

analog dialogue

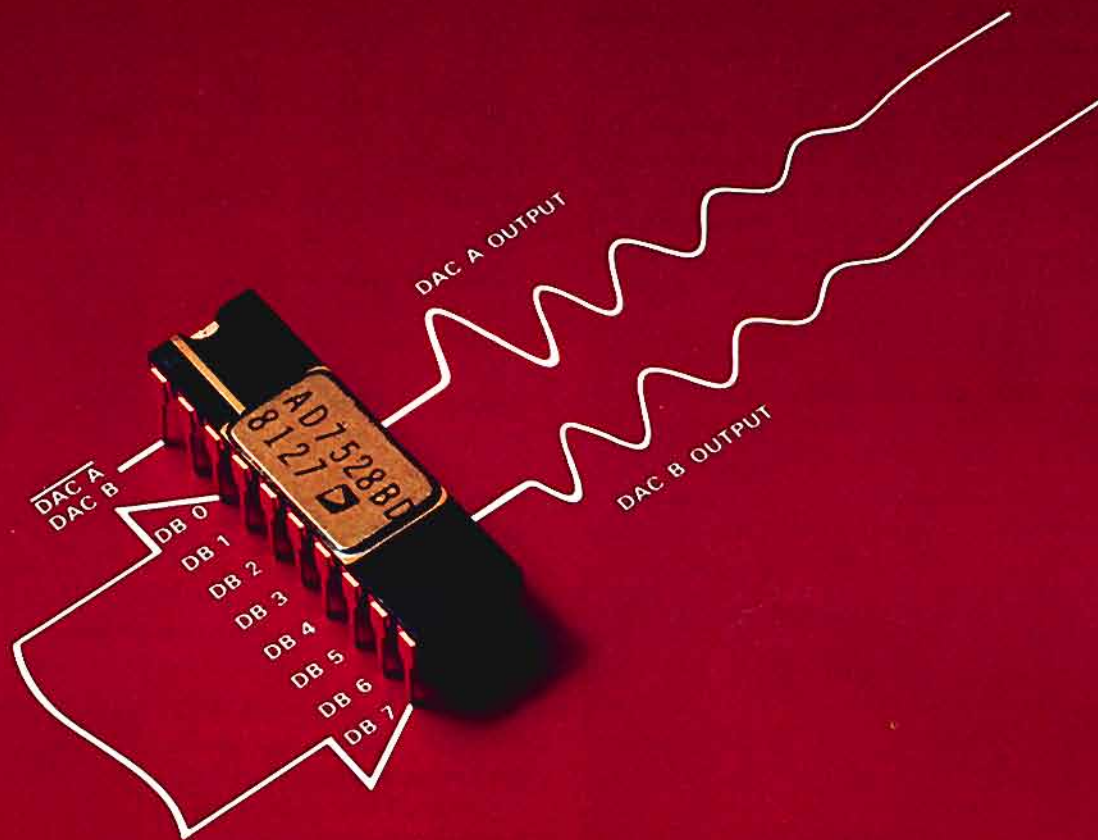
A forum for the exchange of circuits and systems for test, measurement, and control

DUAL MONOLITHIC MULTIPLYING D/A CONVERTERS (see page 3)

Applying High-Performance Monolithic FET-Input Op Amps (page 6)

Use Your Personal Computer for Measurement & Control (page 11)

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Editor's Notes

SOFTWARE & COMPUTERS

Analog Devices has always been noted for software as well as hardware. But the software that until recently has been our forte is the human-to-human kind exemplified by our comprehensive data sheets, by this Journal, by our Technical Handbooks, and by the new 1500+ page Databook (see page 26). This strength in publications is now being augmented by a mastery of software in the more usual sense.

Human-to-machine software first appeared in these pages in rudimentary fashion in *Analog Dialogue* 7-1 (1973 - SERDEX), and—more authoritatively—in 13-1 (1979), where MACSYM 2 and MACBASIC made their debut. It may interest you that, in this issue, articles discuss sophisticated computer software generated by three different entities within ADI:


- At page 11, John Mills, of the Systems Components Division, discusses the new software drivers that make the μ MAC-4000's versatile and intelligent sensor and digital I/O (see back cover) available to the explosively growing family of users of Apple, IBM, and HP personal computers, as well as to users of DEC PDP-11 and LSI-11 hardware.

- At page 12, Bill Schweber, of the Measurement and Control Products Division, discusses the virtues of multitasking, an inherent feature of systems that use MACBASIC. The world is finally beginning to "discover" multitasking in small computers, an invaluable feature of MACSYM systems since before 1978.

- At page 19, Mike Slocumbe and Al Finger, of Component Test Systems, discuss the new generation of compatible, easier-to-use software developed for the LTS-2010 and LTS-2000 test systems.

Impressive as all this may seem, we're seeing just the tip of a massive software iceberg (*software iceberg?*) In our wanderings through the facilities that house the various groups at ADI, software-related activities are everywhere—and they relate to more than just developing yet better, newer, and augmented versions of the user-oriented electronic systems activities mentioned above.

Computers and home-grown software are used every day in the design, manufacture, trimming, and test of virtually all of our products. And in management, marketing, and administration. And, in particular, in our new two million-dollar computerized customer-order system (COS)—that is already making life easier for many of our readers (especially those purchasers of a-few-parts-at-a-time who must welcome the razing of the "minimum-order" barrier).

Finally, we acknowledge a digital debt of gratitude to our word processor, the *sine qua non* of those (formerly known as "ink-stained wretches") whose principal pursuits include putting words together to communicate with others in "writing." Our word processor and the laser-typesetter it communicates with via an RS-232C link weren't on the scene a mere year ago, but it is impossible to picture any future scene without them. If you've noticed that this issue has 28 pages—the most ever—the answer to the unasked question is: if not, it wouldn't have. 

Dan Sheingold

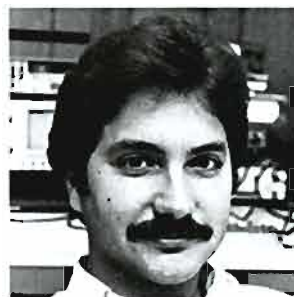


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Terry L. Brown (page 14) joined ADI's Computer Labs Division after receiving his BSEE from North Carolina State University and has already made significant contributions to the Division's high-speed data-acquisition product line. Terry was responsible for the design of the HTC-0300A and HTC-0500 (see page 22) T/Hs and the HDD-1206 DAC. He is currently spearheading CLD's monolithic-circuit development program.



Alan Finger (page 19) is the Senior Software Engineer in the Component Test Systems organization. Previously he was Software Project Leader and Senior Applications Engineer with MACSYM, where he developed the software for MACSYM 20 and a variety of hardware/software packages for MACSYM 2. Before joining ADI, he was a Research Physicist at Eastman Kodak Research Laboratories. He has a BSEE from Clarkson College and occupies his spare hours with photography, bicycling, and personal computing.



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(more authors on page 26)

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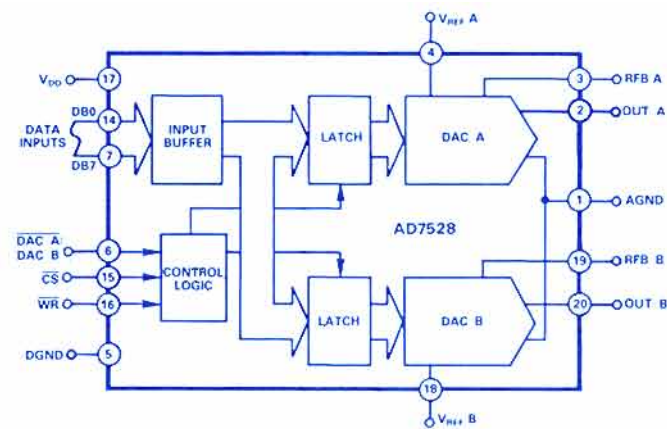
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AD7528: A DUAL MONOLITHIC DAC FOR MANY REASONS

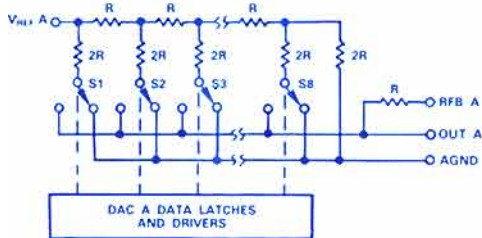
World's First Twin Multiplying 8-Bit DACs in a 20-Pin (0.3") DIP
 Separate On-Chip Latches Provide Easy Microprocessor Interface

by John Wynne and Pat Hickey

The AD7528* is a buffered dual 8-bit CMOS multiplying d/a converter on a single monolithic chip, housed in a small 20-pin 0.3" DIP package. Its twin DACs, matched to within 1%, gain access to the common data bus via a pair of 8-bit latches gated by TTL- or CMOS-compatible logic. As Figure 1a shows, in addition to the usual chip-select (\overline{CS}) and write (\overline{WR}) logic inputs, there is also a steering input ($\overline{DAC A/DAC B}$).



a. Block diagram of the device.



b. Simplified functional circuit of DAC A.

Figure 1. Functional diagrams of the AD7528.

Besides the obvious applications where two or more 8-bit DACs are needed and space is at a premium, the AD7528 makes available a whole subclass of applications calling for paired DACs having essentially identical performance. In addition to conventional fixed-reference applications, they may be used as two- or four-quadrant multiplying DACs with variable dc or ac reference signals. You can think of many of these latter applications as uses for a matched pair of digital pots (either separate or ganged) to manipulate the properties of analog signals or circuits.

The range of such applications is limited only by imagination; it includes, for example, filters, oscillators, resolvers, function generators, X-Y plotters and oscilloscope displays, audio gain controls, cascaded attenuators, interpolators, high-low limit circuits, attenuation-function-gain circuits, and all kinds of test and measurement circuits involving multiple-parameter setting.

*Use the reply card for technical data.

†Useful references from Analog Devices include the free *Application Guide to CMOS Multiplying D/A Converters* and the book, *Analog-Digital Conversion Notes*, available at \$5.95.

THE AD7528 IN DETAIL

The AD7528 contains two 8-bit multiplying d/a converters with latches and control logic. Since both of the DACs are fabricated by a monolithic CMOS process at the same time on the same chip, precise matching and tracking between DAC A and DAC B are inherent. Each DAC (Figure 1b) consists of a highly stable thin-film R-2R ladder, eight N-channel current-steering switches, and a matched feedback resistor. As the simplified circuit shows, an *inverted* ladder structure is used, i.e., binary currents are switched between the DAC output and AGND, thus maintaining fixed currents in each ladder leg, independent of switch state.†

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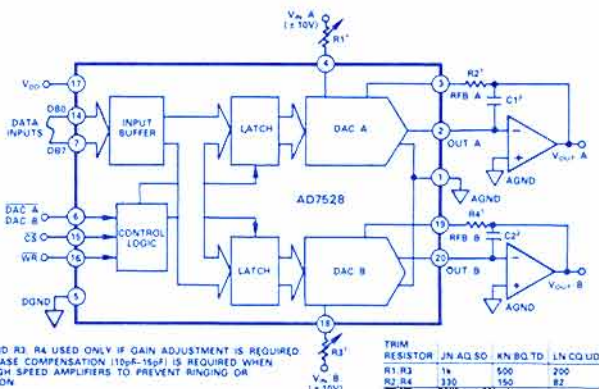


Figure 2. Applying the AD7528 as a unipolar binary DAC pair.

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In normal applications, each DAC is buffered by an external operational amplifier, as shown in Figure 2. The DAC output terminal is maintained by the op amp at ground potential, and the internal R_{FB} is connected as the feedback resistor. Nominally, $V_{OUT} = -D V_{REF}$, where D , a function of the input code, is a fractional binary value from 0 to $(1-2^{-8})$ and V_{REF} is an ac or dc voltage (absolute maximum rating is $\pm 25V$). As the Figure indicates, Schottky diode protection is unnecessary. For four-quadrant multiplication, an additional amplifier takes the difference between $2D V_{REF}$ and the analog input (V_{REF}), to provide a function that swings linearly from $+V_{REF}$ to $-V_{REF}$ as D varies from all-1s to all-0s (offset binary = 2s complement with complemented MSB).

Relative accuracy is guaranteed over the device's full temperature range: ± 1 LSB maximum error for J, A, and S grades, and $\pm 1/2$ LSB max for K, L, B, C, T, and U grades. All grades are guaranteed monotonic over the temperature range ($0^{\circ}C$ to $+70^{\circ}C$ for J, K, and L, $-25^{\circ}C$ to $+85^{\circ}C$ for A, B, and C, $-55^{\circ}C$ to $+125^{\circ}C$ for S, T, and U). Maximum initial gain error is guaranteed at ± 4 LSBs for J, A, & S grades, ± 2 LSBs for K, B, and T grades, and ± 1 LSB for L, C, and U grades. The trim resistors shown in Figure 2 are used to set the gain to better than the specified value; they can be replaced by direct wiring if the performance is satisfactory as specified.

The AD7528 will operate with a single $+5V$ to $+15V$ power supply, and it consumes a maximum of $5mW$ at $V_{DD} = +5V$. Maximum feedthrough for a 20-volt peak-to-peak sine wave is $-70dB$ at $100kHz$, either channel, and $-77dB$ channel-to-channel. Total harmonic distortion is $-85dB$, and digital crosstalk is $30mV-\mu s$.

The AD7528 is available in Cerdip (AQ, BQ, CQ suffixes) and hermetic ceramic (SD, TD, UD); and it will shortly be available in plastic (JN, KN, LN). It is also available in leadless chip carriers ("E" suffix) and in versions processed to the requirements of MIL-STD-883B. Prices start at \$5.95 in 100s (AD7528JN).

BRIEF PERFORMANCE CHARACTERISTICS
 ($V_{REFA} = V_{REFB} = +10V$; $OUT_A = OUT_B = 0V$; $V_{DD} = +15V$; and $T_A = 25^{\circ}C$, unless otherwise specified)

	J, A, S	K, B, T	L, C, U
Resolution (Bits)	8	8	8
Nonlinearity (Endpoint, LSB, max)	± 1	$\pm 1/2$	$\pm 1/2$
Nonlinearity, Differential (LSB, max)	± 1	± 1	± 1
Gain Error (LSB, max)	± 4	± 2	± 1
Gain Tempco (%/°C, max)	± 0.0035	± 0.0035	± 0.0035
Input resistance, min/max (k Ω , V_{REF} A or V_{REF} B input)	8/15	8/15	8/15
Input resistance mismatch (% max)	± 1	± 1	± 1
DC Supply rejection (Δ gain/ Δ V_{DD}) (% per % max)	0.01	0.01	0.01
AC Feedthrough, either channel, 20V p-p sine wave @ 100kHz (dB max)	-70	-70	-70
Channel-to-Channel Isolation, 20V p-p sine wave @ 100kHz (dB)	-77	-77	-77
Harmonic Distortion, 6V rms @ 1kHz (dB)	-85	-85	-85

APPLYING THE AD7528

The AD7528 has a load cycle similar to the write cycle of a random access memory and is compatible with most 8-bit microprocessors, including the 6800, 8080, 8085, and Z80. Data is transferred into either of the two DAC data latches via a common 8-bit TTL/CMOS-compatible input port. Control input, $\overline{DAC\ A/DAC\ B}$, determines which DAC is to be loaded, while separate reference inputs allow each DAC to independently perform 2- or 4-quadrant analog-digital multiplication.

A simple example will show how easy microprocessor interfacing is. Figure 3 is a scheme for interfacing the AD7528 to a 6800-type microprocessor. Outputs A and A + 1 of the address-decode logic

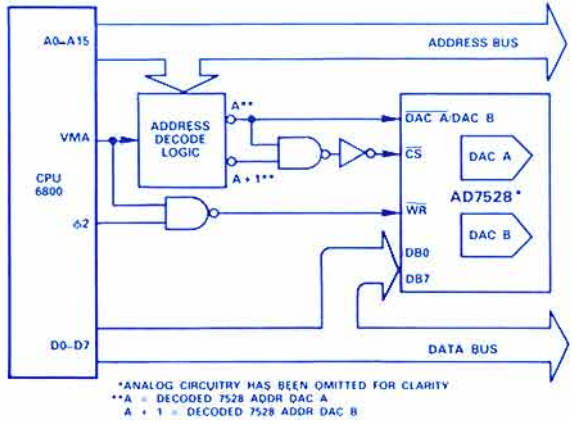


Figure 3. Applying the AD7528 with a 6800-type microprocessor.

drive \overline{CS} and the DAC selector. The logic is arranged so that if neither A nor A + 1 is addressed, \overline{CS} remains high; if A is addressed, \overline{CS} is brought low and DAC A is updated when \overline{WR} goes low; if A + 1 is addressed, \overline{CS} is brought low and DAC B is updated when \overline{WR} goes low. For applications using 8085-type microprocessors, \overline{WR} is generated directly and the gate is unnecessary. The analog circuitry has been omitted for clarity.

Single Supply. In the AD7528, the termination resistors of the R-2R ladder are connected to AGND within the device. This arrangement is convenient for single-supply operation, because AGND may be biased at any voltage between DGND and V_{DD} . In Figure 4, the two DAC outputs are offset by a precise $+5V$ by the use of an AD584J reference to produce an offset AGND. The two DAC reference inputs are both grounded. Thus the reference voltage applied to the DAC is $-5V$, the DAC output swing is 5 volts, and the DAC output range (either DAC) is from $+5V$ to $+10V$, for codes from 00000000 to 11111111.

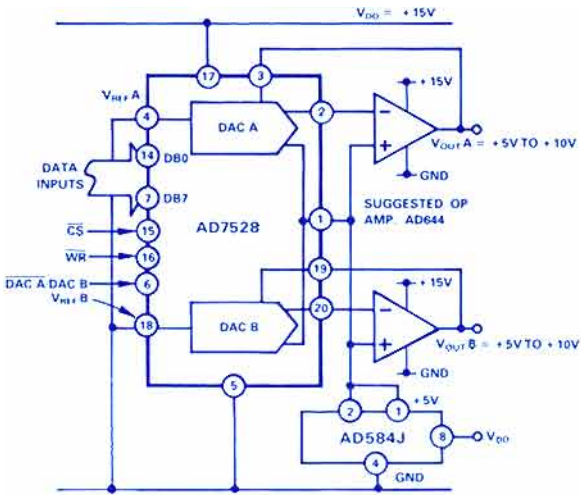


Figure 4. One form of single-supply operation of the AD7528.

APPLICATION EXAMPLE - STATE-VARIABLE FILTER

This application is an excellent example of the advantages of the unique properties of the AD7528 in performing useful functions that rely on DAC matching and benefit from the AD7528's high packing density. Such circuits can be especially compact when employing dual or quad op amps, such as the AD644 or the TL074. The circuit described here is a state-variable 2-pole filter with programmable center frequency, selectivity (Q), and gain.

The second-order state-variable filter (or universal filter, as it is often called) is a convenient building block of higher-order multi-pole filters (Bessel, Butterworth, Chebyshev, etc.) Simultaneously providing low-pass, high-pass, and bandpass responses, its out-

puts can be further combined to provide all-pass (biquad) properties. If available in programmable form, it makes possible a huge variety of filter characteristics, readily provided by a microprocessor, using either computation or a lookup table.

Its parameters are readily adjustable by manipulation of resistance ratios. Figure 5 shows a typical conventional state-variable filter circuit, with the expressions for center frequency (f_0), Q , and gain for the bandpass output.

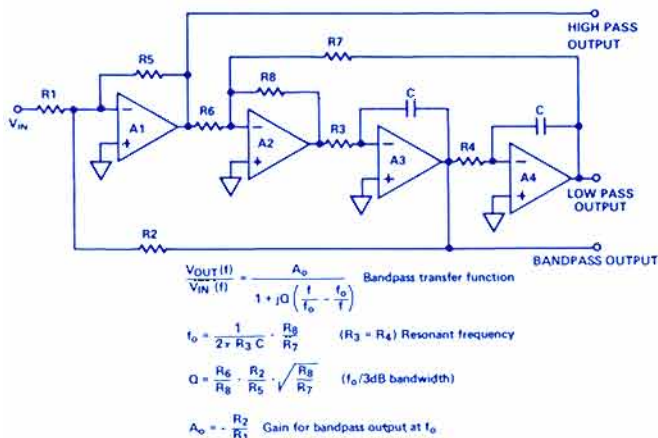


Figure 5. Block diagram of state-variable filter.

In form, it can be recognized as an analog computing circuit that solves the classical second-order differential equation, modelling a mass, spring, and dashpot, or inductance, capacitance, and resistance. If the low-pass output is interpreted as position, the bandpass output—its derivative—can be viewed as velocity, and the high-pass output, which depends on the second derivative, can be considered as acceleration.

The gains of the two cascaded integrators ($1/R_3C$ and $1/R_4C$) determine the resonant frequency: if $R_3 = R_4$ and $R_6 = R_7$, then the natural frequency is $1/(2\pi R_3C)$. And the gain in the loop around integrator A3 determines the damping, which is inverse with Q .

If the filter is to be digitally programmed, the resistor ratios must be replaced by fixed resistors and digitally controlled gains. How this may be done is shown in Figure 6. DACs 2A and 2B, which serve as digitally controlled attenuators with fixed admittance, replace

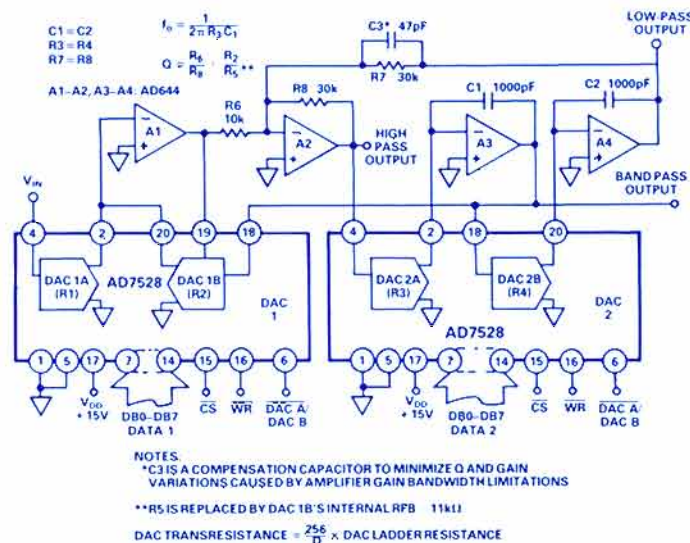


Figure 6. Programmable state-variable filter employing AD7528.

R3 and R4, to control frequency. DAC 1A replaces R1, and controls gain; and DAC 1B replaces R2 and R5, to control $1/Q$.

For the component values shown, the programmable range of f_0 is 0 to 15kHz, and the programmable range of Q is 0.3 to 4.5; Q and f_0 are mutually independent. Figure 7 shows parametric plots of amplitude vs. frequency as functions of Q (a) and f_0 (b).

APPLICATIONS IDEAS

That the AD7528 is "only" an 8-bit double-DAC is a problem for some conventional DAC applications. However, there are many more applications, where the primary fine structure is already analog, that simply consider the 256 codes available to be a limitation only on the number of available gains, but not on signal resolution. Many of the potential applications of the AD7528 rely on its excellent analog properties: low feedthrough and distortion, wide bandwidth and dynamic range, and low gain tempco. The small assortment here is merely intended to stimulate thought.*

If you can build a programmable filter, you can use it in a feedback loop to make a programmable oscillator. If you can build programmable oscillators and filters, you can assemble programmable spectrum analyzers.

With a pair of matched multiplying DACs, you can produce such vector composition/resolution pairs as: $V \sin \omega t \sin \phi$ and $V \sin \omega t \cos \phi$, where the functions of ϕ are established digitally.

The inherent multiplication can be used to advantage in programming analog polynomial functions combining x, x^2 , etc., for example, in constructing simple approximations to the sine. Since all aspects—voltage or current amplitude, phase, frequency, and waveshape—are programmable, the technique can be used to build a powerful ac or dc function generator with multiple outputs for testing at low cost.

*Some worked-out examples can be found in an AD7528 Application Note, available upon request.

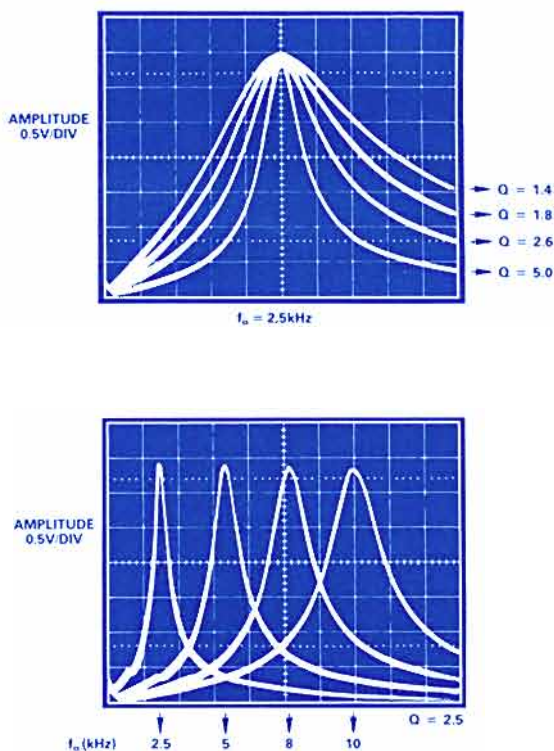


Figure 7. Amplitude vs. frequency as functions of Q and f_0 .

APPLYING HIGH-PERFORMANCE MONOLITHIC FET-INPUT OP AMPS

Super Singles and Duals Use New Trimmed Bipolar-FET Technology The Ideal Op Amp Still Doesn't Exist, But These Come Close Enough

by Don Travers

From the earliest days of the monolithic operational amplifier, new amplifier chips have come to market with continually improving performance. As refinements to existing technologies and manufacturing processing techniques evolve, total operational-amplifier performance approaches that of an ideal amplifier ever more closely, for most practical purposes. Refinements to bipolar operational amplifier processing involving ion-implanted FETs (in some cases called "Bi-FET" techniques), in particular, have narrowed the gap between practical and ideal amplifiers in dc performance without sacrificing bandwidth.

For example, it is now possible to trim single and dual FET-input monolithic op amps for both minimum drift and minimum offset—automatically, at the wafer stage. The improvement in overall performance is a boon to users, simplifying many designs and providing high accuracy at reduced cost.

Here are a few examples of the kind of performance available in off-the-shelf devices: the drift-trimmed AD547LH has maximum offset and drift of 0.25mV and 1 μ V/°C, open-loop gain of 250,000V/V, and bias current of 25pA max, at operating temperature; and the wider-bandwidth AD544LH has 2MHz bandwidth and 13V/ μ s slewing rate, with maximum offset and drift of 0.5mV and 5 μ V/°C. Table 1 outlines the salient properties of the op amps in this series.

Applications requiring excellent dc performance at low cost call for the AD542* and AD547* monolithic FET operational amplifier families and the equivalent duals—AD642* and AD647*. For example, precision instrument front ends, requiring accurate amplification of millivolt-level signals from megohm source impedances, will benefit from the devices' combination of low offset voltage and drift, low bias current, and low 1/f noise. The dual versions of these amplifiers, since they are closely matched, are ideal for true instrumentation amplifiers and log-ratio amplifiers.

The AD544* family of single op amps and the AD644* family of equivalent dual op amps are recommended for any application requiring excellent dynamic—in addition to dc—performance. The wide bandwidth, low offset voltage, and high open-loop gain ensure superior accuracy in high-impedance buffer and sample-and-hold applications. The AD644, with matched amplifiers, can be used for wide-bandwidth instrumentation amplifiers, low-dc-drift active filters, and as output amplifiers for four-quadrant multiplying d/a converters, such as the AD7541A 12-bit CMOS DAC.

In these pages, we will show you some concrete examples of popular op-amp applications that benefit from the improvements in precision monolithic FET-input op amp technology and will offer

suggestions for obtaining best results. The applications include operations with d/a converters and sensors, practical log amps, and high-input-impedance instrumentation amplifier circuits.†

D/A CONVERTER APPLICATIONS

CMOS multiplying DACs, from the earliest 10-bit AD7520 to the modern 16-bit AD7546, rely on op amps for interfacing and buffering. For the best linearity and most stable dynamics, the choice of op amps is by no means trivial‡

CMOS DACs will provide improved overall performance when used with amplifiers in this series to perform both 2-quadrant and 4-quadrant operations. For example, the output impedance of a CMOS DAC varies with the bit composition of the digital word, affecting the noise gain ($1 + R_o/R_{in}$, where R_o is the resistance between OUT1 and common) of the amplifier circuit. The effect is to cause a nonlinearity, the magnitude of which is dependent on the offset voltage of the amplifier and its drift over the operating temperature range.

TABLE 1. Monolithic Bipolar Fet Op Amps

(Typical specifications at 25°C and rated supply unless noted otherwise)

Model ¹	Gain min V/V	Bandwidth Unity Gain MHz	Slewing Rate V/ μ s	Settling Time(0.01%) μ s	Offset max, mV	Voltage Drift, max μ V/°C	I _{bias} max μ A	
SINGLE AMPLIFIERS								
AD542JH	100k	1.0	3.0	5.0	2.0	20	50	
AD542KH	250k	1.0	3.0	5.0	1.0	10	25	
AD542LH	250k	1.0	3.0	5.0	0.5	5	25	
AD542SH	250k	1.0	3.0	5.0	1.0	15	25	
AD544JH	30k	2.0	13	3.0	2.0	20	50	
AD544KH	50k	2.0	13	3.0	1.0	10	25	
AD544LH	50k	2.0	13	3.0	0.5	5	25	
AD544SH	50k	2.0	13	3.0	1.0	15	25	
AD547JH	100k	1.0	3.0	5.0	1.0	5	30	
AD547KH	250k	1.0	3.0	5.0	0.5	2	25	
AD547LH	250k	1.0	3.0	5.0	0.25	1	25	
AD547SH	250k	1.0	3.0	5.0	0.5	5	25	
DUAL OP AMPS								
AD642JH	100k	1.0	3.0	5.0	Each Side 2.0	Match (Note 2) 1.0	Each Side 3.5	Match 75
AD642KH	250k	1.0	3.0	5.0	1.0	0.5	2.0	3.5
AD642LH	250k	1.0	3.0	5.0	0.5	0.25	1.0	3.5
AD642SH	250k	1.0	3.0	5.0	1.0	0.5	3.5	3.5
AD644JH	30k	2.0	13	3.0	2.0	1.0	3.5	3.5
AD644KH	50k	2.0	13	3.0	1.0	0.5	2.0	3.5
AD644LH	50k	2.0	13	3.0	0.5	0.25	1.0	3.5
AD644SH	50k	2.0	13	3.0	1.0	0.5	3.5	3.5
AD647JH	100k	1.0	3.0	5.0	1.0	1.0	10	10
AD647KH	250k	1.0	3.0	5.0	0.5	0.5	5	5
AD647LH	250k	1.0	3.0	5.0	0.25	0.25	2.5	2.5
AD647SH	250k	1.0	3.0	5.0	0.5	0.5	10	10

Notes:
¹J, K, L, suffixes denote 0° to 70°C operation; S denotes -55° to +125°C; H denotes the hermetically sealed 8-pin TO-7W package.
²Maximum drift between T_{max} and T_{min}, mV.

For example, in the one-bit code transition from 0011 1111 1111 to 0010 0000 0000, the output offset voltage changes from 2V_{OS} to (4/3)V_{OS}, a change of (2/3)V_{OS}. If V_{OS} is not much smaller than the voltage equivalent of the least-significant bit, and is of the right (wrong) polarity, the transition will be nonmonotonic. This factor is especially important in multiplying applications, where the reference input can be considerably less than full scale, and the bit voltage accordingly quite small.

These monolithic FETs, with their trimmed offset and low drift,

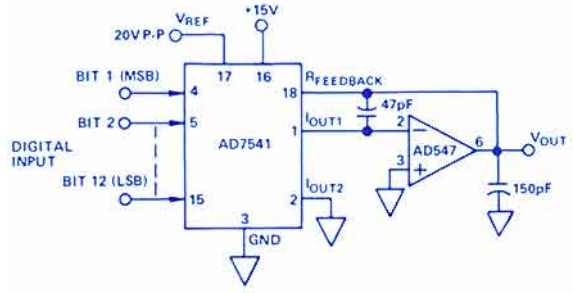
* Use the reply card for technical data.

† This article is condensed from material collected for an Application Note on monolithic FET-input op amps of the above series. For a copy of the complete A/N when available, use the reply card.

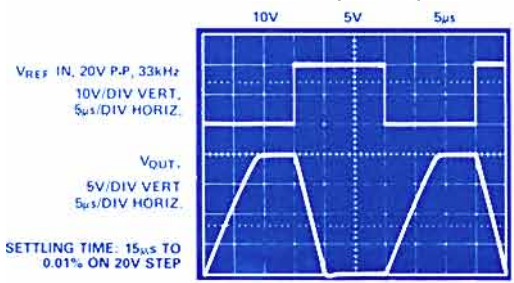
‡ For information on the interaction between op amp and DAC, see "Analog Signal Handling for High Speed and Accuracy," *Analog Dialogue* 11-2, pages 11 & 12.

will minimize this effect. In addition, DAC output circuits using these monolithic FET op amps do not require the Schottky diodes that are recommended for protection of many older CMOS DAC types from amplifier turn-on transients.

Figure 1a shows the AD547 op amp and AD7541 CMOS d/a converter configured for unipolar binary (2-quadrant-multiplying) operation. With a dc reference voltage or current, of either positive or negative polarity, applied at pin 17 of the DAC, the circuit operates as a unipolar fixed-reference converter. With an ac reference voltage or current, the circuit provides two-quadrant multiplication (digitally controlled attenuation).



a. AD547 used as DAC output amplifier.

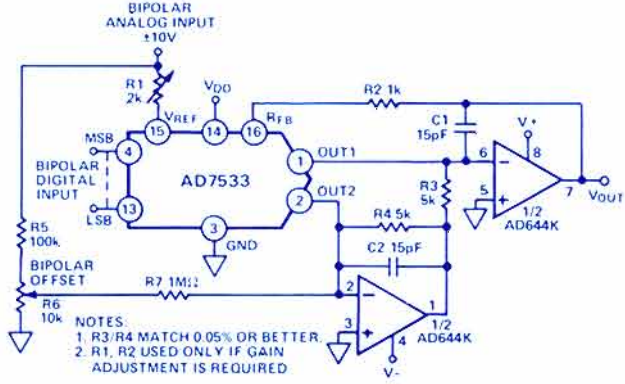


b. Response to ±20V p-p reference square wave.

Figure 1. Voltage-output multiplying DAC.

The oscilloscope photos of Figure 1b show the output of the circuit of Figure 1a. The upper trace represents the ac reference input, a 20V peak-to-peak square wave at 33kHz, and the lower trace shows the output voltage while the digital input to the DAC is all-1's (gain of $1 - 2^{-n}$), representing a settling time to 0.01% of 15µs, with well-behaved dynamics. The 47pF capacitor across the feedback resistor compensates for the DAC output capacitance, and the 150pF load capacitor serves to reduce signal feedthrough spikes at the output.

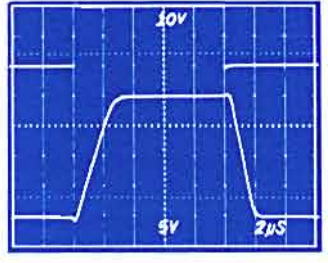
The diagram of Figure 2a illustrates the 10-bit digital-to-analog converter, AD7533, connected for bipolar operation. Since the digital input can accept bipolar numbers and V_{REF} can accept a bipolar analog input, the circuit performs 4-quadrant multiplication.



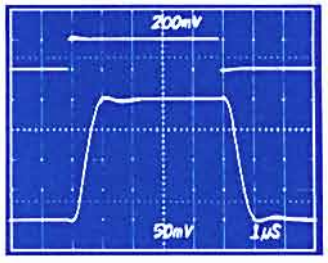
a. AD644 and AD7533 in 4-quadrant application.

This is accomplished with an AD644 dual FET-input op amp to maintain optimal performance at low cost with a low package count.

The scope plots exhibit the response to a step input at V_{REF} . Figure 2b is the large-signal response and 2c shows the small-signal response. C1, as a phase compensator (15pF), is required for stability when using high speed amplifiers; it serves to cancel the pole formed by the DAC's internal feedback resistance and the output capacitance of the DAC.



b. Large-signal response to reference square wave.



c. Small-signal response to reference square wave.

Figure 2. Four-quadrant multiplying DAC configuration.

Figure 3 shows the AD647 used with the AD7546 16-bit DAC, a two-stage device which uses 16 segmented gain levels to represent the 4 most-significant bits, a 12-bit R-2R ladder and switches for the rest, and external op amps for impedance buffering. Since $1 \text{ LSB} = 8\text{V}/65536 = 122\mu\text{V}$, in this application, amplifier performance is critical to the overall performance of the AD7546.

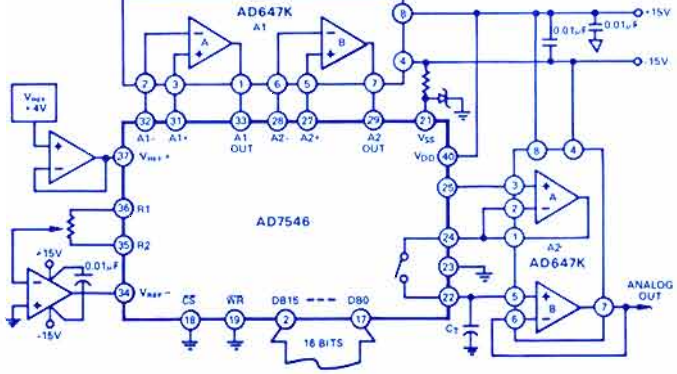


Figure 3. AD647 used with AD7546 16-bit DAC.

The paired amplifiers of A1, the AD647, are used as the high-precision dual buffer. Here, the offset voltage match, the low offset voltage and high open-loop gain of the AD647 ensure monotonicity and high linearity over the entire operating temperature range. A2, also an AD647, used as a track-and-hold, serves a dual function: amplifier A buffers the switched capacitor from the output of the ladder, and amplifier B buffers the hold capacitor from the output. The performance of the amplifiers of A2 is crucial to the accuracy of the system. Their errors are added to the errors due strictly to DAC imperfections. For this reason, great care is needed in

amplifier selection. The low bias current, and low temperature coefficients of the AD647 make it ideal for this application.

Here's another DAC application where a high-performance op amp is desirable: If a CMOS DAC is connected as the feedback element in an op-amp circuit (the 8-bit μ P-compatible AD7524, in Figure 4), rather than as the more-usual input element, the circuit—performing the inverse operation—will divide the input voltage by the fractional digital number, rather than multiplying by it, thus providing a repertoire of gains greater than 1. Since feedback around the amplifier is reduced, for smaller digital numbers, the gains for both signal and noise/errors are increased. Also, since the incremental step changes of gain become increasingly large for smaller values of D, in hyperbolic fashion, any errors in the gain steps, due to either DAC errors or limited open-loop gain of the op amp, are magnified correspondingly.

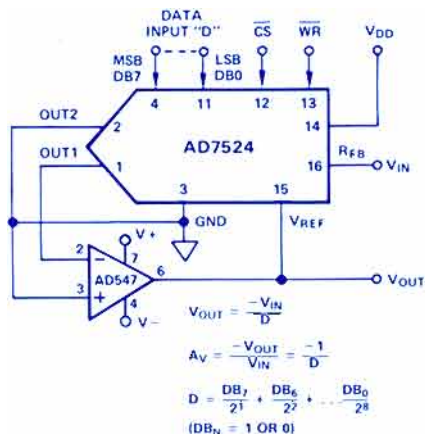


Figure 4. Analog divider with digital denominator.

As a simple analog "fix" to provide a limited gain in the extreme case of all zeros—in order to prevent the output from "taking off"—a large value of resistance (compared to $R_{FB}/2^n$) may be used to shunt the feedback path, e.g., 22M Ω . There are any number of digital fixes that may be used, in hardware or software, ranging from simply tying the LSB High to performing a logical test for all 0s—or for a number less than 1 LSB—and setting the minimum value of the digital word at 1 LSB.

INSTRUMENTATION AMPLIFIERS

When op amps are used as building blocks of high-performance instrumentation amplifiers, low drift and bias current, and high input impedance, are essential characteristics. For most instrumentation-amplifier applications, the definitive performance and low cost of the monolithic AD524 make it preferable to a user-

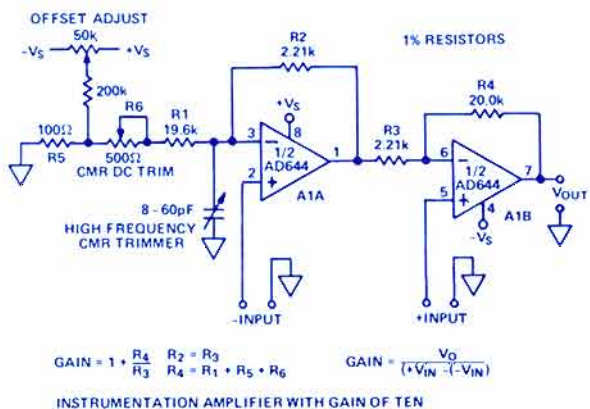


Figure 5. Wide-bandwidth instrumentation amplifier.

assembled version. The uniquely low bias current of a FET-input amplifier is essential.

Figure 5 shows an easily constructed two-amplifier FET-input instrumentation amplifier employing the wider-bandwidth amplifiers in the AD644. DC offset and common-mode error are trimmable, and the CMR-trimming capacitor on the negative input of A1A permits highly accurate signal conditioning at the higher frequencies, with CMR of 80dB over the range dc to 10kHz, and bandwidth of 200kHz (-3 dB) at 20V peak-to-peak output. Offset voltage drift is 10 μ V/ $^{\circ}$ C.

The circuit of Figure 5 can be configured for a practical range of gains from less than 5 to well over 100 with typical nonlinearity of 0.01% at gain of 10. If adjustment of gain by a single resistance is desirable, a resistor, R_C , may be connected between the negative summing points, with some sacrifice in high-frequency common-mode rejection. The gain is then equal to $(1 + R_4/R_3 + 2R_4/R_C)$.

LOG-RATIO AMPLIFIERS

Log amplifiers and log-ratio amplifiers are useful in a wide variety of analog computational applications, ranging from the simple linearization of exponential transducer outputs to the use of logarithms in computations involving multi-term products or arbitrary exponents. Log amps also facilitate the compression of wide-dynamic-range analog signals into a range that can be handled without using esoteric circuit techniques.

The picoamp-level input current and low offset voltage of the AD647 make it suitable for wide-dynamic-range log amplifiers. The log-ratio circuit depicted in Figure 6, employing the AD647, can achieve less than 1% conformance error over 5 decades of current input, 1nA to 100 μ A. For voltage inputs, the dynamic range is typically 50mV to 10V for 1% error, limited at the low end by the amplifiers' input offset voltage, which can be reduced considerably with a pair of trim circuits like that shown in the inset.

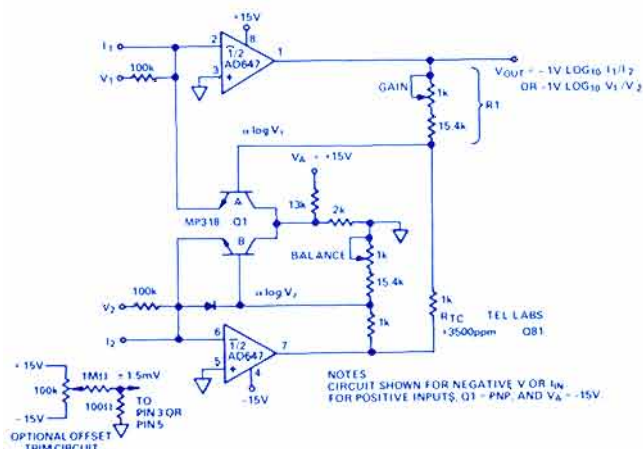


Figure 6. Log-ratio amplifier.

The conversion between current (or voltage) input and log output is accomplished by the base-emitter junctions of the high- β (greater than 100) dual transistor, Q1. If β is high, the base-emitter voltage of Q1A is, to a close approximation,

$$V_{BEA} = \frac{kT}{q} \ln \frac{I_1}{I_{SA}} \quad (1)$$

where k is Boltzmann's constant, T is the absolute (kelvin) temperature, q is the charge on an electron, and I_{SA} is the reverse saturation current of transistor A. This circuit is arranged to take the difference of the V_{BE} 's of Q1A and Q1B, two transistors on the same

chip having matching and tracking I_S , thus producing an output voltage proportional to the log of the ratio of the inputs:

$$\begin{aligned} V_{OUT} &= G(V_{BEA} - V_{BEB}) & (2) \\ &= G \frac{kT}{q} \left(\ln \frac{I_1}{I_{SA}} - \ln \frac{I_2}{I_{SB}} \right) \\ &= G \frac{kT}{q} \ln \left(\frac{I_1}{I_2} \right) \end{aligned}$$

The scaling constant, G , is set by R_1 and R_{TC} to about 16V/V, so as to produce a change of 1V in the output voltage per decade (factor-of-ten change in the ratio of the inputs). R_{TC} is a special resistor with a $+3500\text{ppm}/^\circ\text{C}$ temperature coefficient. Since G is inversely proportional to R_{TC} , it varies in inverse proportion to absolute temperature (T), thus compensating for changes in T . As a result, V_{OUT} is independent of temperature.

This circuit configuration is free from the dynamic problems that plague many other log circuits. The -3dB bandwidth is 50kHz for the topmost three decades, 100nA to 100 μA , and decreases smoothly at lower input levels. No additional compensation is needed for stable operation with input current sources—such as photodiodes—which may have up to 100pF of shunt capacitance. For greater values of input capacitance, a 20-pF integrating capacitor around each amplifier will provide smoother frequency response.

To calibrate this log-ratio circuit, use this procedure: First apply equal voltages ($V_1 = V_2 = -10\text{V}$) and adjust "balance" for $V_{OUT} = 0.00\text{V}$. Then let $V_1 = -10\text{V}$ and $V_2 = -1\text{V}$ and adjust gain for $V_{OUT} = +1.00\text{V}$. Iterate this procedure until gain and balance errors are within 2mV of the ideal values.

SENSOR INTERFACE

In many instrumentation circuits, an operational amplifier is used as a current-to-voltage converter for the low-level output current of a sensor—which may be connected to a high-voltage source. A typical example is a flame detector in a gas chromatograph. In such applications, if there is a sensor fault condition, a very high potential may be applied to the input terminal of the operational amplifier. Some form of input protection must be used to permit the amplifier to survive the fault condition.

Some electrometer-type devices, especially, those involving CMOS circuitry, may require elaborate protection schemes employing Zener diodes. However, the protection scheme may well compromise the overall performance of the circuit, nullifying the advantages for which it was chosen in the first place. In comparison, monolithic FET amplifiers of the type discussed here do not usually require such protection, unless the source is not current-limited; in this respect, they are similar to amplifier types that use discrete JFET devices. The failure mode in such cases is overheating from excess current, rather than a voltage breakdown.

The amplifiers in this series are guaranteed for a maximum safe input potential (either common-mode or normal-mode) equal to the rated power supply voltage. The input-stage design maintains a high practical level of input resistance for differential input voltages of up to ± 1 volt. This property is useful where the amplifier is used as an open-loop comparator of two input signals, either or both of which are directly connected to high-impedance sources.

If the source is not current-limited, adequate protection can be achieved if a resistor is used, inside the loop, in series with the input

terminal to limit the maximum current to 1.0mA (for example, 100,000 ohms for a 100-volt overload). The simple scheme shown in Figure 7 will cause no significant reduction in performance, except for bandwidth, and will provide complete dc overload protection.

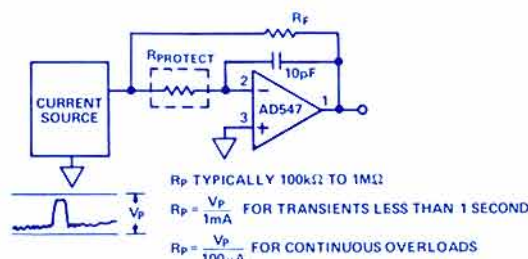


Figure 7. Input protection of I:V converter.

Output voltage of current-to-voltage converters is proportional to the value of feedback resistance (R_F in Figure 8). For greater sensitivity, increased values of feedback resistance are used (for example, 5 megohms, in Figure 9). However, beyond 10^9 ohms, resistors tend to become expensive, large, noisy, and unstable.

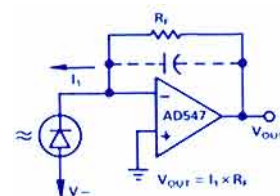


Figure 8. Photodiode amplifier—photoresistive mode.

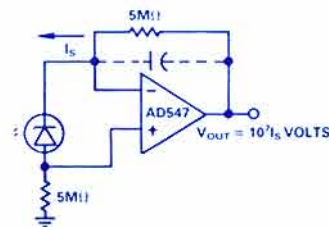


Figure 9. Photodiode amplifier—current-output photovoltaic mode.

Under some circumstances (see Figure 10), it is fruitful to use instead a high value of resistance and a low-impedance resistive divider that attenuates the portion of the output voltage used for feedback (since the signal current must now produce a smaller voltage, R_F may now be smaller than it would otherwise have had to be). For example, a 10-megohm resistor and a 1000:1 divider is nominally equivalent to a 10,000-megohm resistor. The drawback is, of course, that input voltage errors are magnified relative to the attenuated output voltage at the tap of the R_1 - R_2 divider. The low voltage offset, drift, and noise of the AD547 enhance the attractiveness of this circuit technique.

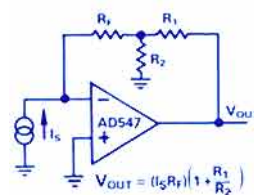


Figure 10. Current-to-voltage conversion with gain.

High-impedance transducers, such as proportional counters and some accelerometers, require an amplifier which converts an increment of charge into a change of voltage, through the use of a feed-

back capacitor. The increment of charge in a circuit of the type shown in Figure 11 is obtained by variation of capacitance in a capacitive transducer sitting at constant voltage between the summing point and a voltage source. ($\Delta Q = C \cdot \Delta V + V \cdot \Delta C$, and, since $\Delta V = 0$, $\Delta Q = V \cdot \Delta C$). The op amp transfers charge to the feedback capacitor and develops the output voltage change ($\Delta V_{OUT} = -\Delta Q/C$).

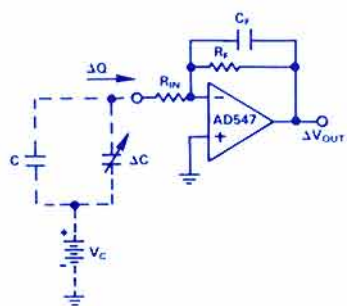


Figure 11. Charge amplifier.

In this circuit, R_f provides a leak for bias current to permit the output voltage change, due to an ac variation of charge, to be observed without excessive dc drift. The time constant, $R_f C_f$, should be long compared with the slowest change of charge ($1/(2\pi f_{min})$); but $R_f I_{BIAS}$ must be small compared to the full-scale output range. R_{IN} serves to protect the amplifier's input and output circuit against transient and steady-state voltage breakdown in the capacitive transducer if V_C is substantial.

Applying a voltage bias to a grounded device is a common need in low-level current measurement, for example, in leakage current testing, or in using low-level current transducers (e.g., Clark oxygen sensors). Figure 12 shows a technique that applies a fixed or adjustable bias at the noninverting terminal of an op amp, thus using feedback to force the inverting terminal to the same potential. The current through the transducer is sensed by R_f , and a low-cost instrumentation amplifier converts the off-ground voltage across R_f to a single-ended output.

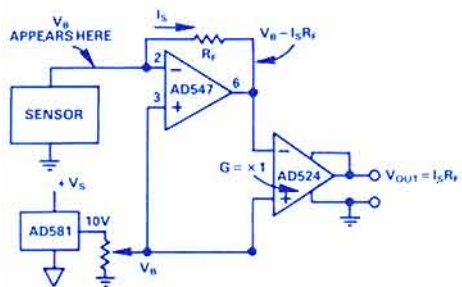


Figure 12. Current-to-voltage converter with grounded bias and sensor.

APPLICATION HINTS

The low input bias current (25pA max) and low noise characteristics of the AD547K make it suitable for electrometer applications, such as photodiode preamplifiers and picoampere-level current-to-voltage converters. In such circuits, it is essential to use guarding techniques in the design and construction of the printed circuit board layout to realize the ultimate low-leakage performance of which the amplifier is capable.

The input guarding scheme shown in Figure 13 for single and dual op amps will minimize leakage to the input circuitry from the supply terminals, the outputs, or other portions of the board wiring.

The guard ring should be connected to a low-impedance potential at the same dc level as the inputs. High-impedance signal lines should be kept as short as possible; they should be surrounded by guard lines and kept away from any sources of noise and leakage. Off-board, rigid shielded cables should be used for wiring.

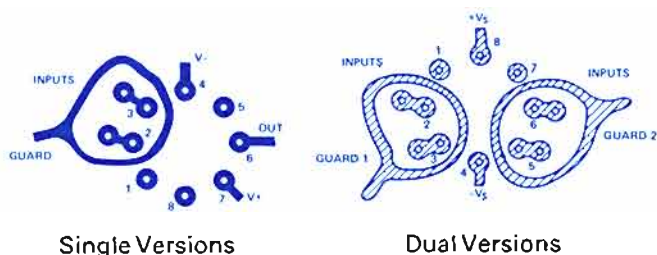


Figure 13. Board layout for guarding inputs.

The fast settling time and low offset voltage of the the AD544 make it an excellent choice as an output amplifier for high-accuracy current-output d/a converters. The upper trace of the oscilloscope photograph in Figure 14b shows the settling characteristic of the AD544 in the circuit of Figure 14a; the lower trace is the input. Although the AD544 by itself will settle fast to within 0.01% of final output value, feedback components, circuit layout, and circuit design must be carefully considered to provide minimum settling time for the overall circuit in which it is used.

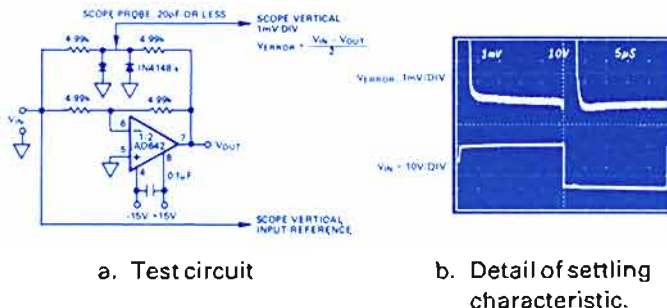


Figure 14. Settling-time tests on AD544.

If substantial capacitive loads must be driven, they will limit the output slewing rate; In addition, the extra pole that they establish in the amplifier transfer function can be destabilizing and provide distortion, even when the circuit is being used for a low-frequency application. Improved dynamic performance can be obtained by the use of the circuit of Figure 15. A 100-ohm isolation resistor removes the capacitive load from the amplifier's output, permitting the 30pF feedback capacitor to provide phase lead in the loop. Low-frequency accuracy is maintained by closing the main loop around the 100-ohm resistor, as shown. Figure 16 shows typical transient response of this circuit.

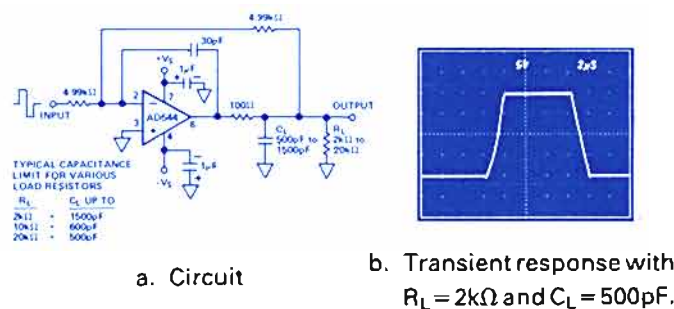


Figure 15. Driving a large capacitive load.

USE YOUR PERSONAL COMPUTER FOR MEASUREMENT & CONTROL

Software Support Packages Translate Between μ MAC-4000 and Apple, H-P, IBM, DEC
Interface with Real World via μ MAC-4000; Use High-Level (e.g., BASIC) Programs

by John Mills

The μ MAC-4000* is an intelligent, expandable, multi-option single-board measurement and control system that accepts analog and digital data, outputs analog and digital control signals, receives instructions, and selectively receives or transmits data under the direction of a host computer, via an RS-232 or 20-mA communications link (Figure 1).

The μ MAC-4000 interfaces directly, via screw terminals, with sources of analog input signals, such as thermocouples, RTDs, strain gages, other millivolt-level sources, and 4-to-20mA current loops. An on-board microcomputer unburdens the host by controlling and locally performing signal amplification, sensor linearization, channel selection, and conversion to engineering units. It provides all this at a price of only \$1488 for four channels of temperature measurement.

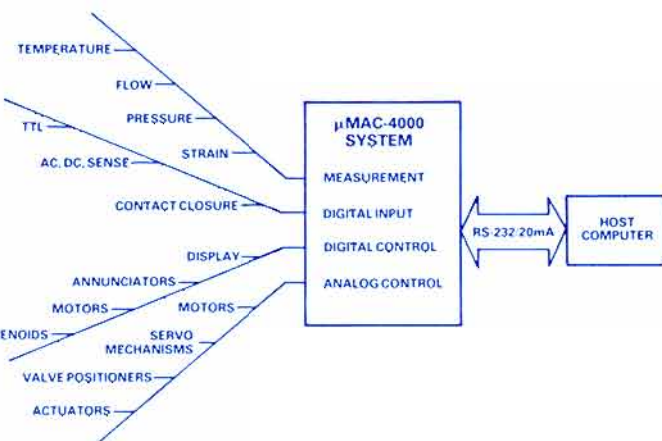
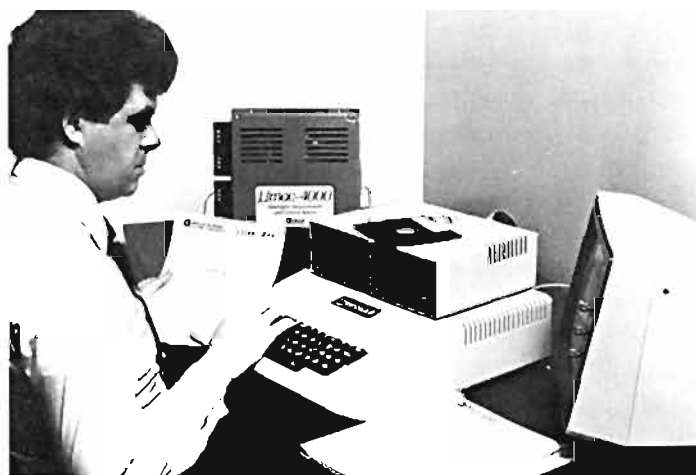


Figure 1. μ MAC-4000 measurement-and-control concept.

The computer furnishes instructions to—and receives information from—the μ MAC-4000, in the form of standard serial ASCII characters, via the standard RS232C/20mA data link. This makes it possible for the μ MAC-4000 to interface with any host computer using this form of communication; since most computers do embrace it, as either a standard feature or an option, the μ MAC-4000 is essentially a universal data-aquisition peripheral.

The communication format, which embodies the transfer of information ("handshake") between the host and the μ MAC-4000—including checks on the validity of the data—is the "C" protocol, described in the μ MAC-4000 technical data. The user must provide appropriate software, for the type of computer being used, to translate between the language of the "application" program and the μ MAC-4000's command set.

Recognizing that this requirement can be a time-wasting burden for scientists and engineers who do not wish to become software specialists, we have developed—and are continuing to develop—software support packages for use with popular computers. The first of these are software drivers using BASIC programs for IBM

and Hewlett-Packard personal computers, Applesoft BASIC for Apple II computers, and MACRO-11 for DEC computers.†

The packages include Driver Diskettes (Cassette for H-P), manuals, and communication cables. An optional RS-232C communications/real-time-clock card, which plugs into the backplane, is available for the Apple. It is ideal for data-logging applications. Prices are: Apple—\$150 (\$388 with Mountain option), IBM—\$200, HP—\$250, and DEC—\$990.

The ease of writing programs using these packages can be seen in the display segment in Figure 2, which LISTs the entire program to read a temperature at one location, and then displays the response to a RUN command. Since the μ MAC-4000 retains updated data in memory, the response appears immediately after the RUN is executed. A scan of a number of temperatures is almost as simple—and speedy—but of course the display portion of the program will call for a few extra program steps if the results are to be listed. ▣

```
LIST 80,130

80 IN$ = "0":TR$ = "3"
90 GOSUB 61080: REM INITIALIZE VALUES
100 IN$ = "1": REM SELECT CHANNEL 1
110 GOSUB 61260: REM INVOKE CHANNEL 1 READ
120 PRINT "TEMP1= " + TR$ + " DEGREES C":
    REM DISPLAY RESULTS
130 END
JRUN

TEMP1= 40025.4 DEGREES C
```

Figure 2. Display of program LIST and results of RUN, using AppleII.

*Use the reply card for technical data. The μ MAC-4000 was first introduced in these pages as the cover feature of Volume 15, Number 1. †AC1820 for Apple II; AC1815 for DEC RSX-11; AC1818 for HP-85; and AC1822 for IBM Personal Computer; use the reply card for technical data.

MULTITASKING

The Key to Effective Measurement and Control

What Is It? How Does It Help Me Accomplish Results with MACSYM?

by Bill Schweber

When you are controlling an experiment in a lab or a process in the plant, you often need a system that allows you to divide your overall operation into smaller, easier-to-define tasks, run them at specified times or under specified circumstances, and perhaps run several stations simultaneously, but at different rates—all under the direction of a single mini- or microcomputer system.

You can do all this—and more—with the “multitasking” that is a standard feature of MACSYM 2* and MACSYM 10* Measurement And Control SYsteMs. Besides making MACSYM easier to use, multitasking allows you to partition your overall program into independent sections and to interact with the system while it is running your test or process.

A SIMPLE EXAMPLE

Suppose you want to test a battery's charge/discharge characteristics under computer control (Figure 1), with the following test requirements:

1. Set the charging current to the battery.
2. Read the cell voltage and temperature once per second.
3. Perform calculations based on the last reading and several previous readings.
4. Compare the results of the calculations to an established value and raise an alarm if it is exceeded.
5. Check the position of an on/off switch mounted near the battery under test.
6. Print out a logging report every 10 minutes.

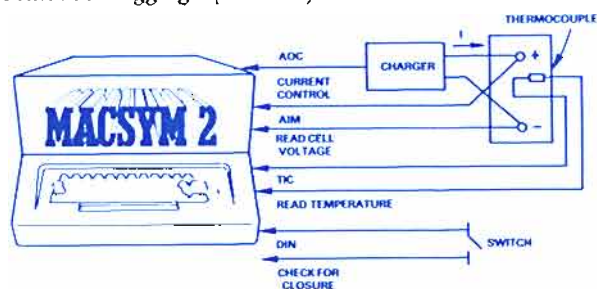


Figure 1. Functional diagram of battery test setup.

You would write an individual task (sub-program) for each function. Task 1 would be set once (initialization) and be activated at startup. Task 2 would be periodically activated (once per second). Task 3 would be activated by Task 2, after the readings had been made. Task 4 would be activated by Task 3. Task 5 would be checking the switch—but on a lower-priority basis. Task 6 would be activated every 10 minutes.

While the tasks are being executed to run your test, you can choose whether the keyboard is to be active (live) or de-activated. When it is live, you can use the keyboard to do the following:

- Change the time period of the tasks
- Inspect and print input values, switch-settings, and results of calculations
- Change the alarm setpoint or the charging rate
- List all or part of the program

*For technical data, use the reply card.

- Manage the running of the tasks—activate or suspend tasks
- Change output voltages, currents, or on/off settings

After you have made changes—or at any time—you can de-activate the keyboard to prevent unauthorized changes. Sample printouts from typical test runs are shown in Figure 2.

```
CELL SERIAL NUMBER (4 DIGITS)? 4820
DESIRED CHARGE RATE (0-1 AMP)? .3
DESIRED FINAL CELL VOLTAGE (0-10 VOLTS)? 7.2
CELL ALARM TEMPERATURE (0-100 DEGREES C)? 95.5
```

```
***ALARM*** CELL OVERTEMPERATURE
TEST TERMINATED
CELL FINAL VOLTAGE= 6.40
CELL FINAL TEMPERATURE= 96.1
```

```
CELL SERIAL NUMBER (4 DIGITS)? 7104
DESIRED CHARGE RATE (0-1 AMP)? .3
DESIRED FINAL CELL VOLTAGE (0-10 VOLTS)? 5.0
CELL ALARM TEMPERATURE (0-100 DEGREES C)? 95.3
```

```
TEST COMPLETE 01/01/79 00:03:51
CELL NUMBER 7104
CELL FINAL VOLTAGE= 5.0
CELL FINAL TEMPERATURE= 75.0
```

Figure 2. Printout of battery test results.

WHAT IS MULTITASKING? WHAT ARE THE PROS & CONS?

As you have seen, multitasking is a scheme that allows you to write the sections of your total program as individual tasks and have them run with independent schedules, times, rates, or occurrences. The MACSYM keyboard can remain live, if you wish, while the program is running. MACSYM automatically shares its time and resources among the tasks, so it appears to you as if the processes are running simultaneously.

In the multitasking system, all variables are global, that is, they are known and available to all tasks. This means that data acquired in one task can be used by another task without any additional programming effort.

Since tasks can be periodically activated at known times, you don't have to put time-wasting loops into your program in order to insure that a reading is taken at a specific time, or that a desired amount of time elapses between software activities. In fact, while executing a WAIT statement, the operating system will automatically go to another task to keep the processor busy. The CPU resource is therefore used much more efficiently and effectively than it would be without multitasking.

Another advantage of multitasking is that a task may be normally “dormant” but suddenly assume special importance and require immediate execution. An example is the procedure associated with the tripping of a safety limit. A separate task can be written to test for the conditions that would invoke this rarely used task.

Yet another advantage exists under startup conditions. When starting up a complex new program for the first time, and integrating it with real-time inputs/outputs, it helps if you can bring up

tasks one at a time, or in small groups at a time, and selectively activate and de-activate them. This enables you to test the system piece-by-piece (hardware and software). The net effect of this approach is to reduce the time needed to debug or certify that a complex large program with many inputs and outputs actually does what it is supposed to do.

The advantages of multitasking are not free—but the price that is paid is relatively small. The operating system for multitasking occupies more memory space than for a system without multitasking. Also, it runs a little more slowly because it has more scheduling to do. However, the small penalty in speed—for most applications—is greatly outweighed by the increase in process utilization you can get with multitasking.

WHAT CONTROL DO I HAVE WHILE THE PROGRAM IS RUNNING?

From the keyboard, or from within your program, you can *activate* a task (as a function of either time or circumstances) and assign it a priority, *suspend* the running of a task, *alert* (or reactivate) the task, starting with its next timed event, or *kill* a task if it is no longer needed (to free up memory space and other resources).

In the example above, you could SUSPEND Task 4, the alarm task, while you fine-tune your program, and then activate it when you are ready to use the alarm function.

Note that tasks can control other tasks with the same task-control statements; this enables you to write flexible and powerful programs. You can also assign relative priorities to tasks so that essential tasks are completed before less-important ones, and even change these priorities as needed within your program.

EXTENDING THE EXAMPLE

Multitasking makes it easier to control several test stations at the same time, yet have individual control over each one. Consider a situation in which you want to control several basically similar battery-test setups, but with different setpoints and charging rates.

MACSYM sets the charging rate for each battery and monitors the cell voltage. With multitasking, you can write a task for each battery that would be identical in concept, but might differ in details, such as charging rate. The multitasking would allow you to change the charging rate—or constants in the calculations—while the tests are running. When you want to change a battery under test, you would SUSPEND the task associated with that cell, then ACTIVATE it when the new cell is installed, either with a local on-off switch or at the system keyboard. The other cell test is unaffected and continues independently without interruption.

WHAT DOES MULTITASKING ACTUALLY DO?

The multitasking capability is automatically available to the user when the MACBASIC operating system is loaded into MACSYM. This operating system takes care of all the necessary work to make multitasking happen. The result is that all the tasks are interwoven automatically in a manner invisible to the user of the system. The multitasking operating system does these things:

- It arbitrates among the tasks and causes the execution of one line of each task on a “round-robin” basis (if the tasks have equal priorities). You can assign a higher priority to a task if you want.
- It handles the time schedule of periodic tasks.
- It goes to the next task when the present task is executing activities that have an inherent dead time and would otherwise tie up the processor needlessly. Examples of such tasks include WAIT, file input/output, analog/digital input/output.

- It keeps track of what tasks are running and what line of each task is being executed.

- It keeps the keyboard “live” (if not de-activated) so you can print, change variable values, control tasks, and list programs, while the programs are running.

SAMPLE MULTITASKING PROGRAM

Perhaps the quickest and most powerful way of demonstrating the power of multitasking is to show how much flexibility *even a single-task* program can gain in the multitasking mode. The program in Figure 3 measures a variable analog input voltage, $X = \text{AIN}(1,0)$, multiplies it by a programmed constant (K), and outputs the result as an analog voltage, $\text{AOT}(2,1) = K \times X$. If X exceeds a programmed limit (L), an alarm is sounded by PNT 7. This sequence is repeated at programmed intervals (T). The initial values of the constants K, L, T are given as 1, 5 volts, and 0.5 seconds.

```

10 TASK 1,50
20 ACTIVATE 1
30 STOP
40
50 K=1 L=5 T=.5
60 X=AIN(1,0)
70 AOT(2,1)=K*X
80 IF X > L PNT 7
90 WAIT T
100 GOTO 60

```

Figure 3. Multitasking: single-task program.

The first three program lines (10, 20, 30) define the name and location of the task (Task 1, at line 50), activate Task 1, and indicate that there are no more tasks to be defined (STOP), therefore proceeding to execute the rest of the program. When the operator starts execution of the program by typing RUN (carriage return), the response is “STOP AT LINE 30 (M)”. (M) indicates that MACSYM is running in the multitasking mode.

If the program were an ordinary single-task program, the constants could not be changed from the keyboard without either a program change or including an INPUT statement in the program, either of which would require an interruption of the running of the program. With MACSYM’s multitasking feature, on the other hand, new values of the multiplying constant, the limit threshold, or the waiting period between repetitions can be keyed in at any time, by typing in new definitions ($K = 0.5, L = 8, T = 0.2$, etc.) while the program is running, and they take effect immediately when the carriage return is keyed. The operator could also, at will, key in the request, PRINT X to print the current value of X.

If a second task were added, to begin at line 140, the program preamble segment might look like Figure 4. Line 30 identifies Task 2 as beginning at line 140. If it were to be assigned priority 1, the line would read, TASK 2, 140, 1. Again, the keyboard could interact with the program, including the activation or suspension of tasks (SUSPEND 2 (carriage return)). The simple examples given above should make it evident that multitasking is a powerful, easily used tool for computer-based measurement and control. ▶

```

10 TASK 1,70
20 ACTIVATE 1
30 TASK 2,140
40 ACTIVATE 2
50 STOP
60

```

Figure 4. Preamble to 2-task program

IMPROVED VECTOR-SCAN DISPLAYS ARE COMING

A Key is the Fast, 12-bit, Deglitched HDD-1206 D/A Converter

A Self-Contained Hybrid, It Updates at up to 6 Megapixels/Second

by Don Brockman and Terry Brown

Reams of material have been written in recent years debating the pros and cons of various cathode-ray-tube (CRT) display systems. An easy conclusion is that there is no "best" system; they must be compared in terms of their advantages and disadvantages for a specific application.

Even the methods of deflecting the electron beam (or beams, for multicolor displays) have been subject to discussion. Systems with electromagnetic deflection use a magnetic yoke around the neck of the CRT to deflect the electrons; systems with electrostatic deflection use voltages applied to sets of deflection plates built into the tube to steer the beam. Electromagnetic systems are slower and require more power than electrostatic systems, but they are cheaper and are widely used in TV-type raster-scan displays.

The two principal forms of display are raster scan and vector scan. The TV-like *raster scan* variably illuminates a large number of closely spaced clusters of dots along a raster of closely spaced horizontal lines every 1/30 or 1/60 of a second. You can find a discussion of raster-scan techniques, and the application to them of the unique HDG family of compact hybrid deglitched DACs for composite waveform generation, in *Analog Dialogue* 15-2, pages 3-6.*

Vector-scan (alias calligraphic, stroke-writing, random-scan, or directed-beam) display systems form X-Y plots of digitally determined points or digitally programmed analog line-segments of random length and direction, in similar manner to oscilloscopes in the X-Y-plot mode. It forms a display on the screen by vectoring the beam, i.e., by varying its X and Y coordinates, and turning it "on" and "off" or modulating its intensity, as appropriate.

Vector-scan systems move the beam only to those portions of the screen forming the illuminated portion of the pattern, while the beam that illuminates the raster scans the entire screen, whether or not intensity information is present. In most applications, raster-scan displays use electromagnetic deflection (an inheritance from TV circuitry), while vector types use electrostatic deflection. The former has the advantages of simplicity and low cost; the latter requires less power, provides better resolution, and can display

data changes with precision. Raster-scan systems are faster if large quantities of data are changing from frame to frame, while vector scan is often the choice where precision is important.

Although its growth doesn't match that of the market for raster-scan systems, which grows by leaps and bounds, the vector-display market is still growing at a modest rate and is expected to continue to do so.

DAC REQUIREMENTS

Figure 1 is a block diagram of a typical vector-scan display system that plots point-by-point, using 12-bit DACs for the X and Y axes and a fast DAC with lower resolution to modulate the Z (intensity) axis. To obtain the perception of continuous lines when the display consists of discrete points, it is essential to use high-resolution d/a converters to drive the X- and Y-axis inputs. For example, a pair of 12-bit converters will provide a display of 4096×4096 bits, or about 16.8 million picture elements (pixels). With a 21" screen, this would provide a resolution of the order of 0.1mm.

The high density of pixels makes it mandatory that only high-resolution, high-quality DACs be used for plotting the digital data stored in memory. Any aberration in the DAC output, static or dynamic, can introduce an error in output voltage and erroneously position the plotted point. The HDD-1206† fast deglitched hybrid 12-bit DACs shown in the figure are a new product of the Computer Labs Division of Analog Devices.

Figure 2 shows a simplified randomly programmable vector-scan beam path. The X-coordinate DAC moves the beam left-and-right, the Y-coordinate DAC moves it up-and-down. The beam is al-

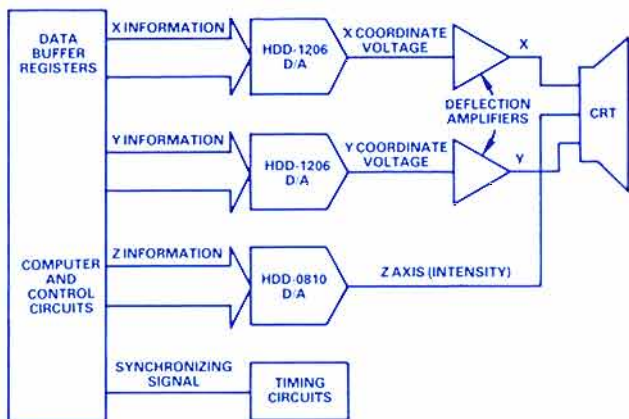


Figure 1. Typical vector display system.

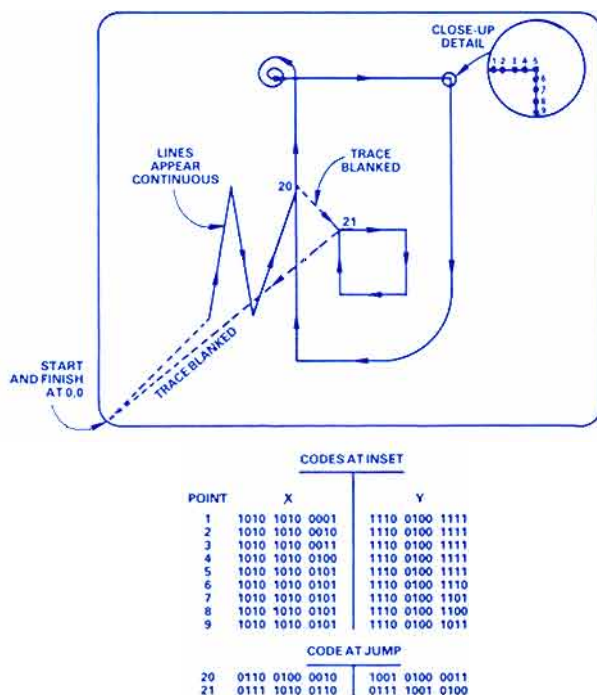


Figure 2. Randomly programmable vector-scan beam path.

blowed to provide continuity between connected points, but it is blanked when it skips over a dark area. Errors in positioning in the X or Y direction produce lines with distorting lumps. D/A converter technology today is sufficiently advanced to ensure that problems with dc linearity and monotonicity are essentially non-existent; so dc characteristics are not a significant source of errors in vector scan displays.

However, besides high dc resolution, the d/a converters need a few other features. First and foremost is speed. The faster the DAC, the more points that can be illuminated within a given scan (usually 1/30 to 1/60 seconds, to avoid flicker). The 60-nanosecond settling time of the HDD-1206 for one-bit changes (while plotting a line) is compatible with a 6MHz refresh rate, and only 2 microseconds are required for an accurate full-scale jump (less time for shorter jumps). Effective plotting strategies would call for many connected points and only short jumps, when feasible.

But high speed and high resolution are useless if the transition from point to point is not clean. A major problem in fast high-resolution DACs is the discontinuity, or "glitch", that can occur at major transitions, for example, in the one-bit transition from 0111111111 to 1000000000. If the less-significant bits turn off faster than the MSB turns on, the output will rapidly swing towards zero, then rapidly swing back towards the original level plus one bit, causing the trace to seek to swing wildly over the face of the CRT in the course of making that small change. Even at less-significant transitions, highly visible perturbations can occur.

Since the glitch is a code-sensitive nonlinear phenomenon, it cannot be simply filtered by linear techniques. It must first be minimized in duration and amplitude by designing the switching to be as symmetrical as possible; then the residual glitch can be eliminated by using a track-and-hold output amplifier circuit. When a new value of digital input is latched in, the output circuit switches to *hold* to retain the previous value until a time when the glitch can be expected to have settled out, then switches to *track* to acquire the new value.

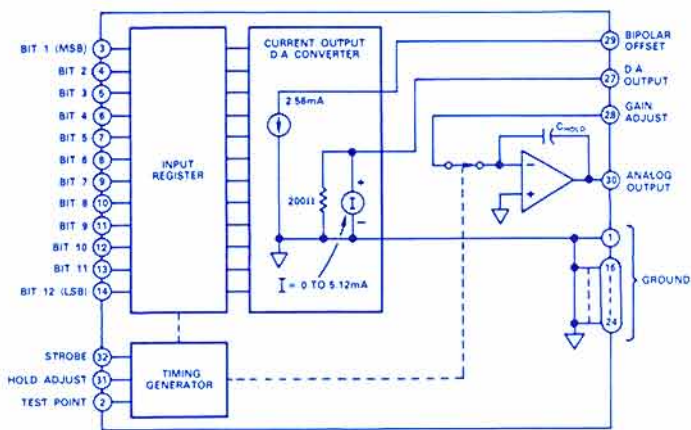


Figure 3. HDD-1206 functional block diagram.

This is the essence of the job performed by the deglitching circuitry incorporated into the HDD-1206, designed for the next generation of high-performance point-by-point vector-graphic displays.

THE HDD-1206

This device represents a truly remarkable achievement in combining many functions in a single thick-film 32-pin hybrid IC. Included are input registers, 12-bit current-output DAC network

and switches, a reference, the output amplifier with track-and-hold switching, timing circuits, and associated electronics. Coding is negative-reference complementary binary for single-ended output (and complementary offset binary for bipolar output); that is, the single-ended output is 0 for all 1s, $-5.119V$ for all 0s (1 LSB = 1.25mV).

Figure 3 is a block diagram of the device. The first step in minimizing the glitch is an input register to remove the effect of differences in the arrival times of the individual bits. All bits are simultaneously latched and arrive at the input of the current-output d/a converter at the same time. Nevertheless, despite the best efforts at balanced design for the converter, there still exists a difference between on and off times for the switches, which produces a glitch.

The block labeled "timing generator" includes a one-shot multivibrator and gating circuitry. This circuit provides a fixed *hold* period that exceeds the expected glitch duration, starting at the time the strobe arrives and independent of strobe frequency. At the conclusion of the *hold* interval, the output amplifier is returned to the *track* mode and slews to the new value established by the digital input.

The role of the FET switches used in the track-and-hold is critical, because they affect the dissipation and complexity of the drive circuit and the smoothness of the converter's output waveform. Chosen for low input capacitance, low gate cutoff voltage, and low drain-to-source "on" resistance, they make possible 6MHz update rates with low power dissipation. Additional benefits are low charge transfer within the device—hence smaller residual spikes—and simplified drive circuitry, resulting in more efficient use of space and lower cost.

WHAT IF I NEED FASTER UPDATE RATES?

Complete and cost-effective,† the HDD-1206 is an ideal choice for vector-scan designs calling for 12-bit resolution and update rates through 6MHz. If 12-bit resolution must be obtained at faster update rates, suitable circuits can be assembled, using external input registers, the HDS-1250‡ (12 bits, 50ns) or HDS-1240E‡ (ECL, 12 bits, 40ns) current-output DACs, and the HTS-0025‡ track-and-hold—to perform deglitched d/a conversion at update rates from 10 to 20MHz. Figure 4 is a block diagram of a scheme using the HDS-1250. ▀

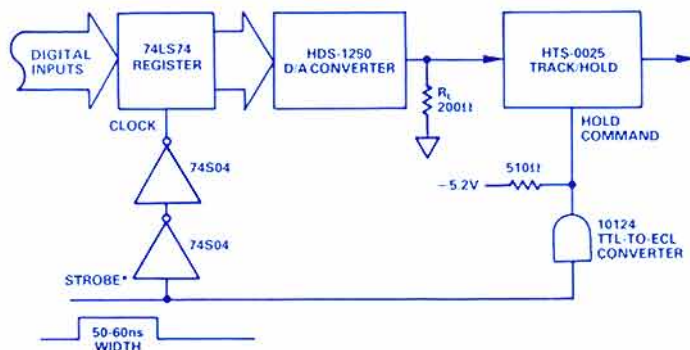


Figure 4. Applying the HDS-1250 and HTS-0025 for fast vector scan.

*Use the reply card for a copy of the article.

†Use the reply card for technical data

‡Prices from \$135 in 100s

DEGLITCHING A 16-BIT MONOLITHIC D/A CONVERTER

AD7546 Has an on-Board Sample-Hold Switch for Deglitching Simple Circuitry Provides Buffered Voltage Output

by John Wynne

The AD7546* 16-bit microprocessor-compatible monolithic d/a converter, a voltage-output device designed to provide 16-bit resolution at high speed—with low power consumption and cost—in a 40-pin DIP package, was introduced in *Analog Dialogue* 16-1, page 6. The plastic AD7546KN and the ceramic AD7546BD provide 65,536 monotonic output levels, in response to 16-bit binary inputs, for respective temperature ranges of 0°C to 70° and -25°C to +85°C.

As Figure 1 shows, the four most-significant bits choose the appropriate segment of a 16-resistor string; the voltage across that resistor is applied, via a pair of external buffer op amps, to a precision 12-bit DAC, employing a voltage-switching R-2R ladder. The output of the AD7546 is equal to the base level voltage, at the lower end of the chosen resistor (0V, 1/16 V_{REF}, 2/16 V_{REF} ... 15/16 V_{REF}), plus the fraction of the voltage across the resistor established by the 12 less-significant bits and the 12-bit DAC.

The dynamic behavior of the analog output during code changes is not clean, because the base level voltage can vary during switching, as intermediate codes appear and disappear; op-amp circuit dynamics also contributes. A typical major-carry "glitch" (8000_H to 7FFF_H) can be seen in the lower waveform of Figure 2a.

The glitch, being large, must be suppressed. Since it is code-dependent and nonlinear, it cannot be filtered out in a short time using linear filtering. It is most successfully dealt with by a track-hold circuit at the output of the converter, switched to *hold* when data is put on the input, then to *track* after the worst-case glitch will have settled out. The glitch occurs but is ignored.

The AD7546 contains a single-pole, single-throw (SPST) switch, for use in track-hold circuits. The switch is synchronized with the two latch-loading signals; it is open when both CHIP SELECT and WRITE are low. The internal logic of the AD7546 ensures that the switch opens before the data to the latches can change. The switch is normally connected as shown in Figure 2b.

A3 buffers the 15kΩ output resistance of the 12-bit converter and drives the hold capacitor, C_H, through the on-chip deglitcher

switch. A3 should have wide bandwidth, be able to drive substantial capacitive load, and have low input bias current flowing through the ladder resistance—for minimal contribution to offset voltage.

A4 buffers the voltage on C_H and supplies the deglitched output at low impedance. A4 should have low input bias current, to minimize droop of the hold-capacitor voltage. Offset voltage of A3 and A4 is added without amplification at the output.

The deglitcher switch is a specially designed CMOS switch with low charge injection (typically 150fC, or 15μV in 10nF) and on resistance of the order of 250 ohms. C_H should be large enough to keep the effects of charge injection to less than 1-LSB-worth of output, yet be small enough for rapid charging through the deglitcher switch. The deglitcher switch is brought out to pins 22 and 24; pin 23, a "no-connection" pin, should be tied to the output of A4 as a guard to minimize feedthrough and droop.

The next-to-bottom trace of Figure 2 shows typical results, using the deglitcher switch in the configuration of Figure 3, with A3 = A4 = TL071, C_H = 10nF, and a *hold* period of 10μs. The scale of the output waveform is about 2 LSBs per division. The maximum glitch amplitude is reduced from 1.4V to about 250μV, a factor of about 5600, or 75dB; the glitch area is reduced from 1.4μV-s to 1.6nV-s, about 875:1; and the delay is known and controllable.

When the deglitcher switch is used, the period of the *write* pulse should be extended to give the output of A3 time to settle to the correct new value. Digital input data should remain stable while the write pulse is low. When it returns high, the deglitcher switch closes, and C_H charges to the new value through the switch. ▀

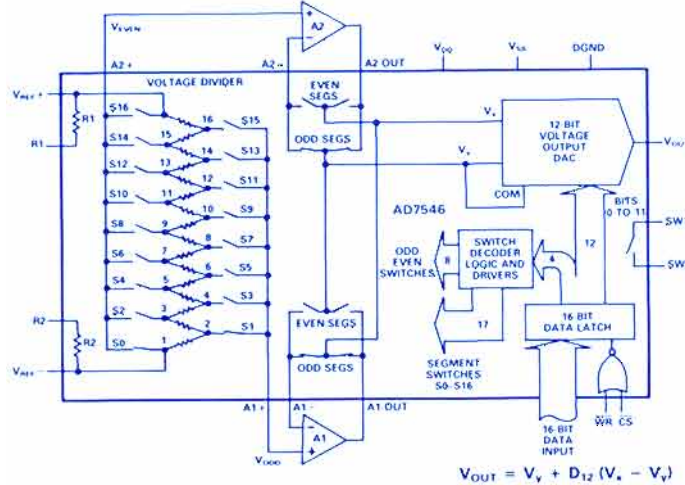
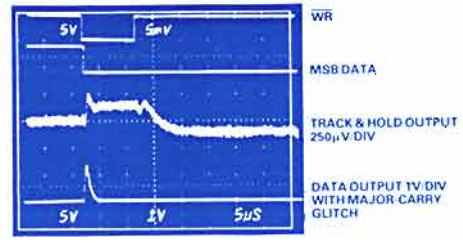
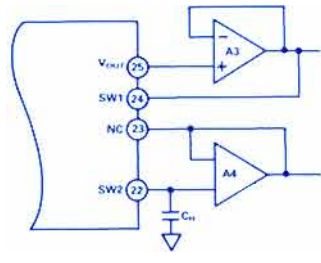


Figure 1. Functional diagram of the AD7546.



a. Waveforms.



b. Circuit connections for deglitching.

Figure 2. Deglitching the AD7546.

* For technical data, use the reply card.

VERSATILE μ P-BASED METERS FOR J-K-T-E-R-S THERMOCOUPLES

AD2050/AD2051 Self-Calibrate, Cold-Junction Compensate, & Linearize
Character-Serial ASCII & RS-232C Digital, 1mV/°C Analog Outputs Available

The AD2050 and AD2051* are single-channel thermocouple temperature meters with a maximum range of -265°F to $+1999^{\circ}\text{F}$ or -165°C to $+1760^{\circ}\text{C}$ and resolution of $1^{\circ}(\text{F or C})$. Microprocessor-based circuitry provides automatic cold-junction compensation, linearization, and self-calibration of gain and offset. The AD2050 is programmed at the factory to interface directly with one of the following six thermocouple types: (J, K, T, E, R, S). The AD2051 is a universal instrument; the user selects appropriate conditioning for one of the six thermocouple types via switch-programming.

Typical applications include temperature monitoring and data logging in industrial and laboratory environments. Performance, comparable to that obtainable with meters costing 2 to 3 times as much, is virtually drift-free; typical drift over the recommended 15-month re-calibration interval is less than $\pm 1^{\circ}\text{F}$ (1 digit). Table 1 shows ranges and readout accuracies with various thermocouple types.

Table 1. Readout accuracy (*at* 25°C ambient).

Sensor Type	Range	Accuracy
J	-165°C to 760°C	$\pm 0.7^{\circ}\text{C}$ $\pm 1/2\text{LSD}$
J	-265°F to 1400°F	$\pm 1.3^{\circ}\text{F}$ $\pm 1/2\text{LSD}$
K	-50°C to 1250°C	$\pm 0.9^{\circ}\text{C}$ $\pm 1/2\text{LSD}$
K	-58°F to 1999°F	$\pm 1.6^{\circ}\text{F}$ $\pm 1/2\text{LSD}$
T	-150°C to 400°C	$\pm 0.8^{\circ}\text{C}$ $\pm 1/2\text{LSD}$
T	-238°F to 752°F	$\pm 1.4^{\circ}\text{F}$ $\pm 1/2\text{LSD}$
E	-100°C to 870°C	$\pm 1.0^{\circ}\text{C}$ $\pm 1/2\text{LSD}$
E	-148°F to 1598°F	$\pm 2.0^{\circ}\text{F}$ $\pm 1/2\text{LSD}$
S, R	$+300^{\circ}\text{C}$ to 1760°C	$\pm 1.5^{\circ}\text{C}$ $\pm 1/2\text{LSD}$
	0° to 299°C	$\pm 6.0^{\circ}\text{C}$ $\pm 1/2\text{LSD}$
S, R	$+572^{\circ}\text{F}$ to 1999°F	$\pm 3.0^{\circ}\text{F}$ $\pm 1/2\text{LSD}$
	$+32^{\circ}\text{F}$ to 571°F	$\pm 12.0^{\circ}\text{F}$ $\pm 1/2\text{LSD}$

Temperature information is displayed on large $0.56''\text{H}$ (14.3mm) LEDs. It is also available digitally in character-serial ASCII format with rate selection (25 or 100 characters per second) for easy interface to printers, terminals, and other peripherals. An optional iso-



lated 20mA bit-serial loop output—capable of 4-wire full-duplex 300- or 1200-baud operation over distances up to 10,000 ft—and a non-isolated TTL-compatible interface are available for computer interfacing.

Linearized temperature information is also optionally available in analog form as a 1mV/degree output voltage, for driving strip-chart recorders and other analog instruments.

The operating ambient temperature range for specified operation of these meters is $+10^{\circ}\text{C}$ to $+40^{\circ}\text{C}$, with $\pm 25\text{ppm}/^{\circ}\text{C}$ typical, $\pm 60\text{ppm}/^{\circ}\text{C}$ maximum tempco. You can order either meter for power supplies of 120V ac, 240V ac, or—at small extra cost $+7.5\text{V}$ to $+15\text{V}$ dc. The meters automatically indicate overrange and open-thermocouple conditions. They are protected for 300V peak input (thermocouple to ac line) and up to 1400V peak common-mode voltage (ac versions).

Before shipment, all devices are burned-in for 168 hours at 50°C , power-on-off cycled, and calibrated (traceable to the National Bureau of Standards). They are supplied in rugged high-impact plastic cases that meet DIN/NEMA standard dimension requirements. Base prices of the AD2050/AD2051 are \$230/\$290 (1-4) and \$161/\$203 in 100s. \blacksquare

*For technical data use the reply card.

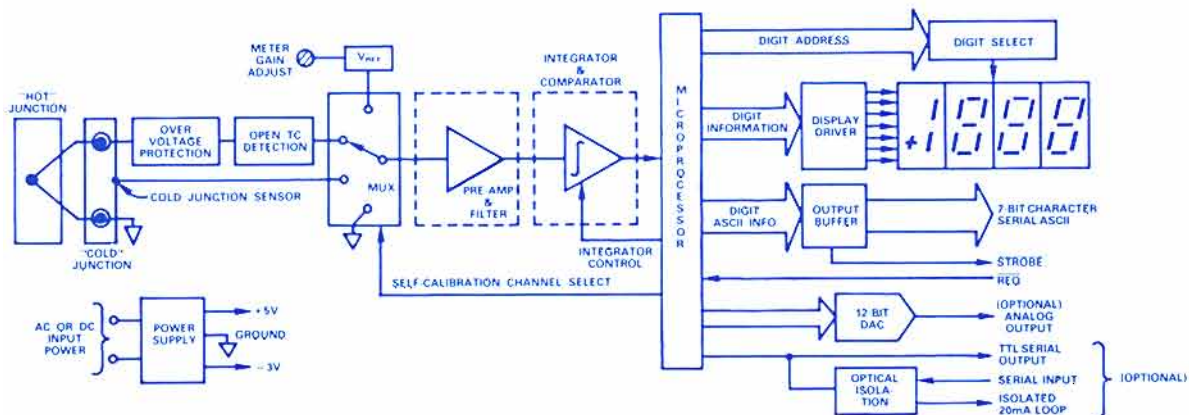


Figure 1. Functional block diagram of the AD2050/AD2051.

NEW SOFTWARE PACKAGE FOR LTS-2010 TEST SYSTEMS

Includes Operating System, Utility Programs, and Family Test Packages Users Perform Tests More Easily; Test Designers Can Be More Creative

by Mike Slocombe and Al Finger

In just two short years since its introduction, hundreds of LTS-2010[®] computer-based automatic benchtop test systems have come into use, testing op amps, d/a converters, a/d converters, v/f converters, and voltage references (employing standard off-the-shelf Family Boards), plus an unknown number of devices whose nature is known only to users who have wired their own test circuitry on User Prototype Family Boards.†

During this time, the first-generation software has proven itself effective and quite a bit more flexible than that of existing alternatives. As always, though, there is plenty of room for improvement. Now, a major effort has resulted in new software that is even more flexible, easier to use, and—very important—*compatible with existing software and hardware*.

The LTS-2010 package includes an Operating System, which features a File Manager program, an interactive Debug program, and several utility programs. A restructured, more versatile, and easier-to-use menu-type “fill-in-the-blanks” Family Test program is available for both the LTS-2000 and the LTS-2010. BASIC may also be used with the LTS-2010 to optimize system throughput.

OPERATING SYSTEM

With the File Manager program, the test programs stored on a single disk are readily accessed (read from, written to, deleted, etc.) without user concern for such details as physical location on the disk, block availability, etc. There are two instructions for saving programs: PSAVE allows a new program, currently in memory, to be saved on disk; DSAVE allows you to overwrite a program already on disk with an edited version without having to first delete the disk version. You can also save portions of a program, so that later only the segments required need be loaded.

The two instructions for loading a program in memory from disk are: NLOAD clears memory before loading so that the program is loaded exactly as on the disk; PLOAD doesn't clear memory, allowing lines to be added to or replaced in the program existing in memory.

The Debug program is an invaluable aid to troubleshooting both hardware and software problems. When you issue the DEBUG instruction and respond to the prompts, it causes the operating system to pause at (“trap”) any selected point in the program (a specific line or test), allowing you to examine and modify hardware and software setups. The following may be displayed:

- Calculated output voltage and state of all voltage sources
- System reference DAC setup conditions
- All measurement system conditions
- Measurement result data
- Codes last specified for the digital control and driver bits
- Digital control readback and digital device readback bits.

Utilities include a *Handler Setup Program*, a menu-type fill-in-the-blanks program for automatic handlers; *Convert to File*, for programs written with previous revisions of the operating system; *Function Switch Module*, for subroutines to automatically per-



form such functions as Datalog Stop on Fail, Yield, Statistical Analysis, etc.; *Statistical Print* of files generated by the Function Switch Module; *Disk Copy*; and *Remember*, which reads a BASIC program from a disk, modifies it, and returns it to the same disk, but with a different file name.

FAMILY TEST PROGRAMS

Family Test programs permit specific classes of devices (op amps, DACs, regulators, etc.) to be comprehensively tested, by the use of menu-type “fill-in-the-blanks” programming. Three executable programs are included: CREATE, used to generate and/or edit the device test program; TEST, which causes the tests to be performed; and CONVERT, which converts programs created with previous software to the correct format for use with the new software.

In CREATE, there is a choice of four modes: Command, Edit, Set I/O, and File. The last three modes can also be reached from COMMAND, which is also the jumping-off point to: Menu, List, and Define. MENU displays the list of available tests. LIST displays a listing of test programs currently in the test program buffer. DEFINE causes the program to enter a question-and-answer dialogue to define the general characteristics and initial conditions of the device to be tested. When you have defined the device to be tested, the program will give you the opportunity to build a test program by stepping through each test function, using these questions:

NEXT TEST IS: test name, DEFINE? (Y,N)

If “N”, the test is skipped and it goes on to the next. If “Y”, the dialogue for that test is entered. After stepping through all the questions, it will repeat to permit checking and revision—escape is possible at any time by up-arrow and carriage return, leading to:

REPEAT THIS TEST? (Y/N)

“Y” indicates that you wish the program to repeat this test; a new dialogue will be started. “N” takes you to the next test.

EDIT mode allows you to edit existing device test programs. It may entail listing, viewing, modifying, inserting, and deleting test functions, as well as editing the Definition conditions. SET I/O permits you to select or de-select output logging devices or switch command input over to the LTS console. FILE allows you to perform various disk maintenance functions and load a new program. ▣

*For technical data, use the reply card.

†The LTS-2000 was described at length in *Analog Dialogue* 13-1 (1979), the LTS-2010 BASIC-programmable version was described in 14-2, page 10.

HIGH-PERFORMANCE HYBRIDS FOR DATA-ACQUISITION

12-Bit AD5210 Series ADCs for Accuracy Over Temperature

AD5240 12-Bit ADC (5 μ s Conversions) and AD346 S/H (2 μ s Acquisition) for Speed

The AD5210* and AD5240* 12-bit a/d converter families and AD346* track-hold amplifier are high-performance-and-reliability DIP-packaged devices with industry-standard pinouts designed for applications in military, industrial, and commercial data-acquisition-system design. They have versions designed for high performance over the -55°C to +125°C temperature range, are available with screening to MIL-STD-883, and have existing second sources.

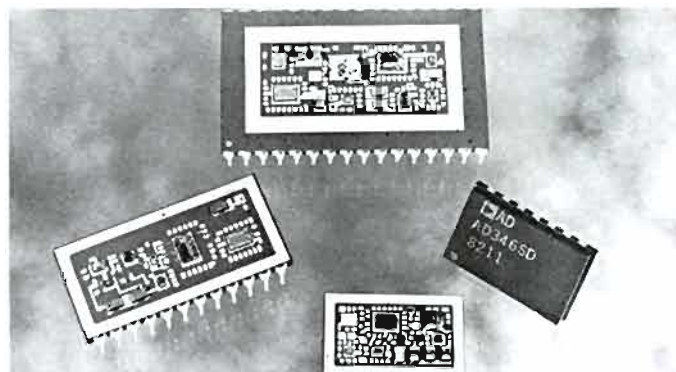
Because of their lower chip count and the use of a hermetically sealed SLAM ceramic DIP package, with its minimal number of bond wires, all three devices are characterized by higher predicted reliability than comparable devices now on the market.

AD5210 HIGH-ACCURACY ADC FAMILY

The members of the AD5210 family are high-performance adjustment-free 12-bit a/d converters that guarantee $\pm 1/2$ LSB non-linearity and no missing codes over the operating temperature range (all versions)—and maximum gain error as small as $\pm 0.1\%$ of full-scale-range (± 4 LSBs) over temperature (AD5214 and AD5215). Maximum conversion time for all versions is a fast 13 microseconds. The table indicates the principal distinctions between members of the family:

Type	-55°C to +125°	-25°C to +85°	-5V to +5V	-10V to +10V	Internal Ref.	External Ref.
AD5211B		X	X		X	
AD5211T	X		X		X	
AD5212B		X		X	X	
AD5212T	X			X	X	
AD5214B		X	X			X
AD5214T	X		X			X
AD5215B		X		X		X
AD5215T	X			X		X

Other input voltage ranges are also available. Prices (100s) are \$158/\$257 for BD/TD versions, \$273/\$385.50 for BD/TD/88.3B, with substantial discounts for higher quantities.



AD5240 HIGH-SPEED ADC FAMILY

The AD5240KD and AD5240SD are 12-bit a/d converters with 5 μ s maximum conversion time and guaranteed no-missing-codes over their operating temperature ranges. Besides being fully compatible with requirements for 5240-type converters, it is pin-compatible with ADC85 sockets and can be used to upgrade conversion speed (from the 10 μ s conversion time specified for ADC85), for a substantial increase in throughput rate, especially when used with the AD346 sample/hold, described below. (The AD ADC85* is available for ADC85 applications where 10 μ s conversion time is adequate).

An important feature of the AD5240 family is a "Z" version, that can provide specified conversion speed over the full-MIL temperature range while operating on ± 12 -volt power supplies. Included in the AD5240 is an on-board buffer, which can be used to unload signal sources that are "soft" at the high switching rates encountered in fast successive-approximation ADCs. Prices of the AD5240 family start at \$151 in 100s (AD5240KD).

AD346 FAST SAMPLE-HOLD

The AD346 is a high-speed sample-hold suitable for use with 12-bit a/d converters, such as the AD5210 and AD5240. Its guaranteed maximum acquisition time is 2 μ s to 0.01% of final value, for a 10-V step, increasing to only 2.5 μ s for a 20-V step. Thus, in a single-channel application with the AD5240, such as that shown in Figure 2, a throughput rate of 143kHz is available. Price of the AD346 starts at \$56 in 100s.

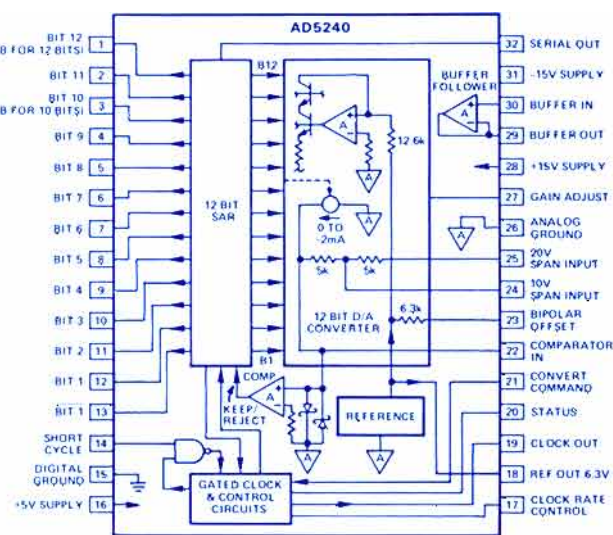


Figure 1. Functional diagram of the AD5240.

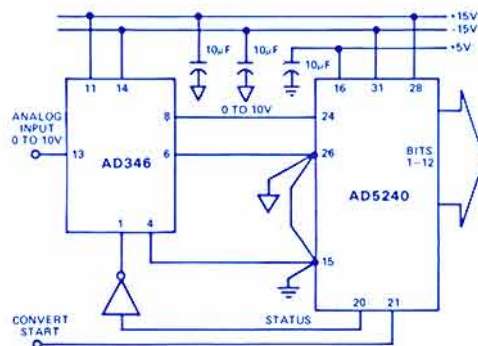


Figure 2. Applying the AD346 with the AD5240 in a 143kHz 12-bit conversion system.

*For technical data, use the reply card.

SUPER-PERFORMANCE HYBRID OP-AMP FAMILIES

Combine Low Offset Voltage, Low Drift, and Low Bias Current
With Clean Fast Settling, Slewing, Wide Bandwidth, and Load Driving

The AD380*, AD381*, and AD382* FET-input op-amp families combine high speed and precision, without external trim circuitry. For example, the AD381L and 382L have 0.25-mV offset and 700ns settling to 0.1%, the AD380L, with 1 μ V maximum offset, settles to 0.01% in 250ns, and the AD380 and AD382 families will drive ± 10 -V loads to ± 50 mA. Their performance (typical at +25°C and nominal supply voltage, unless noted otherwise) is summarized in the following table:

	AD380L	AD381L	AD382L
Open-loop gain (with R_L), V/V min	25k(200 Ω)	100k(2k Ω)	40k(200 Ω)
Offset voltage, mV, max	1.0	0.25	0.25
Drift, μ V/°C, max	10	5	5
I_{BIAS} , μ A, max	100	25	25
Settling time to 0.01% (10V step)	250ns	1.2 μ s	1.3 μ s
Settling time to 0.1%, ns	130	700	700
Slewing rate, V/ μ s	330	30	30
Small-signal bandwidth, MHz	40	5	5
Gain-Bandwidth Product @10MHz, MHz	350		
I_{OUT} , mA min, at ± 10 V	± 50	± 10	± 50
Package configuration	TO-8	TO-99	TO-8

Typical applications of these amplifiers are in high-resolution graphic displays, fast current-to-voltage translation for d/a converter circuits, photodetector signal conditioning, fast sample-holds, pulse conditioning, precision buffering for driving coaxial cables, and pin drivers for automatic testing.

AD380 – FAST-SETTLING 50-mA DRIVER

The AD380 has a slewing rate of 330V/ μ s and will output ± 50 mA into a 200-ohm load. When used without compensation, its 350MHz gain-bandwidth product permits wideband closed-loop response, for example, gain of 70V/V with a 5MHz bandwidth. When compensated, it provides clean, fast settling, as noted in the table. At the same time, its low offset, drift, and bias current make it suitable for general-purpose measurement circuits that must respond stably and accurately to a wide range of high- and low-level dc and ac signals, with a minimum of loading. Prices (J version) start at \$34.50 in 100s.

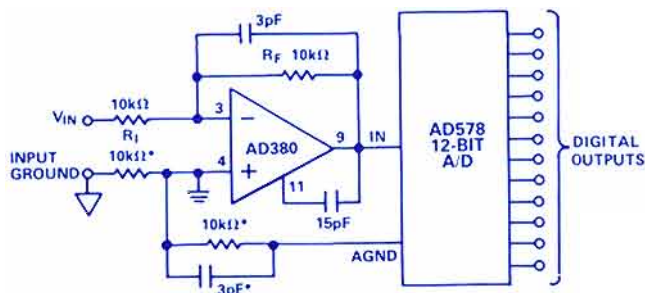


Figure 1. AD380 in a buffer application.

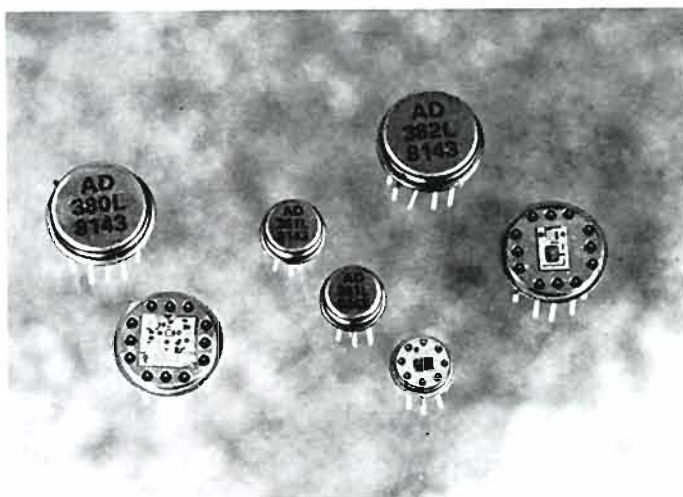


Figure 1 shows how it might be used as a fast-settling buffer between a sensitive dc measurement circuit, having slow response and "soft" dynamic output impedance, and a successive-approximation a/d converter, to keep the fast bit-current pulses appearing at the AD578 input from affecting the accuracy of the measurement circuit.

Figure 2 shows the large-signal output response of the AD380 and the error appearing at a dummy summing point, in a unity-gain inverter circuit employing 5k Ω input and feedback resistors.

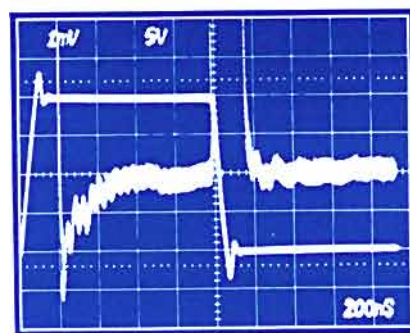


Figure 2. Unity-gain inverter, large-signal response of AD380.

AD381 – LOW-DRIFT OP AMP

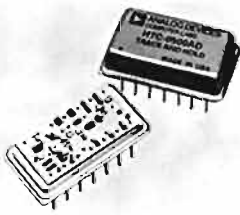
The AD381 combines low offset and drift with compensated, moderately fast response. Its low bias current, as with all Analog Devices FET-input op amps, is specified conservatively. Its output furnishes ± 10 V at ± 10 mA. Prices start at \$8.50 in 100s (J version).

AD382 – LOW-DRIFT HIGH-OUTPUT OP AMP

The AD382 combines the dc and ac characteristics of the AD381 with the high output drive of the AD380, a useful combination in line-driver and buffer applications that need high gain-accuracy over the audio frequency range. Prices (J) start at \$17.50 (100s). ▶

*For technical data, use the reply card.

FAST TRACK-HOLD 1.3 μ s max Acquisition Time To 0.01% for 20-Volt Step



The HTC-0500* is a fast track-hold circuit in a 14-pin hermetically sealed metal DIP. Its combination of speed, low power dissipation, and low cost makes it attractive for applications with a wide variety of monolithic and hybrid a/d converters; for example, to obtain a 250kHz throughput rate with the 12-bit, 2.8- μ s HAS-1202.

As Figure 1 shows, the HTC-0500 provides sign inversion, and the tracking loop is closed externally, permitting the user to add external resistance in series with the input and feedback resistors to adjust the gain around its nominal magnitude of 1.00.

The HTC-0500's acquisition time to $\pm 0.1\%$ is typically 700ns (800ns max) for a 10-volt step, and aperture time is 30ns (± 5 ns), with an uncertainty of 100ps max. Its droop rate of 0.002mV/ μ s permits relatively long hold times. The HTC-0500 has modest quiescent power requirements: 810mW max.

Besides serving as a low-aperture-time front end for a/d converters, the HTC-0500 also has uses as a deglitcher on the output of d/a converters, in analog peak detection, and for other analog applications.

Available for both the -25°C to $+85^{\circ}\text{C}$ and -55°C to $+125^{\circ}\text{C}$ temperature ranges, the HTC-0500 is also available processed to MIL-STD-883, Method 5008. Prices start at \$79 in 100s (HTC-0500AM) \blacktriangle

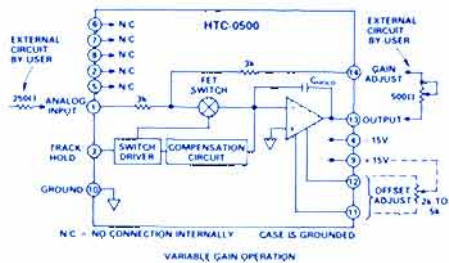


Figure 1. Functional diagram of HTC-0500

*Use the reply card for technical data.

12-BIT, 5-MHz ADC FOR MIL APPLICATIONS

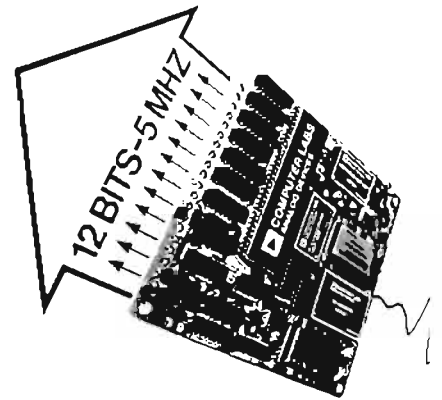
The MOD-1205MB: Complete, Compact, and Characterized A Documented Version of the Proven MOD-1205 A/D Converter

The MOD-1205MB* is a version of the MOD-1205, the popular 12-bit, 5-MHz analog-to-digital converter (see *Analog Dialogue* 14-1, 1980), designed for use in radar/sonar digitizing, real-time spectral analysis, digital communications, and similar functions typically found in defense-related applications.

The following features may be of interest to users for these applications:

- All specifications are characterized with min/max limits.
- All components are procured or screened in accordance with appropriate MILSTDs.
- Each converter bears a serial number for traceability.
- Each converter is shipped with serialized test data showing results of static and dynamic testing.

Each device is complete; no external parts are required. And logic is TTL-compatible,



eliminating the need for external ECL-TTL-ECL circuitry.

Constructed on a single 5" x 5.43" x 0.5" (127 x 138 x 12.7mm³) printed-circuit card, the MOD-1205MB includes a track-hold amplifier with 25ps maximum aperture uncertainty, an encoder, and timing and output registers. The single-piece price is \$4995, with substantial discounts for quantity. \blacktriangle

MONOLITHIC ADC—12 BITS + SIGN CMOS AD7552 is Ratiometric, Microprocessor-Compatible Has Polarity, Overrange, Low Power Dissipation, Low Cost

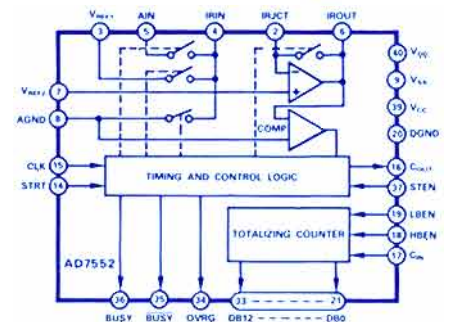
The AD7552* is a monolithic integrating a/d converter with 12-bit-plus-sign resolution, plus overrange, housed in a 40-pin dual in-line package. Drift is minimized by patented Quad-Slope conversion, which converts offsets to a digital number that is then used for correction.

The AD7552's parallel output data lines have three-state logic and are microprocessor-compatible. The lower eight LSBs and the five MSBs can be enabled separately, for a choice of interfacing to 8- or 16-bit data buses. Three flags—OVER-RANGE, BUSY, and $\overline{\text{BUSY}}$, controlled by STATUS ENABLE, simplify interfacing to microprocessors.

The AD7552 is essentially complete, requiring an integrating R-C, a reference circuit, and clock capacitors for self-contained operation. The integrating amplifier, the com-

parator, logic, and analog-switching circuits are on-board. With a 250kHz clock, the conversion time is approximately 160 milliseconds. Conversion may be either self-starting or externally stimulated. A gated serial pulse train is available for isolated conversion using optocouplers and off-chip counters.

The AD7552KN is packaged in plastic and priced at only \$9.95 in 100s. \blacktriangle

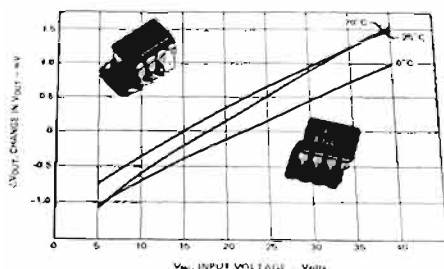


LOW-COST PRECISION IC REFERENCE

AD1403 & AD1403A: 4.5V to 40V In, 2.5V Out Improved Replacements for Standard Types

The AD1403* and AD1403A* are three-terminal devices that accept input voltage from 4.5V to 40V dc and provide a stable, accurate 2.5V at currents up to 10mA. Based on a patented bandgap circuit, these references use laser-wafer-trimmed thin-film resistors to achieve initial tolerances to within $\pm 10\text{mV}$ and temperature stability to better than $\pm 25\text{ppm}/^\circ\text{C}$ (AD1403A).

There are a number of applications for which they are ideal: Their accuracy and stability at low cost make them first choice for d/a and a/d converters. Since they can operate with 5-volt supplies, they are just right for applications where only a single 5-V logic supply is available. They will operate as precision current sources for currents from 1.5mA to 11mA. Last (but hardly least), they will serve interchangeably with economy and distinction as a superior first choice wherever generic 1403 or 1403A-type references have been specified.



The lowest-cost members of a distinguished family (including MIL-temp and 88.3 versions) of monolithic precision bandgap references—including the AD580 (2.5-V), the AD581 (10.0-V), the AD584 pin-programmable reference, and the AD589 1.2-V two-terminal reference—the AD1403 and AD1403A are packaged in 8-pin miniature DIP packages and are specified for operation from 0° to $+70^\circ\text{C}$. Prices for the AD1403N/AD1403AN (100s) are \$1.65/\$4.75. ▶

18-BIT SYNCHRO-TO-DIGITAL CONVERTERS

SDC/RDC1727 Accurate to Within $\pm 19.8''$ Over Temperature Available for Systems with 400Hz or 1000Hz References

Models SDC1727* and RDC1727* are Synchro- and Resolver-to-Digital Converters with resolution of 18 bits (4.9 arc-seconds) and accuracy to within ± 19.8 arc-seconds max over the full temperature range (optionally 0°C to $+70^\circ\text{C}$ or -55°C to $+105^\circ\text{C}$). Packaged compactly in $3.5'' \times 2.5'' \times 0.875''$ ($63.5 \times 88.9 \times 22.2\text{mm}^3$) modules, they are self-contained, including transformers on both the signal and reference inputs.

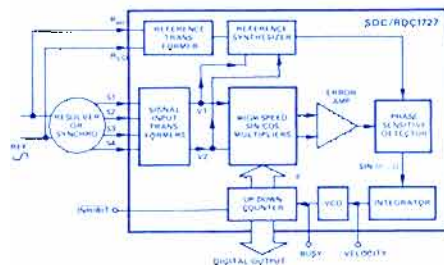
They are intended for use with high-accuracy synchros and resolvers as an alternative to two-speed (coarse/fine) synchro and resolver systems. Used with high-accuracy rotary devices, they can provide an angular measurement system of comparable accuracy but having none of the wear problems associated with coarse/fine mechanical gearing. Applications are to very-high-accuracy angular measurement systems, such as test

equipment, gun sights, stabilized platforms, and fire-control systems.

In addition to digital position information, these devices also make available a dc velocity signal for tachometric feedback. They are pin-compatible with the industry-standard 14-bit-device pinout, but they have extra input pins for the increased resolution.

Small-quantity prices are \$1995 (0°C to 70°C) and \$2295 (-55°C to $+105^\circ\text{C}$). ▶

*Use the reply card for technical data.



10-BIT IC DAC

High-Performance AD DAC100 MIL-STD-883B Available

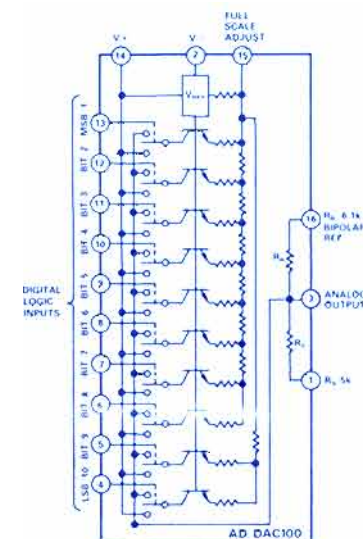
The AD DAC100* is a 10-bit monolithic current-output digital-to-analog converter packaged in a hermetically sealed 16-pin ceramic DIP. The Analog Devices AD DAC100 is form-, function-, and pin-compatible with the industry-standard DAC100; it is available with equivalents to all the popular versions and options, including processing to MIL-STD-883B.

Using ten precision high-speed current-steering switches, a control amplifier, a stable buried-Zener reference, and a laser-trimmed Si-Cr resistor network, the device produces a fast, accurate analog output current. Also included are laser-trimmed application resistors for accurate, stable current-to-voltage conversion, using an external op amp, such as the AD544 or the AD OP-07.

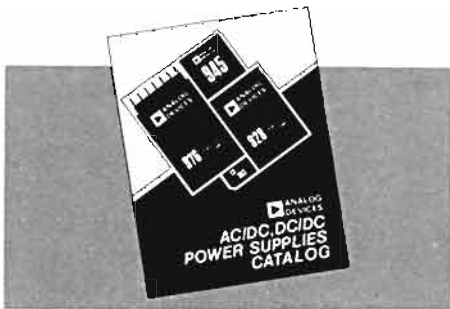
Nonlinearity of the AD DAC100 is less than $\pm 1/2$ LSB (0.05% FS) max for 10-bit conversion in the K, L, and T versions, and max full-scale tempo is ± 15 ppm/ $^\circ\text{C}$ in the L, ± 30 ppm/ $^\circ\text{C}$ in the K & T, and ± 60 ppm/ $^\circ\text{C}$ in the J and S. Maximum settling time to $\pm 0.05\%$ FS (1/2 LSB) is 375ns, dropping to $\pm 100\text{ns}$ for $\pm 0.8\%$ FS (8 LSBs).

The AD DAC100 is available in JD, KD, LD options (-25°C to $+85^\circ\text{C}$), /88.3B versions of those options, and SD/88.3B and TD/88.3B (-55°C to $+125^\circ\text{C}$) options. 5-volt-full scale and chip versions are also available. DIP prices start at \$14.10 (JD-100s). ▶

*Use the reply card for technical data.



POWER SUPPLIES Modular AC/DC & DC/DC Types 18 New Models in New Catalog



If you build anything that uses any of our active components, you need a power supply—to obtain dc power from line voltage or to convert dc power at an existing supply voltage to a more-suitable level (or dual levels). It's not surprising that, recognizing this important requirement, we've always made low-cost, reliable power supplies of various capacities available with the rest of our product line.

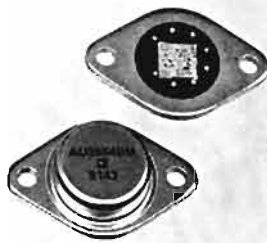
The new 12-page catalog shown above* describes our present line of more than 40 modular ac/dc and dc/dc power supplies of various capacities, sizes, and numbers of outputs for printed-circuit board and chassis mounting. Included in the catalog are separate Selection Guides for ac/dc and dc/dc power supplies and a set of outline drawings. In addition, to aid users in applying the power supplies, there is information on test conditions and procedures, power-distribution, grounding, decoupling, transients, and thermal derating.

AC/DC: P-C-board-mounted supplies in this category provide single 5V outputs at up to 3 amperes, dual $\pm 15V$ output at up to $\pm 350mA$, and combinations of the two at up to 1A/ $\pm 150mA$. Chassis supplies furnish a similar range, with up to $\pm 500mA$ at $\pm 15V$. In addition, there is the unique 2B35 transducer supply, which furnishes a resistor-programmable +1V to +15V at 125mA for transducer excitation and $\pm 15V$ at $\pm 65mA$ for instrumentation.

DC to DC: A wide range of supplies in this class, including a new series of 1-watt 24-pin DIP-compatible units, provides $\pm 15V$ from 5V, 12V, 24V, and 28V dc primaries, at up to $\pm 410mA$, and 5V from 5V at up to 1 ampere. ▶

*Use the reply card to obtain a copy.

2 ULTRAFAST OP AMPS: AD3554 & HOS-050C AD3554 Is User-Compensated to Fit the Application Slews @ 1000V/ μs , Settles to 0.05% in 150ns Max



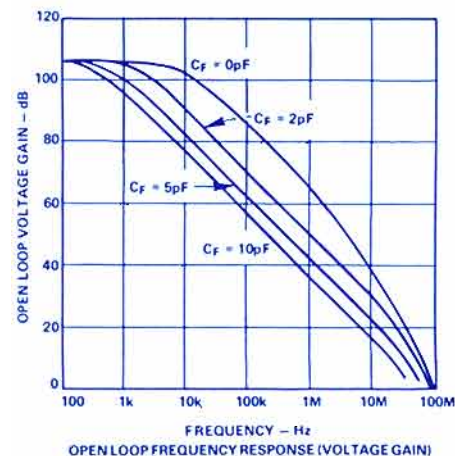
The AD3554* is a FET-input hybrid operational amplifier, packaged in a TO-3-style hermetically sealed metal can, capable of delivering $\pm 100mA$ output current at $\pm 10V$. Its high slewing rate (1V/ns) and fast settling time to 0.01% (250ns max) make it ideal for d/a and a/d conversion, sample-hold, and video instrumentation circuits. It is a pin-compatible replacement in existing applications specifically calling for generic 3554-type amplifiers.

The illustration shows the typical range of gains and bandwidths available as a function of the external compensation capaci-

ance. With its 1.7GHz gain-bandwidth ($A = 1000$), it is an ideal choice for small-signal high-frequency amplifier applications.

DC performance is also excellent: it is laser-trimmed for 1mV max offset (AD3554B) and has bias current of only 50pA max. It is available in 3 offset/drift grades: A & B for $-25^{\circ}C$ to $+85^{\circ}C$, and S for $-55^{\circ}C$ to $+125^{\circ}C$. Prices start at \$47.50 in 100s. ▶

*Use the reply card for technical data.



Low-Cost HOS-050C Is Internally Compensated Settles to 0.1% in 80ns, 0.01% in 200ns



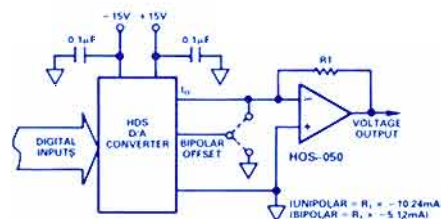
The HOS-050C is the newest—lowest cost—member of the HOS-050 family of high-speed wideband hybrid operational amplifiers, packaged in the hermetically sealed TO-8 can. All members of the family are characterized by a stable, essentially, 6-dB-per-octave rolloff to 100MHz unity-gain bandwidth, slewing rate of 300V/ μs , and settling time of 80ns to 0.1%.

All models have a rated output of $\pm 10V$ at $\pm 100mA$. The "C" version differs only in temperature range ($-25^{\circ}C$ to $+85^{\circ}C$) and offset/drift (65mV max, 200 $\mu V/^{\circ}C$ max). Its price is only \$55 in 100s.

APPLICATIONS

With its high gain-bandwidth, fast settling, and high output drive, the HOS-050C is well-suited to applications with fast current-output d/a converters. The figure shows a circuit employing it in an inverting application as an output (unipolar or bipolar) amplifier for the HDS* series of fast 8-10-12-bit DACs (available in TTL and ECL versions, current-settling times of 10ns to 40ns). ▶

*Use the reply card for technical data.



TEST SUB-PICOAMP BIAS CURRENTS

Automatically on the Computer-Based LTS-2010 Tester Using the LTS-0607 Low-Leakage Socket Assembly



The LTS-2010* can test single, dual, or quad op amps for leakage current from 1nA to 50 fA, using the specially designed LTS-0607 Low-Leakage Socket Assembly with the LTS-2100 Operational Amplifier Family Board and the Low-Leakage Test subroutine option in the Op-Amp Test Create program.

Testing low bias currents† is difficult because leakage in the test circuitry causes errors, and the output voltage of the test must be substantially larger than the amplifier's offset.

The LTS-0607's entire assembly is shielded and grounded to minimize ac pickup, and Teflon pins are used for the socket-assembly inputs and the pins on the DUT socket circuit board. The socket itself is shielded by a hinged cover, which closes over the device. Conscientious care and cleaning on the part of the user are key to continued satisfactory testing.

Instead of unreasonable values of resistance, the LTS-0607 uses a stable, precise 1000pF capacitor. The bias current, flowing through the capacitor, develops a $\Delta V/\Delta t = I/C$. Thus, 1 pA of bias current would produce a $\Delta V/\Delta t$ of 1mV/s. The LTS software allows the capacitor voltage to ramp for a suitable period of time, then computes $I = C(V_2 - V_1)/(\Delta t)$. An AD590* on the fixture measures the ambient temperature to correct its effect on bias current. ▢

* For technical data, use the reply card.

† For details, see *Electronic Design*, Nov. 12, 1981, pages 225-230.

μMAC EXPANSION

Analog Output & Digital I/O Increase System Capacity



μMAC4030* and μMAC4040* are Analog Output and Digital I/O Expansion Boards for use with the μMAC-4000 single-board intelligent measurement-and-control system. Both boards plug directly into the μMAC-4000 card cage and are economically priced from \$790 & \$545.

The μMAC-4030 contains eight separate 12-bit d/a converters and provides eight user-programmable channels of either voltage output (several ranges available) or—optionally—± 1000-volt-peak isolated (input-to-output or channel-to-channel) 4-to-20mA or 0-to-20mA current-loop output.

Its 130-V-rms-protected voltage and isolated current-loop outputs may be mixed on the same board in blocks of four and are intended for use in controlling motors, valve positioners, and servomechanisms, or for displays, using analog indicators or recorders. The high common-mode-voltage isolation ensures reliable operation of the current loop in the presence of transient and fault voltage—a necessity in industrial environments.

The μMAC-4030's on-board microprocessor provides key functions, such as increment/decrement for backup control, data readback for bumpless transfer from manual to automatic control, programmable slew rate to control the rate of advance from one setting to another, and output scaling in engineering units, via a simple command set.

The μMAC-4040 is a low-cost 64-channel digital input/output (I/O) board with 32 channels of digital output and 32 channels of optionally isolated digital input. It interfaces contact closures and parallel digital inputs to the μMAC-4000 for load-control and direct digital control. ▢

* Use the reply card for technical data.

ACCURATE THERMOCOUPLE MEASURING

Reference, Cold-Junction Compensation, and Filtering
MACSYM's STB03 14-Channel Isothermal Termination Panel

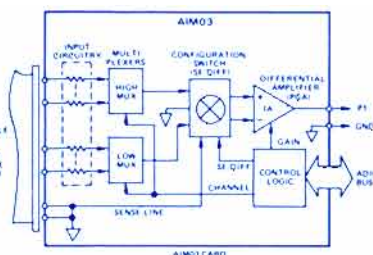
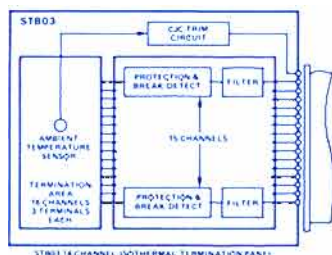
The STB03-01/STB03-02* are 14/28-channel isothermal termination panels that interface thermocouples to MACSYM systems. The STB03 accepts any combination of popular thermocouple types (J, K, T, E, R, S). 28 channels require only 2.71" of vertical space in a standard 19" mounting rack.

The STB03, compatible with the AIM03* solid-state analog input card, provides passive 2-pole filtering, open-thermocouple detection, an AD590 temperature sensor, and input protection against 120V ac rms.

The high-density package design minimizes rack space and insures accurate measurements by maximizing thermal conduction within the terminal area and insulating it from external thermal gradients.

Data acquired via STB03 and AIM03 can be subjected to the software AVG mode—to average many readings of a channel at specified time intervals (at 60Hz for line-frequency rejection), up to 4000 samples per second—and the SCAN mode, to sample many channels at up to 2000/s. ▢

* Use the reply card for technical data.



Worth Reading

2-VOLUME 1982 DATABOOK

The *Analog Devices 1982 Databook* is a 1536-page comprehensive two-volume collection of technical information on data-acquisition components and subsystems for measurement and control. It's free, upon written request.



According to Corporate Director of Marketing, George Adams, "With the introduction of more than 60 new products since our last catalog, Analog Devices continues to offer you the broadest selection of data-acquisition solutions. So many, in fact, that two volumes are now required to describe them. Our broad and rapidly growing line of integrated-circuit products is described in Volume I. Volume II includes our wide range of modules and subsystems, from signal-conditioning components to complete intelligent data-acquisition systems.

"The volumes are organized functionally and are fully cross-indexed, so that you can easily find the solution you're looking for, no matter which volume you hold in your hand. The identical Index in each volume and the Selection Guides provide page locations of all products.

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ADI AUTHORS IN THE TRADE PRESS

"Get a Fast, Accurate Handle on FET-Amplifier Bias Current," by Allan Ryan, *Electronic Design*, November 12, 1981, pp. 225-230

"Low-Level Analog Signal Conditioning," by Bob Butler, *Electronic Products*, November 30, 1981, pp. 65-67

"Low-Cost RMS/DC ICs Upgrade AC Measurements," by Lew Counts, Chuck Kirchin, and Walt Jung, *EDN*, January 20, 1982, pp. 101-112

"Fixture, Tester Whip Through Instrumentation Amplifier Tests," by D. Perkins, *Electronic Design*, February 4, 1982, pp. 131-136

"V-f Converters Demand Accurate Linearity Testing," by Larry DeVito, *Electronic Design*, March 4, 1982, pp. 105-110

"Computerized Measurement & Control," by Bill Schweber, *Quality*, March, 1982, pp. 38-41

FEATURED IN MACSYMIZER

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AUTHORS (continued from page 2)

John Mills (page 11) is Senior Marketing Engineer for Subsystem Products at Analog Devices. John earned his BSEE degree at Northeastern University. He first joined Analog Devices as an Application Engineer, then became a regional sales manager for Datal-Intersil and subsequently rejoined ADI in his present capacity. He enjoys softball, golf, cross-country skiing, and is a racquetball enthusiast.



Bill Schweber (page 12) is a Systems Application Engineer with ADI's MACSYM group. Before this, he designed microprocessor-based controls for materials testing equipment. Bill has a BSEE from Columbia University, an MSEE from the University of Massachusetts, and is a Registered Professional Engineer. His hobbies include bicycling, photography, model railroading, and "just taking care of things around the house, which often has a priority over the first three items."



Mike Slocombe (page 19) joined ADI's Component Test Systems organization as System Software Designer after 5 years in the ADI Semiconductor test-engineering group and a brief stint at LTX. At ADS, he designed computer-based in-house test equipment and implemented testing of many of the monolithic products on commercial testers. He formerly worked at Raytheon and has attended Northeastern University and the Berklee College of Music.



Don Travers (page 6), Senior Applications Engineer at Analog Devices Semiconductor, Wilmington, Mass, has a BSEE from Northeastern University. Before joining Analog Devices, he supervised the converter test department at Hybrid Systems. At ADI, he assisted in the development of data-acquisition products at our Microelectronics Division. After a brief stint at Parlex Corp., where he designed custom thick-film hybrids, he rejoined ADS in 1978 in his present capacity.



John Wynne (pages 3 and 16) is an Applications Engineer at Analog Devices B.V. (Limerick, Ireland). Previously, he was Telecommunications Project Engineer in the City of Dublin Devin Street Technical College, and later a Design Engineer at Sperry Gyroscope Avionics Division U.K.



An Eclectic Collection of Miscellaneous Items of Timely and
Topical Interest. Further Information on Products
Mentioned Here May Be Obtained Via the Reply Card.

IN THE LAST ISSUE (Volume 16, Number 1, 1982 - 24 pages) . . . Hybrid Isolation Amplifiers with a New Twist (AD293, AD294) . . . World's First Monolithic 16-Bit D/A Converter (AD7546). . . Monolithic 12-Bit DAC Has 6-Word FIFO Memory (AD7544) . . . Monolithic Systems DAC (AD7527) . . . First Monolithic FET Op Amp with $\mu\text{V}/^\circ\text{C}$ Drift (AD547) . . . Low-Cost 10- and 12-Bit Interfaces for STD Bus (RTI-1225 & 1226, RTI-1260 & 1261) . . . Testing A/D Converters Automatically . . . MACSYM 10 for Industrial-Plant-Floor Environments . . . Double-Buffered Complete Monolithic 12-Bit D/A Converter (AD567) . . . High-Resolution Data-Acquisition Family. . . and these New-Product Briefs:
Event-Counter Card for MACSYM (EVC01) . . . Pulse-Train Output Card for MACSYM (POC01) . . .
Loop-Powered Isolator for Industrial Applications (2B24). . . 12-Bit μP -Compatible Monolithic Multiplying DAC (AD7545) . . . Improved 12-Bit Complete IC A/D Converter: High-Speed Interfacing and $\pm 12\text{V}$ Operation (AD574A) . . . Fast 10-Bit ADC Converts in $1.8\mu\text{s}$ max (AD579) . . . Software for μMAC -4000 Compatible with DEC RSX-11, HP-85 and Apple II Computers . . . 4-Channel Signal Conditioner and Multiplexer (2B34). . . 12-Bit Tracking Inductosyn/Resolver-to-Digital Converter . . . Ivar Wold Named First Analog Devices Corporate Fellow . . . plus Editor's Notes, Authors, Worth Reading, Potpourri, etc.

ERRATA . . . DATABOOK, General Note: While assembling data-sheet material to appear in the Databook, we seized the opportunity to incorporate corrections of all known errors in previous editions of the data sheets. In cases of conflicts between the Databook and individual data sheets, give the Databook the benefit of the doubt for all data sheets published before December, 1981. If the data sheet is more recent, it is the more likely to be correct. You can find the month and year in which a data sheet was published on the last page at the upper right, following a set of vertically oriented characters, e. g., C692-9-2/82 . . . Some errata corrected in the Databook: DAC1106/1108 Absolute Accuracy Offset is $\pm 20\text{nA}$ (correct on page 10-12 of Volume II). Logic compatibility of the 458/460 v/f converters ("Voltage to Frequency Operation") is correctly stated in the Databook (page 12-19 of Volume II). All AD2040 errata found in previous editions of the data sheet have been corrected in the Databook (pages 16-53 and 16-54 of Volume II); they relate to: (1.) the notes below Figures 1 & 3, (2.) the steps in the calibration procedure, (3.) the mechanical drawing for the AC version, and (4.) the orientation of the Span and Adjust pots in the AC version. THC-0300 Track-and-Hold Amplifier input impedance is 10^{10} ohms, correctly given on page 14-16, Volume II . . . In Analog Dialogue 14-2, page 7, Figure 3, we show a scheme for increasing the resolution of an audio attenuator (using an AD7110) from 1.5 to .75 dB/bit, by adding a sub- ISB . To make it work properly, an inverter should be used in the new LSE line (either furnished externally or derived using the other half of the ADG200).

DIGITAL PANEL-INSTRUMENT CATALOG . . . The Digital Panel-Instrument Catalog is now updated and integrated with the DATABOOK: Volume II, Section 16. It includes Selection Guides, General Information and Definitions of Specifications, and technical data on Logic-Powered and AC-Powered Digital Panel Meters and Temperature-Measurement and Signal-Conditioning Meters

PRODUCT NOTES . . . Here's an interesting angle on the AD579 fast 10-bit a/d converter: When shortcycled for 8-bit conversion, it becomes a high-linearity converter with $1.5\mu\text{s}$ max conversion time for all grades above J. If you compare its cost with that of other fast 8-bit hybrid ADCs on the market, it turns out to be extremely competitive, especially for the MIL-STD-883B versions. And a ± 12 -volt-supply "Z" grade version is available . . . Benchmarks: MACSYM, a minicomputer-based measurement-and-control system, with such important features as integral process I/O statements and multitasking, is beyond comparison with other BASIC-oriented computers simply on the strength of conventional benchmark tests (e.g., empty do-loops, division, subroutine jumps, etc.) Nevertheless, it acquits itself rather well in many such contests when compared to such computers as Apple, IBM, and TRS-80. If you're interested in details, get in touch with our nearby Systems sales office . . . μMAC -4000 has successfully passed humidity tests according to MIL-STD-202, Method 103, Steady-State Humidity Specifications, and has successfully completed more than 11,350 hours of life testing. We also have a report from one customer of flawless operation with no failures over an 8-month period, including last summer's record heat spell, for 12 systems after installation in a remote oil-field application - the equivalent of 8 device-years!

PATENTS . . . The following U. S. Patents have recently been issued: 4,309,693, to Bob Craven, Solid-State Digital-to-Analog Converter . . . 4,313,083, to Barrie Gilbert, Temperature-Compensated IC Voltage Reference . . . 4,323,795, to Peter Holloway and Doug Mercer, Bias Current Network for IC Digital-to-Analog Converters and the Like (AD558).

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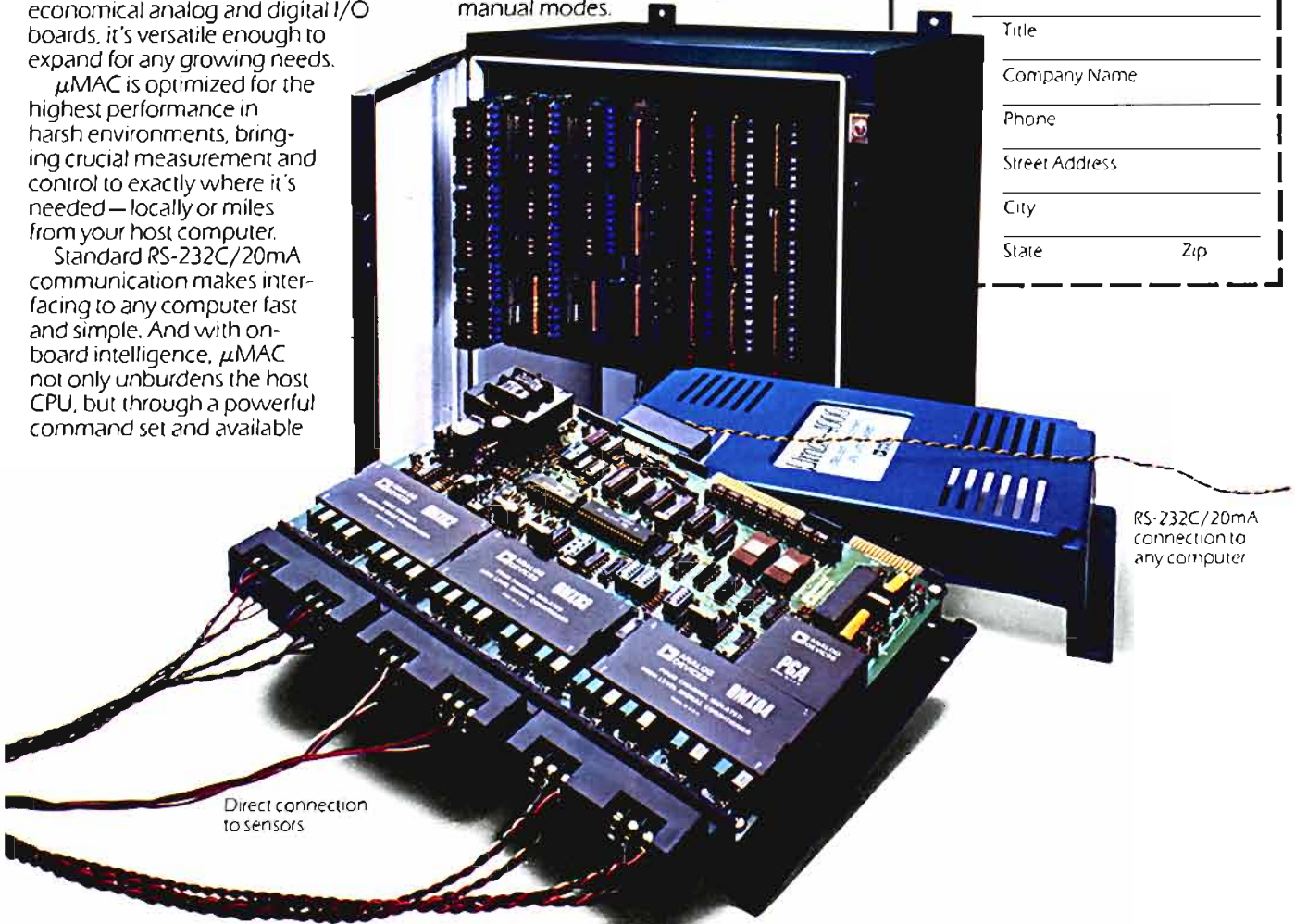
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