffered serial port. An optional analog daughter board provides a 4-channel ADC and a 2-channel DAC—both have 12-bit resolution. Two 27C128 EPROMs contain a system monitor and a Basic interpreter. The monitor can trace the execution of a user program and set as many as eight breakpoints. Using the board's serial link, you can save and load programs on a 5¼-in. disk. Board, with user's manual, $125; assembled and



tested board having 32 kbytes of EPROM and 28 kbytes of RAM, $500.

Allen Systems, 2346 Brandon Rd, Columbus, OH 43221. Phone (614) 488-7122. **Circle No. 390**

Color display station. The model TX600C features a 25-MHz 68030 μP for an X-Window CPU, a 40-MHz 34020 for a graphics CPU, and 6 Mbytes of RAM. Memory is upgradable to 37 Mbytes. A plug-and-play version comes with a 1280×1024-pixel, 19-in. monitor, keyboard, and mouse. A hot-key feature lets you switch between two screen presentations. Local client software connects to any host on the system. $5865. **Visual Technology Inc,** 120 Flanders Rd, Westboro, MA 01581. Phone (508) 836-4400. FAX (508) 366-4337. **Circle No. 391**

GPIO adapter board. The Model 600 GPIO adapter board for the ISA bus connects to HP's Model 98622 GPIO bus. It provides 16 TTL input-data lines, 16 open-collector output-data lines, six handshake and control lines, and four general-purpose lines. The board operates with High Tech Basic software that lets you transfer data between workstations running HP Basic and DOS software. $375. **TransEra Corp,** 3707 N Canyon Rd, Provo, UT 84604. Phone (801) 224-6550. FAX (801) 224-0355. TLX 296438. **Circle No. 392**

SCSI converter. The Parallel-SD10 converts single-ended SCSI-2 signals to differential SCSI-2 signals and vice versa. It handles 10-Mbyte/sec rates and is transparent to devices on the bus. The unit meets ANSI X3T9.2 standards for ports separated by as much as 102 ft. The stand-alone box has a wall-mount power supply. Model SD10, $475; Model SD11, $285. **Paralan Corp,** 7171 Ronson Rd, San Diego, CA 92111. Phone (619) 560-7266. FAX (619) 560-8929. **Circle No. 393**

Dual-channel SCSI-2 adapters. The RF3590 and RF3870 are 9U and 6U, respectively, VMEbus SCSI-2 adapters. Two independent Fast SCSI-2 channels handle asynchronous and 10 Mbyte/sec synchronous data-transfer rates. The boards support both single-ended and differential SCSI connections. Both models handle 8-, 16-, and 32-bit data transfers on the VMEbus as fast as 30 Mbytes/sec. From $3050 (OEM qty). **Ciprico Inc,** 2955 Xenium Lane, Plymouth, MN 55441. Phone (612) 559-2034. **Circle No. 394**

SPARCserver memory package. The CPSM-09A/S16-80 is a 16-Mbyte memory package for Sun's SPARCserver 630MP, 670MP, and 690MP computers. The double-sided surface-mount package employs SOJ 16-bit dynamic RAMs. The package installs in Sun's 64 SIMM-slot (single-inline-memory-module) memory-expansion board to provide as much as 1024 Mbytes of system memory. $6000. **Clearpoint Research Corp,** 35 Parkwood Dr, Hopkinton, MA 01748. Phone (508) 435-2000. FAX (508) 435-7504. **Circle No. 395**

80386SX notebook computer. The NB913 Notebook PC contains a 20-MHz 80386SX μP, 2 Mbytes of RAM, and a 60-Mbyte hard-disk drive. The RAM is expandable to 4, 6, or 8 Mbytes. The computer runs on DOS 4.01 and Windows 3.0 operating systems. A 10-in. black-on-white LCD screen has 640×480 pixels and displays 64 levels of gray. Battery life is approximately 5 hours, and the unit weighs 7.7 lbs. $1999. **Micro Express,** 1801 Carnegie Ave, Santa Ana, CA 92705. Phone (800) 989-9900; (714) 852-1400. FAX (714) 852-1225. **Circle No. 396**

Laser printer. The QMS-PS 1700 intelligent laser printer serves as many as 20 users. It connects directly to either Ethernet or Token-Ring networks and supports DECnet, TCP/IP, Netware, or Ethertalk protocols. The printer has either 600×600- or 300×300-dpi resolution and prints at 17 pages/minute. It comes with a 1000-sheet input tray and has a duty cycle of 50,000 pages/month. $7995. **QMS Inc,** Box 81250, Mobile, AL 36689. Phone (205) 633-4300. FAX (205) 633-0013. **Circle No. 397**

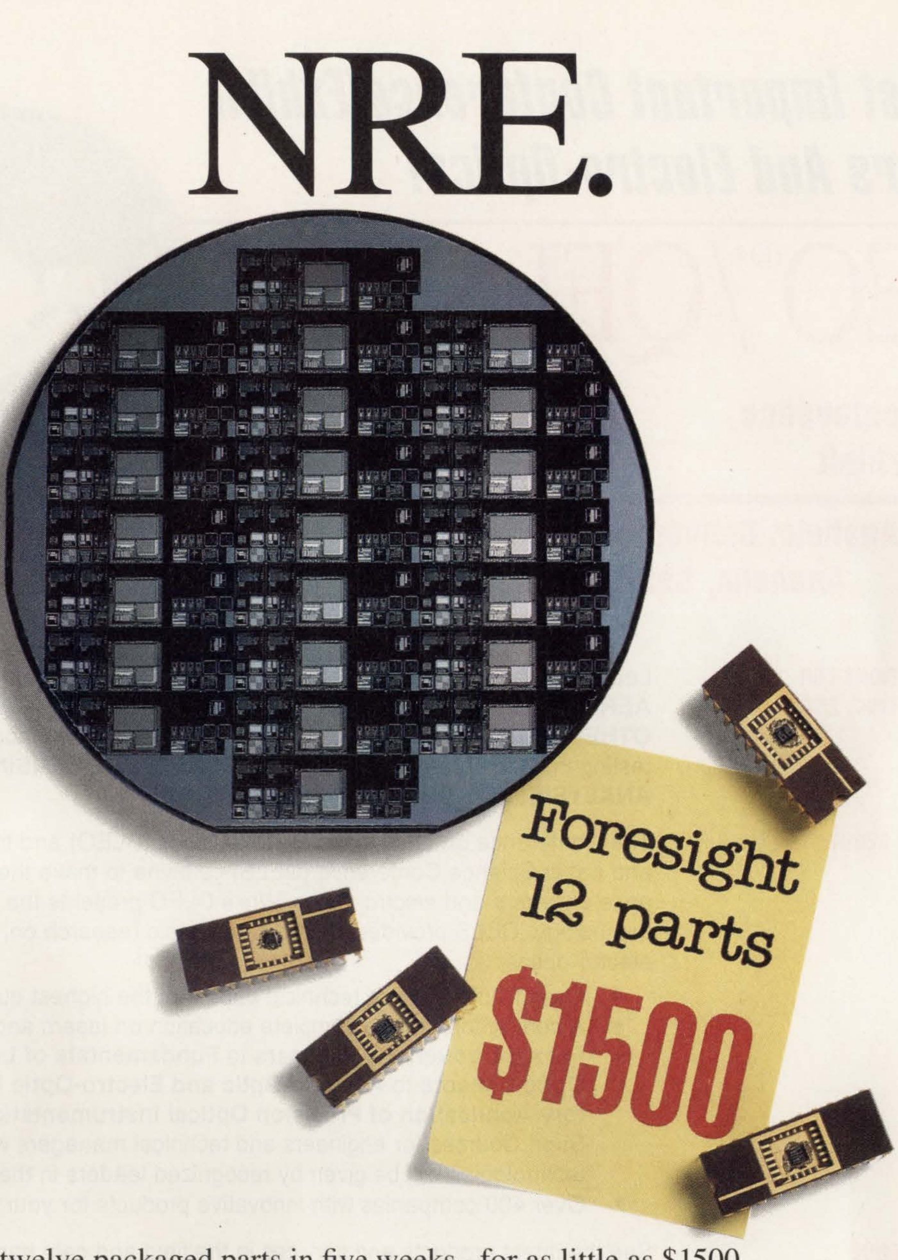
GPS receiver. The GPStar device provides time and frequency with atomic accuracy by receiving the Universal Time Code (UTC) transmitted by Global Positioning System (GPS) satellites. It tracks as many as five satellites at a time and provides an accuracy of 100 nsec for UTC. The stand-alone unit accommodates long cable lengths by placing the down-converter near the antenna. It has an RS-232C port to download time data to a computer. $3995. **Odetics,** 1515 S Manchester Ave, Anaheim, CA 92802. Phone (714) 774-5000. FAX (714) 774-9432. **Circle No. 398**

Color Postscript printer. The G5241-PS/4 prints Adobe Postscript images in Pantone licensed colors on A-size paper or overhead transparencies. The thermal-transfer printer has 300-dpi resolution and 4 Mbytes of RAM. Standard interfaces include Appletalk, Centronics parallel, and RS-232C ports. $6990. **Océ Graphics Inc,** Box 7169, Mountain View, CA 94039. Phone (415) 964-7900. FAX (415) 961-6152. **Circle No. 399**

Plasma display. The model FPF-20000S is a stand-alone ac-memory plasma flat-panel display. The screen has 100-dpi resolution on a 16-in. diagonal viewing area. The 1280×1024-pixel display interfaces to Sun's SPARC-stations. The monitor includes interface circuitry and an ac/dc converter in a chassis measuring 16.85×12.56×3.5 in. The unit weighs approximately 14 lbs and has an operational life of 50,000 hours. $5000. **Fujitsu Microelectronics Inc,** 3545 N First St, San Jose, CA 95134. Phone (800) 642-7616; (408) 992-9000. FAX (408) 428-0640. **Circle No. 400**

Time-to-Market.

NRE.



Get twelve packaged parts in five weeks – for as little as $1500.

Our Foresight multi-project wafer processing program can dramatically cut the cost of IC prototyping while reducing your time to market.

- Foresight runs start every Wednesday
- Five week turnaround
- Dramatic reductions in prototyping costs
- Debug mixed signal ICs while in design

Don't wait to start cutting your NRE.
In fact, call (800) 331-4617, and you can start right away. In California (800) 647-0222 or (408) 744-1800. FAX (408) 747-1263.

ORBIT SEMICONDUCTOR, INC.

What others promise, we guarantee.

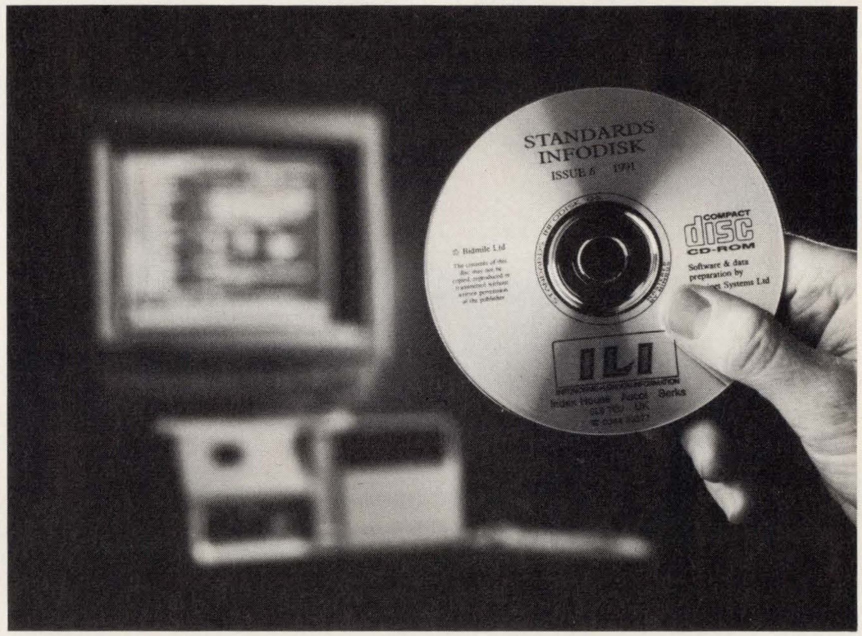
CIRCLE NO. 83

CIRCLE NO. 117

CAE & Software Development Tools

Standards Database Software

- *CD-ROM contains 180,000 standards and specifications*
- *Search criteria are in plain English*



Standards Infodisk is a comprehensive bibliographic database of national and international standards on a CD-ROM disk. It covers more than 180,000 standards and specifications from more than 60 issuing authorities in the US, the UK, Germany, France, Canada, and Australia; it also includes standards from international bodies such as IEC, ISO, and CEN. The more than 40 US organizations covered include AIAA, AMS, AN, ANSI, ASHRAE, ASME, ASQC, ASTM, EIA, IEEE, IPC, MS, NEMA, SAE, and UL. More than two dozen European and international organizations are included. The product is a search tool, not a database of complete document text. The information provided for each standard includes title (in English), revision history, country of origin, subject classification, and equivalent standards. When one standard refers to another, you can instantly access the second one with a "hot" key. The disk contains additional summaries of more than 50,000 standards; summaries of US industry standards specify whether or not the standard is acceptable to the US Department of Defense. Searches are in plain English; you can specify one or more parameters, including document number, title, revision date, country of origin, subject, or key word or phrase. To use the product, you need a PC XT, MS-DOS 3.0, and a CD-ROM drive. $2195.

Document Engineering Co Inc, 15210 Stagg St, Van Nuys, CA 91405. Phone (800) 363-3647; (818) 782-1010. FAX (818) 782-2374.

Circle No. 407

Interactive math for VAX. Maple V for VAX/VMS is an interactive computer algebra system. A user interface for the X-Window system edits input expressions and maintains session logs. It also produces interactive 3-D color graphics. US $1395. **Waterloo Maple Software,** 160 Columbia St W, Waterloo, ON, N2L 3L3, Canada. Phone (519) 747-2373. **Circle No. 408**

Real-time operating system. An optimized version of the OS-9 real-time operating system is now available for the Motorola MVME167 single-board computer. This latest version allows development of real-time software that uses all of the board's features, including onboard serial, SCSI, and Ethernet hardware. The software is available in two versions. The OS-9/167 Development Pak includes the OS-9/167 operating system and a full suite of development tools. A corresponding Run-Time Pak provides only OS modules. The development version includes a Kernighan & Ritchie C compiler, a macro assembler and linker, a user-state debugger, a screen editor, a shell-command interpreter, and utility programs. It also includes device drivers for next-generation I/O peripherals. These include SCSI drivers for the NCR 53C710 controller; the controller supports floppy and hard disks and tape units that use the Common Command Set. **Microware Systems Corp,** 1900 NW 114th St, Des Moines, IA 50322. Phone (515) 224-1929. **Circle No. 409**

Fuzzy-logic design tool. RT/Fuzzy aids the development and implementation of real-time software using rule-based logic. An extension of the supplier's family of tools for graphical modeling, system design, simulation, and code generation, it simulates and generates code for fuzzy-logic designs. Fuzzy logic attempts to mimic imprecise human thinking by operating on IF-THEN statements that describe conditions and actions; it differs from conventional algorithms since all rules are based on qualitative information rather than a set of procedural equations. Software is available for Sun-4, SPARCstations, VAX, and HP workstations. From $5000. **Integrated Systems Inc,** 3260 Jay St, Santa Clara, CA 95054. Phone (408) 980-1500. **Circle No. 410**

VHDL tool set. Silicon 1076 offers a complete concept-to-silicon VHSIC hardware-description language, according to its developer. It lets you start at the architectural level, register-transfer level, or gate level and complete the design of an ASIC. It supports all of its developer's libraries. From $55,000. **LSI Logic,** M/S D-102, 1551 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 433-7161. **Circle No. 411**

Augat offers you a choice in SIMM Metal Latch Sockets.

Augat's 3950 Series Metal Latch SIMM Sockets provide a more reliable, user friendly interconnect for memory modules. Memory upgrades are easy with Augat's patent pending latch design. Our unique design offers you the choice of readily accessing the latch from the front sides of the socket. A great advantage when modules are closely stacked or difficult to reach.

Rugged, stainless steel latches provide positive retention with an audible "click" indicating memory module is fully engaged. High performance LCP molded insulators proven to be dimensionally stable through IR processing combine with an anti-overstress contacts designed to accommodate the full range of JEDEC dimensioned modules.

Augat, "the first name in sockets", continues to provide the quality and innovation you expect.

Available from stock in popular sizes on .050" and .100" centerlines or through your local distributor.

AUGAT® *Quality and Innovation*

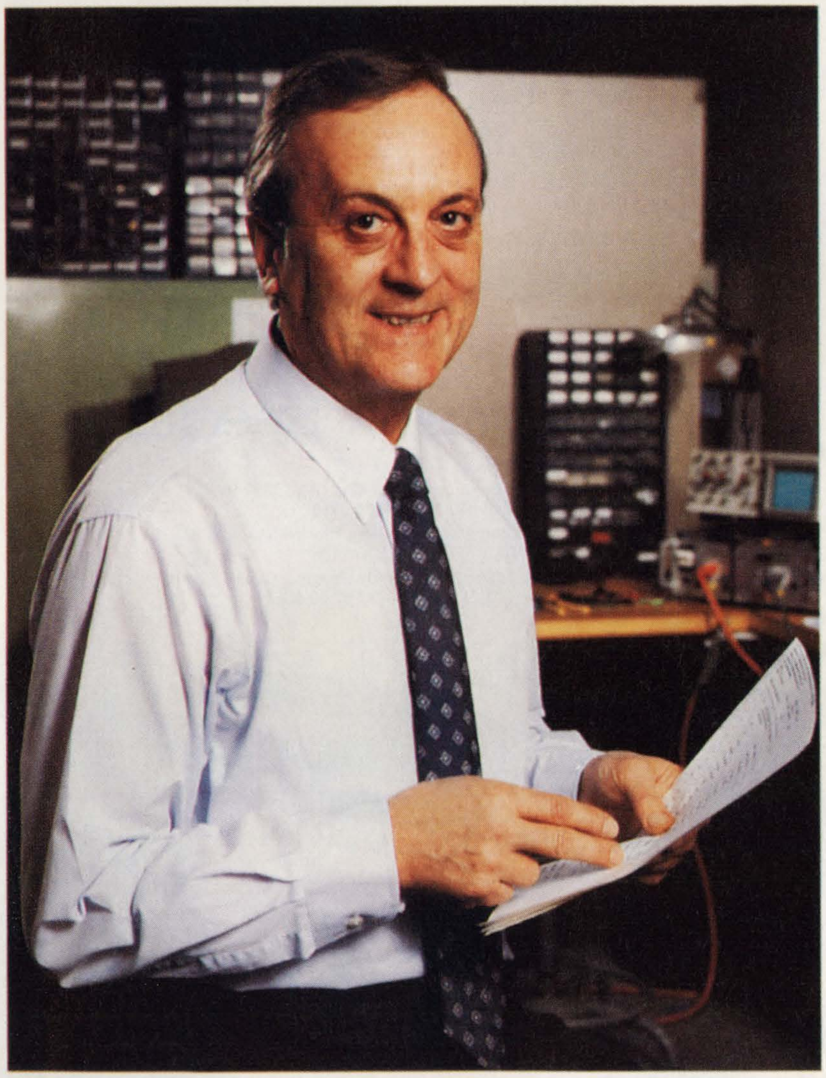
INTERCONNECTION PRODUCTS DIVISION

We encourage you to get complete technical and delivery information on these or any other interconnection components you require.

452 John Dietsch Boulevard
Attleboro Falls, MA 02763 USA
Tel: (508) 699-9800 FAX: (508) 699-6717

CIRCLE NO. 79

"We saved over $19,000 at the demo!"



CAPS® is a productivity-boosting engineering tool that helps you find, select, and specify ICs and semiconductors faster and easier than ever before.

"The microfilm system we purchased for IC and semiconductor search and selection just wasn't working out. It was hard to use and there weren't enough people using it to justify the cost. So, we decided to evaluate CD-ROM-based systems.

"While all this was happening, our purchasing people found a new IC vendor. They wanted to know if the new vendor made equivalents for some of our most commonly-used components. They thought we could get a better price. It would take us hours to find equivalents on the microfilm system, so we decided to challenge a couple of new CD-ROM-based systems.

"The first demonstration was a flop. Their system didn't even include the new vendor. Needless to say, we weren't impressed.

"Then Cahners came to demonstrate the CAPS system. In less than 20 minutes, CAPS found equivalents for the components we wanted. **I figure we saved over $19,000 at the demo!**

"Oh yes . . . we bought the system!"

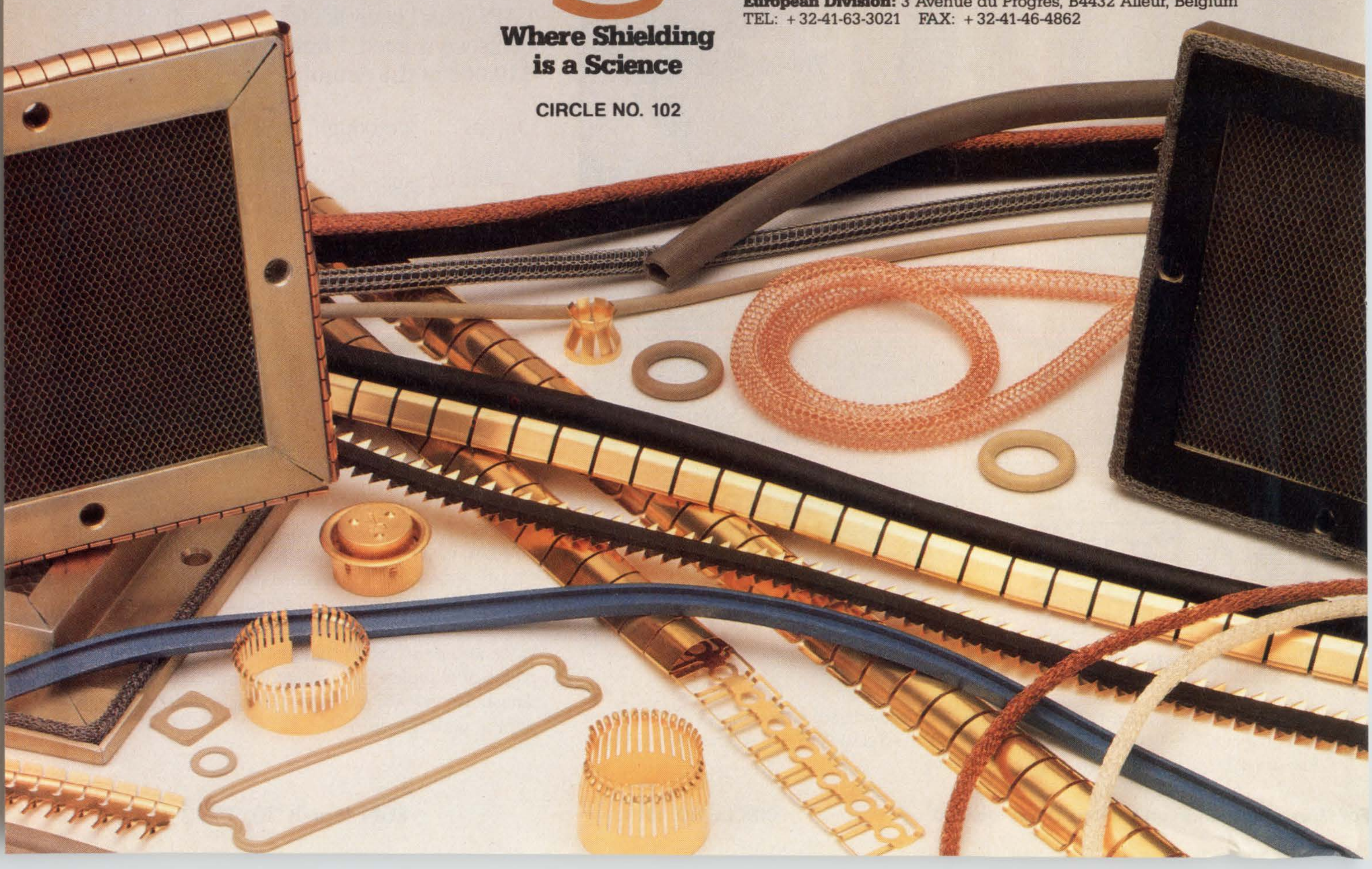
—*Frank Lucas*
Test Engineering Manager
Welch Allyn
Data Collection Division

Updated monthly, the CD-ROM (Compact Disc – Read-Only Memory) based CAPS system gives you fast, easy, query-driven access to technical specifications and applications data for over 575,000 ICs and semiconductors made by nearly 500 companies worldwide. Best of all, CAPS provides instant access to hundreds of thousands of pages of complete, unabridged manufacturers' datasheets, so you have everything you need right at your fingertips.

CAHNERS
CAPS®
Computer Aided Product Selection

It's easy to find out more about CAPS! For your free information kit, call Jill Adams at 800-245-6696. Do it today!

Cahners Technical Information Service • 275 Washington Street • Newton, MA 02158-1630
Telephone: 617-558-4960 • Facsimile: 617-630-2168 • Telex: 940573 • Toll-free: 800-245-6696



EDN Announces

Transform Your World

DSP^{x}

The International Conference and Exposition on Digital Signal Processing Applications and Technology

San Jose Convention Center, October 14 - 16, 1992

The future of Digital Signal Processing is here. Improved technology has combined with decreasing manufacturing costs to produce a remarkably high rate of growth: DSP shipments grew a healthy 35% in 1991 versus 9% for integrated circuits.

Until now a current or prospective user could not turn to one source to learn more about DSP, its applications, and its benefits. Now there is DSP^{x}: The International Conference and Exposition on Digital Signal Processing Applications and Technology.

DSP^{x} focuses on the needs of the commercial market. It offers an applications — oriented approach to DSP, providing both an introduction for those not familiar with the technology and detailed tutorials for those exploring new avenues of implementing DSP.

DSP^{x} promises to bring together top vendors of DSP devices, boards, software, and systems with current and prospective end-users in the computer, communications, automotive, consumer, medical, industrial, military, and aerospace industries.

It's no longer a question of whether DSP will be part of your product, but when.

Managed and produced by Reed Exhibition Companies™

Committed to Excellence

DSP^{x}

The International Conference and Exposition on Digital Signal Processing Applications and Technology

☐ **Yes,** I want to learn more about **DSP^{x}**: *The International Conference and Exposition on Digital Signal Processing Applications and Technology*

☐ Please send me information on attending the One-Day Introductory Course

☐ Please send me information on attending the Three-Day Conference Program

☐ Please send me information on exhibiting

Name: ____________________

Title: ____________________

Company: ____________________

Address: ____________________

City: ____________________

State: __________ Zip: __________

Telephone: ____________________

Fax: ____________________

Fax to: (203) 964-0176 **or Mail to:** DSP^{x}, P.O. Box 3833, 999 Summer Street, Stamford, CT 06905-0833

CIRCLE NO. 103

CIRCLE NO. 104

Reference guide for open systems. *The World of Standards* covers more than 75 standards from 19 organizations worldwide, such as CCITT, IEEE, and ANSI. The first section describes the standards individually and lists the organization that developed each one. The second section discusses the various organizations in detail. **88open Consortium Ltd,** 100 Homeland Ct, Suite 800, San Jose, CA 95112. Phone (408) 436-6600. **Circle No. 401**

VXIbus product catalog. This publication introduces more than 30 VXI modules, including analog and digital I/O, monitors and controllers, signal conditioners, and ARINC-429 and MIL-STD-1553 interfaces. It discusses VXIbus data-acquisition systems that you configure using the National Instruments' VXIpc-386 PC/AT and VXIpc-030 68030 embedded computers. **KineticSystems** 11 Maryknoll Dr, Lockport, IL 60441. Phone (815) 838-0005. **Circle No. 402**

Test equipment cataloged. The 40-pg catalog describes and illustrates recording systems, oscilloscopes, analog and digital snap-arounds, digital multimeters, data-logging digital multimeters, and many related devices. The alphanumeric table of contents lists products by model number. **AW Sperry Instruments Inc,** Box 9300, Smithtown, NY 11787. Phone (516) 231-7050. **Circle No. 403**

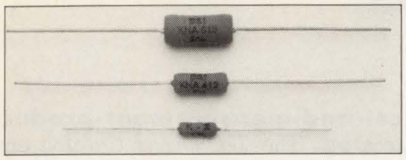
Data sheet for 10× coplanar microprobe. This data sheet presents the 10× coplanar microprobe that's designed to allow internal node probing of multichip modules, mixed-signal hybrids, microwave hybrids, and high-density SMT assemblies. It provides a listing of features and specifications, as well as graphs and diagrams, illustrating performance and verification. **Cascade Microtech Inc,** Box 1589, Beaverton, OR 97075. Phone (503) 626-8245. **Circle No. 404**

Brochure on microcontroller family. This 6-pg foldout deals with the H8/500 family of 8- and 16-bit microcontrollers. In addition to describing and illustrating the products and their features, the brochure presents a listing of specifications. **Hitachi America Ltd,** Semiconductor & IC Div, 2000 Sierra Point Pkwy, Brisbane, CA 94005. Phone (415) 589-8300. **Circle No. 405**

Test-and-measurement-product catalog. The *Tek Direct Catalog* emphasizes that the test-and-measurement equipment listed in this publication is "affordable." It lists meters, handheld and low-end portable oscilloscopes, probes, plotters, accessories, and training aids. The "Tek Tips" section provides helpful hints and suggestions for solving common test-and-measurement problems. **Tektronix Inc,** Tek Direct, Box 1520, Pittsfield, MA 01202. **Circle No. 406**

Brochure of electrostatic plotters. This 8-pg publication discusses large-format electrostatic plotters: the monochrome Model 67436 and the color 68000 Series. It describes the plotters' accuracy and line quality, area and color-fill capabilities, connectivity, and memory options. The brochure provides drawings for applications, such as architecture, mechanics, and IC design; solids modeling; mapping; and graphic arts. **Calcomp Inc,** 2411 W La Palma Ave, MS 52, Anaheim, CA 92801. Phone (800) 932-1212; (714) 821-2000. FAX (714) 821-2714. **Circle No. 412**

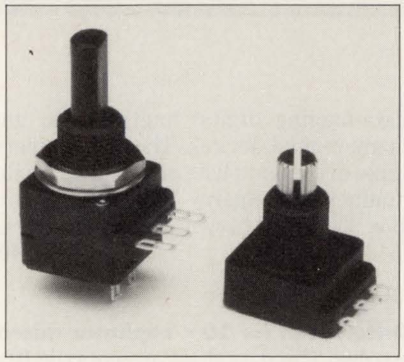
ADVERTISEMENT



Wirewound Resistors

Silicone coated, all-welded construction, completely flameproof. Power ratings 3W to 15W over the ohmic range of 0R025 to 75K with a standard tolerance of 5%. Available in tape pack.

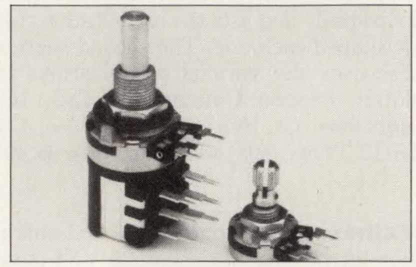
CIRCLE NO. 127



Modular Potentiometers

Completely insulated 16mm potentiometers are made of autoextinguishable plastic UL94 (VO). Modular design allows ganging up to 4 pots and a switch on the same metal or plastic shaft. Dust and solvent resistant.

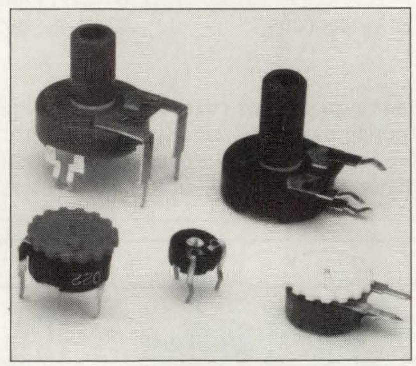
CIRCLE NO. 128



Control Potentiometers

Rotary control potentiometers available in 16mm and 21mm diameter versions. Both models are available with switches to satisfy virtually any design requirement.

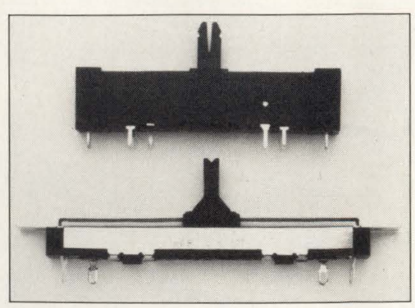
CIRCLE NO. 129



Trimmer Series

Our PT6 model is available in carbon. PT10 and PT15 models come in carbon and are also available in cermet. All trimmers are enclosed to protect against dust, cleaning solvents and water. Wide choice of mounting and adjustment options.

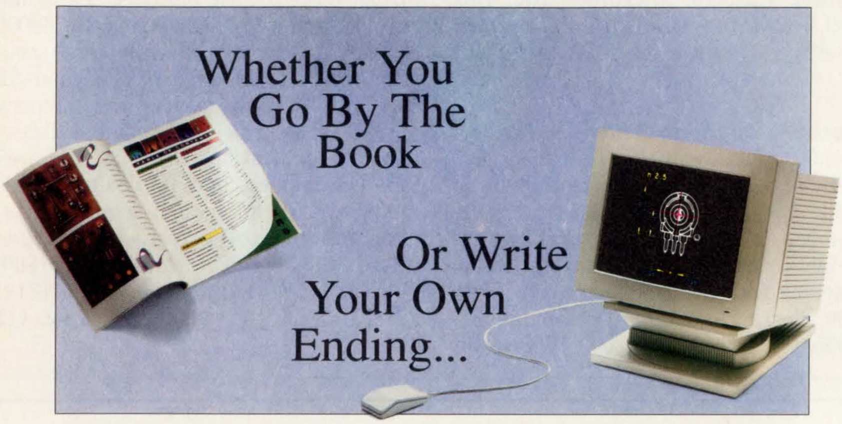
CIRCLE NO. 130



Slide Potentiometers

Featuring a linear adjustment, our slide potentiometers are available in 40mm and 60mm travels. Choose PC or panel mount in a variety of curves. Dust and solvent resistant.

CIRCLE NO. 131



The NEW Piher Opens Up Unlimited Specifying And Design Options

The New Piher is now backed by the resources of The Meggitt Group. Powered by a nationwide sales and distribution network. Poised to offer you unmatched resistive component options and value.

Designers can now team with our international pool of engineering talent to create custom specials.

Specifiers and Purchasers can expect prompt technical support and efficient customer service from people who understand your production requirements.

Choose from a complete, quality line of carbon and cermet trimmer potentiometers in a wide range of specifications. All are competitively priced and readily available from one of the nation's most extensive inventories.

And all Piher components (as evidenced by our prestigious Ford Q-1 award) meet the highest standards for quality and reliability.

Find out more about the New Piher. For a Free 108-page Product Catalog, call 1-800-323-6693, or write Piher, 903 Feehanville Drive, Mt. Prospect, IL 60056.

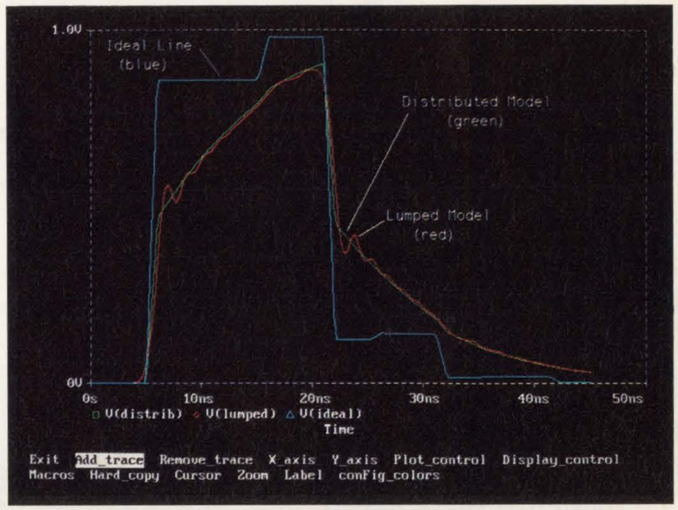
In Illinois call 708-390-6680.
FAX: 708-390-9866.

PIHER

A MEGGITT ELECTRONICS Co.

CIRCLE NO. 132

Our Lossy Transmission Lines Have the Edge!



Comparison of the ideal and lossy transmission line models

Faster Simulation and Greater Accuracy

That's our lossy transmission line edge. We've extended PSpice's intrinsic T device to model lossy transmission lines using the distributed approach rather than the traditional lumped approach. What you get is a smoother approximation of the line's behavior in significantly less time. Here's why.

The Distributed Model Advantage

Our lossy line behavior is computed using impulse responses instead of the commonly used ladder structures associated with lumped models. Using this technique, lossy lines can be easily specified in terms of their electrical length and the resistance; inductance, capacitance, and conductance distributed along the entire length of the line.

Elimination of Spurious Oscillations

Modeling lossy lines as continuous lines eliminates the frequency artifacts observed in lines modeled as a finite set of lumped segments. With the lumped model, oscillations are produced at points where abrupt changes occur in the signal traveling along the line segments. Using the distributed model, these oscillations vanish.

Optimized Simulation Performance

For any given circuit, simulation time using the distributed model can be several times faster than the simulation time using the lumped model. With the lumped model approach, the number of segments required for accurate results can become large. Hence, the simulation time can become very long. The continuous lines produced by the distributed model avoid the performance overhead created by multiple line segments.

Get the PSpice Lossy Line Edge

That way, you can efficiently model the loss and dispersion in your non-ideal lossy transmission lines. Discover for yourself why PSpice continues to hold the industry edge in mixed analog and digital circuit simulation. For more information on PSpice and the **Design Center**, call MicroSim Corporation toll free at (800) 245-3022 or FAX at (714) 455-0554.

MicroSim Corporation

The Standard for Circuit Design

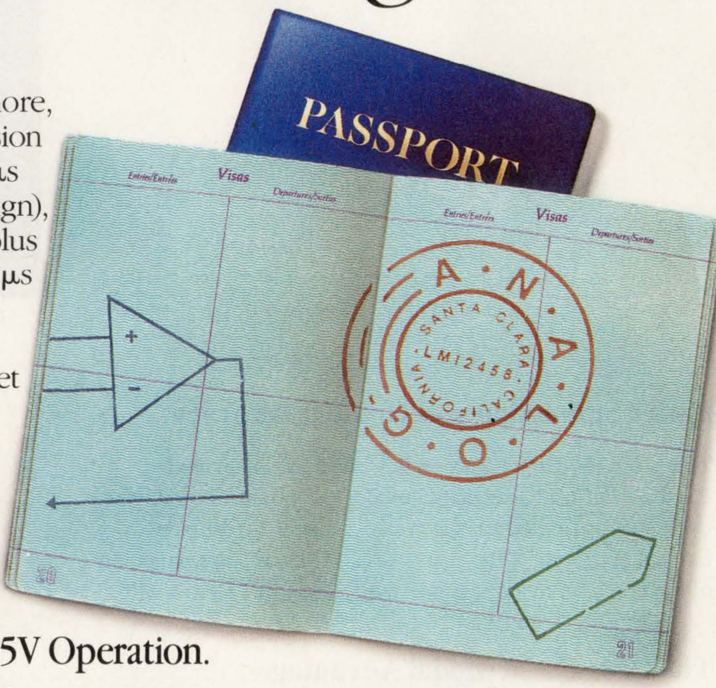
20 Fairbanks • Irvine, CA 92718

THE MAKERS OF PSPICE

CIRCLE NO. 107

12-BIT DATA ACQUISITION SYSTEM

Now you can have easy access to the analog world.



Unsurpassed integration makes analog design easy.

When crossing the border from analog to digital the last thing you want is excess baggage.

That's why we designed the industry's first +5V 12-bit plus sign Data Acquisition System, the LM12458. A one-chip solution that not only shrinks board space but also reduces design and debug time.

Versatility through software programmability.

Easily configured via software, the LM12458 lets you switch the mux from differential to single-ended mode "on the fly."

What's more, with conversion times of 8.8μs (12-bit plus sign), 4.2μs (8-bit plus sign), and 2.2μs ("watchdog" comparison mode) you get optimized system performance at a throughput rate of 87kS/s min.

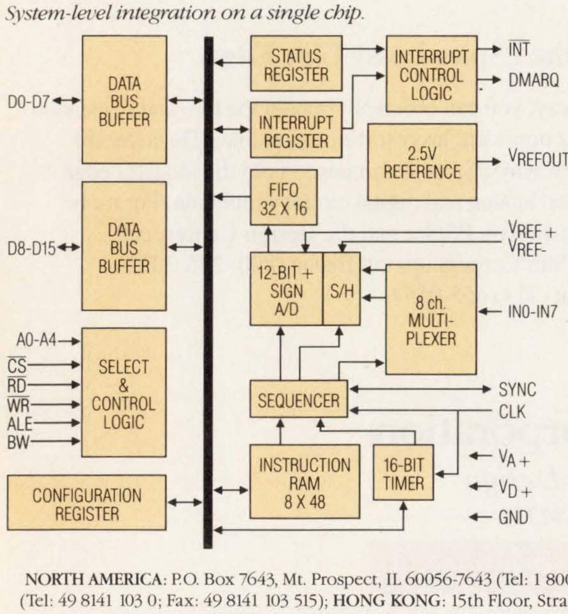
Single +5V Operation.

With single +5V operation, you get all this performance while consuming just 30mW max (50μW in standby mode).

Plus, its self-calibrating architecture ensures high accuracy over time and temperature.

So hurry up and get on board. And gain duty-free passage to the analog world.

System-level integration on a single chip.



FEATURES

- Software-programmable
  - —Conversion speeds
  - —Resolution
  - —Mux
- Configurable for stand-alone operation
- 87kS/s min. throughput rate
- 30mW power consumption @5V
- 50μW standby mode
- 0-5V input
- ±0.5LSB DNL
- 8- or 16-bit wide I/O
- 44-pin PLCC package

Access us with one easy call.

For a free software design kit, call: 1-800-NAT-SEMI, Ext. 143. Or, fax: 1-800-888-5113

National Semiconductor

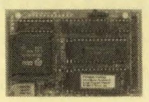
NORTH AMERICA: P.O. Box 7643, Mt. Prospect, IL 60056-7643 (Tel: 1 800 628 7364, ext. 143; Fax: 1 800 888 5113); EUROPE: Industriestraße 10, D-8080 Fürstenfeldbruck, Germany (Tel: 49 8141 103 0; Fax: 49 8141 103 515); HONG KONG: 15th Floor, Straight Block, Ocean Centre, 5 Canton Rd., Tsimshatsui, Hong Kong (Tel: 852 737 1654; Fax: 852 736 9921); JAPAN: Sanseido Building 5F, 4-15-3, Nishi-shinjuku, Shinjuku-ku, Tokyo, Japan 160 (Tel: 81 3 3299 7001; Fax: 81 3 3299 7000).

EDN PRODUCT MART

This advertising is for new and current products.

Please circle Reader Service number for additional information from manufacturers.

Instant Microcontroller



Instant C Programming

Don't use a microprocessor, use a **SmartBlock**™ microcontroller module to build your custom controller. Our $195 interactive **Dynamic C**™ development system makes programming easy. 3.5 x 2.5 inch module includes microprocessor, memory, time/date clock, eeprom, watchdog, serial ports and more. As low as $59 in quantity. The efficiency of a custom design without the headaches.

Z-World Engineering
1724 Picasso Ave., Davis, CA 95616 USA
Tel (916) 757-3737
Regular Fax: (916) 753-5141
Automatic Fax: (916)-753-0618
(Call from **your fax**, request data sheet #14.)

CIRCLE NO. 325

Faster design, prototyping

Compare:
Faster results.
Easier model entry.
Total control.
2D and 3D.
Verified accuracy.
PC,UNIX,VMS,Cray.

Priced from $3000, for PC versions.

Phone our electromagnetics hot-line today:
(514) 849-8752*

*Ask for our free booklet and demo.

MagNet electromagnetics analysis software - based on results.

Since 1978, engineers have used MagNet to improve their performance.

Testing design variations at their desks, before committing lab time, these pioneers have saved their companies design costs and time.

infolytica
The Electromagnetics Specialists

North America: tel:(514) 849-8752 FAX:(514) 849-4239
Europe: Infolytica (+44)793.785.722 FAX:793.782.146
Japan: ADTECH (03)5276-5291 FAX:(03)5276-5293

CIRCLE NO. 326

---

programmable PC-based

US$ 895.00

PATTERN GENERATOR

40 MHz, 9 channels at 8KB. Connected to the parallel printer port of any PC.
FREE Demo Software available.
For more information call or fax us, today

WITTIG TEST TECHNOLOGY Inc.
P.O.Box 8162 WHITE PLAINS, N Y 10602-8162
☎ (914)-948 2606 fax: (914)-948 2641

CIRCLE NO. 327

PROTO EXPRESS

Best Value in the World for
5 DAY TURN
PRINTED CIRCUIT PROTOTYPES

2 PIECE PRICES

	LAYERS	1	2	3&4	5&6	7&8
SQUARE INCH UP TO	15	$212	$265	$581	$715	$850
	30	240	300	658	815	983
	60	283	354	775	954	1034
	90	325	407	891	1097	1304
	120	350	442	949	1092	1417

- 5 PIECES x 1.34
- 10 PIECES x 1.67

EXTRAS
- Photo Plotting
- Testing
- Gold Contacts - $50
- 25% – Below 8 Mil

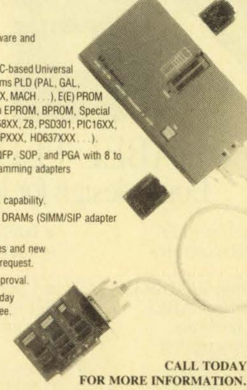
DISCOUNTS
- 10% COD
- 5% NET 10, CREDIT CARD SALES

FOR MORE INFORMATION CALL OR FAX
Ken Bahl
Sierra Circuits, Inc.
Phone (408)735-7137 FAX (408)735-1408 Modem (408)735-9842

CIRCLE NO. 328

UNIVERSAL PROGRAMMER, EMULATOR & TESTER
TUP-400 $745.00

DEVELOPER'S TOOLS



- New improved hardware and software.
- *The* most complete PC-based Universal Programmer. Programs PLD (PAL, GAL, FPL, EPLD, PEEL, MAX, MACH . . .), E(E) PROM (up to 16 Mbit), Flash EPROM, BPROM, Special PROM, MPU (87XX, 68XX, Z8, PSD301, PIC16XX, TMS320EXX, UPD75PXXX, HD637XXX . . .).
- Covers DIP, PLCC, QFP, SOP, and PGA with 8 to 84 pins. Gang Programming adapters available also.
- EPROM EMULATION capability.
- Tests digital ICs and DRAMs (SIMM/SIP adapter available).
- Free software updates and new devices added upon request.
- IC Manufacturers' approval.
- 1 year warranty, 30 day money back guarantee.

CALL TODAY FOR MORE INFORMATION.
Distributors are welcome!

Tribal Microsystems Inc.
44388 S. GRIMMER BLVD. FREMONT, CA 94538
TEL (510)623-8859 FAX (510)623-9925

CIRCLE NO. 329

ROM-IT

EPROM EMULATION SYSTEM

NEW 4-MEGABIT VERSION

- Emulates up to 8 4-Megabit EPROMS with one control card.
- Downloads 2-Megabit programs in less than 23 seconds.
- Allows you to examine and modify individual bytes or blocks.
- Accepts Intel Hex, Motorola S-Record and Binary files.
- Software available for IBM PC and compatibles and Macintosh systems.
- Base 27256 EPROM System **$395.00** Other configurations available.

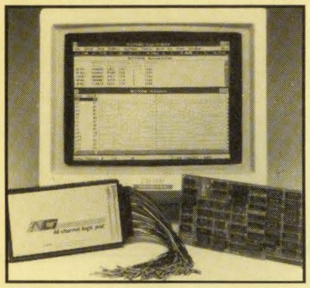
ORDER TODAY--IT'S EASY
CALL OR FAX FOR MORE INFORMATION

Incredible Technologies, Inc.
(708) 437-2433
(708) 437-2473 Fax
VISA now accepted.

CIRCLE NO. 330

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

48 Channel 50MHz Logic Analyzer



Complete System $1895.00

New Windows 3.0 Compatible Software

- 48 Chnnls @ 50 MHz x 4K words deep
- 16 Trigger Words/16Level Trigger Sequence
- Storage and recall of traces/setups to disk
- Disassemblers available for: 68000, 8088, 8086, 6801, 6811, Z80, 8085, 6502, 6809, 6303, 8031

NCI *6438 UNIVERSITY DRIVE, HUNTSVILLE, AL 35806 (205) 837-6667 FAX (205) 837-5221*

CIRCLE NO. 331

BACKGROUND MODE EMULATOR

68332 68340 68HC16

and 68330, 68331, 68333

Complete hardware testing and C source level debugging for thousands less than an ICE. Call for a *free* trial unit.

(617) 828-5588

EST Embedded Support Tools Corp.

10 Elmwood St. Canton, MA 02021

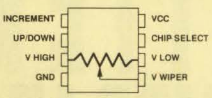
CIRCLE NO. 332

Consistency is key

to the power of EDN Product Mart

CIRCLE NO. 333

"NO KNOBS"



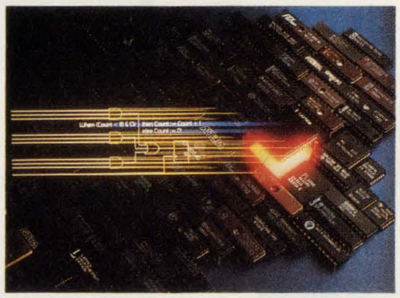
E^2POT™ Digitally Controlled Potentiometers

FEATURES:

- Low Power CMOS Technology
- Non-volatile Wiper Position Storage
- Temperature Compensated
- Low Cost
- ±20% End To End Resistance Range
- Improve System Reliability
- 1-3% Resolution
- 100 Year Wiper Position Retention
- Will Not Wear Out!
- Allow Automated System Adjustments
- 8 Pin Through-hole And Surface Mount Packages

Xicor® Xicor, Inc., 851 Buckeye Court, Milpitas, California 95035-7493 (408) 432-8888 X3549 FAX 408-432-0640

CIRCLE NO. 334



MacABEL

PLD Design on the Apple Macintosh!

Data I/O's industry-standard ABEL PLD design package is now available on the Macintosh, exclusively from Capilano Computing! • Use Boolean and integer equations, state machines and truth tables to describe your design • Communicates directly with any serial PLD programmer • Best device support in the industry, including ALTERA, AMD, ATMEL, CYPRESS, GOULD, HARRIS, ICT, INTEL, LATTICE, NATIONAL, RICOH, SAMSUNG, SGS, SIGNETICS, SSS, TI, VTI and others • Interactive "in-circuit" schematic entry and simulation when used with DesignWorks

Call (800) 444-9064 Today for your free Demonstration Kit!

Capilano Computing

FAX: (604) 522-3972

(604) 522-6200

CIRCLE NO. 335

Now Networkable!

Facts about

625,000

ICs and Semiconductors at Your Fingertips

Cahners CAPS is the newest component search and selection tool for electronic design engineers:

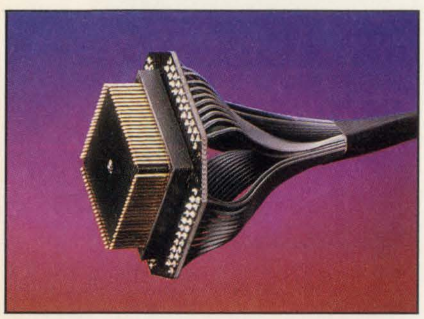
- PC-driven, CD-ROM-based
- Includes unabridged manufacturers' datasheets
- Represents more than 520 manufacturers worldwide

Call toll-free: 1-800-245-6696

CAHNERS CAPS® Computer Aided Product Selection

275 Washington Street
Newton, MA 02158-1630
Telephone: 617-558-4960
Facsimile: 617-630-2168
Telex: 940573

CIRCLE NO. 336



Easy Emulator Pods & Adapters

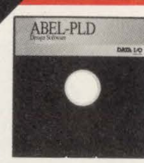
- **Plug your PLCC and LCC packages into your PC board in minutes, with these easy-to-use adapters.**
- **Emulator/logic analyzer users: Adapt-a-Pod™ converts one package type to another (LCC, PLCC, PGA, and DIPs).**
- **Emulator pods and adapters are available in all standard pin counts, with ribbon or ribbon cable headers.**
- **Custom engineering services and do-it-yourself emulator pod converters. Free catalog.**

Emulation Technology, Inc.
2344 Walsh Ave. Santa Clara, CA 95051
Phone: 408-982-0660 FAX: 408-982-0664

ET

CIRCLE NO. 337

Just $495!*



ABEL-PLD: Logic design for less.

- 150 PLD architectures supported (more than 4000 devices)
- Uses ABEL™ Hardware Description Language (ABEL-HDL™)
- Intelligent synthesis and optimization
- Upgradable to full-featured ABEL Design Software

1-800-3-DataIO
(1-800-332-8246)

**U.S. list price only.*

DATA I/O DIRECT Call Data I/O® Direct today to order ABEL-PLD.

DATA I/O

CIRCLE NO. 338

Now $1495!*

Save $1000 on our entry-level logic system.

- Includes the 212 Multi Programmer with logic module, ABEL-PLD™ and PROMlink™ Ltd. PC Interface Software
- Supports 20- and 24-pin CMOS logic devices
- Full-hex keypad for extensive editing
- Optional EPROM and microcontroller modules

1-800-3-DataIO
(1-800-332-8246)

**U.S. list price only.*

DATA I/O DIRECT Call Data I/O® Direct today to order the 212 Logic System.

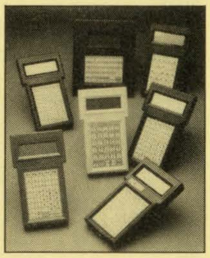
DATA I/O

CIRCLE NO. 339

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

OPERATOR INTERFACE

INDUSTRY PROVEN RELIABILITY

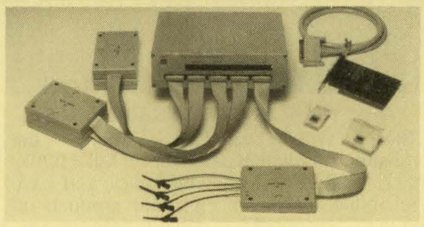


* 30 or 45 key Tactile Keypad
* 80 Character (4 Line X 20 Character)
* 300 to 19200 BAUD
* Programmable Function Keys
* RS-232 or RS-422 Interface
* Simple Menu Set-up
* Standard or Custom Keypad Graphics
* 5 VDC or Extended 8-24 VDC
* Less than 8 Ounces
* Full Two Year Warranty

Two Technologies, Inc.
419 Sargon Way
Horsham, PA 19044
PHONE (215) 441-5305
FAX (215) 441-0423

CIRCLE NO. 349

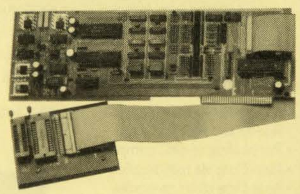
400 MHz Logic Analyzer



- upto 128 Channels, Timing and State
- 400 MHz Max Sampling Rate
- Timing and State Simultanious on Same Probe
- 16K Samples/Channel (high speed mode)
- 16 Levels of Sequential Triggering
- Variable, TTL, or ECL Logic Threshold Levels
- 8 External Clocks
- FREE Software Updates on 24 Hour BBS

$799 - LA12100 (100 MHz)
$1299 - LA32200 (200 MHz-32channels)
$1899 - LA32400 (400 MHz-32channels)
$1950 - LA64200 (200 MHz-64channels)
$2750 - LA64400 (400 MHz-64channels)

UNIVERSAL PROGRAMMER



PAL
GAL
EPROM
EEPROM
PROM
87xxx...
22V10
26CV12

$475

16Bit EPROMs FLASH EPROMs
5ns PALs 4 Meg EPROMs
FREE software updates on BBS

Call - (201) 808-8990
Link Computer Graphics, Inc.
369 Passaic Ave.,# 100, Fairfield, NJ 07004 FAX:879-8786

CIRCLE NO. 753

Combine Your Product Mart Ads

In EDN's Magazine and News Editions for higher impact and a lower rate.

CIRCLE NO. 751

MIL-STD-1553

TEST EQUIPMENT

- Complete error injection/detection capability for 1553 A/B terminals and systems
- Simulates a Bus Controller, up to 32 Remote Terminals and/or a Bus Monitor
- Supports all phases of testing: Development, Validation and Production
- Dynamic/Real-time simulation

2-DAY SEMINAR

- Comprehensive discussion of MIL-STD-1553 and testing
- Lab session illustrates 1553 communication and provides experience in trouble-shooting
- Offered in Phoenix three times a year and available on-site

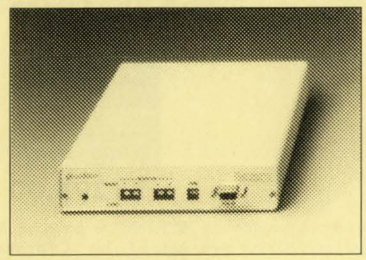
VALIDATION TESTING

- Approved by the Air Force
- Testing to the RT VALIDATION TEST PLAN
- Approved test procedure and test report
- Assistance in analyzing test results and trouble-shooting

TEST SYSTEMS, Inc.
217 W. Palmaire • Phoenix, AZ 85021 • (602) 861-1010
Supporting MIL-STD-1553 since 1979

CIRCLE NO. 752

VGA DISTRIBUTION AMP



QuadSplit™

■ Connects 4 VGA monitors up to 200 feet away at once ■ Supports all VGA/SVGA cards and monitors ■ 2 and 8 output models available ■ Only $495., 1 year warranty

Communications Specialties, Inc.

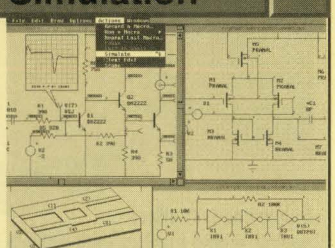
TEL: 516-273-0404 FAX: 516-273-1638

CIRCLE NO. 754

Analog Circuit Simulation

- Schematic Entry
- SPICE Simulation
- Model Libraries
- Waveform Processing

only $990



Powerful - Affordable

FULLY INTEGRATED, EASY TO USE, ANALOG CIRCUIT SIMULATION ENVIRONMENT, FROM ONE VENDOR, FEATURING: A powerful SPICE simulator performing AC, DC, and Transient, analyses, extensive model libraries, schematic entry, graphical waveform processing, and report quality printouts.

Call Or Write For Your Free Demo and Information Kit!
Tel. 310-833-0710

intusoft

P.O. Box 710 San Pedro, CA 90733-0710
Fax 310-833-9658

CIRCLE NO. 755

FINALLY

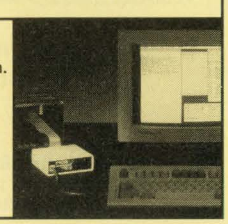
One tool to satisfy all your firmware development needs

PROMICE is a universal system.

- Develops code for any microprocessor
- Complete, real time, source level debugging
- Host software for DOS, Unix, Mac, VMS
- Non intrusive on your target system
- Simply plugs into any ROM socket

PROMICE also supports Turbo Debugger, C_thru_ROM, FreeForm, GDB, and more.

PROMICE
...the affordable solution.



Grammar Engine Inc.

TEL: (614)471-1113
West: (415)750-0219
FAX: (614)475-6871

CIRCLE NO. 756

Communicate Weekly

to the electronics OEM through EDN's Magazine and News Editions Product Mart

CIRCLE NO. 757

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

FREE DEMO DISKS

See why over 20,000 engineers rely on SCHEMA for their design needs.

- ✓ Schematic Capture
- ✓ PCB layout & routing
- ✓ Simulation
- ✓ PLD design

Call 800-553-9119

SCHEMA
FROM OMATION

801 Presidential • Richardson, TX 75081
(214) 231-5167 • FAX (214) 783-9072

CIRCLE NO. 758

Surface Mount Chip Component Prototyping Kits— Only $49.95

CC-1 Capacitor Kit contains 365 pieces, 5 ea. of every 10% value from 1pf to .33µf. CR-1 Resistor Kit contains 1540 pieces; 10 ea. of every 5% value from 10Ω to 10 megΩ. Sizes are 0805 and 1206. Each kit is ONLY $49.95 and available for Immediate One Day Delivery!

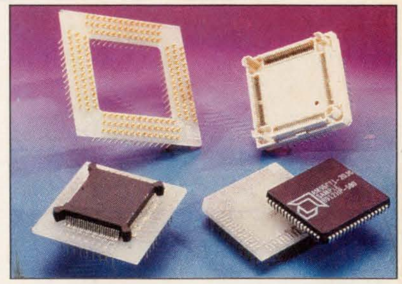
Order by toll-free phone, FAX, or mail. We accept VISA, MC, COD, or Pre-paid orders. Company P.O.'s accepted with approved credit. Call for free detailed brochure.

COMMUNICATIONS SPECIALISTS, INC.
426 West Taft Ave. • Orange, CA 92665-4296
Local (714) 998-3021 • FAX (714) 974-3420

Entire USA 1-800-854-0547

CIRCLE NO. 759

SM LAND/SOCKET



PLUGGABLE SURFACE MOUNT

The QFP and PLCCSM LAND/SOCKET provides a very reliable solution for socketing QFPs or PLCCs in production or ZIF (test/burn-in) patterns. The device is surface mounted to the SM LAND/SOCKET which converts the QFP or PLCC to a base pin array of the production or ZIP QFP socket and can then be soldered to target board or socketed using Ironwood's sockets receptacles. This results in a reliable connection at a reasonable cost. From $20.

IRONWOOD ELECTRONICS
P.O. BOX 21151, ST. PAUL, MN 55121
(612) 431-7025 FAX (612) 432-8616

CIRCLE NO. 760

Now Networkable!

Facts about

625,000 ICs and Semiconductors at Your Fingertips

Cahners CAPS is the newest component search and selection tool for electronic design engineers:

- PC-driven, CD-ROM-based
- Includes unabridged manufacturers' datasheets
- Represents more than 520 manufacturers worldwide

Call toll-free: 1-800-245-6696

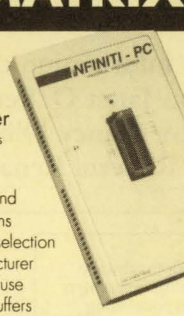
CAHNERS CAPS® Computer Aided Product Selection

275 Washington Street
Newton, MA 02158-1630
Telephone: 617-558-4960
Facsimile: 617-630-2168
Telex: 940573

CIRCLE NO. 761

INFOMATRIX

PC-Based Universal Device Programmer
Certified by IC Manufacturers



INFINITI-PC

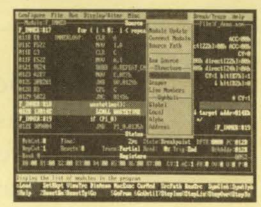
- Programs most PLDs and memories up to 40pins
- Menu driven device selection by P/N and manufacturer
- Full screen editor for fuse maps and memory buffers
- JEDEC standard vector test functions
- New devices can be easily added by yourself
- Self test and diagnosis for high programming yield
- One year warranty and free device update

408 / 371-4642

2265 Bascom Ave. #20, Campbell, Ca 95008

CIRCLE NO. 762

8051 68HC11 COP8



iceMASTER
Your Window To Emulation Productivity

- Easy to learn & use
- Windowed interface -- user configurable
- FAST! Download -- <3 sec. typ. at 115KB
- Source Level debug

- **A 4K frame trace buffer** with advanced searching capabilities.
- **iceMASTER** connects easily to your PC, requires no disassembly, or expansion slots. Works on any PC (DOS or OS/2), MicroChannel or EISA. Even laptops!
- **iceMASTER is versatile:** iceMASTER-8051, iceMASTER-68HC11 and iceMASTER-COP8 support most family derivatives.
- **Rental and 10-day trials available.**
- 68HC11 A,D,E,F; 8XC528; 8XC552; 8XC515A and 8XC517A support.
- **Call today for free demo disk and ask about a free 8051 MacroAssembler! (800) 638-2423**

MetaLink® Corporation

HOT NEW PRODUCTS!

MetaLink Corporation P.O. Box 1329 Chandler, Az 85244-1329
Phone: (602) 926-0797 FAX: (602) 926-1198 TELEX: 4998050MTLNK

CIRCLE NO. 763

8051 80C196 80C186 68HC11 64180

Orion's 8620 Analyzer-Emulator Supports These Processors & Over 180 More!

■ Cost-effective, PC-based emulation for over 180 8- and 16-bit CPUs ■ Source level and symbolic debug support ■ Interactive triggering ■ Program Performance Analyzer ■ Tremendous macro capabilities ■ Built-in EPROM programmer ■ Two-week evaluation program ■ Backed by over 11 years of emulation experience! Call or fax today for more info and a FREE DEMO DISK.

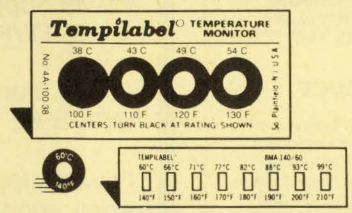
Limited offer — 1 month free with 3 month rental!
1-800-729-7700
Fax 415-327-9881

ORION® INSTRUMENTS

180 Independence Dr., Menlo Park, CA 94025

CIRCLE NO. 764

WRITE OR CALL FOR SAMPLE
Low Cost Tempilabel° Temperature Monitor.



How to put a low cost temperature gauge on everything.

Label's center spot turns black when surface to which it is affixed reaches specified temperature. Single- or multi-spot labels with pre-determined increment of ratings: 100°F (38°C) to 600°F (316°C). 1% accuracy guaranteed. 1 thru 8 ratings on each monitor with various increments. Self-adhesive, removable.

TEMPIL, Big Three Industries, Inc.
2901 Hamilton Blvd., South Plainfield, NJ 07080
Phone: (201) 757-8300 Telex: 138662

CIRCLE NO. 765

SAMTEC PUBLISHES SMT INTERCONNECT HANDBOOK

A new reference book from Samtec addresses the unique design considerations for surface mount interconnects. Topics include insulator, contact, lead and terminal design, with specifications and tolerances for materials and construction. Quality, process control and manufacturability are discussed in detail. An overview of specific interconnects is included. **Samtec, Inc.** P.O. Box 1147 New Albany, IN 47151-1147. **Tel: 800-SAMTEC9** or **FAX: 812-948-5047.**

CIRCLE NO. 766

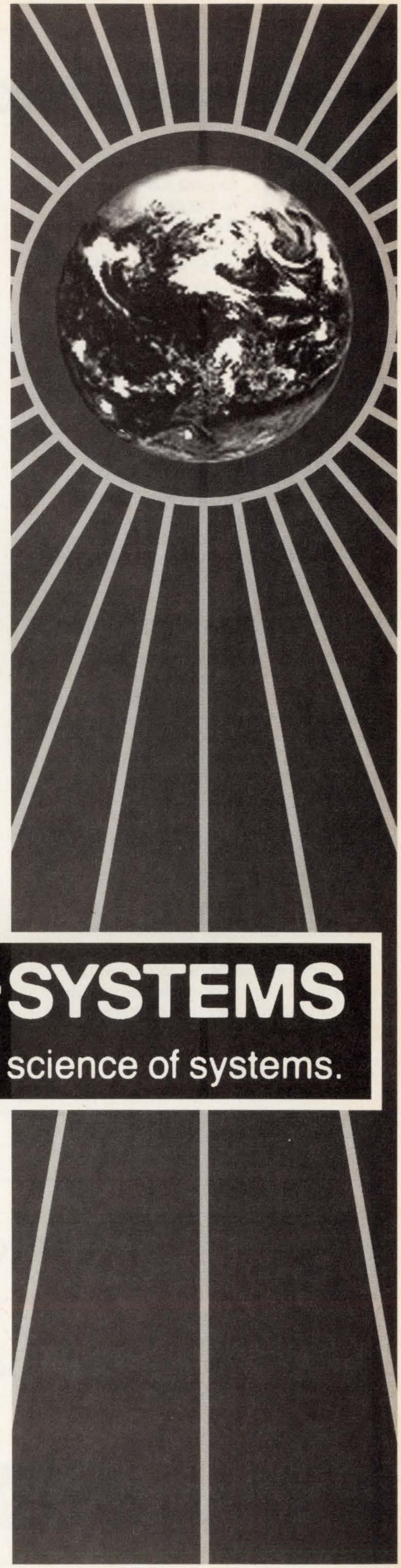
To advertise in Product Mart, call Joanne Dorian, 212/463-6415

1992 Recruitment Editorial Calendar

Issue	Issue Date	Ad Deadline	Editorial Emphasis
Magazine Edition	Apr. 23	Apr. 2	Portable Computer Design • EDN Hands-on Special Project—Part II: Field-programmable Gate Arrays • Electromechanical Devices • Computer Peripherals
News Edition	Apr. 30	Apr. 16	ASICs SPECIAL ISSUE • FPGAs and EPLDs • CICC Hot Products • ASICs • Regional Profile: Northern California
Magazine Edition	May 7	Apr. 16	Communications/Networks • Test & Measurement • Surface-Mount Components • Power Sources • Electro Show & Products Issue
ELECTRO SHOWGUIDE & PRODUCT SPOTLIGHT		Apr. 3	A free page available to all advertisers running a full page in 2 out of 3 Electro issues
News Edition	May 14	Apr. 30	Graphics Technology • Computers & Peripherals
Magazine Edition	May 21	Apr. 30	Analog ICs • Analog CAE • PC Board CAE Tools • Programmable-Logic Devices
News Edition	May 28	May 14	Communication ICs • CAE Software • Regional Profile: Texas, Oklahoma, Kansas
Magazine Edition	June 4	May 14	ASICs/PLDs • DSP Software • CAE/Software/Interoperability • Digital ICs & Semiconductors
News Edition	June 8	May 21	CAE SPECIAL ISSUE • EDA/CASE Supplement • DAC Hot Products • Software Engineering • Diversity Special Series

Call today for information on Recruitment Advertising:
East Coast: Janet O. Penn (201) 228-8610
West Coast: Nancy Olbers (603) 436-7565
National: Roberta Renard (201) 228-8602

When you look through our windows, here's what you'll C.



Take a look at E-Systems Garland Division and you'll see some of the most exciting computer technology on the planet. You'll see dedicated, multi-disciplinary teams working together in an atmosphere that recognizes individual achievement. And you'll see an environment where even the most unconventional ideas are given a chance to grow.

It's this combination of inventiveness, cooperation and resources that makes E-Systems an industry leader. From surveillance systems to advanced electronic imaging to our new EMASS data storage and retrieval system, E-Systems defines the cutting edge of electronic technology.

To open a window of opportunity, look into the following positions:

UNIX PROGRAMMERS— Positions require a BSCS or BSEE and a minimum of 3 years of recent programming experience in working with UNIX and "C" on large-scale computer systems and knowledge of systems and network interfaces and relational databases (ORACLE or INGRES). Preference given to those with X-windows, object oriented design or expert systems experience. Duties involve Software Development, Software Test, Tools Development or Software Integration.

FIRMWARE ENGINEERS—Positions require a BSEE or BSCS and a minimum of 3 years of recent experience developing firmware in 68000 assembly and "C" preferred. Positions involve firmware and embedded software development.

RF HARDWARE ENGINEERS—Positions require a BSEE and 3 years experience in the detailed design of complex RF circuitry including UHF through SHF synthesizers, receivers, and modems. Positions involve development of RF/1F modules for open architecture SHF and Interferometer Systems.

COMMUNICATIONS SYSTEMS ENGINEERS—Positions require a BSEE (MSEE preferred) and 6 years experience in the calculations and trade analysis of complex communications systems, including link budgets, DSP, data/network layer protocols and modem implementations.

DIGITAL PROCESSOR ENGINEERS—Positions require a BSEE and a minimum of 3 years of digital microprocessor implementation design experience using 680x0 embedded processors. In addition, digital signal processing experience with TMS 320 processors and digital demodulator implementation experience is highly desirable.

SYSTEMS ENGINEERS—Positions require a BSEE or BSCS and a minimum of 3 years of experience in systems engineering including design, methodology and development processes on large hardware/software based signal processing systems. Experience with VAX/VMS, CADRE and Oracle desired. Positions involve requirements analysis and conceptual/functional design of large software subsystems.

REAL-TIME SOFTWARE ENGINEERS—Positions require a BSEE or BSCS and experience with 680x0 embedded processors/or TMS 320 digital signal processors. Experience with 680x0 assembly, "C," ADA in a UNIX development environment is desirable. Experience with a disciplined software development methodology (2167-A, NSAM-81-3).

E-SYSTEMS

The science of systems.

A WORLD OF OPPORTUNITIES

Not only does E-Systems Garland Division offer these exciting opportunities, but we also offer competitive pay, a benefits program that can be tailored to meet the needs of you and your family, and an Employee Stock Ownership Program that can help your assets grow into the future.

For a real challenge and a real leadership opportunity, send your resume and salary history to: George Suchowerskij, Senior Staffing Representative, E-Systems, Inc., Garland Division, Department 31, P.O. Box 660023, Garland, Texas 75266-0023.

Principals only, please. U.S. Citizenship Required. An Equal Opportunity Employer, M/F/D/V.

End the connector compromise...

1. 17-490 LOW INSERTION FORCE CONTACTS

2. MODELS QUALIFIED TO D55302

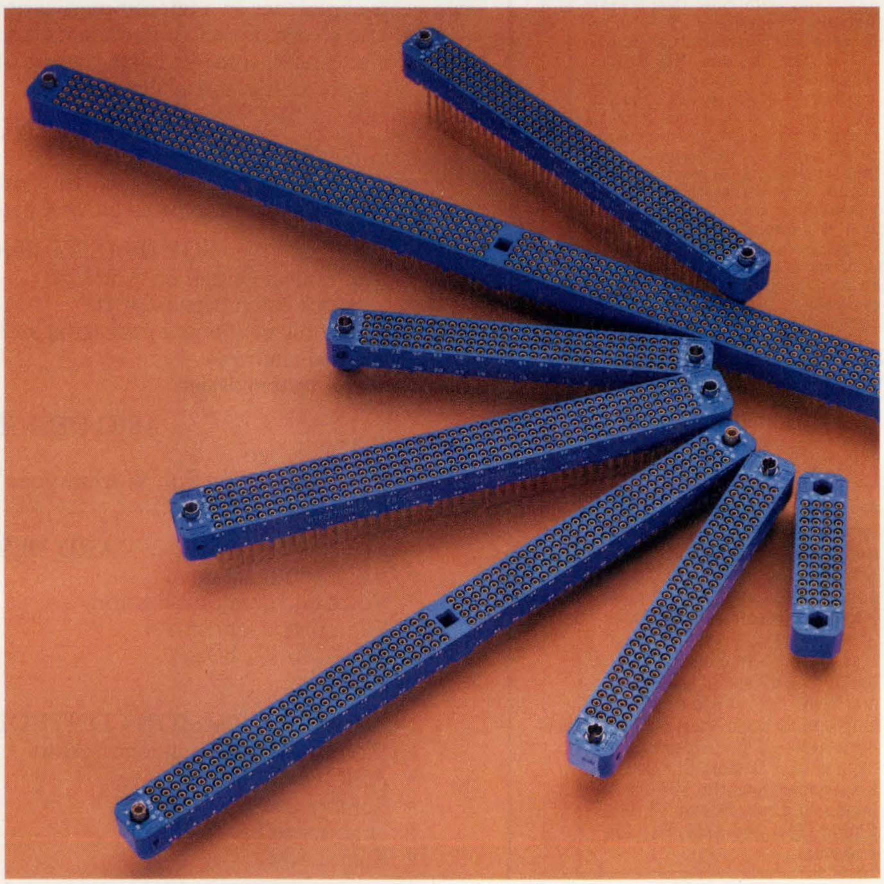
3. METRIC HARDWARE AND DIMENSIONS

...in high-density PC-board connections.

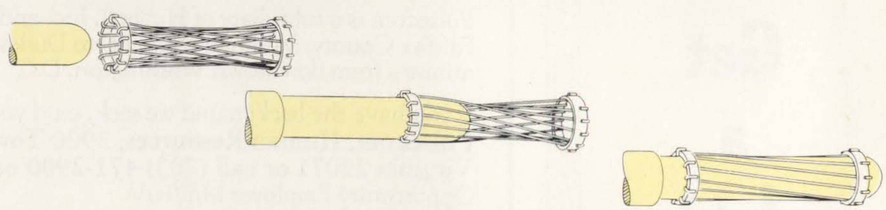
Only Hypertronics ends the compromise in high-density printed circuit board connectors for electronic equipment...by replacing unreliable connections with Low Insertion Force (LIF) high reliability connectors.

The KA 2, 3, 4 and 5 row connectors with .100 row spacing include the Hypertac® hyperboloid socket. The unique design provides contact resistance of less than 5 milliohms, cycle life in excess of 100,000 cycles and electrical integrity under extremes of shock and vibration (tested to 2 nano-seconds), flow solder PC, crimp, wire wrap® and solder cup meet a range of termination requirements.

Now you can have it all...in printed circuit board connectors requiring up to 490 contacts by calling 1-800-225-9228, toll free.



HYPERTAC®: Inserting pin into hyperboloid sleeve.



HYPERTRONICS CORPORATION

"New Horizons in Connectors"

16 Brent Drive, Hudson, MA 01749 (508) 568-0451 FAX (508) 568-0680

CIRCLE NO. 109

EDN-INTERNATIONAL ADVERTISERS INDEX

*Advertiser in European edition

This index is provided as an additional service. The publisher does not assume any liability for errors or omissions.

EDN-ACRONYMS & ABBREVIATIONS

AA—a size of nonrechargeable and rechargeable cell
ACE—Advanced Computing Environment, an industry consortium
ADC—analog-to-digital converter
ALU—arithmetic and logic unit
C—a size of nonrechargeable and rechargeable cell
CMOS—complementary metal-oxide semiconductor
CPI—cycles per instruction
CPU—central processing unit
CRT—cathode-ray tube
CSA—Canadian Standards Association
DAC—digital-to-analog converter
DMA—direct memory access
DMM—digital multimeter
DSO—digital storage oscilloscope
DSP—digital signal processing
ENOB—effective number of bits
FFT—fast Fourier transform
FPU—floating-point unit
I/O—input-output
IC—integrated circuit
IEEE-488—The Institute of Electrical and Electronics Engineers' standard for communication with test instruments
ISA—the Industry Standard Architecture I/O bus of IBM PCs and compatible computers
ISSCC—International Solid-State Circuits Conference
LCD—liquid-crystal display
LSB—least significant bit
MESI—modified, exclusive, shared, or invalid, a cache-coherency protocol
MIPS—million instructions per second
MMU—memory-management unit
NiCd—nickel cadmium, a type of rechargeable cell and rechargeable battery
p-n junction—the region of transition between p-type and n-type material in a single semiconductor crystal
p-p—peak-to-peak
PAX—parallel architecture extension
PC—personal computer
pc board—printed-circuit board
PGA—pin-grid array
ppm—part per million
RAM—random-access memory
RISC—reduced-instruction-set computer
rms—root-mean-square
RS-232C—an Electronic Industry Association standard for serial data communication, popular in PCs
S/H—sample and hold
S/N ratio—signal-to-noise ratio
SFDR—spurious-free dynamic range
SIMM—single in-line memory module
SINAD—signal to noise and distortion
TC—temperature coefficient
T/H—track and hold
THD—total harmonic distortion
3-D—three-dimensional
TLB—translation look-aside buffer
UL—Underwriters' Laboratories Inc

This list includes acronyms and abbreviations found in EDN's Special Report, Technology Updates, and feature articles.

The World's Gone Flat.

Signal's International Flathead™ Circles The Globe.

The whole world's going flat out for Signal's International Flathead transformers, because we went all out to win international approval.

These super rugged, low profile transformers, fully encapsulated and hermetically sealed, meet UL, CSA, VDE, IEC and EN standards for international use.

Thanks to their extremely low profile, these IF series transformers are ideally suited for use on densely packed PC boards.

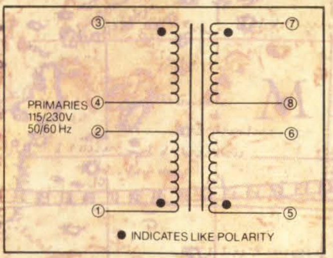
Available in 2VA to 30VA configurations, these Flatheads feature dual primaries (115/230V, 50/60Hz) and non-concentric windings. The result: reduced inter-winding capacitance and the elimination of electrostatic shielding.

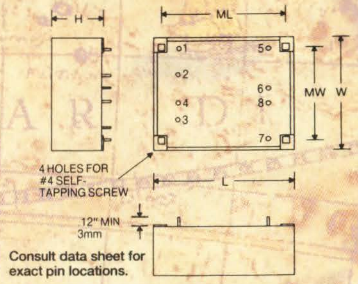
- Low profile (as low as 0.69")
- Precise pin alignment for drop-in applications
- Class B insulation (130° C)

For more information on Signal's International Flathead Series, contact Signal Transformer, 500 Bayview Ave., Inwood, NY 11696.

Sampling of products offered. A total of 80 part numbers are available off-the-shelf in 2, 4, 6, 10, 14, 18, 24, 30 VA sizes.

Part No.	Size	SECONDARY Series	SECONDARY Parallel	PRICE 100-249 Pcs
IF-2-10	2VA	10Vct. @ 200mA	5V @ 400mA	$7.63
IF-2-12	2VA	12Vct. @ 170mA	6V @ 340mA	
IF-2-16	2VA	16Vct. @ 125mA	8V @ 250mA	
IF-2-20	2VA	20Vct. @ 100mA	10V @ 200mA	
IF-2-24	2VA	24Vct. @ 85mA	12V @ 170mA	
IF-2-30	2VA	30Vct. @ 70mA	15V @ 140mA	
IF-2-34	2VA	34Vct. @ 60mA	17V @ 120mA	
IF-2-40	2VA	40Vct. @ 50mA	20V @ 100mA	
IF-2-56	2VA	56Vct. @ 40mA	28V @ 80mA	
IF-2-230	2VA	230Vct. @ 9mA	115V @ 18mA	
IF-10-10	10VA	10Vct. @ 1.00A	5V @ 2.00A	$9.49
IF-10-12	10VA	12Vct. @ 835mA	6V @ 1.67A	
IF-10-16	10VA	16Vct. @ 625mA	8V @ 1.25A	
IF-10-20	10VA	20Vct. @ 500mA	10V @ 1.00A	
IF-10-24	10VA	24Vct. @ 420mA	12V @ 840mA	
IF-10-30	10VA	30Vct. @ 335mA	15V @ 670mA	
IF-10-34	10VA	34Vct. @ 300mA	17V @ 600mA	
IF-10-40	10VA	40Vct. @ 250mA	20V @ 500mA	
IF-10-56	10VA	56Vct. @ 180mA	28V @ 360mA	
IF-10-230	10VA	230Vct. @ 45mA	115V @ 90mA	
IF-30-10	30VA	10Vct. @ 3.00A	5V @ 6.00A	$13.99
IF-30-12	30VA	12Vct. @ 2.50A	6V @ 5.00A	
IF-30-16	30VA	16Vct. @ 1.90A	8V @ 3.80A	
IF-30-20	30VA	20Vct. @ 1.50A	10V @ 3.00A	
IF-30-24	30VA	24Vct. @ 1.25A	12V @ 2.50A	
IF-30-30	30VA	30Vct. @ 1.00A	15V @ 2.00A	
IF-30-34	30VA	34Vct. @ 900mA	17V @ 1.80A	
IF-30-40	30VA	40Vct. @ 750mA	20V @ 1.50A	
IF-30-56	30VA	56Vct. @ 550mA	28V @ 1.10A	
IF-30-230	30VA	230Vct. @ 130mA	115V @ 260mA	





Consult data sheet for exact pin locations.

Size	L	W	H	ML	MW	WGT
2	2.09" 53.0mm	1.73" 44.0mm	0.69" 17.6mm	1.87" 47.5mm	1.48" 37.5mm	4.6oz 0.13kg
10	2.66" 67.6mm	2.24" 57.0mm	0.89" 22.2mm	2.46" 62.5mm	1.97" 50.0mm	10.3oz 0.29kg
30	2.68" 68.0mm	2.26" 57.5mm	1.39" 35.3mm	2.46" 62.5mm	1.97" 50.0mm	19.7oz 0.58kg

signal TRANSFORMER
The American Original.™

BUY DIRECT: 516-239-5777 ■ Fax: 516-239-7208

CIRCLE NO. 113