ANALOG DEVICES

LC²MOS
16-Bit, High Speed Sampling ADCs

AD7884/AD7885

FEATURES
Monolithic Construction
Fast Conversion: 5.3 μs
High Throughput: 166 kSPS
Low Power: 250 mW

APPLICATIONS
Automatic Test Equipment
Medical Instrumentation
Industrial Control
**Data Acquisition Systems**
Robotics

GENERAL DESCRIPTION
The AD7884/AD7885 is a 16-bit monolithic analog-to-digital converter with internal sample-and-hold and a conversion time of 5.3 μsec. The maximum throughput rate is 166 kSPS. It uses a two pass flash architecture to achieve this speed. Two input ranges are available: ±5 V and ±3 V. Conversion is initiated by the $\overline{CONVST}$ signal. The result can be read into a microprocessor using the $\overline{CS}$ and $\overline{RD}$ inputs on the device. The AD7884 has a 16-bit parallel reading structure while the AD7885 has a byte reading structure. The conversion result is in 2s complement code.

The AD7884/AD7885 has its own internal oscillator which controls conversion. It runs from ±5 V supplies and needs a V_{REF+} of +3 V.

The AD7884 is available in a 40-pin plastic DIP package and in a 44-pin PLCC package.

The AD7885 is available in 28-pin plastic DIP package and in a 28-pin PLCC package.

FUNCTIONAL BLOCK DIAGRAMS
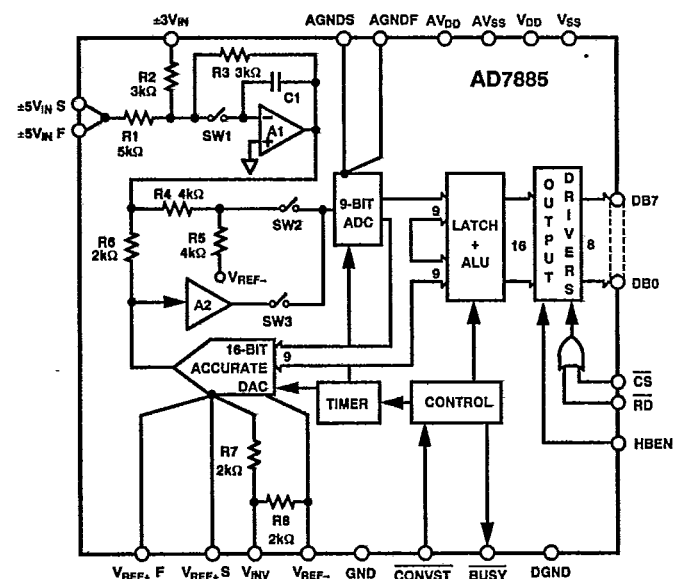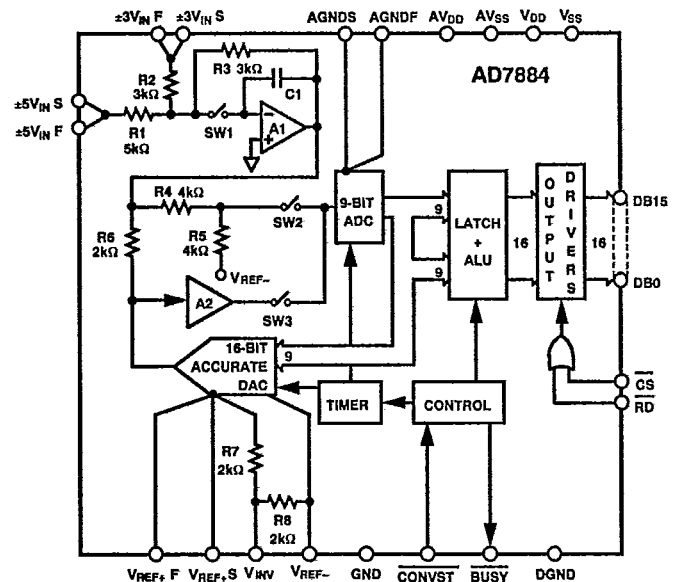
REV. A

AD7884/AD7885—SPECIFICATIONS[1, 2]

(V$_{DD}$ = +5 V ± 5%, V$_{SS}$ = −5 V ± 5%, V$_{REF+}$S = +3 V; AGND = DGND = GND = 0 V; f$_{SAMPLE}$ = 166 kHz. All specifications T$_{MIN}$ to T$_{MAX}$, unless otherwise noted).

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Parameter	A Version[1, 2]	B Version[1, 2]	Units	Test Conditions/Comments
DC ACCURACY				
Resolution	16	16	Bits	
Minimum Resolution for Which No Missing Codes Are Guaranteed	16	16	Bits	
Integral Nonlinearity		±0.006	% FSR max	Typically 0.003% FSR
Positive Gain Error	±0.03	±0.03	% FSR typ	
Positive Gain Error		±0.05	% FSR max	
Gain TC[3]	±2	±2	ppm FSR/°C typ	
Bipolar Zero Error	±0.05	±0.05	% FSR typ	
Bipolar Zero Error		±0.1	% FSR max	
Bipolar Zero TC[3]	±2	±2	ppm FSR/°C typ	
Negative Gain Error	±0.05	±0.05	% FSR typ	
Negative Gain Error		±0.1	% FSR max	
Offset TC[3]	±2	±2	ppm FSR/°C typ	
Noise	120	120	μV rms typ	78 μV rms typical in ±3 V Input Range
DYNAMIC PERFORMANCE				
Signal to (Noise + Distortion) Ratio	84	84	dB min	Input Signal: ±5 V, 1 kHz Sine Wave, Typically 86 dB
	82	82	dB typ	Input Signal: ±5 V, 12 kHz Sine Wave
Total Harmonic Distortion	−88	−88	dB max	Input Signal: ±5 V, 1 kHz Sine Wave
	−84	−84	dB typ	Input Signal: ±5 V, 12 kHz Sine Wave
Peak Harmonic or Spurious Noise	−88	−88	dB max	Input Signal: ±5 V, 1 kHz Sine Wave
Intermodulation Distortion (IMD)				
2nd Order Terms	−84	−84	dB typ	f$_A$ = 11.5 kHz, f$_B$ = 12 kHz, f$_{SAMPLE}$ = 166 kHz
3rd Order Terms	−84	−84	dB typ	f$_A$ = 11.5 kHz, f$_B$ = 12 kHz, f$_{SAMPLE}$ = 166 kHz
CONVERSION TIME				
Conversion Time	5.3	5.3	μs max	
Acquisition Time	2.5	2.5	μs max	
Throughput Rate	166	166	kSPS max	There is an overlap between conversion and acquisition.
ANALOG INPUT				
Voltage Range	±5	±5	Volts	
	±3	±3	Volts	
Input Current	±4	±4	mA max	
REFERENCE INPUT				
Reference Input Current	±5	±5	mA max	V$_{REF}$ + S = +3 V
LOGIC INPUTS				
Input High Voltage, V$_{INH}$	2.4	2.4	V min	V$_{DD}$ = 5 V ± 5%
Input Low Voltage, V$_{INL}$	0.8	0.8	V max	V$_{DD}$ = 5 V ± 5%
Input Current, I$_{IN}$	±10	±10	μA max	Input Level = 0 V to V$_{DD}$
Input Capacitance, C$_{IN}$[3]	10	10	pF max	
LOGIC OUTPUTS				
Output High Voltage, V$_{OH}$	4.0	4.0	V min	I$_{SOURCE}$ = 40 μA
Output Low Voltage, V$_{OL}$	0.4	0.4	V max	I$_{SINK}$ = 1.6 mA
DB15–DB0				
Floating-State Leakage Current	10	10	μA max	
Floating-State Output Capacitance[3]	15	15	pF max	
POWER REQUIREMENTS				
V$_{DD}$	+5	+5	V nom	±5% for Specified Performance
V$_{SS}$	−5	−5	V nom	±5% for Specified Performance
I$_{DD}$	35	35	mA max	Typically 25 mA
I$_{SS}$	30	30	mA max	Typically 25 mA
Power Supply Rejection Ratio				
ΔGain/ΔV$_{DD}$	86	86	dB typ	
ΔGain/ΔV$_{SS}$	86	86	dB typ	
Power Dissipation	325	325	mW max	Typically 250 mW

NOTES
[1]Temperature Ranges are as follows: A, B Versions: −40°C to +85°C.
[2]V$_{IN}$ = ±5 V.
[3]Sample tested to ensure compliance.
Specifications subject to change without notice.

AD7884/AD7885

TIMING CHARACTERISTICS[1, 2] (V_{DD} = +5 V ± 5%, V_{SS} = −5 V ± 5%, AGND = DGND = GND = 0 V. See Figures 2, 3, 4 and 5.)

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Parameter	Limit at +25°C (All Versions)	Limit at T_{MIN}, T_{MAX} (A, B Versions)	Units	Conditions/Comments
t_1	50	50	ns min	$\overline{CONVST}$ Pulse Width
t_2	100	100	ns max	$\overline{CONVST}$ to $\overline{BUSY}$ Low Delay
t_3	0	0	ns min	$\overline{CS}$ to $\overline{RD}$ Setup Time
t_4	60	60	ns min	$\overline{RD}$ Pulse Width
t_5	0	0	ns min	$\overline{CS}$ to $\overline{RD}$ Hold Time
$t_6{}^2$	57	57	ns max	Data Access Time after $\overline{RD}$
$t_7{}^3$	5	5	ns min	Bus Relinquish Time after $\overline{RD}$
	50	50	ns max	
t_8	40	40	ns min	New Data Valid before Rising Edge of $\overline{BUSY}$
t_9	10	80	ns min	HBEN to $\overline{RD}$ Setup Time
t_{10}	25	25	ns min	HBEN to $\overline{RD}$ Hold Time
t_{11}	60	60	ns min	HBEN Low Pulse Duration
t_{12}	60	60	ns min	HBEN High Pulse Duration
t_{13}	55	70	ns max	Propagation Delay from HBEN Falling to Data Valid
t_{14}	55	70	ns max	Propagation Delay from HBEN Rising to Data Valid

NOTES

[1]Timing specifications in bold print are 100% production tested. All other times are sample tested at +5°C to ensure compliance. All input signals are specified with tr = tf = 5 ns (10% to 90% of 5 V) and timed from a voltage level of 1.6 V.

[2]t_6 is measured with the load circuit of Figure 1 and defined as the time required for an output to cross 0.8 V or 2.4 V.

[3]t_7 is derived from the measured time taken by the data outputs to change 0.5 V when loaded with the circuit of Figure 1. The measured number is then extrapolated back to remove the effects of charging or discharging the 100 pF capacitor. This means that the time, t_7, quoted in the Timing Characteristics is the true bus relinquish time of the part and as such is independent of external bus loading capacitances.

Specifications subject to change without notice.

ORDERING GUIDE

Model[1]	Temperature Range	Linearity Error (% FSR)	SNR (dB)	Package Option[2]
AD7884AN	−40°C to +85°C		84	N-40A
AD7884BN	−40°C to +85°C	±0.006	84	N-40A
AD7884AP	−40°C to +85°C		84	P-44A
AD7884BP	−40°C to +85°C	±0.006	84	P-44A
AD7885AN	−40°C to +85°C		84	N-28A
AD7885BN	−40°C to +85°C	±0.006	84	N-28A
AD7885AP	−40°C to +85°C		84	P-28A
AD7885BP	−40°C to +85°C	±0.006	84	P-28A

[1]Analog Devices reserves the right to ship cerdip (Q) packages in lieu of plastic DIP (N) packages.

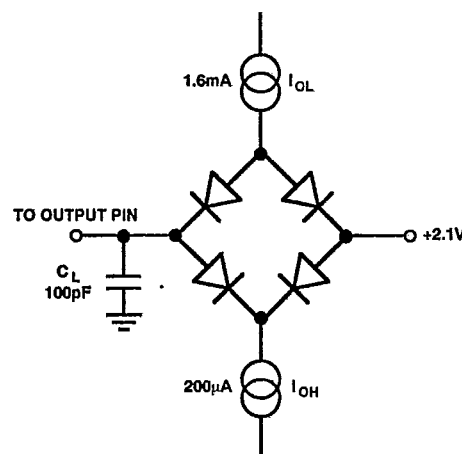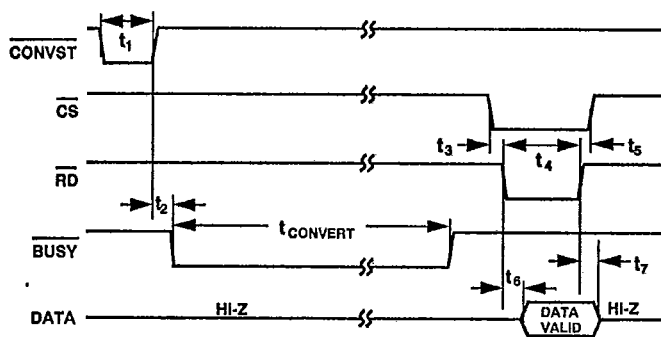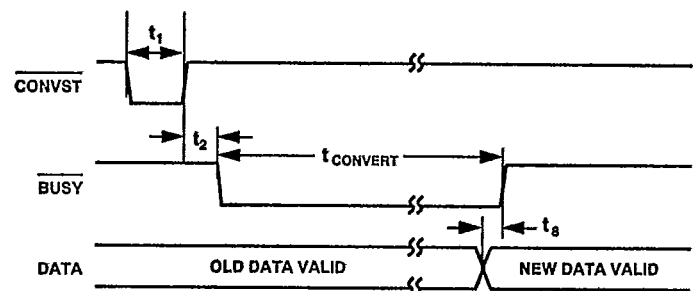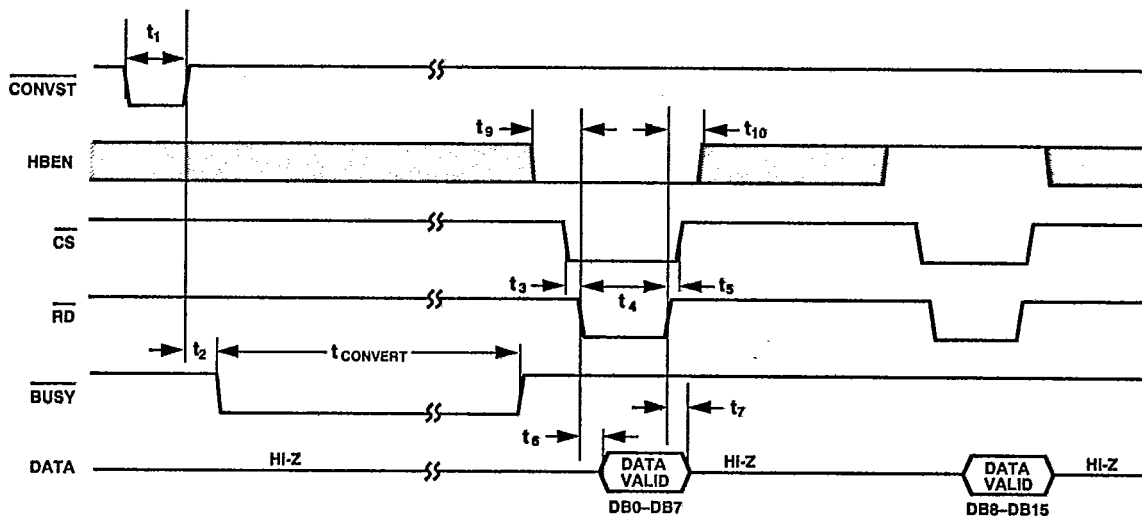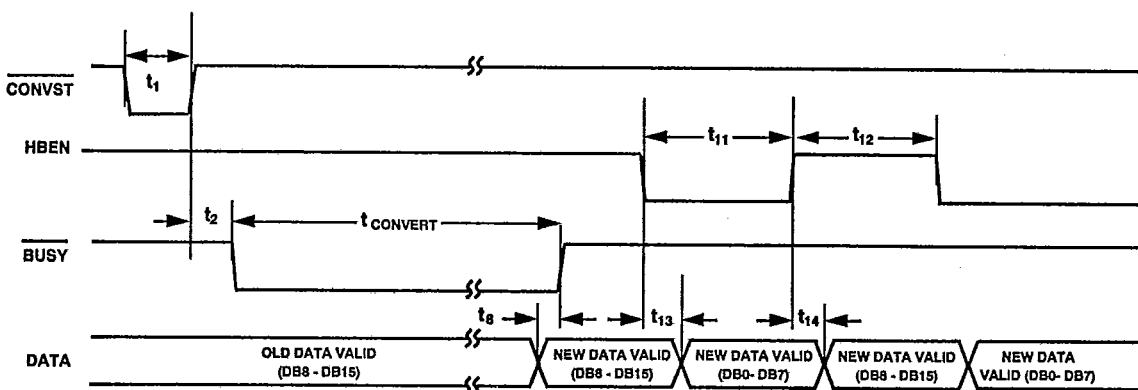[2]N = Plastic DIP; P = Plastic Leaded Chip Carrier (PLCC).

Figure 1. Load Circuit for Access Time and Bus Relinquish Time

AD7884/AD7885

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Figure 2. AD7884 Timing Diagram, Using $\overline{CS}$ and $\overline{RD}$

Figure 3. AD7884 Timing Diagram, with $\overline{CS}$ and $\overline{RD}$ Permanently Low

Figure 4. AD7885 Timing Diagram, Using $\overline{CS}$ and $\overline{RD}$

Figure 5. AD7885 Timing Diagram, with $\overline{CS}$ and $\overline{RD}$ Permanently Low

REV. A

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ABSOLUTE MAXIMUM RATINGS[1]

V_{DD} to AGND .... −0.3 V to +7 V
AV_{DD} to AGND .... −0.3 V to +7 V
V_{SS} to AGND .... +0.3 V to −7 V
AV_{SS} to AGND .... −0.3 V to −7 V
AGND Pins to DGND .... −0.3 V to V_{DD} +0.3 V
AV_{DD} to V_{DD}[2] .... −0.3 V to +7 V
AV_{SS} to V_{SS}[2] .... +0.3 V to −7 V
GND to DGND .... −0.3 V to V_{DD} +0.3 V
$V_{IN}S$, $V_{IN}F$ to AGND .... V_{SS} −0.3 V to V_{DD} +0.3 V
V_{REF+} to AGND .... V_{SS} −0.3 V to V_{DD} +0.3 V
V_{REF-} to AGND .... V_{SS} −0.3 V to V_{DD} +0.3 V
V_{INV} to AGND .... V_{SS} −0.3 V to V_{DD} +0.3 V
Digital Inputs to DGND .... −0.3 V to V_{DD} +0.3 V
Digital Outputs to DGND .... −0.3 V to V_{DD} +0.3 V

Operating Temperature Range
 Commercial Plastic (A, B Versions) ...... −40°C to +85°C
 Industrial Cerdip (A, B Versions) .... −40°C to +85°C
 Extended Cerdip (T Versions) .... −55°C to +125°C
Storage Temperature Range .... −65°C to +150°C
Lead Temperature (Soldering, 10 secs) .... +300°C
Power Dissipation (Any Package) to +75°C .... 1000 mW
Derates above +75°C by .... 10 mW/°C

[1]Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
[2]If the AD7884/AD7885 is being powered from separate analog and digital supplies, AV_{DD} should always come up before V_{DD} and AV_{SS} should always come up before V_{SS}. See Figure 13 for a recommended protection circuit using Schottky diodes.

CAUTION
ESD (electrostatic discharge) sensitive device. The digital control inputs are diode protected; however, permanent damage may occur on unconnected devices subject to high energy electrostatic fields. Unused devices must be stored in conductive foam or shunts. The protective foam should be discharged to the destination socket before devices are removed.
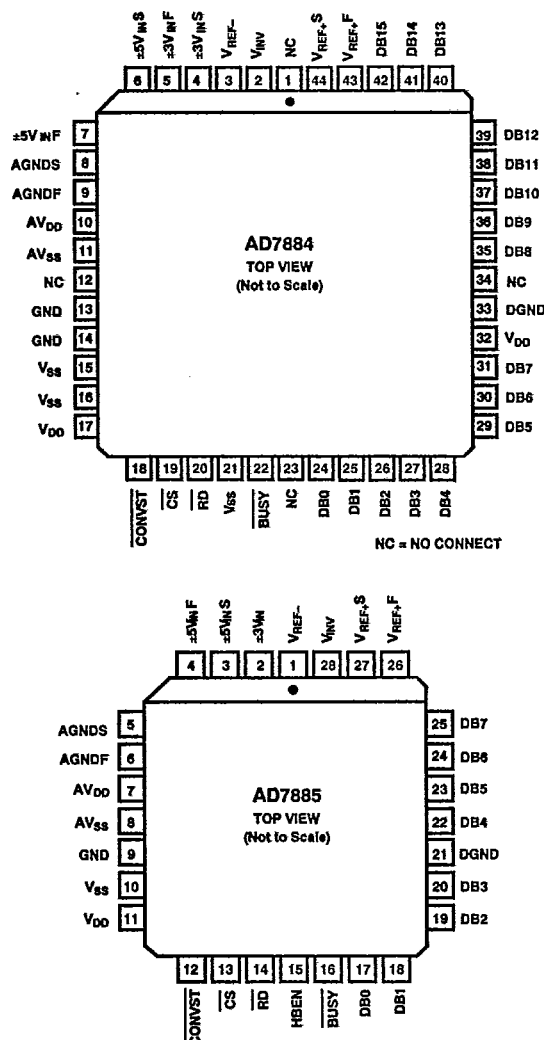

WARNING
ESD SENSITIVE DEVICE

PIN CONFIGURATIONS

DIP

PLCC

NC = NO CONNECT
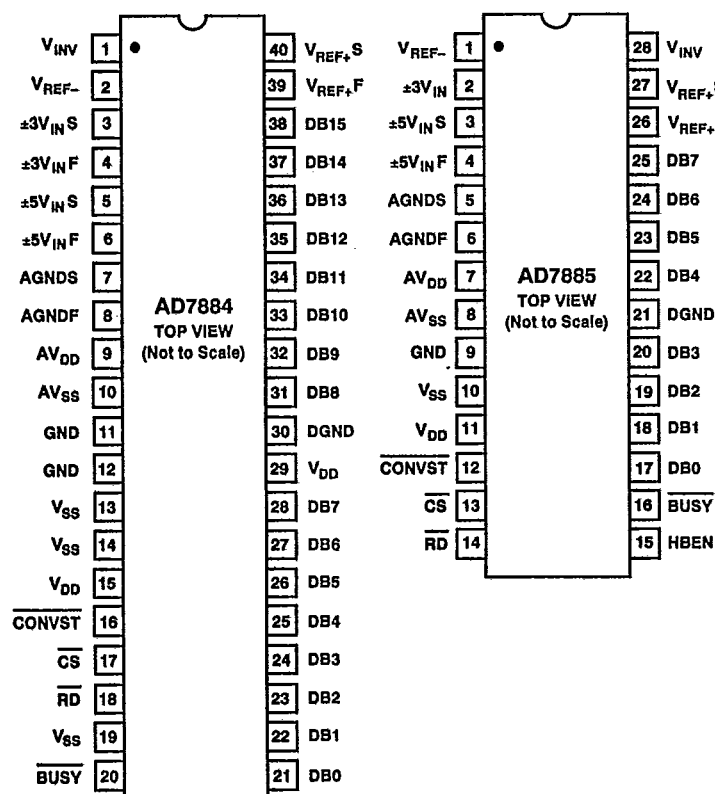
AD7884/AD7885

PIN FUNCTION DESCRIPTION

AD7884 Pin	AD7885 Pin	Description
V_{INV}	V_{INV}	This pin is connected to the inverting terminal of an op amp, as in Figure 6 and allows the inversion of the supplied +3 V reference.
V_{REF-}	V_{REF-}	This is the negative reference input and it can be obtained by using an external amplifier to invert the positive reference input. In this case, the amplifier output is connected to V_{REF-}. See Figure 6.
$\pm 3V_{IN}S$	—	This is the analog input sense pin for the ± 3 volt analog input range on the AD7884.
$\pm 3V_{IN}F$	—	This is the analog input force pin for the ± 3 volt analog input range on the AD7884. When using this input range, the ± 5 $V_{IN}F$ and ± 5 $V_{IN}S$ pins should be tied to AGND.
—	$\pm 3V_{IN}$	This is the analog input pin for the ± 3 volt analog input range on the AD7885. When using this input range, the ± 5 $V_{IN}F$ and ± 5 $V_{IN}S$ pins should be tied to AGND.
$\pm 5V_{IN}S$	$\pm 5V_{IN}S$	This is the analog input sense pin for the ± 5 volt analog input range on both the AD7884 and the AD7885.
$\pm 5V_{IN}F$	$\pm 5V_{IN}F$	This is the analog input force pin for the ± 5 volt analog input range on both the AD7884 and AD7885. When using this input range, the ± 3 $V_{IN}F$ and ± 3 $V_{IN}S$ pins should be tied to AGND.
AGNDS	AGNDS	This is the ground return sense pin for the 9-bit ADC and the on-chip residue amplifier.
AGNDF	AGNDF	This is the ground return force pin for the 9-bit ADC and the on-chip residue amplifier.
AV_{DD}	AV_{DD}	Positive analog power rail for the sample-and-hold amplifier and the residue amplifier.
AV_{SS}	AV_{SS}	Negative analog power rail for the sample-and-hold amplifier and the residue amplifier.
GND	GND	This is the ground return for sample-and-hold section.
V_{SS}	V_{SS}	Negative supply for the 9-bit ADC.
V_{DD}	V_{DD}	Positive supply for the 9-bit ADC and all device logic.
$\overline{CONVST}$	$\overline{CONVST}$	This asynchronous control input starts conversion.
$\overline{CS}$	$\overline{CS}$	Chip Select control input.
$\overline{RD}$	$\overline{RD}$	Read control input. This is used in conjunction with $\overline{CS}$ to read the conversion result from the device output latch.
—	HBEN	High Byte Enable. Active high control input for the AD7885. It selects either the high or the low byte of the conversion for reading.
$\overline{BUSY}$	$\overline{BUSY}$	Busy output. The Busy output goes low when conversion begins and stays low until it is completed, at which time it goes high.
DB0–DB15	—	16-bit parallel data word output on the AD7884.
—	DB0–DB7	8-bit parallel data byte output on the AD7885.
DGND	DGND	Ground return for all device logic.
$V_{REF+}F$	$V_{REF+}F$	Reference force input.
$V_{REF+}S$	$V_{REF+}S$	Reference sense input. The device operates from a +3 V reference.

AD7884/AD7885

TERMINOLOGY

Integral Nonlinearity
This is the maximum deviation from a straight line passing through the endpoints of the ADC transfer function.

Differential Nonlinearity
This is the difference between the measured and the ideal 1 LSB change between any two adjacent codes in the ADC.

Bipolar Zero Error
This is the deviation of the midscale transition (all 0s to all 1s) from the ideal (AGND).

Positive Gain Error
This is the deviation of the last code transition (01 . . . 110 to 01 . . . 111) from the ideal ($+V_{REF+}$ S $-$ 1 LSB), after Bipolar Zero Error has been adjusted out.

Negative Gain Error
This is the deviation of the first code transition (10 . . . 000 to 10 . . . 001) from the ideal ($-V_{REF+}$S + 1 LSB), after Bipolar Zero Error has been adjusted out.

Signal to (Noise + Distortion) Ratio
This is the measured ratio of signal to (noise + distortion) at the output of the A/D converter. The signal is the rms amplitude of the fundamental. Noise is the rms sum of all nonfundamental signals up to half the sampling frequency ($f_S/2$), excluding dc. The ratio is dependent upon the number of quantization levels in the digitization process; the more levels, the smaller the quantization noise. The theoretical signal to (noise + distortion) ratio for an ideal N-bit converter with a sine wave input is given by:

$$Signal\ to\ (Noise + Distortion) = (6.02N + 1.76)\ dB$$

Thus for an ideal 16-bit converter, this is 98 dB.

Total Harmonic Distortion
Total harmonic distortion (THD) is the ratio of the rms sum of harmonics to the fundamental. For the AD7884/AD7885, it is defined as:

$$THD\ (dB) = 20\ log\ \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2 + V_6^2}}{V_1}$$

where V_1 is the rms amplitude of the fundamental and V_2, V_3, V_4, V_5 and V_6 are the rms amplitudes of the second through the sixth harmonics.

Peak Harmonic or Spurious Noise
Peak harmonic or spurious noise is defined as the ratio of the rms value of the next largest component in the ADC output spectrum (up to $f_S/2$ and excluding dc) to the rms value of the fundamental. Normally, the value of this specification is determined by the largest harmonic in the spectrum, but for parts where the harmonics are buried in the noise floor, it will be a noise peak.

Intermodulation Distortion
With inputs consisting of sine waves at two frequencies, fa and fb, any active device with nonlinearities will create distortion products at sum and difference frequencies of mfa ± nfb where m, n = 0, 1, 2, 3, etc. Intermodulation terms are those for which neither m or n are equal to zero. For example, the second order terms include (fa + fb) and (fa − fb), while the third order terms include (2fa + fb), (2fa − fb), (fa + 2fb) and (fa − 2fb).

The AD7884/AD7885 is tested using the CCIFF standard where two input frequencies near the top end of the input bandwidth are used. In this case, the second and third order terms are of different significance. The second order terms are usually distanced in frequency from the original sine waves while the third order terms are usually at a frequency close to the input frequencies. As a result, the second and third order terms are specified separately. The calculation of the intermodulation distortion is as per the THD specification where it is the ratio of the rms sum of the individual distortion products to the rms amplitude of the fundamental expressed in dBs.

Power Supply Rejection Ratio
This is the ratio, in dBs, of the change in positive gain error to the change in V_{DD} or V_{SS}. It is a dc measurement.

OPERATIONAL DIAGRAM
An operational diagram for the AD7884/AD7885 is shown in Figure 6. It is set up for an analog input range of ±5 V. If a ±3 V input range is required, A1 should drive ±3 V_{IN}S and ±3 V_{IN}F with ±5 V_{IN}S, ±5 V_{IN}F being tied to system AGND.

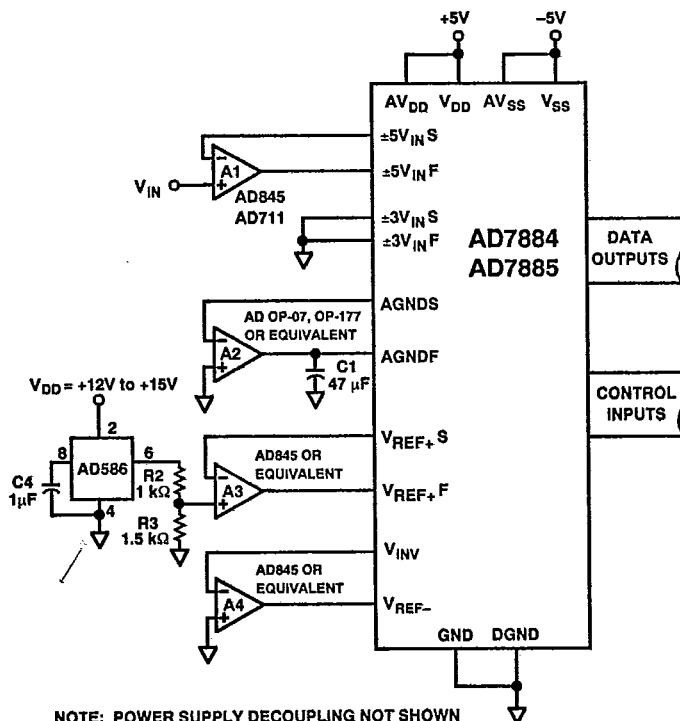NOTE: POWER SUPPLY DECOUPLING NOT SHOWN

Figure 6. AD7884/AD7885 Operational Diagram

The chosen input buffer amplifier (A1) should have low noise and distortion and fast settling time for high bandwidth applications. Both the AD711 and the AD845 are suitable amplifiers.

A2 is the force, sense amplifier for AGND. The AGNDS pin should be at zero potential. Therefore, the amplifier must have a very low input offset voltage and good noise performance. For these reasons, either the AD OP-07 or OP-177 is recommended. The output of A2 is decoupled with a 47 μF solid tantalum capacitor to AGND to deal with the fast current transients on the AGNDS pin. The stability of this arrangement is marginal and if the user wishes to improve the phase margin, the circuit given in Figure 7 may be used. A feedback capacitor (R_F) of 47 μF should be used. This circuit compensates for the load capacitor by adding a low frequency zero and ensures an
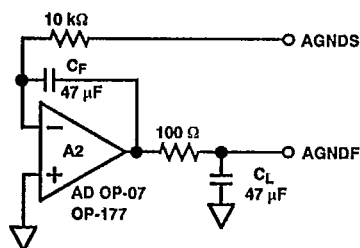
Figure 7. Compensation Circuit for A2

adequate phase margin. An alternative is to use a very fast setting amplifier like the AD845 or AD847. This requires no C_L and thus no compensation. It gives better settling in Multiplexer applications.

If AGNDS and AGNDF are simply tied together to Star Ground instead of buffering, the SNR and THD are not significantly degraded. However, dc specifications like INL, Bipolar Zero and Gain Error will be degraded.

The required +3 V reference is derived from the AD586. The +5 V output is divided down to +3 V by R2 and R3 before being buffered by A3. A4 is a unity gain inverter which provides the −3 V negative reference. The gain setting resistors are on-chip and are factory trimmed to ensure precise tracking of V_{REF+}. Figure 6 shows A3 and A4 as AD845s. These have the ability to respond to the rapidly changing reference input impedance.

CIRCUIT DESCRIPTION
Analog Input Section
The analog input section of the AD7884/AD7885 is shown in Figure 8. It contains both the input signal conditioning and sample-and-hold amplifier. Note that the analog input is truly benign. When SW1a goes open circuit to put the SHA into the hold mode, SW1b is closed. This means that the input resistors, R1 and R2 are always connected to either virtual ground or true ground.
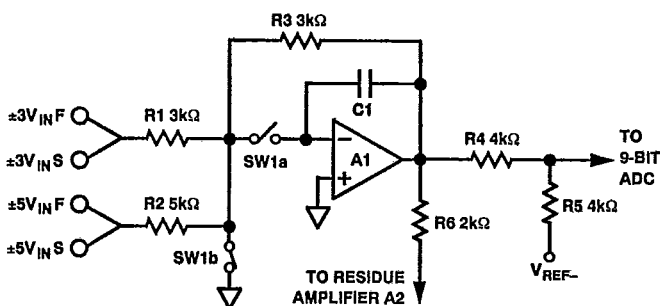
When the ±3 $V_{IN}S$ and ±3 $V_{IN}F$ inputs are tied to 0 V, the input section has a gain of −0.6 and transforms an input signal of ±5 volts to the required ±3 volts. When the ±5 $V_{IN}S$ and ±5 $V_{IN}F$ inputs are grounded, the input section has a gain of −1 and so the analog input range is now ±3 volts. Resistors R4 and R5, at the amplifier output, further condition the ±3 volts signal to be 0 to −3 volts. This is the required input for the 9-bit A/D converter section.

With SW1a closed, the output of A1 follows the input (the sample-and-hold is in the track mode). On the rising edge of the $\overline{CONVST}$ pulse, SW1a goes open circuit, and capacitor C1 holds the voltage on the output of A1. The sample-and-hold is now in the hold mode. The aperture delay time for the sample-and-hold is nominally 50 ns.

A/D Converter Section
The AD7884/AD7885 uses a two-pass flash technique in order to achieve the required speed and resolution. When the $\overline{CONVST}$ control input goes from low to high, the sample-and-hold amplifier goes into the hold mode and a 0 V to −3 V signal is presented to the input of the 9-bit ADC. The first phase of conversion generates the 9 MSBs of the 16-bit result and transfers these to the latch and ALU combination. They are also fed back to the 9 MSBs of the 16-bit DAC. The 7 LSBs of the DAC are permanently loaded with 0s. The DAC output is subtracted from the analog input with the result being amplified and offset in the Residue Amplifier Section. The signal at the output of A2 is proportional to the error between the first phase result and the actual analog input signal and is digitized in the second conversion phase. This second phase begins when the 16-bit DAC and the Residue Error Amplifier have both settled. First, SW2 is turned off and SW3 is turned on. Then, the SHA section of the Residue Amplifier goes into hold mode. Next SW2 is turned off and SW3 is turned on. The 9-bit result is transferred to the output latch and ALU. An error correction algorithm now compensates for the offset inserted in the Residue Amplifier Section and errors introduced in the first pass conversion and combines both results to give the 16-bit answer.
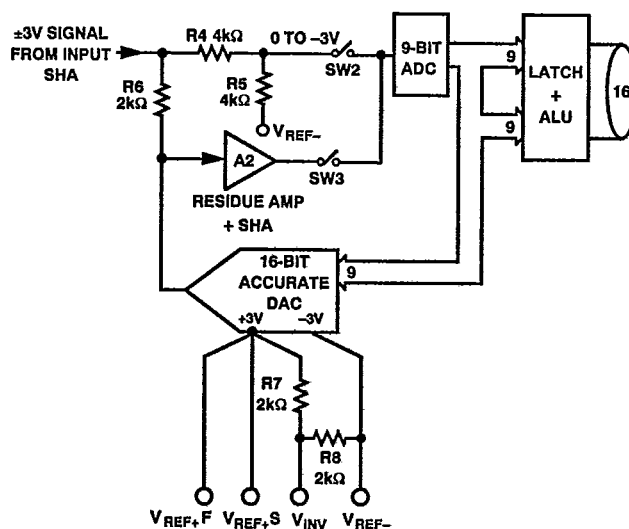

Figure 8. AD7884/AD7885 Analog Input Section

Figure 9. A/D Converter Section

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Timing and Control Section

Figure 10 shows the timing and control sequence for the AD7884/AD7885. When the part receives a $\overline{CONVST}$ pulse, the conversion begins. The input sample-and-hold goes into the hold mode 50 ns after the rising edge of $\overline{CONVST}$ and $\overline{BUSY}$ goes low. This is the first phase of conversion and takes 3.35 μs to complete. The second phase of conversion begins when SW2 is turned off and SW3 turned on. The Residue Amplifier and SHA section (A2 in Figure 9) goes into hold mode at this point and allows the input sample-and-hold to go back into sample mode. Thus, while the second phase of conversion is ongoing, the input sample-and-hold is also acquiring the input signal for the next conversion. This overlap between conversion and acquisition allows throughput rates of 166 kSPS to be achieved.

FIRST PHASE OF CONVERSION
1ST 9-BIT CONVERSION
DAC SETTLING TIME
RESIDUE AMPLIFIER
SETTLING TIME

SECOND PHASE OF CONVERSION
2ND 9-BIT CONVERSION
ERROR CORRECTION
OUTPUT LATCH UPDATE
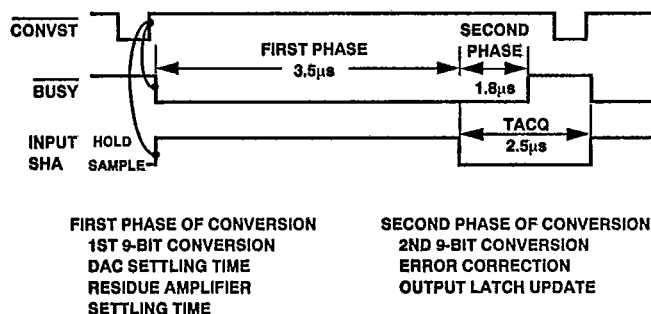
Figure 10. Timing and Control Sequence

USING THE AD7884/AD7885

Analog Input Ranges

The AD7884/AD7885 can be set up to have either a ±3 volts analog input range or a ±5 volts analog input range. Figures 11 and 12 show the necessary corrections for each of these. The output code is 2s complement and the ideal code table for both input ranges is shown in Table I.

Reference Considerations

The AD7884/AD7885 operates from a ±3 volt reference. This can be derived simply from a single +5 volt reference as shown in Figure 6.
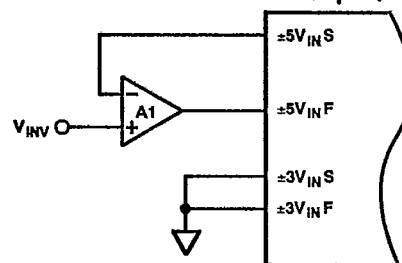
Figure 11. ±5 V Input Range Connection
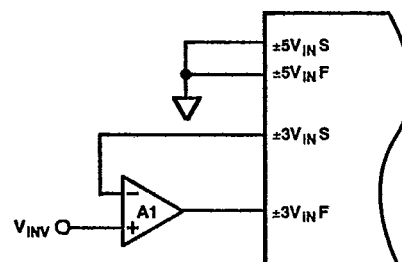
Figure 12. ±3 V Input Range Connections

The critical performance specification for a reference in a 16-bit application is noise. The reference pk-pk noise should be insignificant in comparison to the ADC noise. The AD7884/AD7885 has a typical rms noise of 120 μV. For example a reasonable target would be to keep the total rms noise less than 125 μV. To do this the reference noise needs to be less than 35 μV rms. Using a crest factor of 3.3 this corresponds to a pk-pk noise of 230 μV. Both the AD586 and the AD REF-02 noise is lower than this, making both suitable.

The buffer amplifier used to drive the device V_{REF+} should have low enough noise performance so as not to affect the overall system noise requirement.

Table I. Ideal Output Code Table for the AD7884/AD7885

Analog Input			Digital Output
In Terms of FSR[2]	±3 V Range[3]	±5 V Range[4]	Code Transition[1]
+FSR/2 − 1 LSB	2.999908	4.999847	011 . . . 111 to 011 . . . 110
+FSR/2 − 2 LSBs	2.999817	4.999695	011 . . . 110 to 011 . . . 101
+FSR/2 − 3 LSBs	2.999726	4.999543	011 . . . 101 to 011 . . . 100
AGND + 1 LSB	0.000092	0.000153	000 . . . 001 to 000 . . . 000
AGND	0.000000	0.000000	000 . . . 000 to 111 . . . 111
AGND − 1 LSB	−0.000092	−0.000153	111 . . . 111 to 111 . . . 110
−(FSR/2 − 3 LSBs)	−2.999726	−4.999543	100 . . . 011 to 100 . . . 010
−(FSR/2 − 2 LSBs)	−2.999817	−4.999695	100 . . . 010 to 100 . . . 001
−(FSR/2 − 1 LSB)	−2.999908	−4.999847	100 . . . 001 to 100 . . . 000

NOTES
[1]This table applies for $V_{REF+}S = +3$ V.
[2]FSR (Full-Scale Range) is 6 volts for the ±3 V input range and 10 volts for the ±5 V input range.
[3]1 LSB on the ±3 V range is $FSR/2^{16}$ and is equal to 91.5 μV.
[4]1 LSB on the ±5 V range is $FSR/2^{16}$ and is equal to 152.6 μV.

AD7884/AD7885

Decoupling and Grounding

The AD7884 has one AV$_{DD}$ pin and two V$_{DD}$ pins. It also has one AV$_{SS}$ pin and three V$_{SS}$ pins. The AD7885 has one AV$_{DD}$ pin, one V$_{DD}$ pin, one AV$_{SS}$ pin and one V$_{SS}$ pin. Figure 6 shows how a common +5 V supply should be used for the positive supply pins and a common −5 V supply for the negative supply pins.

For decoupling purposes, the critical pins on both devices are the AV$_{DD}$ and AV$_{SS}$ pins. Each of these should be decoupled to system AGND with 10 µF tantalum and 0.1 µF ceramic capacitors right at the pins. With the V$_{DD}$ and V$_{SS}$ pins, it is sufficient to decouple each of these with ceramic 1 µF capacitors.

AGNDS, AGNDF are the ground return points for the on-chip 9-bit ADC. They should be driven by a buffer amplifier as shown in Figure 6. If they are tied directly together and then to ground, there will be a degradation in linearity performance.

The GND pin is the analog ground return for the on-chip linear circuitry. It should be connected to system analog ground.

The DGND pin is the ground return for the on-chip digital circuitry. It should be connected to the ground terminal of the V$_{DD}$ and V$_{SS}$ supplies. If a common analog supply is used for AV$_{DD}$ and V$_{DD}$ then DGND should be connected to the common ground point.

Power Supply Sequencing

If the AD7884/AD7885 is being powered from separate analog and digital supplies, then care should be taken with power supply sequencing. AV$_{DD}$ should always come up before V$_{DD}$ and AV$_{SS}$ should always come up before V$_{SS}$. If this cannot be guaranteed, Schottky diodes (HP5082-2810 or equivalent) should be used to ensure that V$_{DD}$ never exceeds AV$_{DD}$ by more than 0.3 V and that V$_{SS}$ never goes below AV$_{SS}$ by more than 0.3 V.
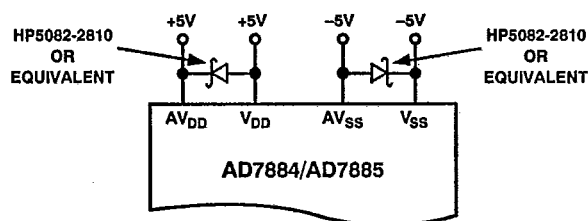

Figure 13. Schottky Diodes Used to Protect Against Incorrect Power Supply Sequencing

AD7884/AD7885 PERFORMANCE

Linearity

The linearity of the AD7884/AD7885 is determined by the on-chip 16-bit D/A converter. This is a segmented DAC which is laser trimmed for 16-bit DNL performance to ensure that there are no missing codes in the ADC transfer function. Figure 14 shows a typical INL plot for the AD7884/AD7885.
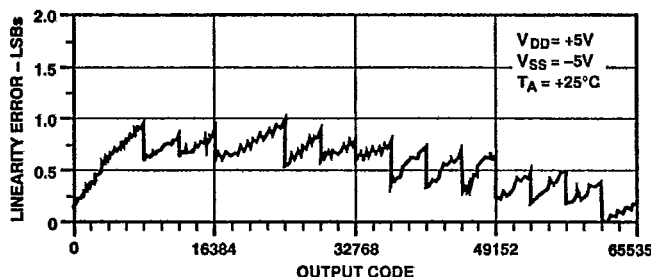

Figure 14. AD7884/AD7885 Typical Linearity Performance

Noise

In an A/D converter, noise exhibits itself as code uncertainty in dc applications and as the noise floor (in an FFT, for example) in ac applications.

In a sampling A/D converter like the AD7884/AD7885, all information about the analog input appears in the baseband from dc to 1/2 the sampling frequency. An antialiasing filter will remove unwanted signals above f$_S$/2 in the input signal but the converter wideband noise will alias into the baseband. In the AD7884/AD7885, this noise is made up of sample-and-hold noise and a/d converter noise. The sample-and-hold section contributes 51 µV rms and the ADC section contributes 59 µV rms. These add up to a total rms noise of 78 µV. This is the input referred noise in the ±3 V analog input range. When operating in the ±5 V input range, the input gain is reduced to −0.6. This means that the input referred noise is now increased by a factor of 1.66 to 120 µV rms.

Figure 15 shows a histogram plot for 5000 conversions of a dc input using the AD7884/AD7885 in the ±5 V input range. The analog input was set as close as possible to the center of a code transition. All codes other than the center code are due to the ADC noise. In this case, the spread is six codes.
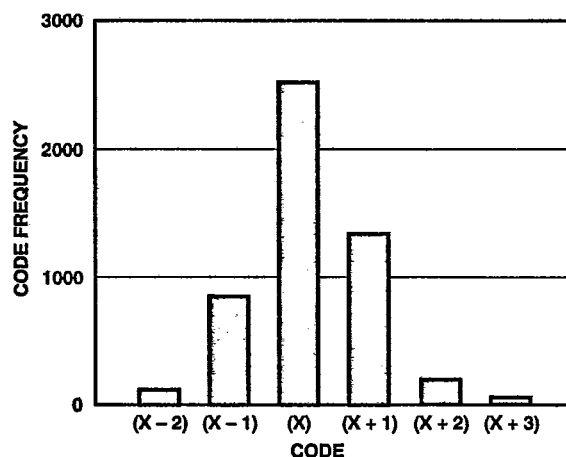

Figure 15. Histogram of 5000 Conversions of a DC Input

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If the noise in the converter is too high for an application, it can be reduced by oversampling and digital filtering. This involves sampling the input at higher than the required word rate and then averaging to arrive at the final result. The very fast conversion time of the AD7884/AD7885 makes it very suitable for oversampling. For example, if the required input bandwidth is 40 kHz, the AD7884/AD7885 could be oversampled by a factor of 2. This yields a 3 dB improvement in the effective SNR performance. The noise performance in the ±5 volt input range is now effectively 85 μV rms and the resultant spread of codes for 2500 conversions will be four. This is shown in Figure 16.
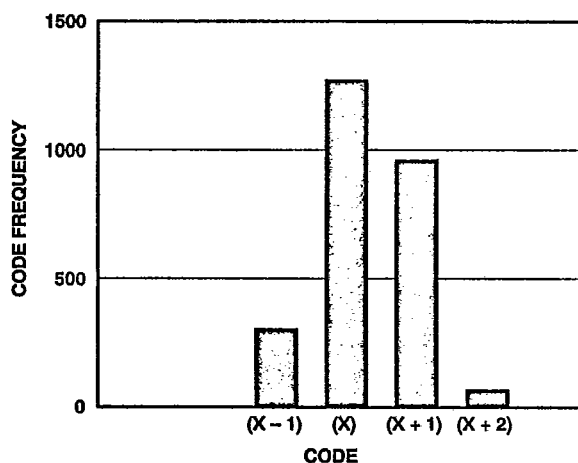
Figure 16. Histogram of 2500 Conversions of a DC Input Using a ×2 Oversampling Ratio

Dynamic Performance
With a combined conversion and acquisition time of 6 μs, the AD7884/AD7885 is ideal for wide bandwidth signal processing applications. Signal to (Noise + Distortion), Total Harmonic Distortion, Peak Harmonic or Spurious Noise and Intermodulation Distortion are all specified. Figure 17 shows a typical FFT plot of a 1.8 kHz, ±5 V input after being digitized by the AD7884/AD7885.
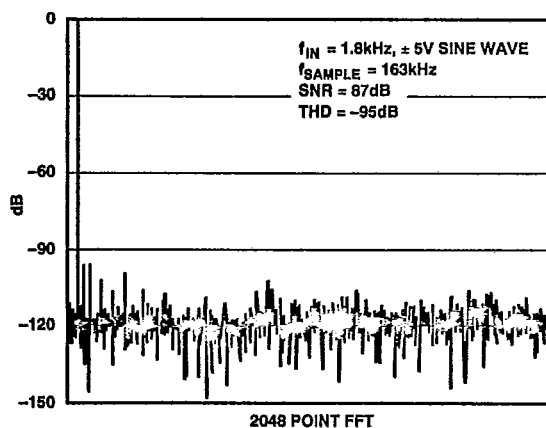
f_{IN} = 1.8kHz, ± 5V SINE WAVE
f_{SAMPLE} = 163kHz
SNR = 87dB
THD = −95dB

Figure 17. AD7884/AD7885 FFT Plot

Effective Number of Bits
The formula for SNR (see Terminology Section) is related to the resolution or number of bits in the converter. Rewriting the formula, below, gives a measure of performance expressed in effective number of bits (N).
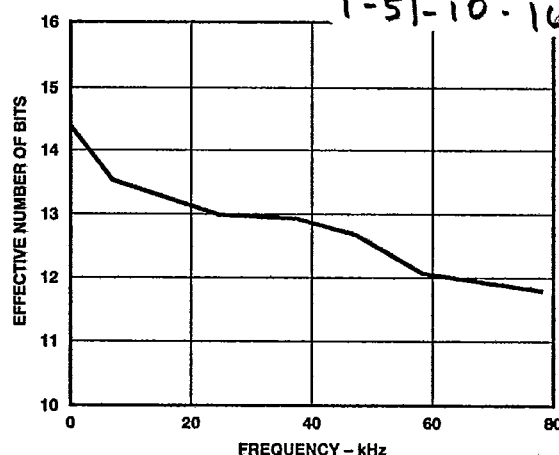
$$N = (SNR - 1.76)/6.02$$

Figure 18. Effective Number of Bits vs. Frequency

The effective number of bits for a device can be calculated from its measured SNR. Figure 18 shows a typical plot of effective number of bits versus frequency for the AD7884. The sampling frequency is 166 kHz.

MICROPROCESSOR INTERFACING
The AD7884/AD7885 is designed on a high speed process which results in very fast interfacing timing (Data Access Time of 57 ns max). The AD7884 has a full 16-bit parallel bus, and the AD7885 has an 8-bit wide bus. The AD7884, with its parallel interface, is suited to 16-bit parallel machines whereas the AD7885, with its byte interface, is suited to 8-bit machines. Some examples of typical interface configurations follow.

AD7884 to MC68000 Interface
Figure 19 shows a general interface diagram for the MC68000, 16-bit microprocessor to the AD7884. In Figure 19, conversion is initiated by bringing $\overline{CSA}$ low (i.e., writing to the appropriate address). This allows the processor to maintain control over the complete conversion process. In some cases it may be more desirable to control conversion independent from the processor. This can be done by using an external sampling timer.
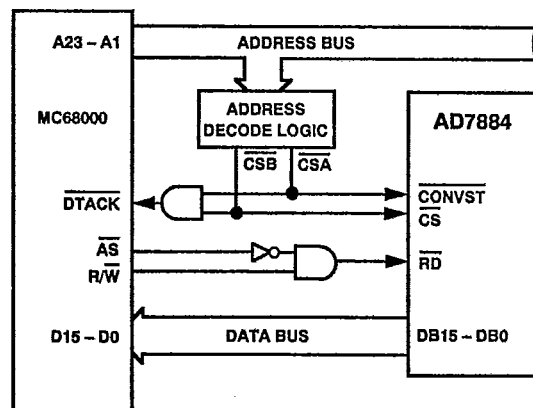
Figure 19. AD7884 to MC68000 Interface

Once conversion has been started, the processor must wait until it is completed before reading the result. There are two ways of ensuring this. The first way is to simply use a software delay to wait for 6.5 μs before bringing $\overline{CS}$ and $\overline{RD}$ low to read the data.

The second way is to use the $\overline{BUSY}$ output of the AD7884 to generate an interrupt in the MC68000. Because of the nature of its interrupts, the MC68000 requires additional logic (not shown in Figure 19) to allow it to be interrupted correctly. For full information on this, consult the MC68000 User's Manual.

AD7884 to 80286 Interface
The 80286 is an advanced high performance processor with special capabilities aimed at multiuser and multitasking systems.

Figure 20 shows an interface configuration for the AD7884 to such a system. Note that only signals relevant to the AD7884 are shown. For the full 80286 configuration refer to the iAPX 286 data sheet (Basic System Configuration).

In Figure 20 conversion is started by writing to a selected address and causing it to go low. When conversion is complete, $\overline{BUSY}$ goes high and initiates an interrupt. The processor can then read the conversion result.
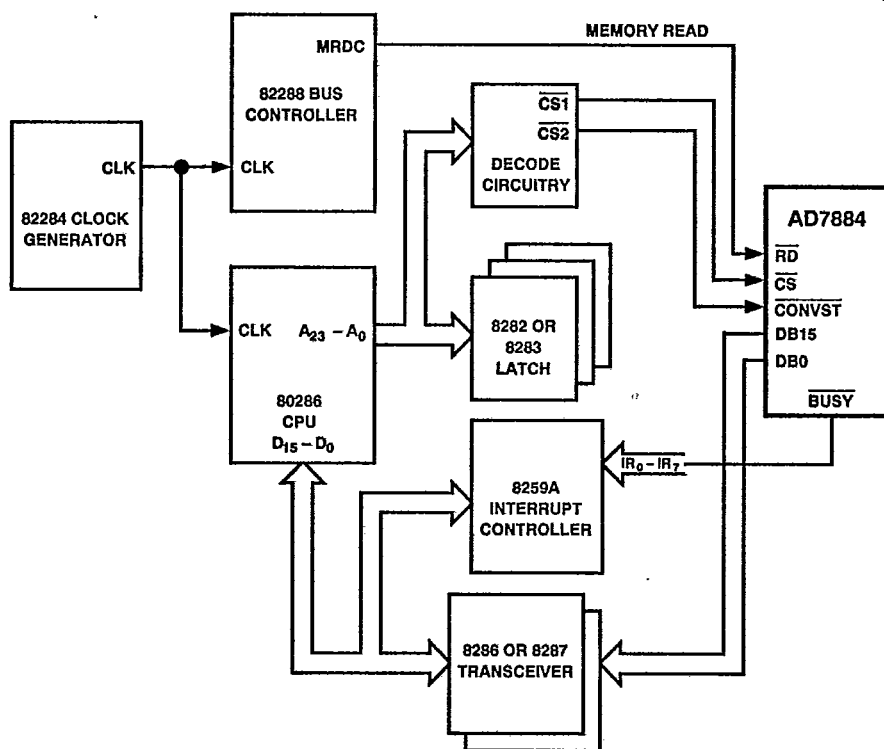

Figure 20. AD7884 Interfacing to Basic iAPX 286 System

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AD7885 to 8088 Interface

The AD7885, with its byte (8 + 8) data format, is ideal for use with the 8088 microprocessor. Figure 21 is the interface diagram. Conversion is started by enabling $\overline{CSA}$. At the end of conversion, data is read into the processor. The read instructions are:

MOV AX, C001	Read 8 MSBs of data
MOV AX, C000	Read 8 LSBs of data
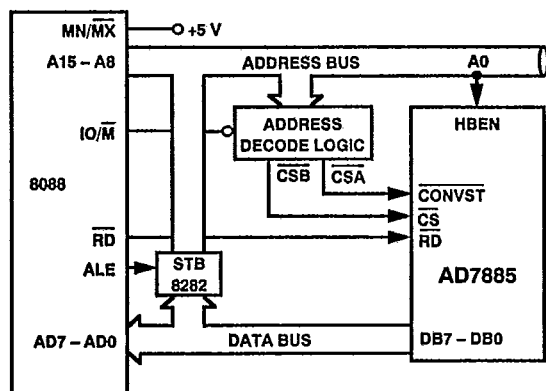
Figure 21. AD7885 to 8088 Interface

AD7884 to ADSP-2101 Interface

Figure 22 shows an interface between the AD7884 and the ADSP-2101. Conversion is initiated using a timer which allows very accurate control of the sampling instant. The AD7884 $\overline{BUSY}$ line provides an interrupt to the ADSP-2101 when conversion is completed. The $\overline{RD}$ pulse width of the processor can be programmed using the Data Memory Wait State Control Register. The result can then be read from the ADC using the following instruction:

$$MR0 = DM (ADC)$$

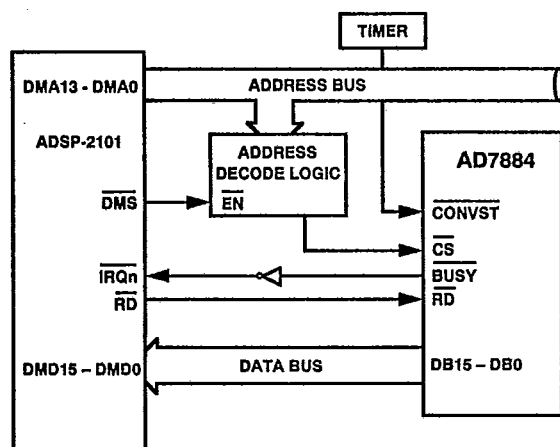where MR0 is the ADSP-2101 MR0 register, and
        ADC is the AD7884 address.

Figure 22. AD7884 to ADSP-2101 Interface

Stand-Alone Operation

If $\overline{CS}$ and $\overline{RD}$ are tied permanently low on the AD7884, then, when a conversion is completed, output data will be valid on the rising edge of $\overline{BUSY}$. This makes the device very suitable for stand-alone operation. All that is required to run the device is an external $\overline{CONVST}$ pulse which can be supplied by a sample timer. Figure 23 shows the AD7884 set up in this mode with the $\overline{BUSY}$ signal providing the clock for the 74HC574 3-state latches.
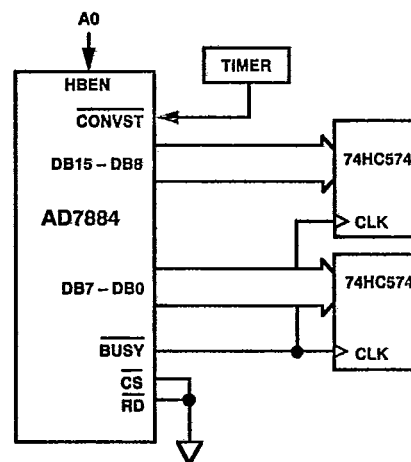

Figure 23. Stand-Alone Operation

Digital Feedthrough from an Active Bus

It is very important when using the AD7884/AD7885 in a microprocessor-based system to isolate the ADC data bus from the active processor bus while a conversion is being executed. This will yield the best noise performance from the ADC. Latches like the 74HC574 can be used to do this. If the device is connected directly to an active bus then the converter noise will typically increase by a factor of 30%.

AD7884/AD7885
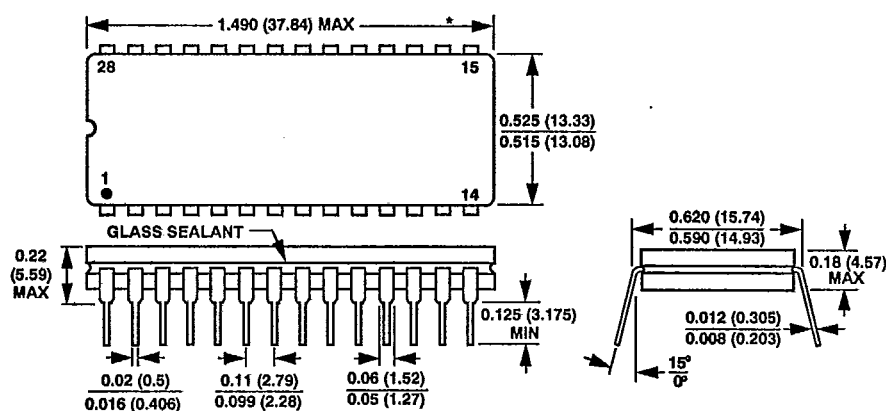
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MECHANICAL INFORMATION
Dimensions shown in inches and (mm).

28-Pin Plastic DIP (N-28A)
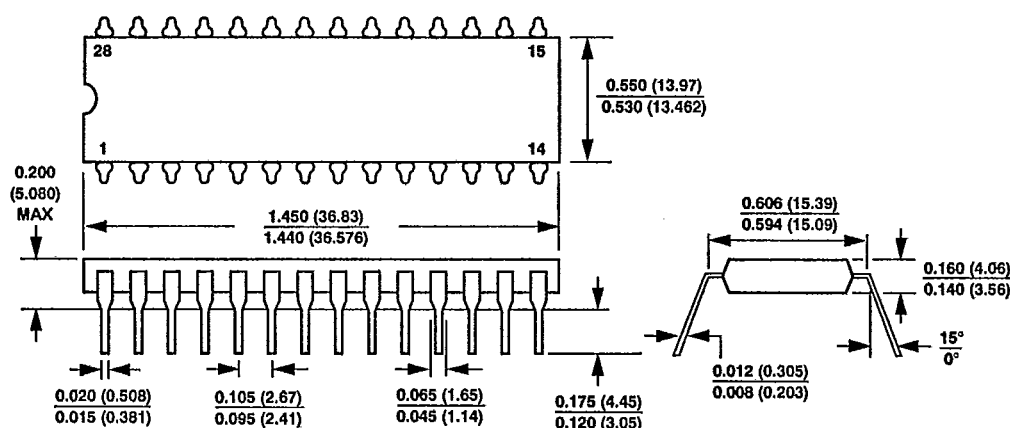
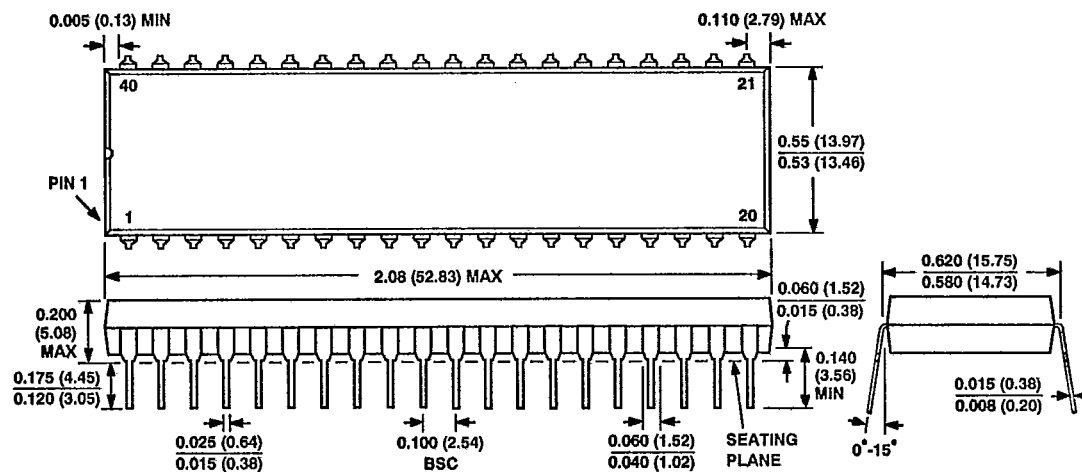LEADS ARE SOLDER DIPPED OR TIN-PLATED ALLOY 42 OR COPPER.
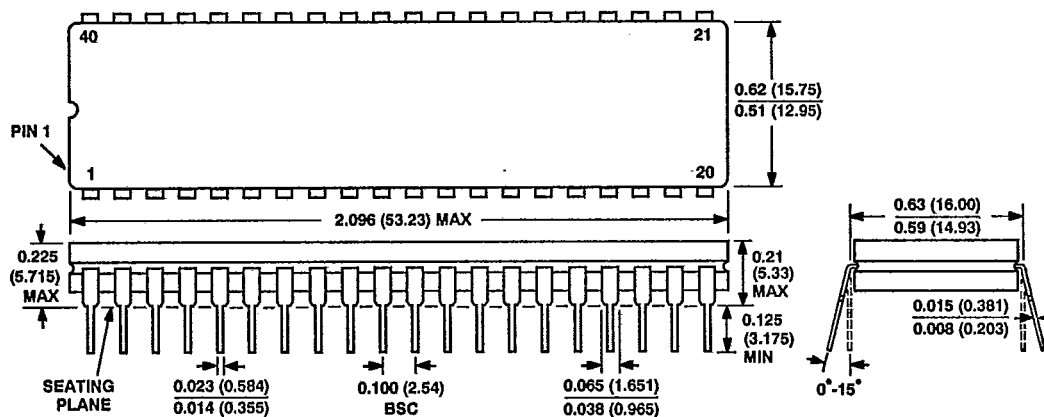
28-Pin Cerdip (Q-28)

GLASS SEALANT

28-Pin PLCC (P-28A)

PIN 1 IDENTIFIER

REV. A
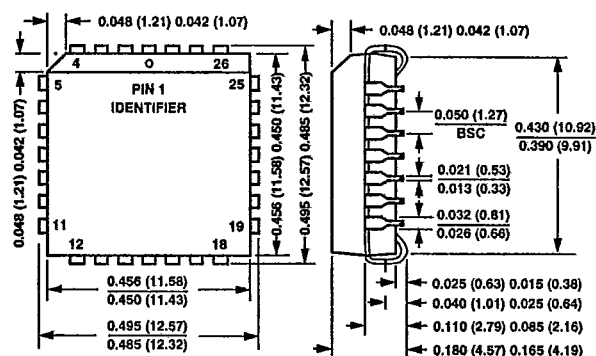
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40-Pin Plastic DIP (N-40A)

40-Pin Cerdip (Q-40)

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44-Pin PLCC (P-44A)

0.045 TYP

0.045
TYP

PIN 1
IDENTIFIER

TOP VIEW

0.656 (16.662)
0.650 (16.510) SQ

0.695 (17.65)
0.685 (17.40) SQ

R.020 MAX
3 PLCS

0.045 TYP

0.045
TYP

0.050 ± 0.005
(1.27 ± 0.13)

0.630 (16.00)
0.590 (14.99)

0.021 (0.533)
0.013 (0.331)

0.032 (0.812)
0.026 (0.661)

0.020 MIN

0.120 (3.04)
0.090 (2.29)

0.180 (4.57)
0.165 (4.20)
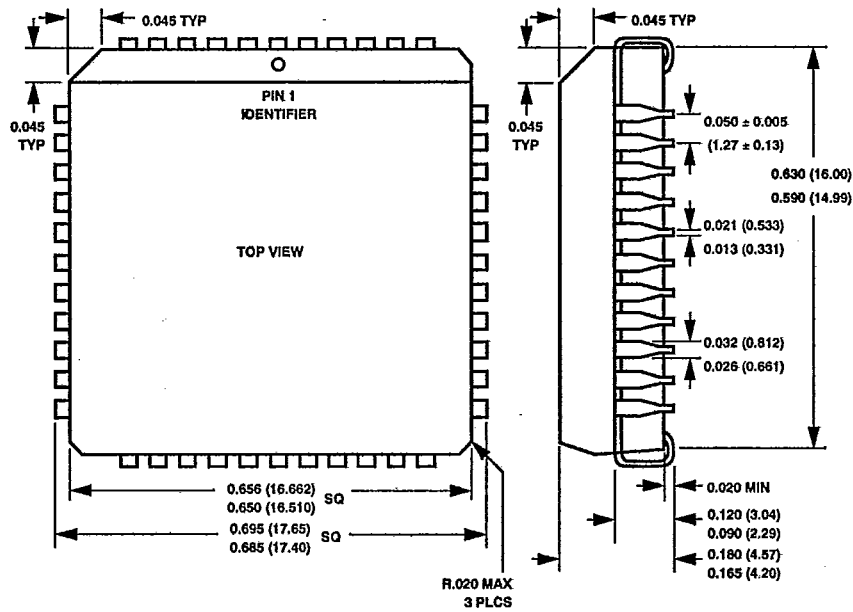
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