

AD7545

FEATURES

12-Bit Resolution

Low Gain TC: 2 ppm/°C typ

Fast TTL Compatible Data Latches

Single +5 V to +15 V Supply

Small 20-Lead 0.3" DIP and 20-Terminal Surface Mount

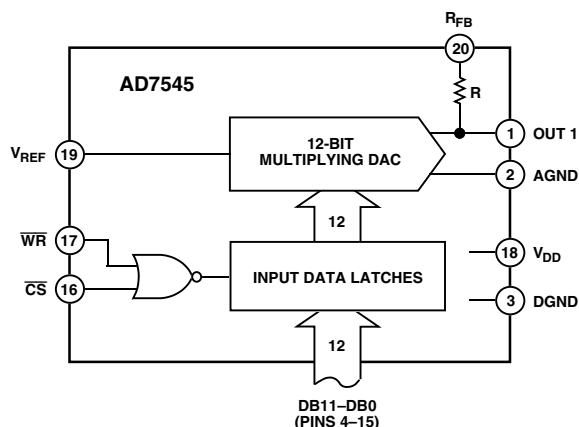
Packages

Latch Free (Schottky Protection Diode Not Required)

Low Cost

Ideal for Battery Operated Equipment

FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

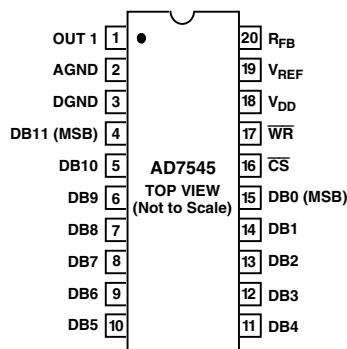
The AD7545 is a monolithic 12-bit CMOS multiplying DAC with onboard data latches. It is loaded by a single 12-bit wide word and directly interfaces to most 12- and 16-bit bus systems. Data is loaded into the input latches under the control of the $\overline{CS}$ and $\overline{WR}$ inputs; tying these control inputs low makes the input latches transparent, allowing direct unbuffered operation of the DAC.

The AD7545 is particularly suitable for single supply operation and applications with wide temperature variations.

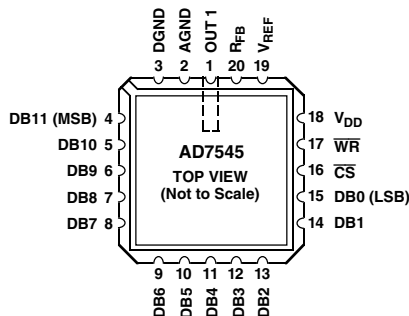
The AD7545 can be used with any supply voltage from +5 V to +15 V. With CMOS logic levels at the inputs the device dissipates less than 0.5 mW for $V_{DD} = +5$ V.

PIN CONFIGURATIONS

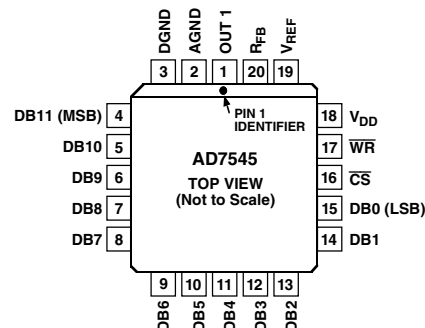
DIP



LCCC



PLCC



REV. A

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AD7545—SPECIFICATIONS (V_{REF} = +10 V, V_{OUT1} = 0 V, AGND = DGND unless otherwise noted)

		V _{DD} = +5 V Limits		V _{DD} = +15 V Limits				
Parameter	Version	T _A = + 25°C	T _{MIN} , T _{MAX} ¹	T _A = + 25°C	T _{MIN} , T _{MAX} ¹	Units	Test Conditions/Comments	
STATIC PERFORMANCE								
Resolution	All	12	12	12	12	Bits	10-Bit Monotonic T _{MIN} to T _{MAX} 12-Bit Monotonic T _{MIN} to T _{MAX} 12-Bit Monotonic T _{MIN} to T _{MAX} 12-Bit Monotonic T _{MIN} to T _{MAX} DAC Register Loaded with 1111 1111 1111 Gain Error Is Adjustable Using the Circuits of Figures 4, 5, and 6	
	J, A, S	±2	±2	±2	±2	LSB max		
	K, B, T	±1	±1	±1	±1	LSB max		
	L, C, U	±1/2	±1/2	±1/2	±1/2	LSB max		
	GL, GC, GU	±1/2	±1/2	±1/2	±1/2	LSB max		
Differential Nonlinearity	J, A, S	±4	±4	±4	±4	LSB max		
	K, B, T	±1	±1	±1	±1	LSB max		
	L, C, U	±1	±1	±1	±1	LSB max		
	GL, GC, GU	±1	±1	±1	±1	LSB max		
Gain Error (Using Internal RFB) ²	J, A, S	±20	±20	±25	±25	LSB max		
	K, B, T	±10	±10	±15	±15	LSB max		
	L, C, U	±5	±6	±10	±10	LSB max		
	GL, GC, GU	±1	±2	±6	±7	LSB max		
Gain Temperature Coefficient ³ ΔGain/ΔTemperature	All	±5	±5	±10	±10	ppm/°C max		Typical Value is 2 ppm/°C for V _{DD} = +5 V
DC Supply Rejection ³ ΔGain/ΔV _{DD}	All	0.015	0.03	0.01	0.02	% per % max		ΔV _{DD} = ±5%
Output Leakage Current at OUT1	J, K, L, GL	10	50	10	50	nA max		DB0–DB11 = 0 V; $\overline{WR}$, $\overline{CS}$ = 0 V
	A, B, C, GC	10	50	10	50	nA max		
	S, T, U, GU	10	200	10	200	nA max		
DYNAMIC PERFORMANCE								
Current Settling Time ³	All	2	2	2	2	μs max	To 1/2 LSB. OUT1 Load = 100 Ω. DAC Output Measured from Falling Edge of $\overline{WR}$, $\overline{CS}$ = 0.	
Propagation Delay ³ (from Digital Input Change to 90% of Final Analog Output)	All	300	–	250	–	ns max	OUT1 Load = 100 Ω, C _{EXT} = 13 pF ⁴	
Digital-to-Analog Glitch Impulse	All	400	–	250	–	nV sec typ	V _{REF} = AGND	
AC Feedthrough ⁵ At OUT1	All	5	5	5	5	mV p-p typ	V _{REF} = ±10 V, 10 kHz Sinewave	
REFERENCE INPUT								
Input Resistance (Pin 19 to GND)	All	7 25	7 25	7 25	7 25	kΩ min kΩ max	Input Resistance TC = –300 ppm/°C typ Typical Input Resistance = 11 kΩ	
ANALOG OUTPUT								
Output Capacitance ³ C _{OUT1}	All	70	70	70	70	pF max	DB0–DB11 = 0 V, $\overline{WR}$, $\overline{CS}$ = 0 V	
		200	200	200	200	pF max	DB0–DB11 = V _{DD} , $\overline{WR}$, $\overline{CS}$ = 0 V	
DIGITAL INPUTS								
Input High Voltage V _{IH}	All	2.4	2.4	13.5	13.5	V min	V _{IN} = 0 or V _{DD}	
Input Low Voltage V _{IL}	All	0.8	0.8	1.5	1.5	V max		
Input Current ⁶ I _{IN}	All	±1	±10	±1	±10	μA max		
Input Capacitance ³ DB0–DB11	All	5	5	5	5	pF max		
$\overline{WR}$, $\overline{CS}$	All	20	20	20	20	pF max		
SWITCHING CHARACTERISTICS ⁷								
Chip Select to Write Setup Time t _{CS}	All	280 200	380 270	180 120	200 150	ns min ns typ	See Timing Diagram	
Chip Select to Write Hold Time t _{CH}	All	0	0	0	0	ns min		
Write Pulse Width t _{WR}	All	250 175	400 280	160 100	240 170	ns min ns typ	t _{CS} ≥ t _{WR} , t _{CH} ≥ 0	
Data Setup Time t _{DS}	All	140	210	90	120	ns min		
Data Hold Time t _{DH}	All	100	150	60	80	ns typ		
	All	10	10	10	10	ns min		
POWER SUPPLY								
I _{DD}	All	2 100 10	2 500 10	2 100 10	2 500 10	mA max μA max μA typ	All Digital Inputs V _{IL} or V _{IH} All Digital Inputs 0 V to V _{DD} All Digital Inputs 0 V to V _{DD}	

NOTES

¹Temperature range as follows: J, K, L, GL versions, 0°C to +70°C; A, B, C, GC versions, –25°C to +85°C; S, T, U GU versions, –55°C to +125°C.

²This includes the effect of 5 ppm max gain TC.

³Guaranteed but not tested.

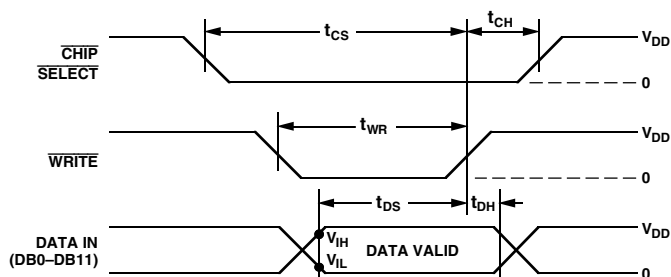
⁴DB0–DB11 = 0 V to V_{DD} or V_{DD} to 0 V.

⁵Feedthrough can be further reduced by connecting the metal lid on the ceramic package (Suffix D) to DGND.

⁶Logic inputs are MOS gates. Typical input current (+25°C) is less than 1 nA.

⁷Sample tested at +25°C to ensure compliance.

Specifications subject to change without notice.



Write Cycle Timing Diagram

ABSOLUTE MAXIMUM RATINGS*(T_A = +25°C unless otherwise noted)

V _{DD} to DGND	−0.3, +17 V
Digital Input Voltage to DGND	−0.3 V, V _{DD} + 0.3 V
V _{RFB} , V _{REF} to DGND	±25 V
V _{PIN1} to DGND	−0.3 V, V _{DD} + 0.3 V
AGND to DGND	−0.3 V, V _{DD} + 0.3 V
Power Dissipation (Any Package) to +75°C	450 mW
Derates above +75°C	6 mW/°C
Operating Temperature	

CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD7545 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

TERMINOLOGY**RELATIVE ACCURACY**

The amount by which the D/A converter transfer function differs from the ideal transfer function after the zero and full-scale points have been adjusted. This is an endpoint linearity measurement.

DIFFERENTIAL NONLINEARITY

The difference between the measured change and the ideal change between any two adjacent codes. If a device has a differential nonlinearity of less than 1 LSB it will be monotonic, i.e., the output will always increase for an increase in digital code applied to the D/A converter.

PROPAGATION DELAY

This is a measure of the internal delay of the circuit and is measured from the time a digital input changes to the point at which the analog output at OUT1 reaches 90% of its final value.

DIGITAL-TO-ANALOG GLITCH IMPULSE

This is a measure of the amount of charge injected from the digital inputs to the analog outputs when the inputs change state. It is usually specified as the area of the glitch in nV secs and is measured with V_{REF} = AGND and an ADLH0032CG as the output op amp, C1 (phase compensation) = 33 pF.

MODE SELECTION

WRITE MODE:	HOLD MODE:
$\overline{CS}$ and $\overline{WR}$ LOW, DAC RESPONDS TO DATA BUS (DB0-DB11) INPUTS.	EITHER $\overline{CS}$ OR $\overline{WR}$ HIGH, DATA BUS (DB0-DB11) IS LOCKED OUT; DAC HOLDS LAST DATA PRESENT WHEN $\overline{WR}$ OR $\overline{CS}$ ASSUMED HIGH STATE.

NOTES:V_{DD} = +5V; t_r = t_f = 20nsV_{DD} = +15V; t_r = t_f = 40nsALL INPUT SIGNAL RISE AND FALL TIMES MEASURED FROM 10% TO 90% OF V_{DD}.TIMING MEASUREMENT REFERENCE LEVEL IS V_{IH} + V_{IL}/2.

Commercial (J, K, L, GL) Grades	0°C to +70°C
Industrial (A, B, C, GC) Grades	−25°C to +85°C
Extended (S, T, U, GU) Grades	−55°C to +125°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 secs)	+300°C

*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

**ORDERING GUIDE¹**

Model ²	Temperature Range	Relative Accuracy	Maximum Gain Error T _A = +25°C V _{DD} = +5 V	Package Options ³
AD7545JN	0°C to +70°C	±2 LSB	±20 LSB	N-20
AD7545AQ	−25°C to +85°C	±2 LSB	±20 LSB	Q-20
AD7545SQ	−55°C to +125°C	±2 LSB	±20 LSB	Q-20
AD7545KN	0°C to +70°C	±1 LSB	±10 LSB	N-20
AD7545BQ	−25°C to +85°C	±1 LSB	±10 LSB	Q-20
AD7545TQ	−55°C to +125°C	±1 LSB	±10 LSB	Q-20
AD7545LN	0°C to +70°C	±1/2 LSB	±5 LSB	N-20
AD7545CQ	−25°C to +85°C	±1/2 LSB	±5 LSB	Q-20
AD7545UQ	−55°C to +125°C	±1/2 LSB	±5 LSB	Q-20
AD7545GLN	0°C to +70°C	±1/2 LSB	±1 LSB	N-20
AD7545GCQ	−25°C to +85°C	±1/2 LSB	±1 LSB	Q-20
AD7545GUQ	−55°C to +125°C	±1/2 LSB	±1 LSB	Q-20
AD7545JP	0°C to +70°C	±2 LSB	±20 LSB	P-20A
AD7545SE	−55°C to +125°C	±2 LSB	±20 LSB	E-20A
AD7545KP	0°C to +70°C	±1 LSB	±10 LSB	P-20A
AD7545TE	−55°C to +125°C	±1 LSB	±10 LSB	E-20A
AD7545LP	0°C to +70°C	±1/2 LSB	±5 LSB	P-20A
AD7545UE	−55°C to +125°C	±1/2 LSB	±5 LSB	E-20A
AD7545GLP	0°C to +70°C	±1/2 LSB	±1 LSB	P-20A
AD7545GUE	−55°C to +125°C	±1/2 LSB	±1 LSB	E-20A

NOTES

¹Analog Devices reserves the right to ship either ceramic (D-20) in lieu of cerdip packages (Q-20).

²To order MIL-STD-883, Class B process parts, add /883B to part number. Contact local sales office for military data sheet. For U.S. Standard Military DRAWING (SMD) see DESC drawing 5962-87702.

³E = Leadless Ceramic Chip Carrier; N = Plastic DIP; P = Plastic Leaded Chip Carrier; Q = Cerdip.

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CIRCUIT INFORMATION—D/A CONVERTER SECTION

Figure 1 shows a simplified circuit of the D/A converter section of the AD7545 and Figure 2 gives an approximate equivalent circuit. Note that the ladder termination resistor is connected to AGND. R is typically 11 kΩ.

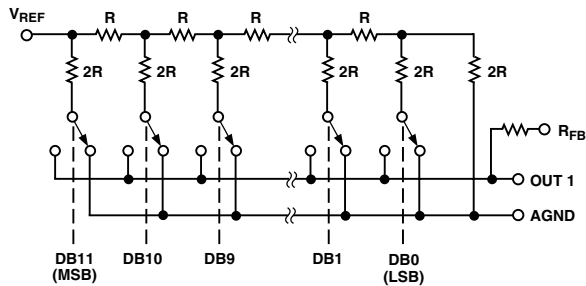


Figure 1. Simplified D/A Circuit of AD7545

The binary weighted currents are switched between the OUT1 bus line and AGND by N-channel switches, thus maintaining a constant current in each ladder leg independent of the switch state.

The capacitance at the OUT1 bus line, COUT1, is code dependent and varies from 70 pF (all switches to AGND) to 200 pF (all switches to OUT1).

One of the current switches is shown in Figure 2. The input resistance at VREF (Figure 1) is always equal to RLDR (RLDR is the R/2R ladder characteristic resistance and is equal to value “R”). Since RIN at the VREF pin is constant, the reference terminal can be driven by a reference voltage or a reference current, ac or dc, of positive or negative polarity. (If a current source is used, a low temperature coefficient external RFB is recommended to define scale factor.)

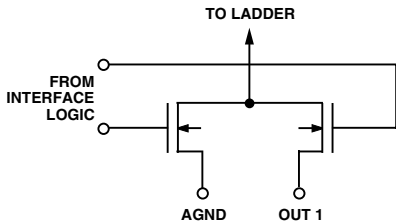


Figure 2. N-Channel Current Steering Switch

CIRCUIT INFORMATION—DIGITAL SECTION

Figure 3 shows the digital structure for one bit.

The digital signals CONTROL and CONTROL are generated from CS and WR.

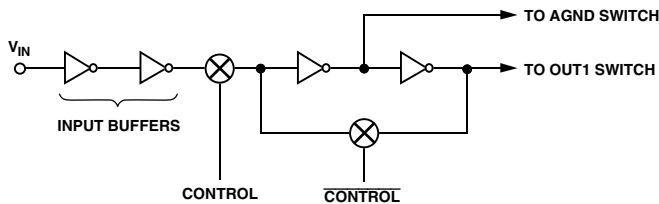


Figure 3. Digital Input Structure

The input buffers are simple CMOS inverters designed so that when the AD7545 is operated with VDD = 5 V, the buffers convert TTL input levels (2.4 V and 0.8 V) into CMOS logic levels. When VIN is in the region of 2.0 volts to 3.5 volts, the input buffers operate in their linear region and draw current from the

power supply. To minimize power supply currents it is recommended that the digital input voltages be as close as practically possible to the supply rails (VDD and DGND).

The AD7545 may be operated with any supply voltage in the range 5 ≤ VDD ≤ 15 volts. With VDD = +15 V the input logic levels are CMOS compatible only, i.e., 1.5 V and 13.5 V.

BASIC APPLICATIONS

Figures 4 and 5 show simple unipolar and bipolar circuits using the AD7545. Resistor R1 is used to trim for full scale. The “G” versions (AD7545GLN, AD7545GCQ, AD7545GUD) have a guaranteed maximum gain error of ±1 LSB at +25°C (VDD = +5 V), and in many applications it should be possible to dispense with gain trim resistors altogether. Capacitor C1 provides phase compensation and helps prevent overshoot and ringing when using high speed op amps. Note that all the circuits of Figures 4, 5 and 6 have constant input impedance at the VREF terminal.

The circuit of Figure 1 can either be used as a fixed reference D/A converter so that it provides an analog output voltage in the range 0 to –VIN (note the inversion introduced by the op amp), or VIN can be an ac signal in which case the circuit behaves as an attenuator (2-Quadrant Multiplier). VIN can be any voltage in the range –20 ≤ VIN + 20 volts (provided the op amp can handle such voltages) since VREF is permitted to exceed VDD. Table II shows the code relationship for the circuit of Figure 4.

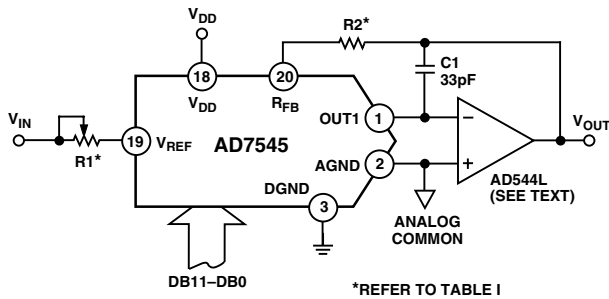


Figure 4. Unipolar Binary Operation

Table I. Recommended Trim Resistor Values vs. Grades for VDD = +5 V

Trim Resistor	J/A/S	K/B/T	L/C/U	GL/GC/GU
R1	500 Ω	200 Ω	100 Ω	20 Ω
R2	150 Ω	68 Ω	33 Ω	6.8 Ω

Table II. Unipolar Binary Code Table for Circuit of Figure 4

Binary Number in DAC Register	Analog Output
1 1 1 1 1 1 1 1 1 1	$-V_{IN} \left(\frac{4095}{4096} \right)$
1 0 0 0 0 0 0 0 0 0	$-V_{IN} \left(\frac{2048}{4096} \right) = -1/2 V_{IN}$
0 0 0 0 0 0 0 0 0 1	$-V_{IN} \left(\frac{1}{4096} \right)$
0 0 0 0 0 0 0 0 0 0	0 Volts

[illegible]

Table III. Twos Complement Code Table for Circuit of Figure 5

Figure 6 shows an alternative method of achieving bipolar output. The circuit operates with sign plus magnitude code and has the advantage of giving 12-bit resolution in each quadrant, compared with 11-bit resolution per quadrant for the circuit of Figure 5. The AD7592 is a fully protected CMOS change-over switch with data latches. R4 and R5 should match each other to 0.01% to maintain the accuracy of the D/A converter. Mismatch between R4 and R5 introduces a gain error.



Sign Bit	Binary Number in DAC MSB LSB	Analog Output, V_{OUT}
0	1 1 1 1 1 1 1 1 1 1 1 1	+ V _{IN} × $\left(\frac{4095}{4096} \right)$
0	0 0 0 0 0 0 0 0 0 0 0 0	0 Volts
1	0 0 0 0 0 0 0 0 0 0 0 0	0 Volts
1	1 1 1 1 1 1 1 1 1 1 1 1	- V _{IN} × $\left(\frac{4095}{4096} \right)$

APPLICATIONS HINTS

General Ground Management: AC or transient voltages between AGND and DGND can cause noise injection into the analog output. The simplest method of ensuring that voltages at AGND and DGND are equal is to tie AGND and DGND together at the AD7545. In more complex systems where the AGND and DGND intertie is on the backplane, it is recommended that two diodes be connected in inverse parallel between the AD7545 AGND and DGND pins (IN914 or equivalent).

Another cause of digital glitches is capacitive coupling from the digital lines to the OUT1 and AGND terminals. This should be minimized by screening the analog pins of the AD7545 (Pins 1, 2, 19, 20) from the digital pins by a ground track run between Pins 2 and 3 and between Pins 18 and 19 of the AD7545. Note how the analog pins are at one end of the package and separated from the digital pins by V_{DD} and DGND to aid screening at the board level. On-chip capacitive coupling can also give rise to crosstalk from the digital-to-analog sections of the AD7545, particularly in circuits with high currents and fast rise and fall times. This type of crosstalk is minimized by using

AD7545

$V_{DD} = +5$ volts. However, great care should be taken to ensure that the +5 V used to power the AD7545 is free from digitally induced noise.

Temperature Coefficients: The gain temperature coefficient of the AD7545 has a maximum value of 5 ppm/°C and a typical value of 2 ppm/°C. This corresponds to worst case gain shifts of 2 LSBs and 0.8 LSBs respectively over a 100°C temperature range. When trim resistors R1 and R2 are used to adjust full-scale range, the temperature coefficient of R1 and R2 should also be taken into account. The reader is referred to Analog Devices Application Note "Gain Error and Gain Temperature Coefficient of CMOS Multiplying DACs," Publication Number E630-10-6/81.

SINGLE SUPPLY OPERATION

The ladder termination resistor of the AD7545 (Figure 1) is connected to AGND. This arrangement is particularly suitable for single supply operation because OUT1 and AGND may be biased at any voltage between DGND and V_{DD} . OUT1 and AGND should never go more than 0.3 volts less than DGND or an internal diode will be turned on and a heavy current may flow which will damage the device. (The AD7545 is, however, protected from the SCR latch-up phenomenon prevalent in many CMOS devices.)

Figure 7 shows the AD7545 connected in a voltage switching mode. OUT1 is connected to the reference voltage and AGND is connected to DGND. The D/A converter output voltage is available at the V_{REF} pin and has a constant output impedance equal to R_{FB} . R_{FB} is not used in this circuit.

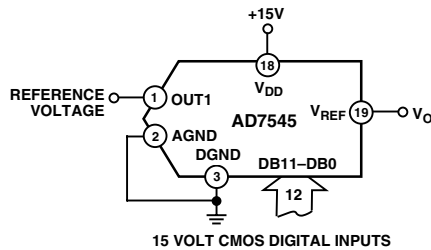


Figure 7. Single Supply Operation Using Voltage Switching Mode

The loading on the reference voltage source is code dependent and the response time of the circuit is often determined by the behavior of the reference voltage with changing load conditions.

To maintain linearity, the voltages at OUT1 and AGND should remain within 2.5 volts of each other, for a V_{DD} of 15 volts. If V_{DD} is reduced from 15 V, or the differential voltage between OUT1 and AGND is increased to more than 2.5 V, the differential nonlinearity of the DAC will increase and the linearity of the DAC will be degraded. Figures 8 and 9 show typical curves illustrating this effect for various values of reference voltage and V_{DD} . If the output voltage is required to be offset from ground by some value, then OUT1 and AGND may be biased up. The effect on linearity and differential nonlinearity will be the same as reducing V_{DD} by the amount of the offset.

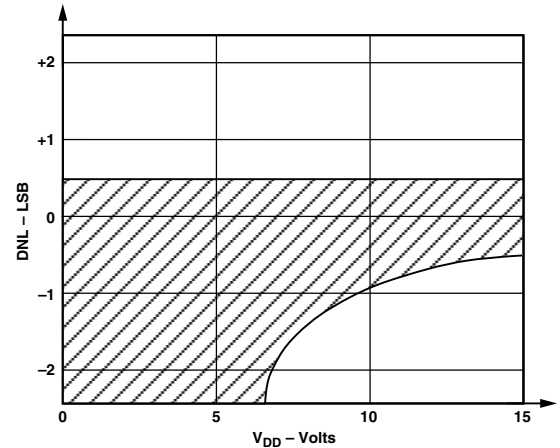


Figure 8. Differential Nonlinearity vs. V_{DD} for Figure 7 Circuit. Reference Voltage = 2.5 Volts. Shaded Area Shows Range of Values of Differential Nonlinearity that Typically Occur for L, C and U Grades.

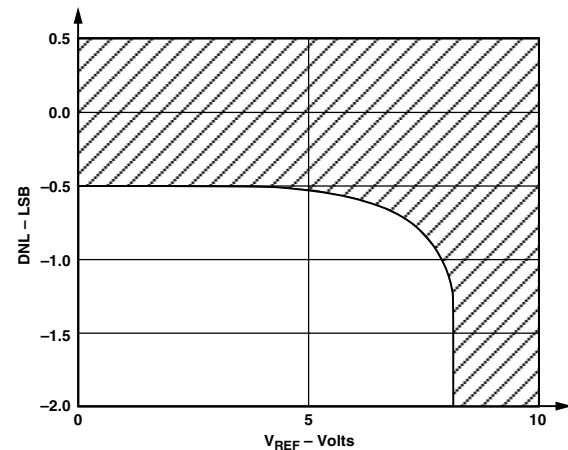


Figure 9. Differential Nonlinearity vs. Reference Voltage for Figure 7 Circuit. $V_{DD} = 15$ Volts. Shaded Area Shows Range of Values of Differential Nonlinearity that Typically Occur for L, C and U Grades.

The circuits of Figures 4, 5 and 6 can all be converted to single supply operation by biasing AGND to some voltage between V_{DD} and DGND. Figure 10 shows the two complement bipolar circuit of Figure 5 modified to give a range from +2 V to +8 V about a "pseudo-analog ground" of 5 V. This voltage range would allow operation from a single V_{DD} of +10 V to +15 V. The AD584 pin-programmable reference fixes AGND at +5 V. V_{IN} is set at +2 V by means of the series resistors R1 and R2. There is no need to buffer the V_{REF} input to the AD7545 with an amplifier because the input impedance of the D/A converter is constant. Note, however, that since the temperature coefficient of the D/A reference input resistance is typically -300 ppm/°C; applications that experience wide temperature variations may require a buffer amplifier to generate the +2.0 V at the AD7545 V_{REF} pin. Other output voltage ranges can be obtained by changing R4 to shift the zero point and (R1 + R2) to change the slope, or gain, of the D/A transfer function. V_{DD} must be kept at least 5 V above OUT1 to ensure that linearity is preserved.

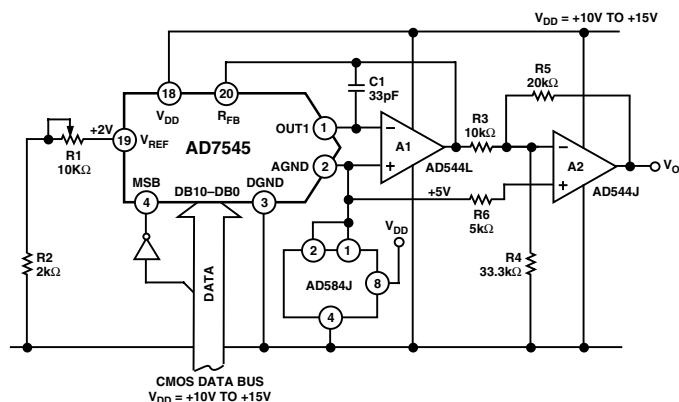


Figure 10. Single Supply "Bipolar" Twos Complement D/A Converter

MICROPROCESSOR INTERFACING OF THE AD7545

The AD7545 can directly interface to both 8- and 16-bit microprocessors via its 12-bit wide data latch using standard CS and WR control signals.

A typical interface circuit for an 8-bit processor is shown in Figure 11. This arrangement uses two memory addresses, one for the lower eight bits of data to the DAC and one for the upper four bits of data into the DAC via the latch.

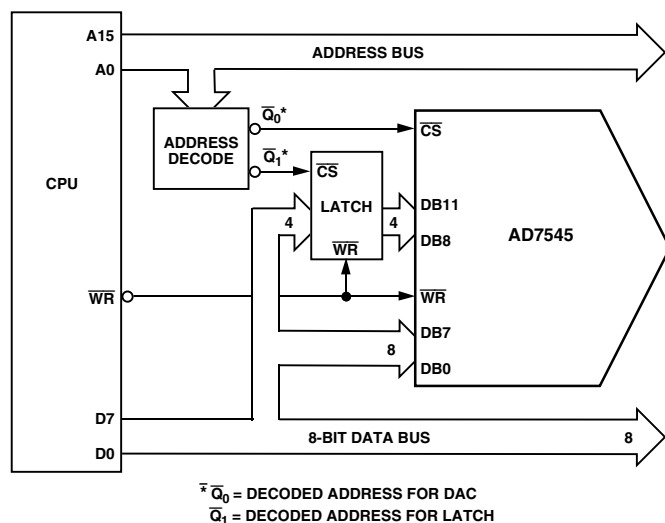


Figure 11. 8-Bit Processor to AD7545 Interface

Figure 12 shows an alternative approach for use with 8-bit processors which have a full 16-bit wide address bus such as 6800, 8080, Z80. This technique uses the 12 lower address lines of the processor address bus to supply data to the DAC, thus each AD7545 connected in this way uses 4k bytes of address locations. Data is written to the DAC using a single memory write instruction. The address field of the instruction is organized so that the lower 12 bits contain the data for the DAC and the upper 4 bits contain the address of the 4k block at which the DAC resides.

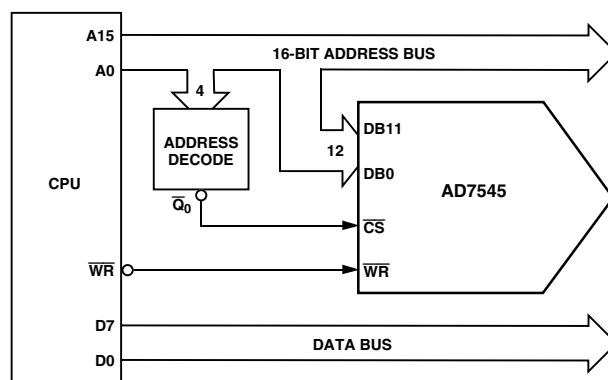


Figure 12. Connecting the AD7545 to 8-Bit Processors via the Address Bus

SUPPLEMENTAL APPLICATION MATERIAL

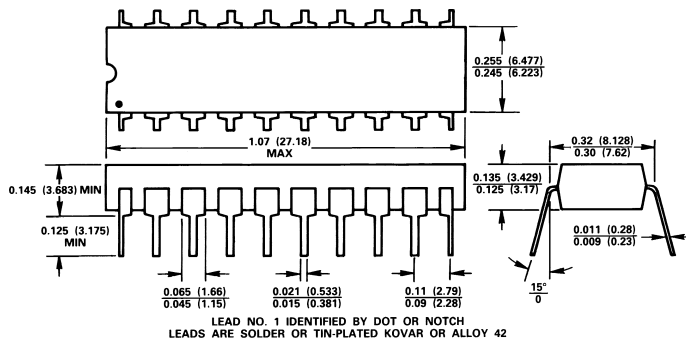
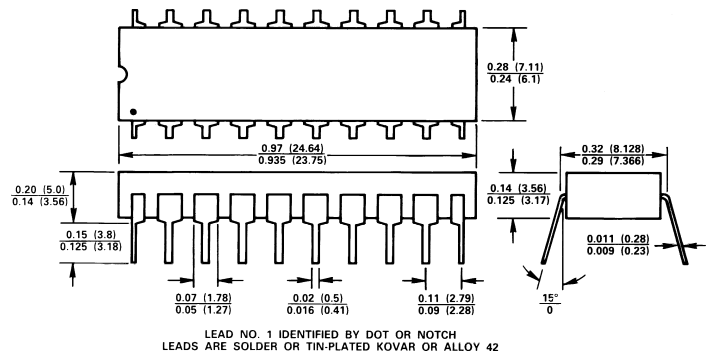
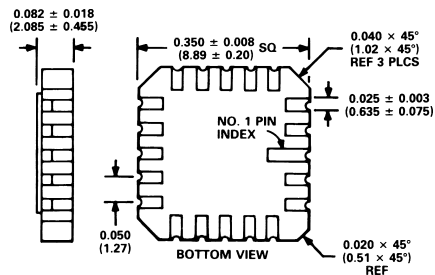
For further information on CMOS multiplying D/A converters the reader is referred to the following texts:

Application Guide to CMOS Multiplying D/A converters available from Analog Devices, Publication Number G479.

Gain Error and Gain Temperature Coefficient of CMOS Multiplying DACs—Application Note, Publication Number E630-10-6/81 available from Analog Devices.

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

20-Lead Plastic DIP
(N-20)20-Lead Cerdip
(Q-20)20-Terminal Leadless Ceramic Chip Carrier (LCCC)
(E-20A)20-Lead Plastic Leaded Chip Carrier (PLCC)
(P-20A)