

analog dialogue

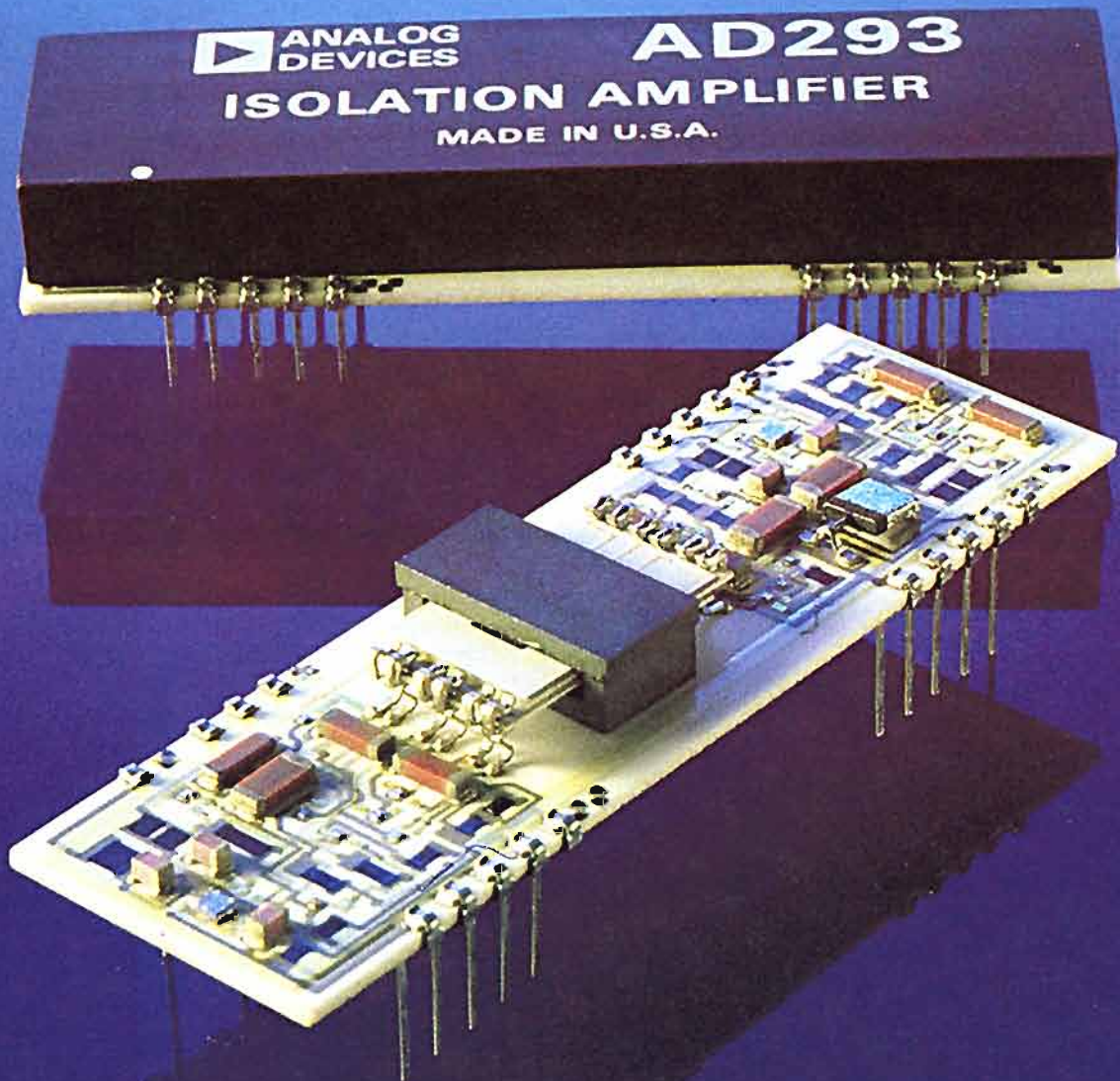
A forum for the exchange of circuits and systems for measurement, control, and test

HIGH-PERFORMANCE HYBRID-CIRCUIT ISOLATION AMPLIFIER (Page 3)

New Ideas in D/A Conversion (pp. 6, 7, 8)

Automated Testing of A/D Converters

Complete contents on page 3



 **ANALOG
DEVICES**

Editor's Notes

PREVIEWING THE ISSUE

This issue's unusually large number of pages are graced by a bulging menu of new products, many of which represent substantial technological advances. There are also more than a few industry firsts. To save you a little time and thought, we've selected a few of the highlights to discuss here:




The AD293 hybrid-circuit 3-port isolation amplifier, depicted on the cover, speaks eloquently for itself. The objectives were small size, ruggedness, low production cost, high reliability, and no sacrifices in performance. The key to meeting them was the design of a transformer with thick-film windings—fired at high temperature—and an interconnection system that eliminated the need for expensive bonding of fragile wire leads. This transformer, and an innovative circuit combining dc-dc power conversion with precision modulation/demodulation, made the AD293/294 possible.

If you've tried it, you know that testing a/d converters is not easy under any circumstances. To meet the objective of designing an a/d test subsystem for devices with resolutions up to 16 bits and linearities up to 12 bits—one that must fit into the space allotted to the family board of a general-purpose linear test system (e.g., LTS-2010) and be usable by production-test personnel, evaluation engineers, and circuit designers (and be programmable in BASIC)—requires a mixture of innovation, patience, and passion. The successful scheme, which resulted in a family board now in production, is described at page 12.

Until now, there hadn't been a monolithic chopperless FET-input op amp in production with drift trimmed to a guaranteeable $1\mu\text{V}/^\circ\text{C}$; now there is—the AD547 (page 9). Until now, there hadn't been a monolithic 16-bit voltage-output DAC in production; now there is—the AD7546 (page 6)!

In no way is the significance of these products diminished by our pointing out that, in these cases, the goals were quantitative, predictable (as in a race, *someone* was expected to be the first), and had existing visible well-known potential applications that exemplify the better-faster-cheaper aspect of progress, mentioned in this column last year ("What's News?", *Analog Dialogue* 14-2, 1980). You may recall our suggestion that there is, however, another dimension of progress, where the innovation is in the area of new potential applications, rather than improved value for an old application. Two products in these pages exemplify this:

The AD7544 12-bit multiplying DAC with 6-word FIFO memory (page 7), capable of being loaded in haste and converting at leisure (with a choice among the two bottommost words) greatly unburdens the processor's data bus and the software, and offers an unusual tool for the imaginative designer of accurate analog-digital systems. Then there's the AD7527 10-bit "Renaissance Man" among monolithic systems DACs (page 8). Features sported by this multiplying DAC include: flexible data format, double buffering, data readback, data override, and a counter and clock for incrementing. Its versatility boggles the mind! 

Dan Sheingold

THE AUTHORS

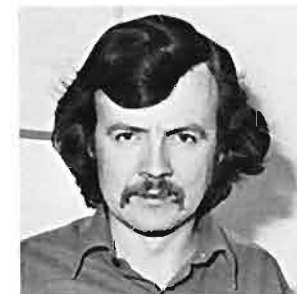
Ted Serafin (page 3) is a Marketing Engineer for Systems Components Products at Analog Devices. Ted earned his B.E.E.T. degree at DeVry Institute of Technology and Educational Certificate from Loyola University and has done graduate work in Systems Science and Business Management. Before joining ADI, he was Product Marketing Manager for Data-Acquisition Components at Teledyne Philbrick. He enjoys flying, music, woodworking, and sports.



Delip Bokil (page 3) joined the Systems Components Division of Analog Devices in September, 1978. Since that time, he has set up a hybrid prototype engineering laboratory and a pilot production facility. Earlier, he had worked for 9 years at RCA on various aspects of hybrid design and manufacturing. Delip has a B.S.E.E. and an M.S. in Engineering Management from Northeastern University. He and his family enjoy Sunfish-sailing and skiing.



Mike Tuthill (page 6) is a Senior Design Engineer at Analog Devices, B.V., in Limerick, Ireland. He has been with Analog Devices since the start of our analog CMOS operation five years ago. Earlier, he had worked with Marconi Radar Division, in England, and with Teletron, a communications firm in Dublin. Born in Limerick, he was graduated from University College, in Cork, with a B.E. degree, in 1970.



John Wynne (page 6) is an Applications Engineer at AD BV (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.



(Continued on page 22)

analog dialogue

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HYBRID ISOLATION AMPLIFIERS WITH A NEW TWIST

AD293 & AD294 Have High Performance, Low Cost, Small Size

A Technological Advance in Transformer Design is the Key

by Ted Serafin and Delip Bokil

Models AD293 and AD294* are electromagnetically isolated amplifiers in a 40-pin-size DIP package, featuring gains adjustable from 1 to 1000, bandwidths of 2.5kHz (small signal) and 200Hz (large signal, unity gain), and linearity error well below 0.1%. The AD293, with versions for industrial and military applications (including screening and testing to MIL-STD-883B†), provides $\pm 2500V$ peak isolation to protect users and equipment against high transient voltage and lethal ground-fault currents. The AD294, with $\pm 8000V$ peak common-mode voltage and $2\mu A$ rms maximum line-frequency leakage current, meets needs of patient safety and defibrillator protection for clinical instrumentation.

Safe, accurate, low-cost measurement of transducer signals in the presence of substantial common-mode voltage, and ground systems of questionable integrity, has long been a challenge to designers of instrumentation systems for industry and medicine.‡ Since we brought the first isolation amplifier module to market ten years ago (Model 272: *Analog Dialogue* 5-2, 1971), Analog Devices has successfully sought ways to reduce size and cost, while improving performance and reliability. Now, not only do the hybrid AD293 and AD294 represent a further significant advance in isolator design; they are also the first fruits of a revolutionary approach to compact-transformer design and construction.§

HOW IT WORKS

The basic design of both amplifiers is identical. As shown in Figure 1, an amplifier is divided into three isolated sections—input, output, and power—coupled together by a single transformer. An oscillator (which may be powered by system power or a separate power source) furnishes isolated power to the input amplifier, plus a carrier, which is modulated by the amplified input signal, coupled across the isolation barrier to the output section, demodulated, and buffer-amplified by a system-powered output amplifier.

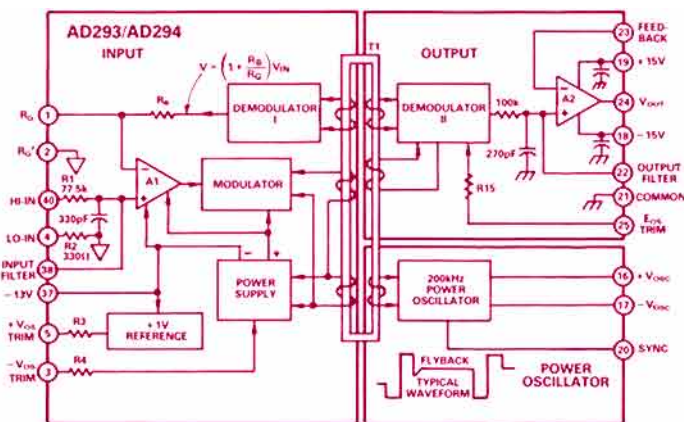


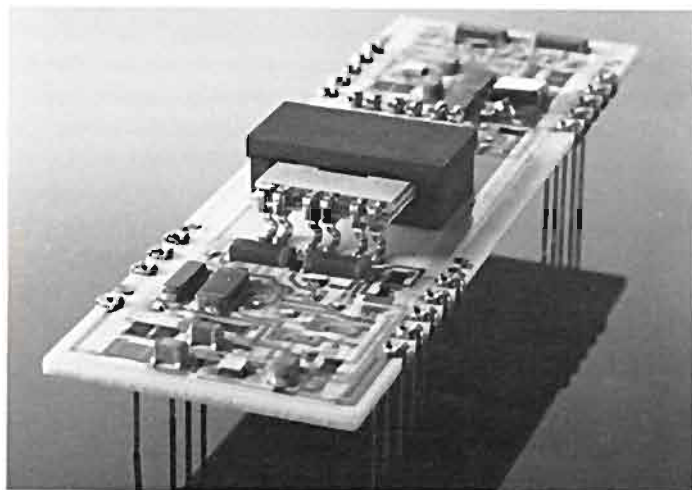
Figure 1. Simplified block diagram of the AD293/AD294.

*Use the reply card for technical data.

†Available in mid-1982

‡For typical applications of isolators with transducers see the *Transducer Interfacing Handbook—a guide to analog signal conditioning*, D. H. Sheingold, ed., Analog Devices, Inc., 1980, \$14.50.

§Patents applied for



Two significant innovations are responsible for the small size and excellent performance of these amplifiers. The first is an ultra-compact transformer, using screened wiring and well-conceived assembly technology (see page 5). The second is an improvement

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in the use of the flyback (unclamped) portion of a blocking-oscillator waveform as the modulated signal carrier (U.S. Patent 4,286,225).

As the block diagram shows, the synchronizable oscillator requires a two-wire power supply, which may be different (and isolated) from the power supply for the output amplifier, A2. The oscillator's output is coupled to (and loaded by, but isolated from) the circuitry connected to the other five identical transformer windings. One winding delivers power to the input amplifier, A1.

The flyback portion of the oscillator waveform is amplitude-modulated by A1's output signal, then coupled through separate transformer windings to a demodulator (I) in the amplifier's feedback path. Since A1 is an operational amplifier, the feedback signal must replicate the input signal (gain, from 1 to 100V/V, is equal to $1 + R_g/R_C$), and the transformer flux during flyback must be whatever is necessary to make this happen. The common flux, through an identical winding, applied to an identical demodulator (II), causes its output to be very nearly identical to the voltage at the output of the first demodulator, i.e., an accurately amplified version of the input signal. The other winding connected to Demodulator II provides a reference signal. The output of the demodulator is filtered and buffered by output amplifier, A2, which may be connected for gain values from 1 to 10V/V.

The AD293 and AD294 are 3-port isolators; the input, output, and power sections are mutually isolated from one another. The use of separate substrates for the spiral-winding triplets of the transformer makes possible isolation of $\pm 2500V$ (peak or con-

tinuous) for the AD293, and $\pm 8000V$ (pulse, 10ms pulse) for the AD294, between the input and output/power circuits. The high-temperature-fired dielectrics between the individual windings permit 250V rms of isolation between the output and power ports.

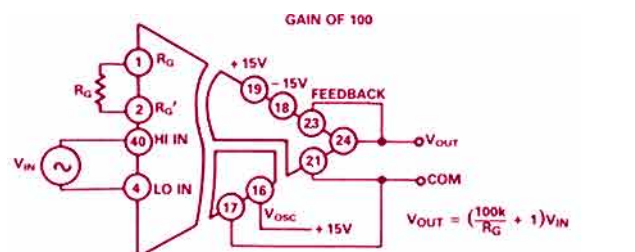
PERFORMANCE

Table 1 summarizes the salient specifications of the AD293 and AD294. Users can tilt the specifications to optimize performance in a given application by the use of offset adjustments and choice of their location, by the use of added filtering, and by choice of the respective amounts of gain in the input and output sections. Some examples of these techniques are mentioned below.

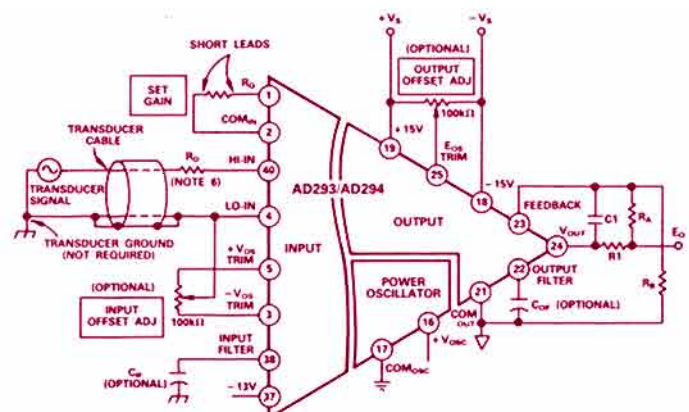
APPLYING THE AD293 AND AD294

Figure 2a shows the basic connections of the amplifiers for a fixed value of gain in the simplest case. Figure 2b shows the options made possible by the many degrees of freedom. Gain setting and filtering can be accomplished at the input and/or the output stages without impairing the true galvanic isolation. Two additional poles of filtering can be easily provided without the addition of external operational amplifiers.

Since gain can be set independently at the input and the output amplifiers, properties of the isolator can be tailored to the application to minimize errors and optimize response. For example, Figure 3 shows that *linearity* can be improved by increasing the output gain and reducing the input gain (nonlinearity comes from slight differences in responses of the transformer windings and the matched demodulators, and rectification of carrier signal at large signal amplitudes in the input section).



a. The simplest mode of connection.



NOTES:

1. GAIN RESISTORS R_G , R_A AND R_B , 1% 50ppm/°C METAL FILM TYPE.
2. INPUT GAIN = $1 + \frac{100k}{R_G}$; $R_G > 1k$; MAX INPUT GAIN = 100V/V.
 $R_1 = 100\Omega$ AND $C_1 = 100pF$ (OPTIONAL); REQUIRED ONLY FOR DRIVING CAPACITIVE LOADS $> 1000pF$.
3. OUTPUT GAIN = $\frac{R_A + R_B}{R_B}$; $1 < \text{OUTPUT GAIN} < 10$.
4. $C_{OF} = \frac{1}{2\pi f(97.5 \times 10^4)}$ FARADS.
5. $C_{OF} = \frac{1}{2\pi f(10^5)}$ FARADS.
6. R_D IS REQUIRED ONLY FOR THE AD294 TO PROVIDE PROTECTION AGAINST DEFIBRILLATOR PULSES. USE TWO 240k Ω 1/2 WATT RESISTORS. WHEN MOUNTING, PLACE THEM IN SERIES AND AWAY FROM THE PCB.

b. Interconnection options and filter parameters.

Figure 2. Connections to the AD293/294.

Table 1. Performance characteristics of the AD293 and AD294.

(Typical at +25°C and rated supply voltage, all devices, except as noted)

Gain formulae, nominal, 10V p-p Output	Input: $1 + 100k\Omega/R_G$ Output: $1 + R_A/R_B$
Temperature coefficient, $G = 1V/V$ $G > 1V/V$	$\pm 50ppm/^\circ C$ max $\pm 120ppm/^\circ C$ max
Nonlinearity, max (10V p-p out, AD293A/B/294)	0.1%/0.05%/0.1%
Input Voltage Rating, Differential	
Linear Range	$\pm 10V$ min 240V rms/120V rms
Maximum safe, one minute/continuous	
Input Voltage Rating, Common-Mode Input-to-Output	
Continuous (ac or dc)	$\pm 2500V$ peak 2500V rms
AC, 60Hz, 1-Minute Duration	
Pulse, 10ms Duration, 0.1% Duty Cycle, AD294A Only	$\pm 8000V$ peak
Common-Mode Rejection (60Hz), $G = 10V/V$	
Balanced Source Impedance, 1k Ω	108dB
1k Ω Source Imbalance	100dB min
Balanced Source Impedance, 5k Ω , AD294A Only	113dB
5k Ω Source Imbalance, AD294A Only	100dB min
Leakage Current, Input to Output, 115V ac, 60Hz	2 μA rms max
Input Impedance, $G = 1$	
Differential	150pF in parallel with $10^8\Omega$
Differential, overload	100k Ω
Common Mode	30pF in parallel with $5 \times 10^{10}\Omega$
Input Difference Current/Tempeco	2nA (5nA max)/2pA/°C
Input Noise ($G = 100V/V$)	
Voltage, 0.05Hz to 100Hz	10 μV p-p
Current, 0.05Hz to 100Hz	50pA p-p
Rated Output Voltage, 2k Ω Load	$\pm 10V$ min
Frequency Response	
Small Signal (-3dB), $G = 1V/V$ to 100V/V	2.5kHz
Full power, 20V p-p Output	
$G = G_{IN} \times G_{OUT} = 1V/V \times 1V/V$	200Hz
$G = 10V/V = 1V/V \times 10V/V$	2.5kHz
$G = 100V/V = 100V/V \times 1V/V$	100Hz
Slewing Rate	9.1V/ms
Offset Voltage, Referred to Input	
Initial, at +25°, max	($\pm 3 \pm 15/G$)mV
Tempco, (0 to +70°C), typ.	($\pm 3 \pm 150/G$) $\mu V/^\circ C$
(-25°C to +85°C), max. AD293A/AD294A	($\pm 10 \pm 500/G$) $\mu V/^\circ C$
(-25°C to +85°C), max. AD294B	($\pm 3 \pm 250/G$) $\mu V/^\circ C$
vs. Supply Voltage	($\pm 0.01 \pm 3/G$)mV
Quiescent Power at $\pm 15V$ (V_{OSC} connected to +15V Supply)	+12mA/-1mA
Package Dimensions, 40-Pin-Size DIP	2.64" L. \times 0.86" W \times 0.35" H
Price in 100s, AD293A/B, AD294A	\$55/\$65, \$65

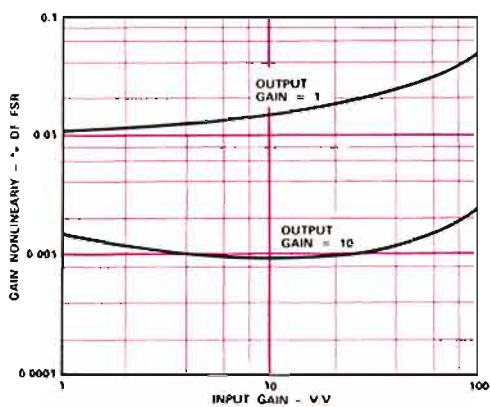


Figure 3. Linearity error vs. input-gain-stage gain – as a function of output-stage gain.

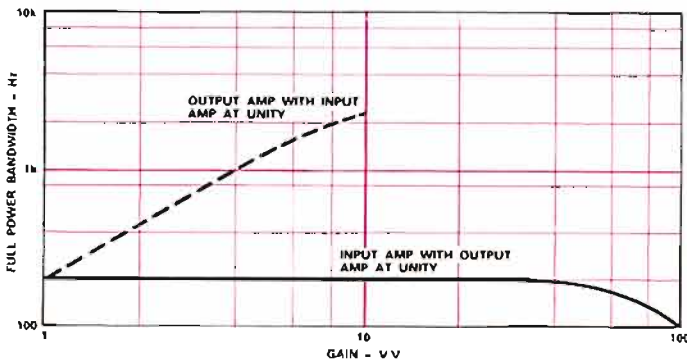


Figure 4. Large-signal bandwidth vs. gain.

Inherent *gain errors* and *gain drift* due to mismatch in the demodulators are quite small because of the highly predictable and uniform nature of the transformer windings. Hence, gain is most accurate and stable when input and output gains are set at unity. Gain accuracy and stability depend on the match of resistance pairs. Since the internal 100k Ω resistor will in general have a different tempo from the external resistor chosen for RG, this mismatch will have the greatest effect on gain error. Because the user chooses both gain resistors for the output section, they can be matched and track as accurately as desired. Thus, for gain accuracy at low gain, the last choice is best.

Offset errors Offset trim terminals exist at both the input and output stages for correction of offsets at a single gain or over a range of gains. Output-stage offset drift, referred to the input, is unchanged for higher values of gain in the output stage and reduced for higher values of gain taken in the input stage. In general: for small signals, take gain at the input; for large signals, take gain—if any—at the output.

Full-power bandwidth Since the gain of the output amplifier stage produces a corresponding amplification of the slew rate (which is limited internally by the demodulators), Figure 4 shows that, for maximum bandwidth, gain should be taken in the output stage.

INSIDE THE TRANSFORMER

The key element of the AD293 and AD294 is the transformer. It must be compact and economical, have excellent coupling, low interwinding capacitance and high-voltage insulation, and be reproducible and easy to test and use in a hybrid circuit environment.

The innovative transformer that finally evolved uses an EI ferrite core set and two identical ceramic substrates, each having three printed flat spiral windings (Figures 5 and 6). The 8-turn printed windings, of a special copper composition, with 5-mil line width and 7-mil spacing, are alternated with layers of dielectric; each layer is laid down separately, dried, and fired. The two substrates are then stacked, metal side up, but rotated 180° relative to one another, so that the connections to the input and output sections are at opposite ends. An insulator is then used to cover the upper set of windings, thus forming a bonded corona-resistant sandwich, which is mounted on the center arm of the E core. The sets of input and output windings are separated from one another, and from the outside world, by the thickness of a ceramic substrate.

No wire-bonds are used in the transformer. Even the crossovers on each substrate are printed and fired in a separate insulated metallization layer. Connections between the pads on the substrates and the parent substrate are made via soldered-on uniformly spaced edge clips which provide physical support and a secure electrical connection.

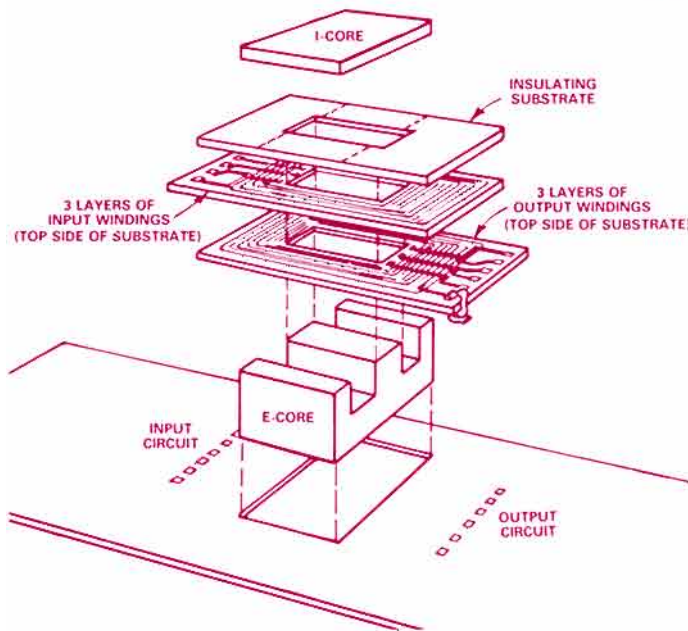


Figure 5. How the transformer is assembled.

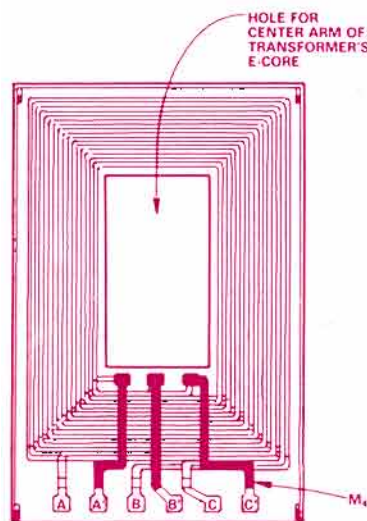


Figure 6. Pictorial top view of a transformer substrate, showing overlaid spiral windings.

WORLD'S FIRST MONOLITHIC 16-BIT D/A CONVERTER

Voltage-Output AD7546KN & BD Are Monotonic Over Temperature Have CMOS/TTL/ μ P-Compatible Latched Inputs, On-Chip Deglitch Switch

by Mike Tuthill and John Wynne

The AD7546 family of monolithic microprocessor-compatible d/a converters* are designed to provide 16-bit resolution at high speed—with low power consumption and cost—in a 40-pin DIP package. The AD7546KN, in plastic, and the AD7546BD, in ceramic, provide 65,536 monotonically increasing output-voltage levels in response to 16-bit binary input codes, over the entire temperature range of 0° to 70°C for the former, -25° to +85°C for the latter. Prices in 100s start at \$29.75 (KN).

Typical applications for which the AD7546's monotonic behavior and low cost would appear well-suited include digital audio playback, high-resolution vector-scan graphics, and control systems.

HOW IT WORKS

The AD7546 is a two-stage converter, consisting of a tapped 16-level voltage divider and a voltage-output 12-bit R-2R-ladder-type d/a converter.† The four most-significant bits of the 16-bit data word establish a base-level voltage from 0 through 15/16 of the reference voltage, in intervals of 1/16 V_{REF} . The 12-bit converter augments this base-level voltage by a fraction of the interval corresponding to the fractional value of the lower 12 bits.

The tapped divider is inherently monotonic, and accurate 12-bit CMOS DACs have been routinely manufactured by Analog Devices. The tricky part of the design is to make sure that the range of the 12-bit DAC coincides with each of the 1/16 intervals, even if the intervals are mismatched by many 1LSBs. This is done by tapping differentially, with the result that the actual voltage across each segment is applied to the 12-bit DAC as its full scale (Figure 1).

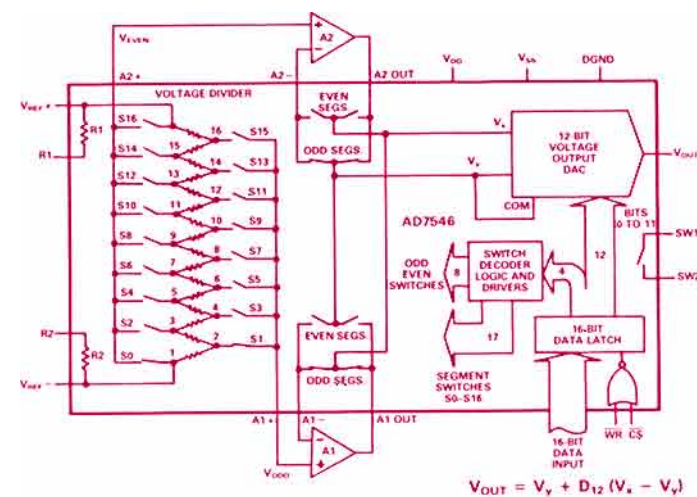


Figure 1. Block diagram of the AD7546 16-bit DAC.

*For technical data, use the reply card.

†The design of the AD7546 was described in some detail in *Electronic Design*, June 11, 1981, "Monolithic 16-Bit DAC Aids High-Resolution Process Control," by the present authors. Voltage-output connection of R-2R-ladder-type CMOS DACs was described in *Analog Dialogue* 14-1, 1980, pp. 16-17, "CMOS DACs in the Voltage-Switching Mode," by Steve Stephenson.

To avoid loading of the voltage divider by the variable-input-resistance 12-bit DAC, a pair of external follower-connected op amps provide buffering. As Figure 1 shows, the alternate nodes of the divider are switched to odd and even buses at the amplifier inputs (odd to A1, even to A2), and the switch decoding causes the tap to "walk" up the ladder, one switch at a time. The reversal of polarity of the difference voltage with each step is counter-reversed by switching of the amplifier outputs between the input terminals of the 12-bit DAC, V_X and V_Y . The output of the device is, with respect to V_{REF-}

$$V_{OUT} = V_Y + D_{12}(V_X - V_Y) \quad (1)$$

where V_Y is always at the base-level voltage, V_X is the voltage at the next higher tap, and D_{12} is the interpolation coefficient (from 0 to $1-2^{-12}$) determined by the input code of the 12-bit DAC.

In order to minimize errors due to switch resistance in series with the 12-bit DAC, the odd-even segment switches are connected inside the amplifier feedback loops. The double-reversal of the intervals, described above, provides an important benefit: it reduces the potentially nonlinearizing (differential) effect of the amplifier offsets at the 15 segment-transitions to a harmless $\pm(V_{OS1} - V_{OS2})/4096$. Integral nonlinearity on the chip is determined principally by the ratio accuracy of the resistive divider; it is also affected by offsets in amplifiers A1 and A2. Integral linearity (relative accuracy) is specified as a maximum error of $\pm 0.012\%$ of full-scale range over temperature for AD7546BD and KN, in terms of the end points, with A1 and A2 zeroed.

Figure 2 is a block diagram of a typical bipolar-output application, in which the pushpull reference permits an output swing of $\pm 4V$. A3 and the internal resistors, R1 & R2, provide sign inversion for V_{REF-} . For unipolar applications, pin 34 can be grounded and A3 eliminated. The output voltage is buffered by op amp A4, not needed if the output circuit feeds a high or a constant impedance, since the output impedance of the 12-bit DAC is code-independent.

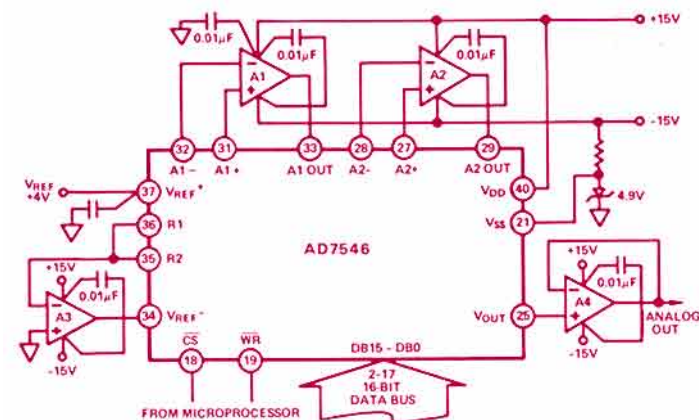


Figure 2. Typical circuit configuration for the AD7546 as a bipolar-output converter with buffered analog input.

MONOLITHIC 12-BIT DAC HAS 6-WORD FIFO MEMORY

AD7544 Can Accept Data in Bursts, Output Analog Data Asynchronously
Has Flexible Handshaking Facility, Top-Notch Conversion Performance

Phil Burton and Jerry Whitmore

The AD7544* is an unusual 12-bit monolithic multiplying digital-to-analog converter with 6 words of first-in-first-out (FIFO) memory, all on a single CMOS chip, housed in a 28-pin plastic or ceramic DIP. Typical applications include graphic displays¹, complex waveform generation, and semiconductor ATE.

As Figure 1 shows, the AD7544 is essentially a high-performance 12-bit-wide double-buffered DAC with a sophisticated digital front end. Its analog performance characteristics include linearity to within $\pm 1/2$ LSB and guaranteed 12-bit monotonicity, over the temperature range (1 LSB and 11 bits for JN/AD/SD versions), and gain error laser-trimmed to within ± 1 LSB (GKN/GBD/GTD). Prices of 12-bit devices start at \$21 in 100s.

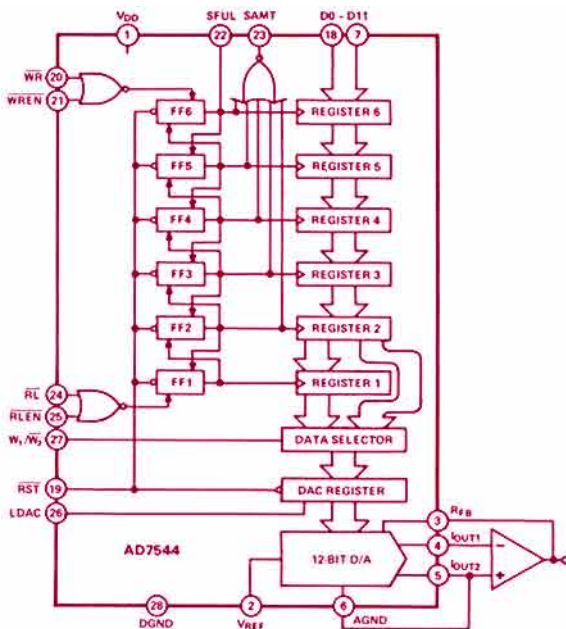


Figure 1. AD7544 functional block diagram.

FIFO MEMORY

Loading Data. Data arrives via the 12 data lines (D0 through D11, at the top of Figure 1), under control of the NOR'd \overline{WR} and \overline{WREN} (Write and Write ENable) control lines. As each 12-bit word is written, it drops through the stack to the bottommost empty register. Hence, an initially empty stack is full after six Write instructions.

Status. Two status flags come High to indicate certain conditions of the stack: SFUL (Stack Full) can be used to stop the writing of data into the AD7544, SAMT (Stack Almost eMpTy, one word remaining) can call for more data.

Moving and Converting Data. The contents of the stack can be asynchronously rolled downward towards the DAC register under the control of \overline{RL} (RoLL) and \overline{RLEN} (RoLL ENable) inputs, deleting the data previously in Register 1 with each roll. When LDAC (Load DAC) comes High, the DAC register will be loaded

with the contents of either Register 1 or Register 2, depending on the state of the $\overline{W1/W2}$ control line, without deleting data. \overline{RST} resets all registers to zero.

USING THE AD7544

The stack may be used as a time buffer. It can accept data from a data bus under processor control while constantly updating the d/a converter output at some real-time clock rate. Figure 2 shows a typical set of connections for generating analog time functions.

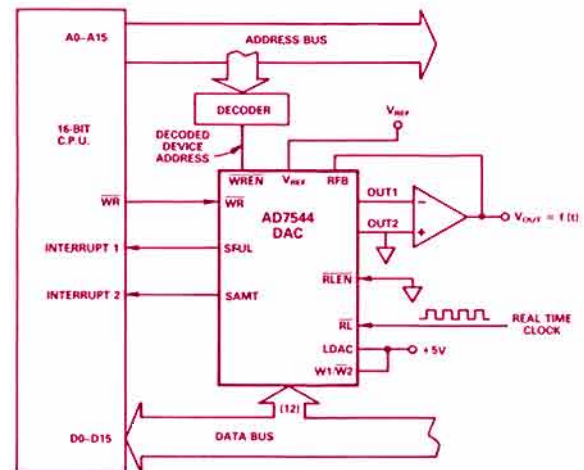


Figure 2. Interfacing the AD7544 to a 16-bit processor in a real-time-clock application.

\overline{RLEN} is grounded, and \overline{RL} is connected to a real-time clock, which moves data down through the stack one-step-per-cycle, each time it goes Low. This periodically updates the analog output with the contents of Register 1, since LDAC and $\overline{W1}$ are tied High.

\overline{WREN} is driven by the decoded device address, and \overline{WR} is tied to the μP Write signal. Thus, data is loaded into the stack under CPU control at the CPU rate, but pushed through the stack at the real-time-clock rate.

The flags ensure that the CPU services the stack often enough so that it neither overflows nor fully empties. SFUL raises a service interrupt when the stack is full, stopping the data; SAMT raises an interrupt when only Register 1 has data, causing new data to be (generated and or) transferred. The timing is shown in Figure 3.

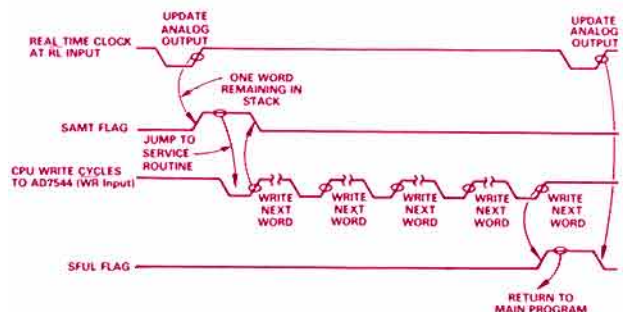


Figure 3. Typical timing diagram for the application of Figure 3.

*Use the reply card for technical data.

¹Use the reply card for a free application note: "Methods for Generating Complex Waveforms and Vectors using Multiplying DACs," by Phil Burton.

MONOLITHIC SYSTEMS DAC

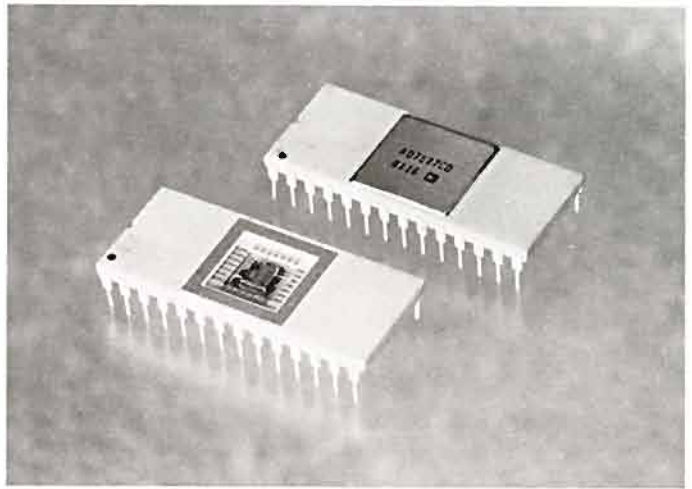
μ P-Compatible 10-Bit AD7527 Has Double-Buffering, Data Readback Plus Incrementation Facility and System Calibration Override

The AD7527* is a 4-quadrant multiplying 10-bit d/a converter on a single CMOS chip, housed in a plastic or a ceramic dual in-line package. In addition to the basic conversion function, with gain error of ± 1 LSB max (G versions), it has a wide range of pin-programmable logic functions that endow it with flexible bus interfacing, memory, and several modes of data manipulation that are independent of the computer's data bus. These functions make it invaluable for applications in process control, automatic test, and intelligent-instrument design, as well as the design of DAC-based tracking analog- or synchro-to-digital converters.

WHAT IT DOES (Figure 1)

Flexible Data Format The AD7527 interfaces directly with 8- or 16-bit data buses. The contents of its internal register can be written into and read from in left- or right-justified format. This means that it can be used as a microprocessor-compatible 10-bit-wide DAC (16-bit buses), a high-accuracy 8-bit-wide DAC (8-bit buses), an 8-bit DAC with full-scale precision offset capability, or a 2-byte 10-bit DAC with either right- or left-justified input (that is, the word 1001110011 may be placed on the bus as 00000010 & 01110011 or 10011100 & 11000000).

Double Buffering The AD7527 is double-buffered—the DAC register is loaded with the contents of the input register, to update the analog output, only on command. This means that new data, including both bytes of a two-byte word, may be loaded into the input register without disturbing the DAC output. The analog output may be updated at any time thereafter.



Readback The data stored in the DAC register may be read back to the data bus, via 3-state drivers, in the same choice of data formats. This feedback is invaluable. For example, it makes it unnecessary for the computer to remember and continually update the last setting, since the AD7527 acts as read/write memory. If the contents of the DAC register have changed since the last update from the bus, the computer can receive an update of its new value.

Data Override The output of the DAC may be set at the analog value corresponding to top-, bottom-, or mid-scale (all 1s, all 0s, or 1-followed-by-all-0s) without disturbing any of the data or control settings of the DAC, and without requiring any data-transfer operations by the computer. It should be evident that this is a useful function for system initializing or calibration.

Counter and Clock for Incrementing The output of the DAC may be increased or decreased in 1-LSB steps by using pulses from an internal slow clock (sub-1Hz to 1kHz), or by driving the clock terminal with an external clock (up to 1MHz), to apply pulses to an internal up/down counter. The counter's output may be selected, instead of the data from the bus, to update the input register. This function is quite useful in control or tracking applications because it permits a variable to be incremented until a certain result is achieved (for example, the output of the DAC reaches and crosses the reference input of a comparator) without the necessity of measuring the variable's value or transferring data to the DAC. The DAC continues to increment automatically until the comparator flips over and triggers an Interrupt (and/or a reversal of the direction of the DAC output). Great savings in software and processor time in system applications are inherent.

Many of the features of the monolithic AD7527 were originally found in the modular DAC1423* (*Analog Dialogue* 14-2, page 6), which has the added fillip of 1500V isolation and remote powering from its 4-to-20mA 2-wire analog output line

The AD7527 is available in ceramic or plastic DIP, with a choice of three temperature ranges, and graded for accuracy. Prices of 10-bit units start from \$16 in 100s.

* For technical data, use the reply card.

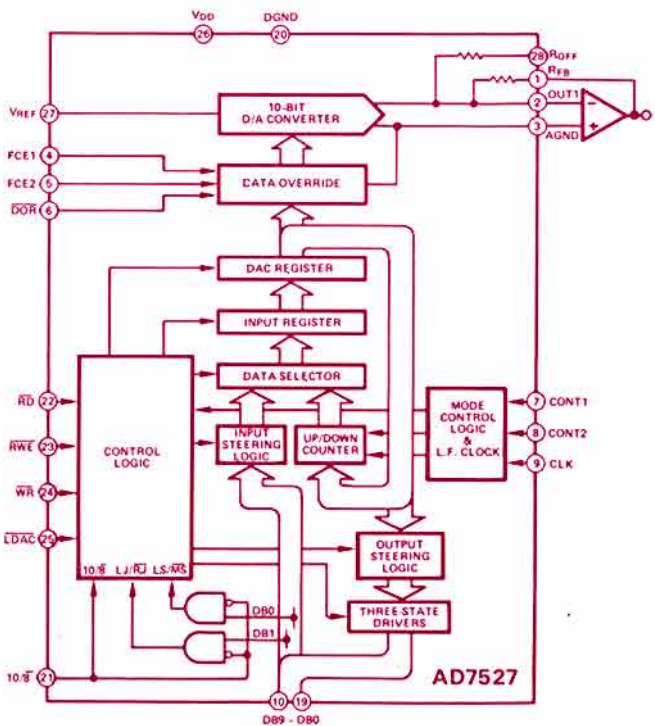


Figure 1. Functional block diagram of the AD7527 D/A Converter.

FIRST MONOLITHIC FET OP AMP WITH $1\mu\text{V}/^\circ\text{C}$ DRIFT

AD547 Is Laser-Trimmed on the Wafer for Both Offset and Drift

25pA Warm-Up Bias Current Is Lower than for Any BIFET Op Amp

The AD547* is a monolithic FET-input operational amplifier that combines in one low-cost device the low bias current inherent in FET circuitry, the low offset voltage and drift that are more typical of bipolar circuitry, high open-loop gain—for accurate performance in high-closed-loop-gain circuits—and smooth dynamic performance with low distortion.

The AD547L, which has the highest performance of any amplifier in its class, is characterized by offset voltage of 0.25mV max and bias current (either input) of 25pA max (in thermal equilibrium at +25°C), drift of $1\mu\text{V}/^\circ\text{C}$ max, and open-loop gain of 250,000 min, over the temperature range, with a 2k Ω load. The other members of the family offer performance approaching that of the "L", at somewhat lower cost, as Table 1 shows.

Laser-trimmed offset temperature coefficient synergizes with thermally balanced circuitry for low turn-on drift. Figure 1 shows the $6\mu\text{V}$ warmup drift of a typical device. Combined with the low quiescent current (1.5mA max), this feature makes the AD547 a first choice for critical front-end circuitry in high-availability stationary and portable precision instrumentation, both battery- and line-powered.

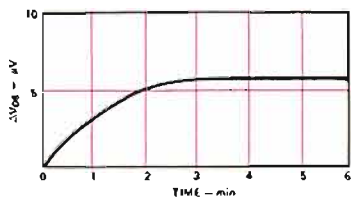


Figure 1. Input offset voltage, turn-on drift vs. time.

The high open-loop gain means—among other things—that, in a typical application as a follower with a gain of 10, total harmonic distortion remains below 0.01% at frequencies well beyond 1kHz, a useful feature in signal conditioning and analog computation.

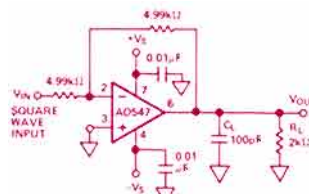
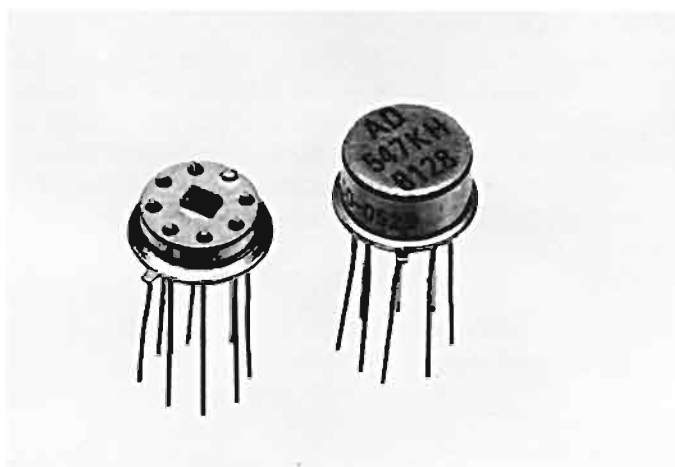
Dynamically, the 1-MHz unity-gain small-signal frequency, 50kHz full-power bandwidth, and 3V/ μs slewing rate allow the device to maintain precision performance well into the audio band. Response is smooth and fast; Figure 2 shows that, as a unity-gain inverter, without a feedback capacitor, small-signal pulse response has only a small, controlled, overshoot; and settling time for 10-V full-scale square waves is typically less than 5 μs to within 0.01%, a useful feature for many applications with latched CMOS 12-bit d/a converters, when updated at moderate data rates. ▶

TABLE 1. Specifications in brief

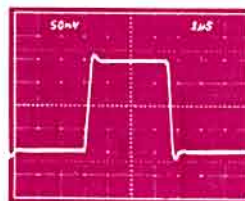
(at +25°C and $V_{CC} = \pm 15\text{V}$ unless specified otherwise)

	AD547J	AD547K	AD547L	AD547S
Input Offset Voltage, mV, max vs. Temperature, Unnull'd, $\mu\text{V}/^\circ\text{C}$ max	1.0	0.5	0.25	0.5
Input Bias Current, Either Input, Warm'd-Up, pA, max	50	25	25	25
Open-Loop Gain, Over Temperature $R_1 \cong 2\text{k}\Omega$, V/mV, min	100	250	250	250
Operating Temperature Range, $^\circ\text{C}$	0 to +70		-55 to +125	
Price, 100s	\$4.50	\$7.95	\$15	\$17.50

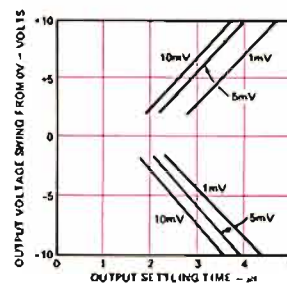
* Use the reply card for technical data.



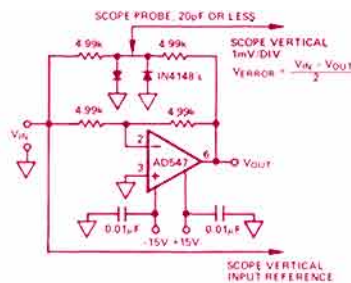
a. Pulse response test circuit: unity-gain inverter.



b. Pulse response of unity-gain inverter circuit (small signal).



c. Output settling time vs. output swing and error.



d. Circuit for measuring settling time.

Figure 2. Dynamic performance of the AD547.

ANALOG I/O INTERFACE CARDS FOR STD BUS

10-Bit I/O & Input: RTI-1225 & 1226; 12-Bit I & O: RTI-1260 & 1261

Compatible with all STD CPU Cards; Memory-Mapped I/O; Requires +5V Power Only

by John Mills

THE STD BUS

The STD bus is emerging as one of the most popular microcomputer buses, for reasons that are easy to understand. Instead of confining the system designer to a single processor, it permits the use of the best device for the job—or the most familiar device—with a common bus structure (data, address, control, power). This means that CPU cards, based on any popular 8-bit microprocessor—including the 8080A, 8085, 6800, 6809, and Z80—can be used, allowing the designer's software investment to be preserved.

Other factors that make the STD bus popular include its modular function-per-card approach, permitting the use of small low-cost cards, chosen in just the right combination for the application and expandable for future more-complex applications.

ANALOG I/O

Most of the cards used with the STD bus have to do with processing, transmission, and control of digital data. However, because the purpose of many microcomputer systems is the measurement and control of real-world (i.e., analog) phenomena, analog I/O cards, which include signal conditioning and conversion, are necessary to interface the STD-based microcomputer with the analog world.

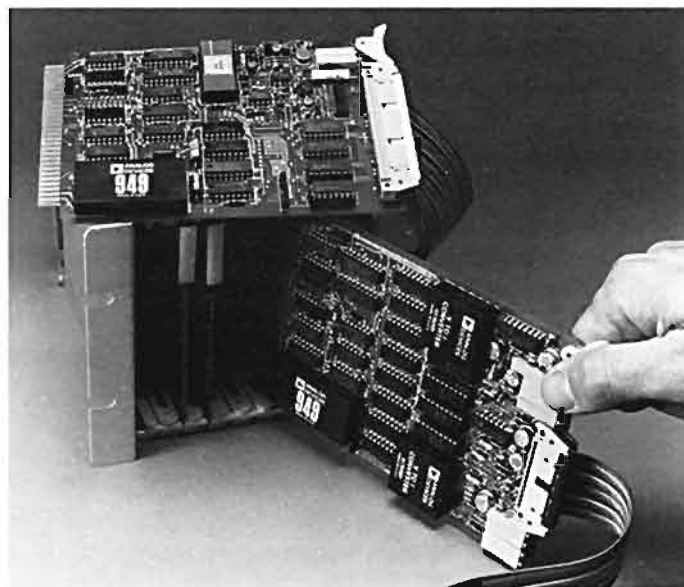
To satisfy the needs of such typical applications as laboratory data-logging, environmental and energy monitoring, machinery test stands, process measurement and control, and quality-control testing, Analog Devices produces cost-effective, easy-to-use, high-quality cards for analog interfacing with this versatile bus.

What to look for in analog input/output cards. Analog I/O cards are available for input only, output only, or both input and output, and with various digital resolutions. To select the right card for a given application, the designer must understand the differences in architecture and the advantages of the various options.

Input cards for data acquisition. The basic architecture of an analog input card is shown in Figure 1. Analog inputs arrive at the terminals of a multiplexer, which selects one of 16 or 32 channels. The multiplexer can be configured for single-ended, differential, or pseudo-differential modes. The single-ended mode is used when all signals are referred to a common ground, and are of sufficient magnitude in relation to noise to provide appropriate resolution; 16 or 32 channels are available. For noisier environments, or where signals come from sources at differing common-mode levels, the differential mode can be used by pairing signal inputs to minimize the effects of common-mode noise; this halves the number of inputs. If all signals have a common connection (not at system ground), it can be used as one side of the differential input; this pseudo-differential connection takes advantage of the differential inputs without sacrificing channel capacity.

The outputs of the multiplexers (which use dielectric isolation and can handle signals of up to $\pm 35V$ without damage) feed a subtractor or a differential-input instrumentation amplifier having gains programmable from 1 to 1000 to amplify the signal ($\pm 10mV$ to

*For technical data, use the reply card.



$\pm 10V$ effective input range, depending on gain) to the specified input range of the a/d converter (normally 0 to +10V or $\pm 10V$). The sample-and-hold tracks the signal and freezes it during a/d conversion. The converter produces an 8-, 10-, or 12-bit digital representation of the signal, and this result is made available to the microcomputer bus, via a set of three-state program-controlled registers.

The multiplexers accept software-determined commands from the microcomputer to select a specific analog channel and start an a/d conversion. Power for the analog circuits is furnished by a dc-to-dc converter on the card, transforming the +5V dc available on the bus to low-noise, isolated $\pm 15V$.

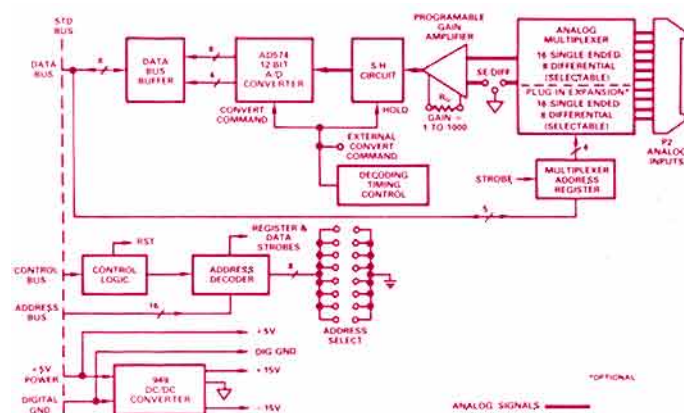


Figure 1. Block diagram of RTI-1260 Analog Input Card.

Output cards for control. Analog output cards (Figure 2), contain independent d/a conversion channels for driving chart recorders, servomechanisms, control valves, and output transducers. The analog output is set by writing a digital code to the appropriate address. If the resolution of the data exceeds 8 bits, the DAC requires two bytes of data. The DACs are double-buffered, so that

Table 1. Example of 12-bit a/d-conversion program

This example uses 8085 assembly language to address channel 1, do an A/D conversion and store 12 bits of A/D data in register pair B and C. Base address has been set at FFFB.

```

LXI H,FFFB
MVI M,ϕ1    SELECT MUX ADDRESS
LXI H,FFFD
LOOP MOV A,M
RLC
JC LOOP     TEST BUSY BIT
MOV B,M     READ ADC DATA HI
DEC H
MOV C,M     READ ADC DATA LO
    
```

The RTI-1225* 10-bit Combination Input/Output Card combines analog input and output functions on a single card. It will acquire analog signals from 16 single-ended or 8 differential channels. Containing a differential amplifier, sample-hold circuit, and a 10-bit a/d converter (AD571), it can achieve a throughput rate of 25,000 channels per second. The analog output section has 2 independent 8-bit DACs.

The RTI-1226* Analog Input Card provides the same analog functions as the RTI-1225, excluding the d/a-conversion section.

The RTI-1260* 12-bit Analog Input Card acquires analog signals from up to 32 single-ended or 16 differential voltage inputs, and provides user-configured gain from 1 to 1000 for ±10mV to ±10V input ranges, for use with low-level transducers, such as strain gages and thermocouples. Throughput of 25,000 channels per second is available at unity gain, using our AD574 a/d converter.

The RTI-1262* 4-Channel Output Card provides 4 independent channels of output voltage. Two of the channels can be optionally configured for current (4-to-20mA), for use in process-control applications.

Configured as a single block of memory locations, all of these cards are accessed by simple memory-reference instructions. Conversion of the analog input at any randomly addressed analog channel is initiated by a single byte, which selects the analog input channel and automatically initiates the a/d conversion. All cards have on-board dc/dc converters, operating from the microcomputer's +5V supply.

In addition to low unit prices, attractive discount prices are available for quantities of these cards. Single-card prices are shown in Table 2.

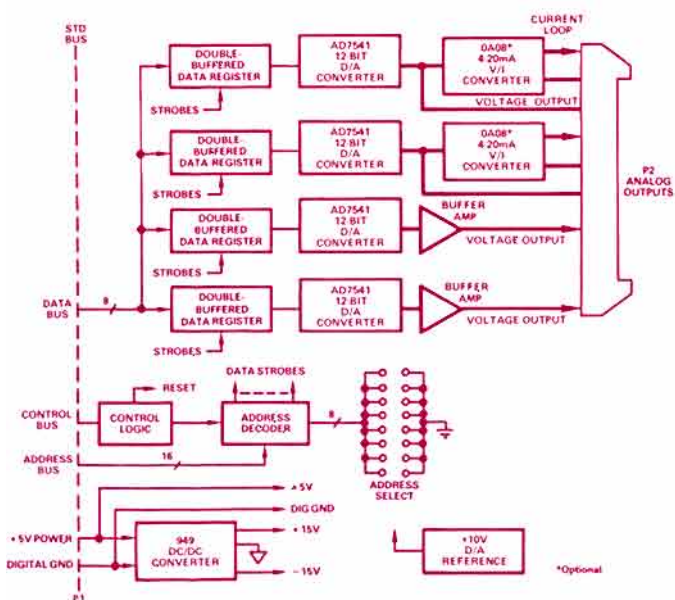


Figure 2. Block diagram of RTI-1262 Quad Output Card, indicating two channels of current output.

both bytes may be separately loaded into input register and then strobed simultaneously into the DAC, avoiding intermediate outputs and insuring cleaner transitions from one output value to the next.

Usually, the cards offer output-voltage ranges of 0 to +5V, 0 to +10V, ±5V, or ±10V. Driven by operational amplifiers, the outputs can handle moderate capacitive loads. In control applications, especially, where the load is at some distance from the µC system, it is useful to transmit the analog signal as a current rather than as a voltage for immunity from voltage noise and IR drops in the output wiring. Current-output options typically provide proportional output current of 4 to 20mA. As in the case of the analog input card, a dc-to-dc converter provides analog circuit power.

Simple interface compatible to all CPU cards. By the use of memory-mapped I/O, Analog Devices cards are compatible with all STD-bus CPU cards. The analog card is treated as a block of memory and is accessed by the use of any memory-reference instruction. Table 1 shows an example of a data-acquisition subroutine. Wire-wrap jumpers allow the cards to be positioned in unoccupied memory space.

WIDE VARIETY OF CARDS

Table 2 summarizes the key features of these four cards, currently available from Analog Devices for use with the STD bus. Their ease-of-use is furthered by the optional AC1585 series of field-wiring adaptors (barrier-strip screw terminals to RTI-card edge connector).

Table 2. Summary of capabilities of STD-bus-compatible data-acquisition cards

Card Type	Model No.	INPUT			A/D Resolution	OUTPUT			PRICES Standard 1-4
		Channel Capacity Standard	Channel Capacity Optional	Gain Range		Channel Capacity	D/A Resolution	4-20mA (Optional)	
Input/Output	RTI-1225	16SE/8D	N/A	1	10-Bits	2	8-Bits	N/A	\$439
Input	RTI-1226	16SE/8D	N/A	1	10-Bits	—	N/A	—	\$359
Input	RTI-1260	16SE/8D	32SE/16D	1-1000	12-Bits	—	N/A	—	\$550
Output	RTI-1262	—	—	N/A	—	4	12-Bits	2	\$349

TESTING A/D CONVERTERS AUTOMATICALLY

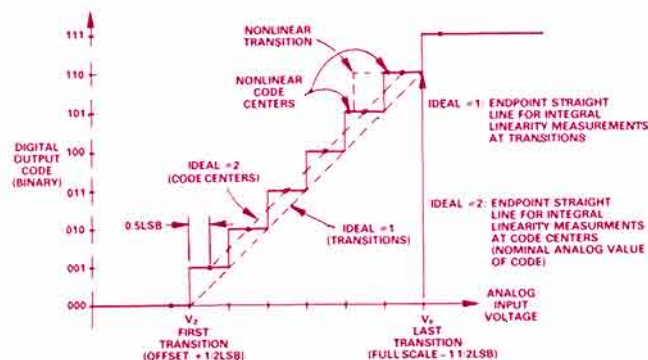
How the LTS-2010 Tests High-Performance ADCs

Test Routines are Downloaded to a Smart Family Board

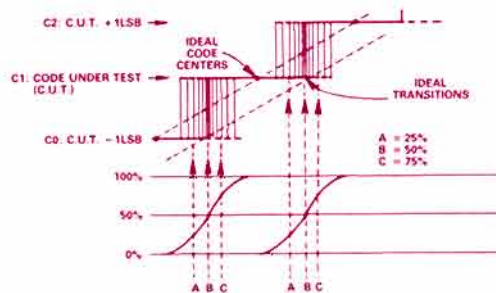
by Tim Wilhelm

Testing a/d converters for linearity—a key specification—is a lengthy and difficult procedure because each of the 2^n output codes could be produced by a continuum of analog input values. Although only the two values bounding each code (the *transitions*) are of interest for each test (Figure 1a), they are not known *a priori* or directly measurable; they must be found by some sort of search requiring a series of discrete conversions.

This process must be repeated for as many codes as are necessary to insure that all the significant linearity errors have been found. In addition, one group of conversions may establish transition values that are significantly different from those found in subsequent repetitions of the test, due to noise, drifts, and dynamic errors in conversion (Figure 1b). To eliminate this as a problem, the measurements must be repeated a sufficient number of times to provide an adequate statistical evaluation of the errors.



1a. Output vs. input for a 3-bit converter, showing ideal transitions and code centers.



1b. The transition as a probability function.

Figure 1. A/D converter output staircase.

To speed up evaluation of data, the most widely used benchtop approaches involve repeated conversions of a fixed voltage summed with a 2-bit slow dither, and inspection of the "stepstool" figure produced by an oscilloscopic expanded crossplot of the decoded output variations vs. the input dither. Individual code widths, their variations, and transition noise are easily seen in plots of this kind, but the technique calls for time, technical knowhow, and the unique integrating ability of the human visual function.¹

¹The technique is described in *Analog-Digital Conversion Notes*, D. H. Shengold, ed. Analog Devices, 1977. \$5.95. pp. 211-215

If automated high-speed ADC testing, with recorded test data, is needed, using a standard bench-top test system, such as the LTS-2010, the most productive techniques are those based on the use of slave microprocessors to operate and control tests and perform calculations. Test data can be easily produced in suitable form, whether pass/fail or as a datalogged list of the errors at all codes, with appropriate statistical parameters. The Analog Devices LTS-2010 Linear Test System's A/D-Conversion Family Board,* employing a 16-bit TMS9900, tests a/d converters, including high-performance (12-bit, 5-50 μ s successive-approximation) types, for a wide range of parameters, including offset, gain, and linearity errors, rapidly and by fully automatic means.† This note discusses the approach to determining the key parameters of linearity error and transition uncertainty.

FINDING TRANSITIONS

Transition locations are the key to measuring converter performance. Transition voltage (for a voltage-input converter) is defined as that input voltage which has equal probability of producing either of the adjacent existing codes. The nominal analog value corresponding to the digital code produced by any analog input value in the range between a pair of transitions is defined by the midpoint of the range. If the transitions are known, the midpoint can be computed easily and automatically, as can differential and integral linearity errors.

The tests (except for device calibration) are normalized to the ADC's output range, by measuring the first (V_1) and last (V_F) transitions and dividing the total interval by the number of codes between them, i.e., $(V_F - V_1)/(2^n - 2)$, to establish the magnitude of the ideal LSB value.

Figures 2 and 3 illustrates an automated means of finding a transition. A 16-bit DAC feeds an accurately known voltage, corres-

*For technical data on the LTS-2010 Linear Test System and its A/D-Conversion Family Board, use the reply card.

†For example, an optional software package exists to thoroughly test 5200 and 5210 Series 12-bit a/d converters to subgroups 1 and 4 of the JEDEC 38510 slash-sheet.

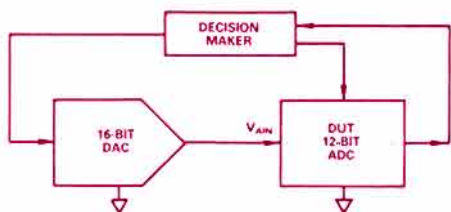


Figure 2. 16-bit DAC as a forcing input for an ADC under test in a feedback loop.

ponding to the ideal value for the transition between a given pair of codes, into a 12-bit ADC under test. A conversion is performed (A), and the "decision maker" checks the resulting output code of the ADC-under-test (DUT) to determine whether it corresponds to a voltage below or above the ideal transition (in this case, the low-side transition—LST). If it is below, the DAC output is incremented by 1 LSB (of the DUT's resolution), and a new conversion and comparison (B) are performed (if it were above, the DAC output would be decremented by 1 LSB).

As Figure 3 shows, if the voltage is still below the transition, the DAC output is again incremented by 1 LSB and the cycle is repeated (C). When the code is eventually identified as above the transition (for a linear DAC, this would happen on the first trial), the DAC output is decremented by 1/2 LSB, and the cycle is repeated (D). After several conversions (E,F,G), with successively smaller DAC-output increments or decrements—as appropriate, in the manner of successive approximations—the analog value of the DAC output is within 0.06 LSB (1/16 of 1 LSB) of the actual transition voltage, and the input to the DAC is the corresponding digital code, to 16 bits ± 1 count.

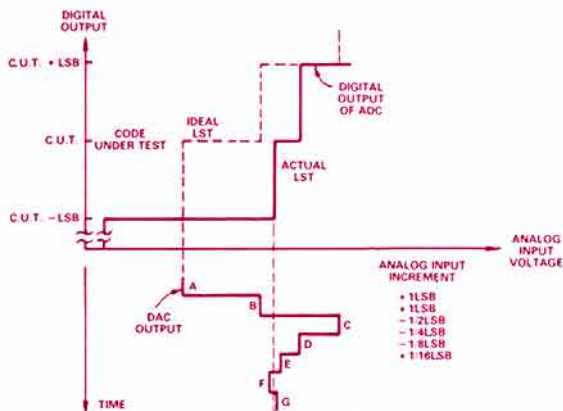


Figure 3. Finding the transition by tracking and successive approximations.

To correct for variations in the transition produced by noise, a number of readings of the transition voltage are taken and averaged. However, it is unnecessary to start from the theoretical transition; since the value obtained by the above procedure is presumably close to any other likely reading of the transition voltage, it is used as the starting point for determining the next value. The same kind of search is used, except that the initial constant increment (or decrement) is 1/4 LSB until the transition has been crossed, then successive approximations are used for subsequent conversions, until the DAC output is again within 0.06 LSB of the transition. This value is the starting point for the next search, etc. After the desired number of values, m , have been found, they are summed and divided by m to determine the average transition value.

For flexibility, the scheme actually used in the LFS-2010 employs a 12-bit main DAC calibrated to 16-bit accuracy and a 12-bit "Dither DAC" (Figure 4), with 100:1 or 500:1 (or user-arbitrary)

attenuated output. The ideal transition code is set in the main DAC; and the dither DAC is set for a bipolar output contribution in increments of 1/2-LSB of the DUT (instead of 1 LSB increments, as above), followed by successive approximations of 1/4, 1/8, 1/16, and 1/32 LSB, for a final resolution to within 0.03 LSB (at 100:1, 3 counts of the Dither DAC, in this case).

LINEARITY TESTING

A code is tested for differential linearity by comparing its width (between two adjacent transitions) with $1/(2^n - 2)$ of the voltage between the first and last transitions. If the code is missed, its width will be zero, since its transitions, in effect, coincide. The code is tested for integral linearity by comparing its low-side transition (LST) with the calculated LST (on locus "Ideal 1" in Figure 1a), or by comparing its center (half the sum of the adjacent transitions) with the LST + 1/2 LSB (locus "Ideal 2").

ADC linearity tests typically call for differential linearity measurements at the codes involved in all major carries (e.g., 1000/0111, 0100/0011, etc.), the carries at the sums of the MSBs (e.g., 1100/1011, 1110/1101, etc.), and plus/minus two codes around each. To this might be added a bit-superposition test at the expected worst-case summation codes: first determine the nonlinearity associated with each bit, then form two words, one consisting of all bits having positive errors (the worst-case positive error), the other consisting of all bits having negative errors (the worst-case negative error), and test them and plus/minus two codes around each.

Finally, if the DUT is expected to perform at high conversion rates, if it is of a type whose history records anomalous nonlinearities, or if it is a characterization sample, it may be desirable that all codes be tested for nonlinearity. Typically, the LFS-2010 can test all 4094 intermediate codes of a 12-bit 25 μ s converter for nonlinearity within about 15 seconds, using these techniques.

The technology used here permits quantitative evaluation of transition uncertainty by the performance of large numbers of measurements in a short time to map out the statistical behavior of transitions. Figure 1b shows that, as the input to the converter is reduced from the center of the code under test (C1) to the center of the next lower one (C0), the proportion of conversions to C1 decreases from nearly 100% to 50% (at the transition) to nearly 0 (at the center of C0). The transition could be mapped by fixing the Dither DAC output at a sequence of values; performing (say) 1000 conversions at each input value; counting the number of conversions to C1 and C0; and computing the ratio for each input value by dividing conversions to C1 by the total. The entire mapping of the transition, plus computation of the 50% point and the standard deviation, could be completed in less than a second. ▶

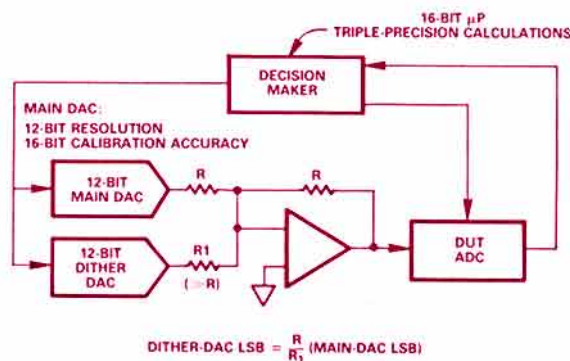


Figure 4. Using compounded main and dither DACs in testing.

MACSYM 10 FOR INDUSTRIAL-PLANT-FLOOR ENVIRONMENTS

PROM Eliminates Unreliable Moving Parts in Mass Storage

Same Software and ADIO Interface Hardware as Proven MACSYM 2

MACSYM 10* is a stand-alone minicomputer-based Measurement-And-Control SYstem designed for use in real-time process control, discrete manufacturing, and product testing.

Like its companion product, MACSYM 2,* first introduced in 1978 and now in wide use, the MACSYM 10 is complete, with the same 16-bit processor, family of analog and digital input/output (ADIO) cards, and multitasking Measurement-And-Control BASIC (MACBASIC).

However, it uses UV-eraseable PROM instead of such movable mass-storage devices as floppy disks or cartridges. Eliminating devices with moving parts cures the most common causes of computer system failures; there are no heads to get dirty or out of alignment, no bearings to wear out. The user's program is burned into PROM by the user, since the MACSYM 10 functions as its own development system.

Combined with the lack of moving parts, its operating temperature-range of 41° to 122°F (5° to 50°C) and up-to-95% relative-humidity (non-condensing) specification make MACSYM 10 a system which is truly at home on the plant floor.

Its dual-bus architecture (Figure 1), like that of MACSYM 2, provides high noise immunity and good accuracy at reasonable cost. High-speed digital logic elements (such as the CPU, memory, etc.), which generate potentially troublesome electrical noise, are separated from low-level analog inputs and other vulnerable analog signals by a Central Interface Unit.

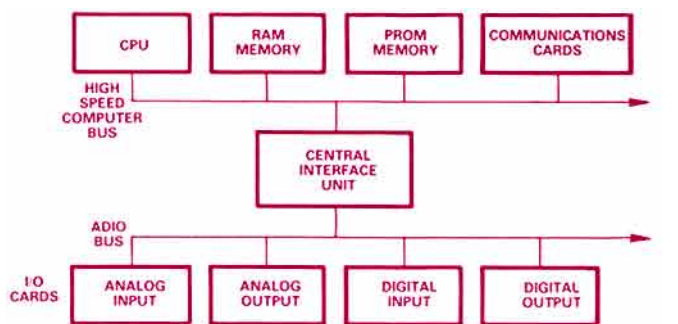


Figure 1. Block diagram of MACSYM dual-bus architecture.

To simplify the job of interfacing to the types of sensors, actuators, and instruments normally found in an industrial application, a complete family of input/output cards are available, including a wide variety of specialized plug-in signal-conditioning cards. The MACSYM chassis will accommodate 16 cards; with expansion chassis, as many as 256 cards may be used. External circuit wiring may be connected either directly to the cards or to optional screw-terminal boards. Cards currently available for use with MACSYM 10 are listed in Table 1.

MACSYM 2 vs. MACSYM 10 The MACSYM 2 is a stand-alone system, with mass storage in the form of either floppy disk or cartridge tape, designed for light-manufacturing, control-room, or laboratory environments. Both systems use identical software, so programs written on the MACSYM 2 will execute on the



MACSYM 10. Since the two systems use similar hardware and identical input/output cards, the MACSYM 10 user benefits from the experience devolving from the more than 1000 successful MACSYM 2 field installations.

PROGRAMMING MACSYM 10

MACBASIC makes programming the MACSYM 10 easy. In MACBASIC, there are special variable names which designate particular functions that commonly occur in measurement and control; the functions are easily addressed by the use of these names. They are:

- AIN Analog Input
- AOT Analog Output
- DIN Digital Input
- DOT Digital Output
- FIN Frequency Input

To illustrate:

$$V = \text{AIN}(2,5) \tag{1}$$

measures the analog voltage on Channel 5 of the Analog Input card in I/O slot 2 of the MACSYM 10. When this simple one-line instruction is executed, the card in slot 2 is selected, channel 5 of that card is selected, the voltage appearing at that channel is converted to digital and stored in memory. If the instruction were

$$V = 5^{\circ} \text{AIN}(2,5) + \text{AIN}(3,6) \tag{2}$$

Solid-State Isolated Analog Input Multiplexer
Strain-Gage Input
RTD Input
Thermocouple Input
AD590 (Semiconductor Temperature Sensor) Input
Analog Output (10/12-bit conversion, V or I)
Isolated AC-coupled Digital Input
Isolated DC Digital Input
Isolated DC Digital Output
Isolated AC-coupled Digital Output
Relay Output
Isolated Interrupt Input
Nonisolated Interrupt Input
Frequency Input
Event-Counter Input
Pulse Output
Pacer Clock
Battery-Backed Calendar Clock

the voltage at slot 3, channel 2 would also be measured and added to 5 times the voltage at slot 2, channel 5, and the result stored in memory.

Output variable AOT is used in a similar manner. The statement

$$\text{AOT}(8,3) = 3.42 \quad (3)$$

places 3.42 volts on channel 3 of the Analog Output card in slot 8.

If (2) were changed to read

$$\text{AOT}(8,3) = 5 * \text{AIN}(2,5) + \text{AIN}(3,6) \quad (4)$$

then the result of the computation in (2) would appear as a voltage on channel 3 of the Analog Output card in slot 8, *all in real time*.

For the Digital Input variable, DIN, the statement

$$X = \text{DIN}(3,4) \quad (5)$$

takes the digital logic level (a 1 or a 0) from channel 4 of the Digital Input card in I/O slot 3 and assigns it to the variable, X. The Digital Output variable DOT is used similarly:

$$\text{DOT}(6,4) = X \quad (6)$$

This statement turns on channel 4 of the Digital Output card in I/O slot 6 if X is equal to logic 1 and off if X is equal to logic 0.

Frequency inputs from tachometers, pulse generators, etc., are measured using FIN. To illustrate,

$$S = \text{FIN}(2,6,1) \quad (7)$$

sets the variable S equal to the numerical magnitude of the frequency of the input signal connected to channel 6 of the Frequency Input card in I/O slot 2, with a time base designated by "1". (There are five time bases, which cover the ranges from 1.6-to-100Hz to 16k-to-500kHz.)

MACBASIC also includes a group of commands that allow a user's program to access and use the system's clock for timing and time-keeping functions. The statement

WAIT 5.6

causes the program to "wait" for 5.6 seconds before proceeding to the next statement in the program segment allotted to the task.

The following example incorporates some of the above commands into a MACBASIC program:

```

40      K = 0.5
50      L = 5
60      X = AIN(8,0)
70      AOT(0,1) = K*X
80      IF X > L DOT(2,1) = 1
90      IF X < L DOT(2,1) = 0
100     WAIT .5 GOTO 60

```

This program assigns values to variables K and L, instructs MACSYM 10 to input analog data (AIN) from card slot 8, channel 0, set the analog output of card slot 0, channel 1, to K times X. Compare X to L; if greater, sound alarm on slot 2, channel 1; if less, turn off alarm. Wait 1/2 second, read again.

MULTITASKING

Since MACBASIC is multitasking, WAIT 5.6 does not mean that the computer does nothing for 5.6 seconds. MACSYM allows the user to write the sections of the total process as individual tasks, and have them run with independent schedules, times, rates, or occurrences. MACSYM automatically shares its time and resources among the tasks, in a priority set by the user, so that it appears to the user as if the processes are running simultaneously. Thus, while one segment is waiting 5.6 seconds, other tasks are being carried out as instructed, essentially in real time.

There are a number of advantages to multitasking:

- All variables and data 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 additional programming effort.
- A task may normally be dormant but suddenly assume special importance and require immediate execution. An example is the procedure (perhaps a set of frequent readings) that might be initiated by the tripping of a safety limit.
- When a complex new program is being started up for the first time and integrated with real-time inputs and outputs, it is helpful if separate tasks can be brought up, tested, and debugged, one (or a few) at a time and selectively activated and deactivated, to test pieces of the system (hardware and software).
- Multitasking makes it easier to control several processes at the same time, yet have individual control over each one, for example, when controlling several control loops, each calling for different setpoints and P-I-D constants.

MACSYM's operating system interweaves the tasks automatically by arbitrating among the tasks according to priority, handling the timing of periodic tasks, and going to the next task during a wait; it also keeps track of what tasks are running and what line of each task is being executed.

A wide selection of options permits MACSYM 10's to be configured for a variety of applications. These options include up to 8 asynchronous communication ports (RS232C or 20mA), Input/Output card expansion chassis, screw-terminal strips for field wiring, printers, and CRT terminals. The U.S. price of MACSYM 10 with 96KB RAM and space for 40KB of user PROM is \$12,300. ▶



The NEM01 is a special NEMA 12 enclosure for MACSYM products. It provides internal power distribution, cable management, and protection against dust, dirt, and splashing. Its closed-loop air conditioner maintains specified temperature at ambients up to 52°C.

* For technical data, use the reply card.

DOUBLE-BUFFERED COMPLETE 12-BIT D/A CONVERTER

Current-Output AD567 Interfaces with 4-, 8-, 12-, 16-Bit Buses

Laser-Wafer Trims & On-Board Buried-Zener Reference Ensure Stability

The AD567* is a complete current-output 12-bit monolithic digital-to-analog converter housed in a hermetically sealed 28-pin DIP. On board (Figure 1) are two ranks of latches with controls, a 10-volt buried-Zener reference, a basic current-output DAC—consisting of a laser-trimmed resistance network and a set of current steering switches—plus a set of matched and tracking Si-Cr resistors for bipolar offset and for output op-amp feedback (or for input, in a/d conversion applications).

The AD567 essentially adds a set of double-buffered latches to a proven self-contained AD565A d/a converter (*Analog Dialogue* 12-3, 1978). Capable of operating on ± 12 -volt supplies, the entire device is integrated on a single monolithic chip. The internal buried-Zener reference is laser-trimmed to 10.00V, with a maximum $\pm 1\%$ maximum error; available externally, the reference can spare up to 1.5mA for system use, beyond the current required internally for DAC referencing and the bipolar-offset resistors.

The precision high-speed current-switch design† provides high dc accuracy and an optimally damped settling characteristic. Output current-settling time is 500ns maximum to within $\pm 1/2$ LSB. Monotonicity—and, for the K and T options, $1/2$ -LSB max linearity error—is guaranteed over temperature. The TTL-compatible latches will operate with \overline{WR} pulses as short as 100 nanoseconds, allowing the AD567 to be used with the fastest available microprocessors.

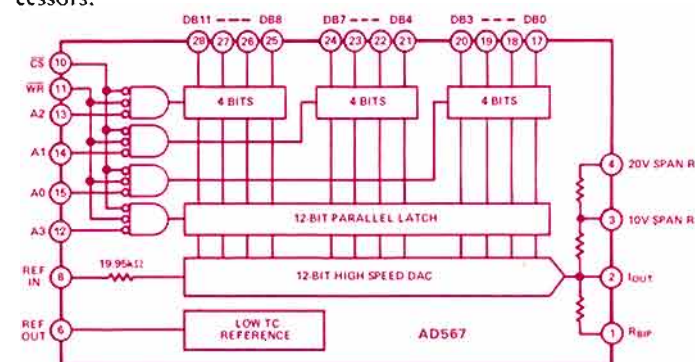


Figure 1. Block diagram of the AD567.

DOUBLE-BUFFERED LATCHES

The 12 input-data terminals connect to 3 quad input latches. The level-triggered latch control inputs permit the latches to be transparent when low, and latched when high. They in turn drive a 12-bit parallel latch, which drives the converter inputs. Depending on how the latch controls are operated, the converter will function appropriately with a 4-, 8-, 12-, or 16-bit processor bus; with an 8-bit bus, the data may be left- or right-justified (8 MSBs and 4 LSBs, or 4 MSBs and 8 LSBs). The latch inputs, A3, A2, A1, A0, are controlled overall by the \overline{CS} and \overline{WR} (Chip Select and WRite) inputs, as directed by the address decoder and processor WRite line. Table 1 shows the versatile repertoire of modes of operation.

* Use the reply card for technical data.

† U.S. Patents 3,803,590, 3,890,611, 3,932,863, 3,978,473, 4,020,486, and other patents pending.

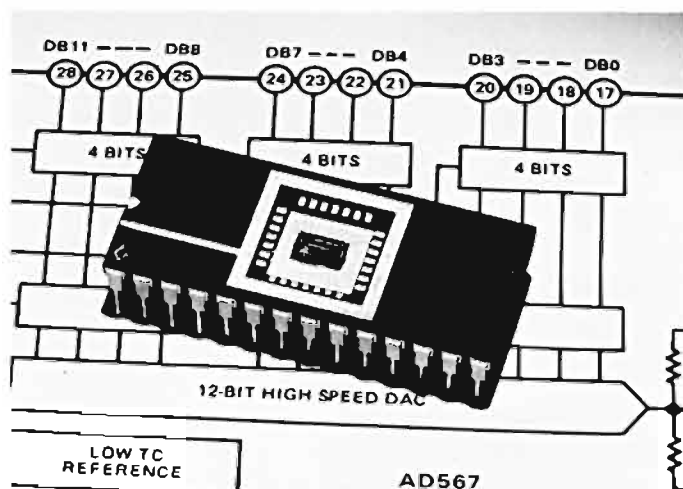


Table 1. AD567 truth table

(X = "Don't Care", 1 = latched, 0 = enabled)

\overline{CS}	\overline{WR}	$\overline{A3}$	$\overline{A2}$	$\overline{A1}$	$\overline{A0}$	REMARKS
1	X	X	X	X	X	No Operation
X	1	X	X	X	X	No Operation
0	0	1	1	1	1	Both ranks remain latched
0	0	1	1	1	0	4 LSBs enabled; Rank 2 latched
0	0	1	1	0	1	Mid-bits enabled; Rank 2 latched
0	0	1	0	1	1	4 MSBs enabled; Rank 2 latched
0	0	1	0	0	0	All bits enabled; Rank 2 latched
0	0	0	1	1	1	Inputs latched; Rank 2 enabled
0	0	0	0	0	0	All latches transparent

Figure 2 shows how the AD567 can provide 12-bit-accurate data to a processor that uses a 4-bit bus. Each AD567 occupies 4 memory locations; as they are incremented, each of the 3 quads is loaded, then the output is updated in one step. A single 74LS139 2-to-4 decoder provides sequential addresses for the four AD567 registers. \overline{CS} is derived from an address decoder driven from the high-order address bits. The system \overline{WR} drives the \overline{WR} input of the AD567.

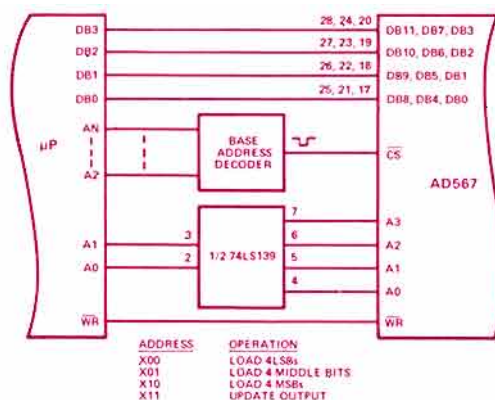


Figure 2. 4-bit microprocessor interface.

HIGH-RESOLUTION DATA-ACQUISITION FAMILY

Compact, Low-Cost 16-Bit ADC; 14- and 15-Bit Sampling ADCs;
Low-Level Resistor-Programmable-Gain 14/15-Bit Single-Channel DASs

by Ted Serafin

High-resolution data-acquisition is an art, and usually an expensive one; but when you need high resolution, there can be no substitute. It should be refreshing, then, to know that there are available five related new products that give you more bang for the buck in this esoteric area—and in several convenient forms.

The ADC1140* (Figure 1) is a self-contained 16-bit-resolution a/d converter that performs a conversion within 35 μ s max. Its guaranteed performance includes integral and differential non-linearity of $\pm 0.003\%$ of full-scale range, differential non-linearity tempco of $\pm 2\text{ppm}/^\circ\text{C}$ max, offset tempco of $\pm 30\mu\text{V}/^\circ\text{C}$ max, and gain tempco of $\pm 12\text{ppm}/^\circ\text{C}$ max. Its power-supply sensitivity is only 10ppm of full scale per percent ΔV_S , and it will work with power supplies ranging from $\pm 12\text{V}$ to $\pm 17\text{V}$. It is housed in a 2" \times 2" \times 0.44" (51 \times 51 \times 11.2mm³) module; and its price in 100s is only \$149!

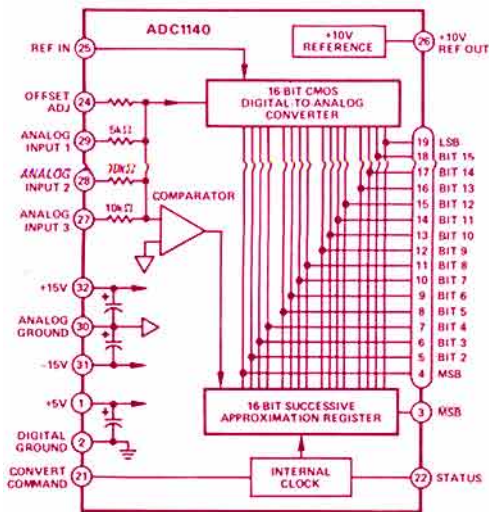


Figure 1. Functional block diagram of the ADC1140.

You can use the ADC1140 as the key element in a data-acquisition system to fit applications in process control, seismic data acquisition, nuclear or medical instrumentation, automated test equipment, pulse-code-modulation telemetry, robotics, etc. However, recognizing that the converter alone does not solve *all* the analog problems, if you prefer a higher level of system integration, including such elements as sample-hold, three-state latches, and preamplification, to reduce design and debug time and simplify the system problem, four new products may be of interest:

The 14-bit DAS1152 and the 15-bit DAS1153* are sampling single-channel data-acquisition systems (Figure 2), which include—in a compact 2" \times 4" \times 0.44" module—a precision sample-hold amplifier, a 14/15-bit ADC, three-state output buffers for right-justified interfacing to an 8- or 16-bit bus, gain- and offset-trim potentiometers, and on-board power-supply bypass capacitors. Price in 100s is only \$199/\$249 for DAS1152/1153.

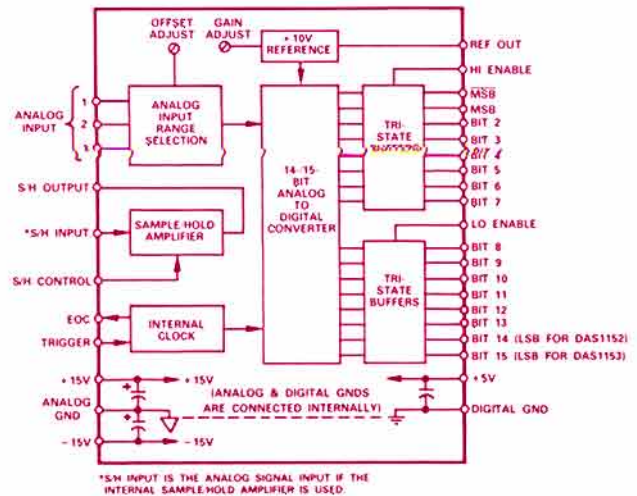


Figure 2. Block diagram of the DAS1152/1153.

The 14-bit DAS1155 and 15-bit DAS1156* are similar to the DAS1152/1153, except that they incorporate true-differential resistor-programmable instrumentation amplifiers at the input to provide gain and common-mode rejection in low-level signal applications (Figure 3). High-accuracy measurements can be made in the presence of common-mode interference without the addition of any external active components. Price of the DAS1155/1156 in 100s is \$249/\$299. ▶

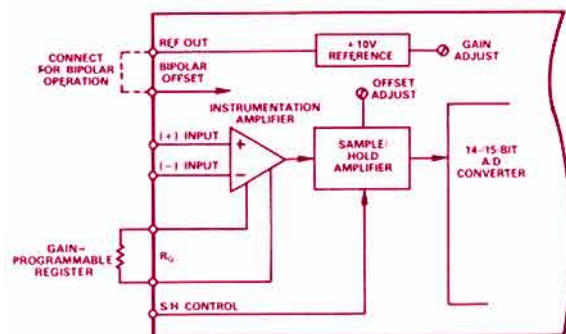


Figure 3. Analog front end of the DAS1155/1156.

Use the reply card for technical data. Specify products of interest.

MACSYM INPUT CARD

EVC01 Event Counter Unburdens System

The EVC01* has two independent 16-bit counters (65,536 counts), which can be used in a variety of ways to count and accumulate pulse inputs from external transducers or pulse-output devices. It accepts non-isolated TTL pulses at rates up to 100kHz and isolated inputs at up to 20kHz.

Each channel is independently presettable via software for count value and direction (up/down). When a preset value is reached, the card can interrupt the processor, under program control. The number of pulses accumulated can also be programmed to be read at any instant of time. When gated from an external timing source, it will measure rate (events per unit time).

A member of the family of Analog-Digital Input-Output (ADIO) cards for use with MACSYM, the EVC01, with its independent counters, increases the power of MACSYM and makes it easier to use in event-counting applications. It does this by eliminating the need to write software for event counting and by greatly reducing the role of MACSYM's processor in counting.

By counting pulses off-line, the EVC01 greatly reduces system overhead associated with counting, thus saving time and memory in applications that require event counting, rate measurements, and pulse accumulation. Quantities measured include flow, power, and production throughput.

The *count direction* (up or down) and *signal polarity* (leading or trailing edge of pulses) are selected by the user via jumpers on the board. When a channel under program control is preset to an initial count value, the card will interrupt the system on an overflow (or underflow, depending on the count direction selected).

On overflow/underflow, each channel automatically wraps around, permitting the count to be extended indefinitely, via software—a feature unique to EVC01.

Input debounce is provided; it uses a 20ms delay to eliminate false triggering associated with multiple inputs from bouncing mechanical contacts or noisy electronic comparators. ▶

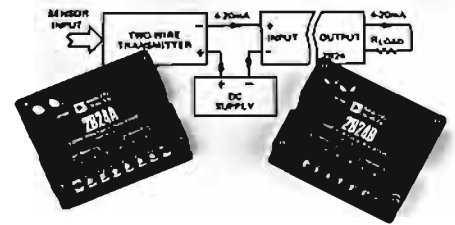
INDUSTRIAL LOOP-POWERED ISOLATOR

± 1500V-pk Isolation Between Current Loops CMR of 120dB @ 60Hz, 0.1% Total Output Error

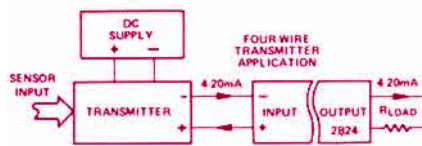
The Model 2B24* is a loop-powered isolator designed to accept current-loop signals in the range of 1 to 50mA and precisely re-transmit the current applied to the input with an accuracy of ±0.1% and ±1500-V peak isolation. A portion of the input signal is used to power the 2B24; no other power supply is required.

Two basic models are available (2B24A/B); both will handle the 4-to-20mA input signal range, but the 2B24B will also handle 10-to-50mA signals.

The 2B24 is designed to eliminate ground-loop problems and high common-mode noise interference in process control, moni-



toring and factory automation systems. It is especially useful for providing individual isolation of many current-loop outputs operating from a common source of dc power. It has low sensitivity to variations in load and excellent stability (±0.01%/°C) over a wide ambient temperature range (-30° to +85°C). Its rugged metal enclosure offers environmental protection and screw-terminal connections. Prices start at \$91 in 100s. ▶



MACSYM PULSE-TRAIN OUTPUT CARD

POC01 Offers Two Independent Pulse Generators Frequency, Duration, Duty Cycle Are Adjustable

The POC01* card has two independent programmable pulse generators. The TTL or isolated open-collector output pulses may be switch-programmed for any rate from 0.2 to 20kHz, in four ranges; they may either be free running or synchronized to an external signal, or run for a programmed time interval or number of pulses (up to 65,536). The duty cycle (or pulse width) can be adjusted by the user.

In typical applications, the POC01 may position valves, instruments, or machine tools, generate pulse trains for testing, and drive stepping-motor translators, analog controllers, or X-Y incremental plotters.

The POC01 is programmed by standard MACBASIC DIN and DOT software commands (see the MACSYM 10 article on pages 14-15). DOT statements provide both control signals and data information to the card; DIN statements read the status of the

card's output. In addition to specifying the output count, the control word selects and configures the channel to which the data word is sent. The POC01 interfaces with most popular analog controllers and stepper motor translators.

On-board oscillators are programmed either to output a given number of pulses or to run in a continuous mode. An external clock may also be used as the output pulse source or to synchronize the on-board oscillators to external events; it is also useful when the desired range of controlled output exceeds the range of the internal oscillators.

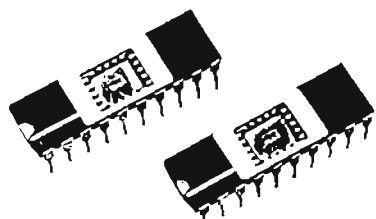
Pulses can be enabled either internally or externally, a useful feature in process-control applications—for example, where a logic interlock must be checked before initiating a stepping motion or altering a setpoint. ▶

*Use the reply card for technical data.

12-BIT MONOLITHIC MULTIPLYING DAC

Has On-Chip High-Speed 12-Bit Data Latch

AD7545AQ is Lowest-Priced in Its Class: \$9.50 (100s)



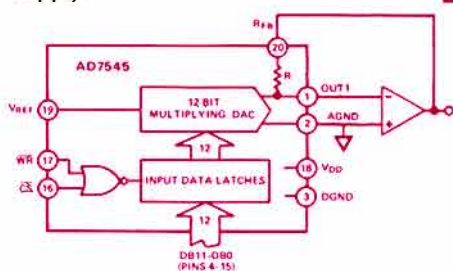
The AD7545* is a monolithic 12-bit CMOS multiplying DAC with on-board data latches, packaged in a 20-pin DIP. It is loaded by a single 12-bit-wide word and interfaces directly to most 12- and 16-bit bus systems. With supply voltages of +15V or +5V, it will respond to CMOS or TTL logic.

Data is loaded into the input latches under the control of the \overline{CS} and \overline{WR} inputs. When these inputs are low, the data latches are transparent; otherwise they are latched.

They may be tied low to allow direct unbuffered operation of the DAC.

A 4-quadrant multiplying DAC, the AD7545 may be used either as a DAC with an external reference or as a digitally controlled gain control for ac signals. Gain accuracy of the AD7545GL/GC/GU is to within 2 LSBs max over temperature.

When necessary, the AD7545 may be connected in the voltage-output mode for completely single-supply operation—DAC, reference, and output amp, all on one positive supply.

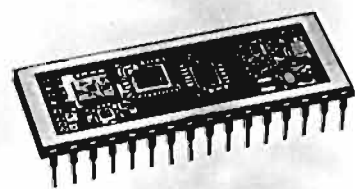


AD7545 Functional Diagram

FAST 10-BIT ADC

Converts in 1.8µs max

AD579 Is Self-Contained



The AD579*, a complete 10-bit a/d converter in a 32-pin hermetic ceramic package, has an internal reference, comparator, and clock, and requires no external components to perform a conversion to full accuracy in 1.8µs, max (2.2µs max, JN grade).

It is designed for applications in data acquisition with throughput requirements of up to 550kHz. This high conversion speed allows accurate digitization of high-frequency signals and high throughput rates in multi-channel data-acquisition systems. It may be short-cycled for even faster conversion at lower resolution.

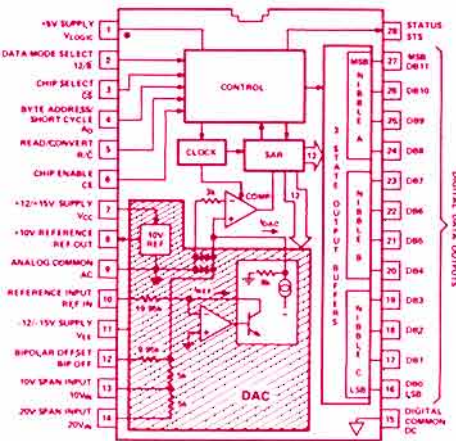
Key specs include: linearity error of $\pm 1/2$ LSB max and no missing codes over temperature, gain tempco of ± 30 ppm/°C, max, and low power drain, 775mW. A "Z" option is available for operation on ± 12 -volt power supplies.

Features that make the AD579 easy to use include adjustable internal clock, choice of parallel or serial output, and of jumper programmed input ranges. The 10V reference will supply up to 1mA externally. Prices (JN) start at \$103.50 (100s).

IMPROVED 12-BIT IC A/D CONVERTER

AD574A Features Faster Bus Interface,

Guaranteed for Operation with ± 12 -Volt Supplies



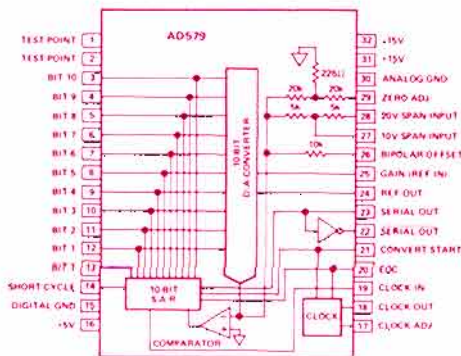
The AD574A* is an improved version of the AD574 and AD574Z 12-bit successive-approximation a/d converters, packaged in a 28-pin ceramic DIP. The three-state output buffer circuitry has been speeded up for direct interfacing to an 8-, 12-, or 16-bit

microprocessor bus. It is guaranteed to meet all of its specifications while operating on ± 12 V ($\pm 5\%$) supplies.

Its 3-state output buffers feature 250ns max access time and 150ns max output float delay. Control signals are easily derived from the system control bus.

The 12 bits of output data can be read as either one 12-bit word or as a left-justified pair of 8-bit bytes. It will operate equally well in a self-cycling stand-alone mode and can perform conversions and latch data into an external latch at a 28kHz min, 40kHz typical, sampling rate.

A reliable, laser-wafer-trimmed 2-chip device, the AD574A is available in 6 different grades. Prices start from \$34.50 (100s).



* For technical data, use the reply card.

μMAC-4000

Software Drivers for DEC, H-P, & APPLE II Computers



The μMAC-4000* Single-Board Measurement-and-Control System (see *Analog Dialogue* 15-1), as an intelligent front end, unburdens the host computer by controlling its own data-acquisition process, linearizing sensors, converting to engineering units, and checking limits for energy management, laboratory data logging, factory automation, and process control.

Three new software packages, designed for use with DEC's RSX-11-based systems, and HP-85 and Apple II computers, allow you to develop data acquisition and control routines for μMAC-4000* in high-level languages (FORTRAN and BASIC), using callable subroutines. An IBM package will also be available soon.

These software packages contain a compatible I/O driver routine, which assumes all communication responsibility between the μMAC-4000 and the host computer, eliminating any need for the user to write communications software.

The *AC1815 DEC Software Package**, available on a single floppy diskette, consists of loadable I/O drivers, which communicate with μMAC-4000. Simple, yet powerful, subroutine calls in FORTRAN and BASIC access analog channels and digital I/O ports. Price of the package is \$990.

The *AC1818 H-P Software Package*, a data cartridge,* provides a complete measurement-and-control function for any HP-85 or 9915A, using the μMAC-4000, the HP-82939A Serial Interface Card, and BASIC programming. Price of the package is \$250.

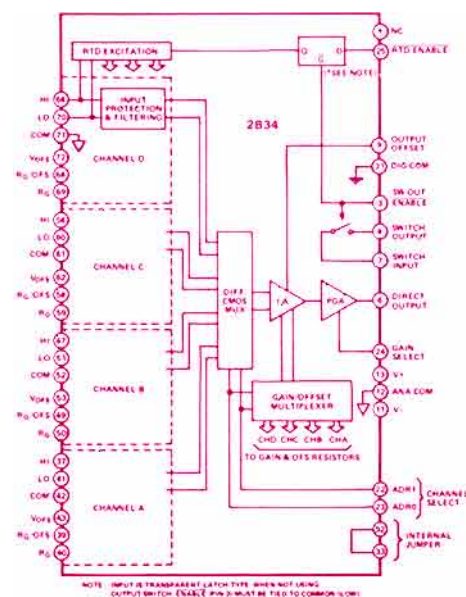
The *AC1820 Apple II Software Package*, written in BASIC, is available on a diskette. Price of the package is \$150. ▶

The 2B34* is a 4-channel, ±5V-output, signal conditioner. Designed to accept low-level signals directly from sensors, and condition them, it provides input protection, filtering, multiplexing, and programmable gain for strain gages and RTDs. For resistance temperature-detector (RTD) applications, the 2B34 provides a constant-current excitation source and lead-wire compensation.

Performance matches the rigorous demands of industrial applications: 1μV/°C offset drift, 94dB CMR at 60Hz (100Ω source imbalance), ±0.01% max nonlinearity, 25ppm/°C gain drift, and 130V rms differential input protection. Price of the 2" × 4" × 0.4" module is \$128 (100s).

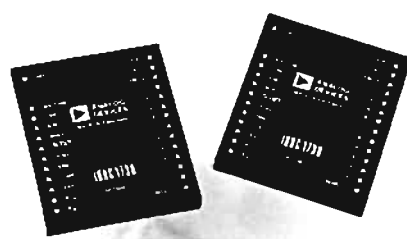
Solid state switching permits a scan rate of 3000-channels per second, considerably better performance—with longer life—than relays provide. User-selectable direct or

4-CHANNEL SIGNAL CONDITIONER 2B34 Provides Input Protection, Filtering, Gain, & Solid-State Multiplexing for Strain Gages and RTDs



switched output permits direct connection of several modules on an analog bus for more-than-4-channel applications. ▶

RESOLVER-TO-DIGITAL CONVERTER IRDC1730 Handles Resolvers & Inductosyns Isolated Inputs, 12-Bit Parallel Output



Model IRDC1730* is an Inductosyn-† or Resolver-to-Digital Converter that converts resolver-format (sine and cosine) signals into a 12-bit parallel word. Inputs may be either from a resolver (MSB = 180°) or an Inductosyn slider, via external preamps (MSB = 1/2 pitch, or one pole, of the Inductosyn track).

The converter is of the continuously tracking type in a Type 2 servo loop; this has the

advantages of zero drift and up-to-date, instantly available data with no velocity error. The system can track at rates up to 170 revolutions, or pitches, per second.

Because the signal and reference inputs are transformer isolated, they can be externally scaled with resistance to accommodate the user's particular voltage levels. Since the IRDC1730 works on a ratiometric, amplitude-comparison principle, any voltage drops between the resolver and the converter do not substantially affect accuracy. The technique also fosters high noise immunity. No external trims or adjustments are required.

The IRDC1730 is well-suited to digital display of Inductosyn or resolver information in robotics and machine-tool measurements, and industrial control. The low-profile (0.4" high) module weighs only 3.5oz. U.S. prices start at \$255 (1-9). ▶

*Use the reply card for technical data.
†Trademark of Farrand Industries, Inc.

IVAR WOLD IS NAMED ANALOG DEVICES CORPORATE FELLOW



"I am pleased to announce the appointment of Ivar Wold as ADI's first Corporate Fellow. Ivar came to Analog Devices in 1972 with the objective of researching, from the viewpoints of both market and technology, the opportunities to combine our data-acquisition components with computer hardware

and software to form computerized measurement and control subsystems.

"After a brief stint at designing panel meters and modular components, Ivar was given the assignment, as Director of the Systems Development Group, of recruiting a team of computer hardware and software engineers to explore innovative new approaches to analog subsystem designs. This was a pioneering effort, since—in 1973—the concept of data-acquisition subsystems was still embryonic.

"After several years of development and test marketing, the concept of the MACSYM II Measurement And Control subSYsteM evolved. This novel product embodied several important conceptual innovations, which have since set the standards for data-acquisition subsystems in the industry. These innovations include:

A bus concept, which permitted the direct integration of an unlimited variety of analog measurement-and-control functions, physically and logically, with the computer.

A unique software concept that provided the user with a measurement-and-control-oriented language that was real-time, multi-tasking, and used the popular BASIC syntax.

A physically integrated package, which could be sold as a sophisticated measurement-and-control tool for less than \$15,000.

"Ivar not only conceived the idea of MACSYM II; he also became the principal architect and implementer of the software package, as well as the design leader of the electronics hardware.

"The market for computerized measurement-and-control systems is still in its early development stage. In spite of this, since its introduction in October, 1978, Analog Devices has delivered more than 1000 MACSYM systems, totalling more than \$17 million in cumulative sales. More fundamentally, under Ivar's leadership, Analog Devices has assembled a competent organization with technical, manufacturing, and marketing skills, and experience much different from our conventional components businesses.

"Based on his experience with MACSYM II, Ivar has conceived an innovative approach to a software structure that will permit it, with modest modifications, to be used on very large—as well as very small—systems, independent of the microprocessor chosen. In addition, it will offer important competitive features which will provide a proprietary advantage for our next generation of MACSYM and μ MAC products, and could one day extend to programmable components as well.

"In order to expedite the development of this new software, Ivar,

in his new role as Corporate Fellow, will initiate the formation of a Systems Technology Center, reporting to Senior Vice President John Corsi. This center will initially concentrate on providing a software umbrella to encompass and tie together our various subsystem product developments. This charter will be extended to include other system technology developments that are seen as common to our multi-divisional subsystem product-development thrust.

WHAT IS A CORPORATE FELLOW?

"Ivar's contributions in leading Analog Devices into the subsystems business exemplify the criteria which we have established for Corporate Fellows. As *innovator*, Ivar has demonstrated unusually imaginative and original ideas for combining complex arrays of technology into commercially viable products. As *entrepreneur*, Ivar has charted new waters for Analog Devices and has taken personal and professional risk in pulling a components company into a world of computer hardware and software, despite the intense resistance which accompanies such a major cultural transition. As *strategist*, he has accurately mapped a course by concentrating on innovations in software and systems architecture, which has been confirmed as sound by the marketplace. As *sponsor*, he has influenced the organization to invest major resources in a new business and in a new market.

"His career illustrates organizational flexibility in moving back and forth between a management role (Division Manager of ADI Measurement-and-Control Products) and that of technologist. This is especially important in high-technology businesses, where roles change dramatically in moving from the early-stage startup of a new business to later full-scale commercialization.


"We hope that Ivar, with his new charter, will come up with another business/product idea that he can again lead through early development stages, where technology plays the major part, and once again enact the roles of entrepreneur, strategist, and sponsor.

"The impact and the benefits of Ivar's pioneering efforts have yet to be fully realized by the corporation, but thanks to his foresight and perseverance, we are now launched into a subsystems business which offers very great promise and potential for the future."

Ray Stata, President and Chairman of the Board

19 October 1981

A native of Harstad, Norway, Ivar spent a considerable portion of his life in England, where he obtained a B.Sc. in Aeronautics and Astronautics from the University of Southampton, with First-Class Honors. Following graduate work, during which he designed a hot-wire anemometer and a time-delay correlator (and obtained the first of many patents), he has developed complex analog and digital measuring instruments and a real-time multi-terminal banking computer.

He lives in Medfield, Massachusetts, with his wife, Maggie, née Jarvis, and their three children. When he tears himself away from his computer terminal, the family enjoys soccer in the summer and skiing in the winter. 

Worth Reading

NEW PUBLICATIONS FROM ANALOG DEVICES*

Catalog 1981/1982 *Short-Form Guide*® to Analog Devices Electronic Products for Precision Measurement and Control, 50 pages of key specs for standard data-conversion products, signal-conditioning products, temperature instrumentation, digital panel instruments, power supplies, computational circuits, measurement-and-control subsystems and systems, component test systems. Technologies range from monolithic ICs to system-level products.



Periodical *Macsymizer*, the MACSYM User's Newsletter, Volume 1, No. 2^o: Graphics, Auto Restart/Auto Reboot, Multitasking, Trig Functions, Binary Representation of Decimal Inputs, μ MAC-4000 and MACSYM 2 Checksum Generation and Checking, plus "System Notebook," "What's New," and Classifieds. 12 pages.

Periodical *Macsymizer*, the MACSYM User's Newsletter, Volume 1, No. 3^o: Analog and Digital Signal-Handling Techniques - 1, Tone Burst Testing, Large Numbers, Sampling Rates, plus "System Notebook," "What's New," Classifieds. 16 pages.

Application Note *On Gain Error and Gain Temperature Coefficient of CMOS Multiplying DACs*®, by Phil Burton, 4 pages

Application Note *Operational Amplifier Testing in BASIC* by Phil Carrier and Greg LaBonte, 58 pages, available upon request from Analog Devices Component Test Systems, 3 Corporate Place, Burlington MA 01803.

System Note *Multitasking: What Is It? What Can It Do for Me?*®, 4 pages

System Note *P-I-D Control Loops Are Easy with MACBASIC and MACSYM 2*®, 4 pages

System Note *The RS-232 Interface & MACSYM Products*®, 10 pages

System Note *Thermocouple Compensation and Linearization: How Can MACSYM Help Me Do It?*® 4 pages

System Note *Using the CLK03 Real-Time Calendar/Clock*®, 4 pages

Brochure *MACSYM 2: Computer-Based Measurement and Control Made Easy*®, 12 pages

Brochure *MACSYM 2: It's Measurement and Control Made Easy*®, 4 pp.

Brochure *MACSYM: A Powerful Control System for Batch-Control Applications*®, 6 pages

Brochure *MACSYM 10: Computer Control for Harsh Industrial Environments*®, 12 pages

REPRINTS*

"A CMOS Digitally Controlled Audio Attenuator for Hi-Fi Systems," by Michael J. Hynes and D. Philip Burton, reprinted from *IEEE Journal of Solid State Circuits*, Vol. SC-16, No. 1, February 1981, pages 15-20 (AD7110)

*Use the reply card to obtain free copies of any of the above publications.

"Voltage-Output Monolithic DAC Resolves 16 Bits," by Mike Tuthill and John Wynne, *Electronic Design*, June 11, 1981 (cover article)

"Isolate Analog Signals Safely and Accurately," by Delip Bokil, *Electronic Design*, September 17, 1981



MORE AUTHORS

(Continued from page 2)

Phil Burton (page 7) is Manager of Development engineering at Analog Devices B.V. in Limerick, Ireland. He holds a postgraduate degree in control systems and a Ph.D. in logic system design. He has been an independent consultant, Chief Engineer of Infotronics, Ltd., and Lecturer at the National Institute of Higher Education.



Jerry Whitmore (page 7) is New-Product Marketing Manager for Analog Devices, B.V. His photo and a brief biography appeared last year in *Analog Dialogue* 15-2 (page 18)

John Mills (page 10) is Senior Marketing Engineer for Subsystems Products at Analog Devices, Norwood, Massachusetts. His photo and a brief biography appeared last year in *Analog Dialogue* 15-1 (page 2).

Tim Wilhelm (page 12), Systems Design Engineer at CTS, has been with Analog Devices since graduating from Northeastern University with a BSEE. As a Test Engineer at ADS, he designed and developed μ P-based test systems and configurable environmental chambers for linear-IC production testing. Also responsible for a/d and d/a converter testing of ICs and hybrid circuits, he designed the LTS-2010 ADC Family Test Board.



Bill Miller (page 14) is Product-Line Manager for MACSYM systems. Before joining ADI, he was Product Manager for Process-Control Systems at Digital Equipment Corp. His breadth of experience in Measurement and Control includes earlier positions with Leeds & Northrup and Rochester Instrument Systems. Bill has a B.S.E.E. from Northeastern University and an M.B.A. from Clark, and he is a member of the Eta Kappa Nu and Tau Beta Pi honor societies.



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 15, Number 2, 1981) . . . Hybrid Digital-to-Analog Converters for Graphic Displays: HDG-0405/0605/0805 Family . . . Measurement-and-Control System with Mass Storage: MAC02-28 . . . New Package is the Key to Superior Hybrids: Slam Package . . . and these New-Product Briefs: Real-World Digital I/O with 2500-V rms Isolation (uMAC-4020); Thermocouple Signal Conditioner (2B50); RTD-to-4-to-20mA Transmitter (2B59); High-Performance Dual-FET-Input Op Amps (AD642/644); CMOS Logarithmic Multiplying DAC (AD7118); Fast 12-Bit Monolithic IC DACs (AD565A/566A); Resolver/Inductosyn-to-Digital Converter (IRDC1731); Fast (8 μ s) 12-Bit Hybrid ADCs (AD ADC84/85); Fast Sample-Hold Settles to ± 1 mV in 300ns (ADSHC-85) . . . Application Briefs: Advantages of 3-States in Synchro Conversion . . . User Prototype Family Board Tests "Anything" with LTS-2010 . . . Behind the Switch Symbol -- Using CMOS Effectively . . . Across the Editor's Desk: AD7581 and Microprocessors . . . plus Editor's Notes, Authors, Potpourri, etc.

NEW DATA SHEET (IMPROVED PRODUCT) . . . A data sheet describing the new, improved AD7524 Latched 8-bit CMOS Multiplying DAC is now available. Among the improvements: Latchup-free -- a Schottky diode is not required for protection; TTL/CMOS compatibility is guaranteed over temperature with $V_{DD} = +5V$ or $+15V$; Up-to-an-order-of-magnitude-faster input loading speeds, making the new version compatible with Motorola microprocessors; and, of course, linearity is an end-point specification.

ERRATA . . . AD7118 CMOS Log DAC Data Sheet, page 2, specification of accuracy relative to V_{IN} over the range, 0 to -30 dB, for L/C/U grades, should be 0.4 dB max at both supply voltages and all temperatures . . . 1981-1982 Short-Form Guide, page 6, proper units for input and output offset voltage of AD521 are mV max . . . AD7555 CMOS 4-1/2/5-1/2-Digit ADC Subsystem, Figure 6a on page 8, lead from pin 3 of A2 should continue straight through to tap of potentiometer R5, without any nodes or interruption . . . Combined data sheet HTS-0025 & HTC-0300 Ultra-High-Speed Hybrid Track-and-Hold Amplifiers: on page 1, HTS-0025 block diagram should not have note about pin 12; on page 2, Acquisition Time to 0.1% should read 170 (200) and 170 (200), Offset vs. Temperature should read 40 (75) ppm/ $^{\circ}$ C, Input Bias Current should read 15 μ A, HOLD COMMAND (DIGITAL INPUT) should read "Hold" Input, "0" = Hold / "1" = Track; POWER REQUIREMENTS -- HTS, V_{EE} condition should read $-5.2V \pm 0.25V$ (Pin 4).

PRODUCT NOTES AND APPLICATIONS The maximum data-transfer rate of the ACPO5 IEEE-488 GPIB Card is 500 bytes per second . . . Lists of available lenses for digital panel instruments are available from your local ADI sales engineer . . . Additional input-sensor options for the 2B59 Two-Wire RTD Transmitter include 1000-ohm Ni-Fe in the four standard temperature ranges specified for platinum, plus two additional ranges: for 2000-ohm NiFe, -30° F to $+130^{\circ}$ F (-34° C to $+54^{\circ}$ C) and $+200$ to $+400^{\circ}$ F ($+93$ to $+204^{\circ}$ C) . . . Full-load regulation for multiple-output power supplies (ac/dc and dc/dc) is tested by loading each output separately, (not together) according to standard industry practice . . . For proper converter operation, the $+15V$ power supplies for the MOD-1005 and MOD-1205 Video A/D Converters require close matching (to within 100mV) and must track over temperature . . . The 2B22 Isolated Voltage-to-Current Converter, designed for industrial applications as a transmission link between transmitters, indicators, controllers, and recorders must be reliable. Here is some recent data: It is designed to meet IEEE 472-1974 Surge Withstand Capability Standards for surges up to $+1500V$ peak; its MTBF prediction, performed by an independent test lab, is in excess of 271,000 hours; customer testing for use in nuclear plants has shown it able to operate in a radiation density level of 1 megard.

PATENTS . . . The following U. S. Patents have recently been issued: 4,268,759, to Barrie Gilbert, "Signal-Processing Circuitry with Intrinsic Temperature Insensitivity" . . . 4,270,118, to A. Paul Brokaw, "Parallel Analog-to-Digital Converter" . . . 4,286,225, to William H. Morong, III, "Isolation Amplifier."

PRICES, ETC. . . . Recently, prices of our AD7590DI series of dielectrically isolated switches were substantially reduced. If you haven't checked our switch prices lately, it would be worth your while to do so . . . If you're using (or trying to use) someone else's monolithic and hybrid linear integrated circuits (op amps, a/d, d/a, and v/f converters, voltage references, switches, temperature transducers, analog multipliers, etc.), and feel the need for improvement in price, performance, support, or just the joy of doing business with Analog Devices, ask your local ADI sales engineer for our "Alternate Sources" guide.

Our new HDG series hybrid digital-to-analog converters are today's best high performance D/A solutions for raster scan graphics displays. Available in 8-, 6-, and 4-bit models, they offer clear superiority in speed, size, price and performance.

Ideal for raster scan graphics systems, these DAC's can also be used in TV video reconstruction, digital VCO's, analytical instrumentation, or any application requiring ultra-fast voltage or current settling times.

FASTEST

They're the fastest D/A's with full composite capabilities available today. Our 8-bit model offers an ultra-fast 7ns settling time to 0.4% (8ns Max), and our 6-bit and 4-bit models typically settle in 5ns (6 Max) and 3ns (4 Max) respectively.

SMALLEST

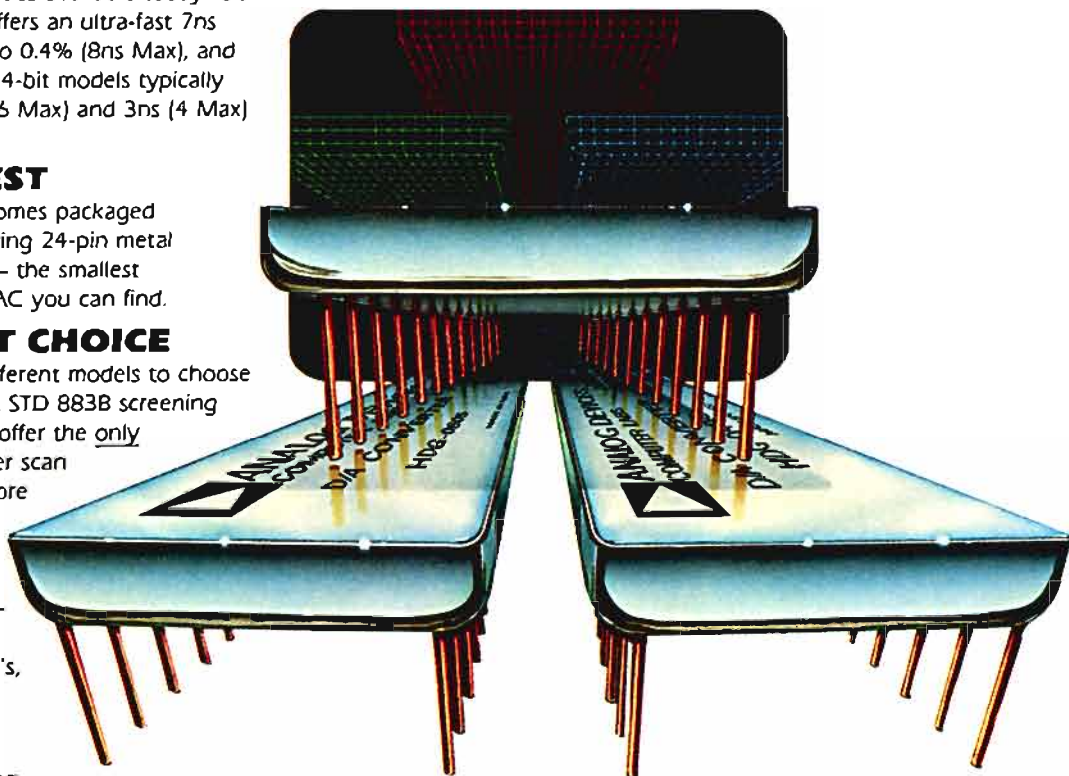
Each model comes packaged in a space-saving 24-pin metal hermetic DIP – the smallest raster scan DAC you can find.

BIGGEST CHOICE

With three different models to choose from, and MIL STD 883B screening available, we offer the only choice in raster scan DAC's. For more information on these ultra-fast, compact, cost-effective, full-featured DAC's, call our Applications Engineers at (919) 292-6427.

MOST COMPLETE

All three units have input latches and composite video controls, including sync, blanking, and a unique feature—10% bright. The HDG's have a reference white input control and are designed to be compatible with EIA standards. Absolute accuracies on the 8-, 6-, and 4-bit models range from ± 0.19 (8-bits) to $\pm 3.2\%$ of gray scale. Logic inputs are ECL compatible; glitch energy is only 50 pV-s; and output current develops 1V across a 75 ohm load. The units are monotonic from -25°C to $+85^{\circ}\text{C}$, and require only a single -5.2V power supply.



LOWEST PRICE

The HDG series is the most cost-effective DAC solution for raster scan designs. And production quantities are immediately available from stock. Prices start as low as \$46 (in 100s) for our 4-bit model (\$57.50 for 6-bit and \$63 for 8 bits).

The last words in raster scan DAC's

Analog Devices, Inc., One Technology Way, Norwood, MA 02062. Headquarters (617) 329-4700. California (714) 842-1717. (408) 947-0633. Illinois (312) 653-5000. Ohio (614) 764-8795. Pennsylvania (215) 643-7790. Texas (214) 231-5094. (713) 664-6704. Belgium 031/374803. Denmark 02/845800. France 01/6873411. Holland 016/2051080. Israel 052/21023. Italy 02/6898045. Japan 03/7636876. Sweden 08/782740. Switzerland 022/315760. United Kingdom 01-9410466. West Germany 089/530319.

Use the reply card for Technical Data.