



**THE DATASHEET OF
AD7547JNZ**



FEATURES

Two 12-Bit DACs in One Package
 DAC Ladder Resistance Matching: 0.5%
 Space Saving Skinny DIP and Surface Mount Packages
 4-Quadrant Multiplication
 Low Gain Error (1LSB max Over Temperature)
 Fast Interface Timing

APPLICATIONS

Automatic Test Equipment
 Programmable Filters
 Audio Applications
 Synchro Applications
 Process Control

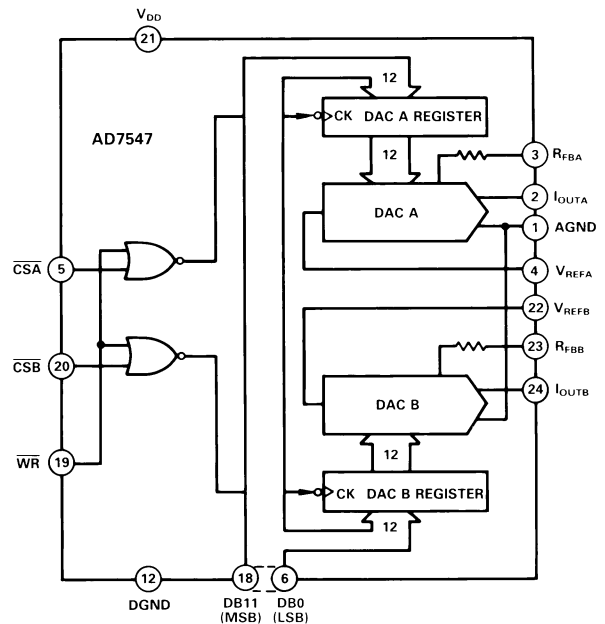
GENERAL DESCRIPTION

The AD7547 contains two 12-bit current output DACs on one monolithic chip. Also on-chip are the level shifters, data registers and control logic for easy microprocessor interfacing. There are 12 data inputs. \overline{CSA} , \overline{CSB} , \overline{WR} control DAC selection and loading. Data is latched into the DAC registers on the rising edge of \overline{WR} . The device is speed compatible with most microprocessors and accepts TTL, 74HC and 5V CMOS logic level inputs.

The D/A converters provide 4-quadrant multiplication capabilities with separate reference inputs and feedback resistors. Monolithic construction ensures that thermal and gain error tracking is excellent. 12-bit monotonicity is guaranteed for both DACs over the full temperature range.

The AD7547 is manufactured using the Linear Compatible CMOS (LC²MOS) process. This allows fast digital logic and precision linear circuitry to be fabricated on the same die.

FUNCTIONAL BLOCK DIAGRAM



PRODUCT HIGHLIGHTS

- DAC to DAC Matching**
 Since both DACs are fabricated on the same chip, precise matching and tracking is inherent. Many applications which are not practical using two discrete DACs are now possible. Typical matching: 0.5%.
- Small Package Size**
 The AD7547 is available in 0.3" wide 24-pin DIPs and SOICs and in 28-terminal surface mount packages.
- Wide Power Supply Tolerance**
 The device operates on a +12V to +15V V_{DD} , with $\pm 10\%$ tolerance on this nominal figure. All specifications are guaranteed over this range.

REV. A

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AD7547 — SPECIFICATIONS¹ ($V_{DD} = +12V$ to $+15V$, $\pm 10\%$, $V_{REFA} = V_{REFB} = 10V$; $I_{OUTA} = I_{OUTB} = AGND = 0V$. All specifications T_{min} to T_{max} unless otherwise specified.)

Parameter	J, A Versions	K, B Versions	L, C Versions	S Version	T Version	U Version	Units	Test Conditions/Comments
ACCURACY								
Resolution	12	12	12	12	12	12	Bits	All grades guaranteed monotonic over temperature. Measured using R_{FBA} , R_{FBB} . Both DAC registers loaded with all 1's.
Relative Accuracy	± 1	$\pm 1/2$	$\pm 1/2$	± 1	$\pm 1/2$	$\pm 1/2$	LSB max	
Differential Nonlinearity	± 1	± 1	± 1	± 1	± 1	± 1	LSB max	
Gain Error	± 6	± 3	± 1	± 6	± 3	± 2	LSB max	
Gain Temperature Coefficient ² ; $\Delta\text{Gain}/\Delta\text{Temperature}$	± 5	± 5	± 5	± 5	± 5	± 5	ppm/°C max	Typical value is 1ppm/°C
Output Leakage Current								
I_{OUTA} + 25°C	10	10	10	10	10	10	nA max	DAC A Register loaded with all 0's.
T_{min} to T_{max}	150	150	150	250	250	250	nA max	
I_{OUTB} + 25°C	10	10	10	10	10	10	nA max	DAC B Register loaded with all 0's.
T_{min} to T_{max}	150	150	150	250	250	250	nA max	
REFERENCE INPUT								
Input Resistance	9 20	9 20	9 20	9 20	9 20	9 20	k Ω min k Ω max	Typical Input Resistance $\approx 14k\Omega$
V_{REFA} , V_{REFB} Input Resistance Match	± 3	± 3	± 1	± 3	± 3	± 1	% max	Typically $\pm 0.5\%$
DIGITAL INPUTS								
V_{IH} (Input High Voltage)	2.4	2.4	2.4	2.4	2.4	2.4	V min	$V_{IN} = V_{DD}$
V_{IL} (Input Low Voltage)	0.8	0.8	0.8	0.8	0.8	0.8	V max	
I_{IN} (Input Current) + 25°C	± 1	± 1	± 1	± 1	± 1	± 1	μA max	
T_{min} to T_{max}	± 10	± 10	± 10	± 10	± 10	± 10	μA max	
C_{IN} (Input Capacitance) ²	10	10	10	10	10	10	pF max	
POWER SUPPLY³								
V_{DD}	10.8/16.5	10.8/16.5	10.8/16.5	10.8/16.5	10.8/16.5	10.8/16.5	V min/V max	
I_{DD}	2	2	2	2	2	2	mA max	

AC PERFORMANCE CHARACTERISTICS

These characteristics are included for Design Guidance only and are not subject to test.

($V_{DD} = +12V$ to $+15V$; $V_{REFA} = V_{REFB} = +10V$, $I_{OUTA} = I_{OUTB} = AGND = 0V$. Output Amplifiers are AD644 except where stated.)

Parameter	$T_A = +25^\circ\text{C}$	$T_A = T_{min}, T_{max}$	Units	Test Conditions/Comments
Output Current Settling Time	1.5	—	μs max	To 0.01% of full-scale range. I_{OUT} load = 100Ω , $C_{EXT} = 13\text{pF}$. DAC output measured from rising edge of WR. Typical Value of Settling Time is $0.8\mu\text{s}$.
Digital-to-Analog Glitch Impulse	7	—	nV-s typ	Measured with $V_{REFA} = V_{REFB} = 0V$. I_{OUTA} , I_{OUTB} load = 100Ω , $C_{EXT} = 13\text{pF}$. DAC registers alternately loaded with all 0's and all 1's.
AC Feedthrough⁴				
V_{REFA} to I_{OUTA}	-70	-65	dB max	V_{REFA} , $V_{REFB} = 20\text{V}$ p-p 10kHz sinewave. DAC registers loaded with all 0's.
V_{REFB} to I_{OUTB}	-70	-65	dB max	
Power Supply Rejection $\Delta\text{Gain}/\Delta V_{DD}$	± 0.01	± 0.02	% per % max	$\Delta V_{DD} = V_{DD\text{ max}} - V_{DD\text{ min}}$
Output Capacitance				
C_{OUTA}	70	70	pF max	DAC A, DAC B loaded with all 0's.
C_{OUTB}	70	70	pF max	
C_{OUTA}	140	140	pF max	DAC A, DAC B loaded with all 1's.
C_{OUTB}	140	140	pF max	
Channel-to-Channel Isolation				
V_{REFA} to I_{OUTB}	-84	—	dB typ	$V_{REFA} = 20\text{V}$ p-p 10kHz sinewave, $V_{REFB} = 0V$. Both DACs loaded with all 1's.
V_{REFB} to I_{OUTA}	-84	—	dB typ	$V_{REFB} = 20\text{V}$ p-p 10kHz sinewave, $V_{REFA} = 0V$. Both DACs loaded with all 1's.
Digital Crosstalk	7	—	nV-s typ	Measured for a Code Transition of all 0's to all 1's. I_{OUTA} , I_{OUTB} Load = 100Ω , $C_{EXT} = 13\text{pF}$
Output Noise Voltage Density (10Hz-100kHz)	25	—	nV/ $\sqrt{\text{Hz}}$ typ	Measured between R_{FBA} and I_{OUTA} or R_{FBB} and I_{OUTB} . Frequency of measurement is 10Hz-100kHz.
Total Harmonic Distortion	-82	—	dB typ	$V_{IN} = 6\text{V}$ rms, 1kHz. Both DACs loaded with all 1s.

NOTES

¹Temperature range as follows: J, K, L Versions: -40°C to $+85^\circ\text{C}$.

A, B, C Versions: -40°C to $+85^\circ\text{C}$.

S, T, U Versions: -55°C to $+125^\circ\text{C}$.

²Sample tested at 25°C to ensure compliance.

³Functional at $V_{DD} = 5V$ with degraded specifications.

⁴Pin 12 (DGND) on ceramic DIPs is connected to lid.

Specifications subject to change without notice.

TIMING CHARACTERISTICS ($V_{DD} = 10.8V$ to $16.5V$, $V_{REFA} = V_{REFB} = +10V$, $I_{OUTA} = I_{OUTB} = AGND = 0V$)

Parameter	Limit at $T_A = +25^\circ C$	Limit at $T_A = -40^\circ C$ to $+85^\circ C$	Limit at $T_A = -55^\circ C$ to $+125^\circ C$	Units	Test Conditions/Comments
t_1	60	80	80	ns min	Data Setup Time
t_2	25	25	25	ns min	Data Hold Time
t_3	80	80	100	ns min	Chip Select to Write Setup Time
t_4	0	0	0	ns min	Chip Select to Write Hold Time
t_5	80	80	100	ns min	Write Pulse Width

NOTE
Specifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS*

($T_A = 25^\circ C$ unless otherwise stated)

V_{DD} to DGND	-0.3V, +17V
V_{REFA} , V_{REFB} to AGND,	$\pm 25V$
V_{RFBA} , V_{RFBB} to AGND,	$\pm 25V$
Digital Input Voltage to DGND	-0.3V, $V_{DD} + 0.3V$
I_{OUTA} , I_{OUTB} to DGND	-0.3V, $V_{DD} + 0.3V$
AGND to DGND	-0.3V, $V_{DD} + 0.3V$
Power Dissipation (Any Package)	
To $+75^\circ C$	450mW
Derates above $+75^\circ C$	6mW/ $^\circ C$

Operating Temperature Range

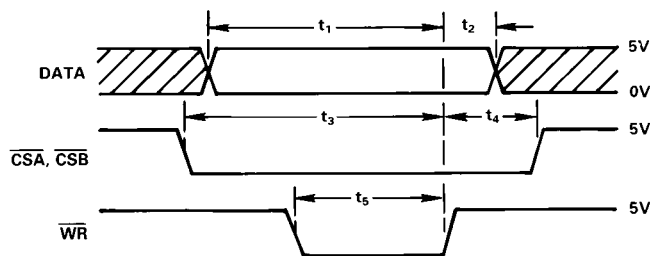
Commercial Plastic (J, K, L Versions)	-40°C to +85°C
Industrial Hermetic (A, B, C Versions)	-40°C to +85°C
Extended Hermetic (S, T, U Versions)	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Lead Temperature (Soldering, 10secs)	+300°C

*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 indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

\overline{CSA}	\overline{CSB}	\overline{WR}	FUNCTION
X	X	1	No Data Transfer
1	1	X	No Data Transfer
		0	A Rising Edge on \overline{CSA} or \overline{CSB} Loads
0	1		Data to the Respective DAC from the Data Bus
1	0		DAC B Register Loaded from Data Bus
0	0		DAC A and DAC B Registers Loaded from Data Bus

NOTES
1. X = Don't care
2. means rising edge triggered

Table I. AD7547 Truth Table



NOTES
1. ALL INPUT SIGNAL RISE AND FALL TIMES MEASURED FROM 10% TO 90% OF +5V. $t_r = t_f = 20ns$.
2. TIMING MEASUREMENT REFERENCE LEVEL IS $\frac{V_{IH} + V_{IL}}{2}$

Figure 1. Timing Diagram for AD7547

ORDERING GUIDE¹

Model ²	Temperature Range	Relative Accuracy	Gain Error	Package Option ³
AD7547JN	-40°C to +85°C	$\pm 1LSB$	$\pm 6LSB$	N-24
AD7547KN	-40°C to +85°C	$\pm 1/2LSB$	$\pm 3LSB$	N-24
AD7547LN	-40°C to +85°C	$\pm 1/2LSB$	$\pm 1LSB$	N-24
AD7547JP	-40°C to +85°C	$\pm 1LSB$	$\pm 6LSB$	P-28A
AD7547KP	-40°C to +85°C	$\pm 1/2LSB$	$\pm 3LSB$	P-28A
AD7547LP	-40°C to +85°C	$\pm 1/2LSB$	$\pm 1LSB$	P-28A
AD7547JR	-40°C to +85°C	$\pm 1LSB$	$\pm 6LSB$	R-24
AD7547KR	-40°C to +85°C	$\pm 1/2LSB$	$\pm 3LSB$	R-24
AD7547LR	-40°C to +85°C	$\pm 1/2LSB$	$\pm 1LSB$	R-24
AD7547AQ	-40°C to +85°C	$\pm 1LSB$	$\pm 6LSB$	Q-24
AD7547BQ	-40°C to +85°C	$\pm 1/2LSB$	$\pm 3LSB$	Q-24
AD7547CQ	-40°C to +85°C	$\pm 1/2LSB$	$\pm 1LSB$	Q-24
AD7547SQ	-55°C to +125°C	$\pm 1LSB$	$\pm 6LSB$	Q-24
AD7547TQ	-55°C to +125°C	$\pm 1/2LSB$	$\pm 3LSB$	Q-24
AD7547UQ	-55°C to +125°C	$\pm 1/2LSB$	$\pm 2LSB$	Q-24
AD7547SE	-55°C to +125°C	$\pm 1LSB$	$\pm 6LSB$	E-28A
AD7547TE	-55°C to +125°C	$\pm 1/2LSB$	$\pm 3LSB$	E-28A
AD7547UE	-55°C to +125°C	$\pm 1/2LSB$	$\pm 2LSB$	E-28A

NOTES
¹Analog Devices reserves the right to ship ceramic packages (D-24A) in lieu of cerdip packages (Q-24).
²To order MIL-STD-883, Class B processed parts, add /883B to part number. Contact your local sales office for military data sheets.
³E = Leadless Ceramic Chip Carrier; N = Plastic DIP; P = Plastic Leaded Chip Carrier; Q = Cerdip; R = SOIC.

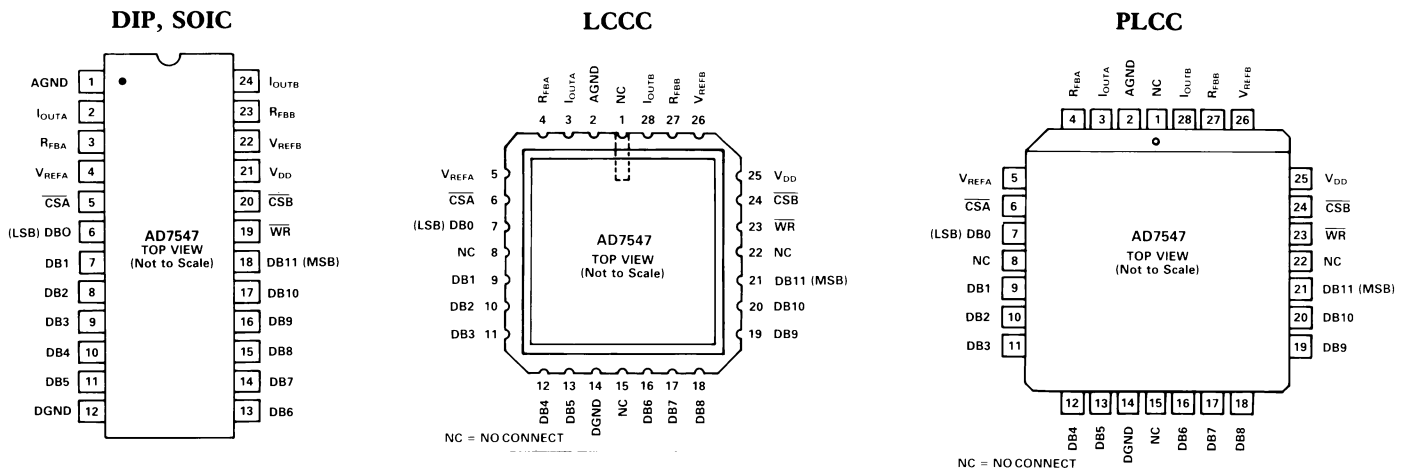
CAUTION

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.



AD7547

PIN CONFIGURATIONS



PIN FUNCTION DESCRIPTION (DIP)

PIN	MNEMONIC	DESCRIPTION
1	AGND	Analog Ground.
2	IOUTA	Current output terminal of DACA.
3	R _{FBA}	Feedback resistor for DACA.
4	V _{REFA}	Reference input to DACA.
5	\overline{CSA}	Chip Select Input for DAC A. Active low.
6-18	DB0-DB11	12 data inputs, DB0 (LSB)–DB11 (MSB).
12	DGND	Digital Ground.
19	\overline{WR}	Write Input. Data transfer occurs on rising edge of \overline{WR} . See Table I.
20	\overline{CSB}	Chip Select Input for DACB. Active low.
21	V _{DD}	Power supply input. Nominally +12V to +15V with ±10% tolerance.
22	V _{REFB}	Reference input to DACB.
23	R _{FBB}	Feedback resistor of DACB.
24	IOUTB	Current output terminal of DACB.

CIRCUIT INFORMATION

D/A SECTION

The AD7547 contains two identical 12-bit multiplying D/A converters. Each DAC consists of a highly stable R-2R ladder and 12 N-channel current steering switches. Figure 2 shows a simplified D/A circuit for DAC A. In the R-2R ladder, binary weighted currents are steered between I_{OUTA} and AGND. The current flowing in each ladder leg is constant, irrespective of switch state. The feedback resistor R_{FBA} is used with an op-amp (see Figures 4 and 5) to convert the current flowing in I_{OUTA} to a voltage output.

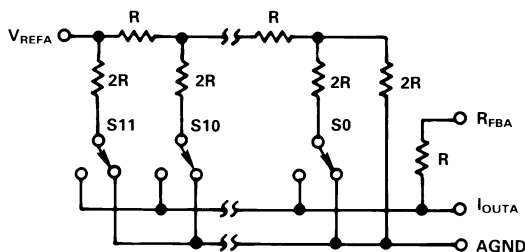


Figure 2. Simplified Circuit Diagram for DACA

EQUIVALENT CIRCUIT ANALYSIS

Figure 3 shows the equivalent circuit for one of the D/A converters (DAC A) in the AD7547. A similar equivalent circuit can be drawn for DACB. Note that AGND is common to both DAC A and DAC B.

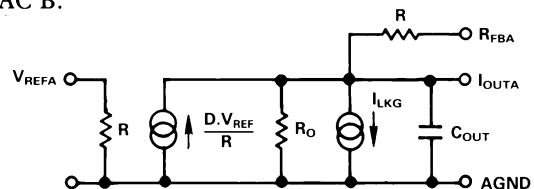


Figure 3. Equivalent Analog Circuit for DACA

C_{OUT} is the output capacitance due to the N-channel switches and varies from about 50pF to 150pF with digital input code. The current source I_{LKG} is composed of surface and junction leakages and approximately doubles every 10°C. R₀ is the equivalent output resistance of the device which varies with input code.

DIGITAL CIRCUIT INFORMATION

The digital inputs are designed to be both TTL and 5V CMOS compatible. All logic inputs are static-protected MOS gates with typical input currents of less than 1nA.

**UNIPOLAR BINARY OPERATION
(2-QUADRANT MULTIPLICATION)**

Figure 4 shows the circuit diagram for unipolar binary operation. With an ac input, the circuit performs 2-quadrant multiplication. The code table for Figure 4 is given in Table II.

Operational amplifiers A1 and A2 can be in a single package (AD644, AD712) or separate packages (AD544, AD711, AD OP-27). Capacitors C1 and C2 provide phase compensation to help prevent overshoot and ringing when high speed op-amps are used.

For zero offset adjustment, the appropriate DAC register is loaded with all 0's and amplifier offset adjusted so that V_{OUTA} or V_{OUTB} is 0V. Full-scale trimming is accomplished by loading the DAC register with all 1's and adjusting R1 (R3) so that V_{OUTA} (V_{OUTB}) = $-V_{IN}$ (4095/4096). For high temperature operation, resistors and potentiometers should have a low Temperature Coefficient. In many applications, because of the excellent Gain T.C. and Gain Error specifications of the AD7547, Gain Error trimming is not necessary. In fixed reference applications, full-scale can also be adjusted by omitting R1, R2, R3, R4 and trimming the reference voltage magnitude.

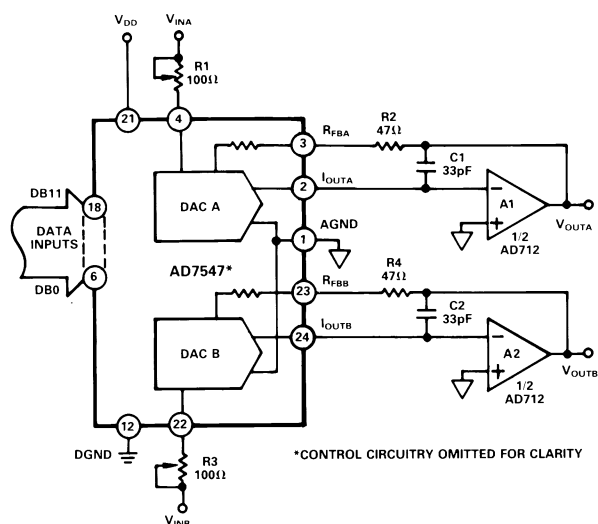


Figure 4. AD7547 Unipolar Binary Operation

Binary Number in DAC Register MSB LSB	Analog Output, V_{OUTA} or V_{OUTB}
1111 1111 1111	$-V_{IN} \left(\frac{4095}{4096} \right)$
1000 0000 0000	$-V_{IN} \left(\frac{2048}{4096} \right) = -1/2 V_{IN}$
0000 0000 0001	$-V_{IN} \left(\frac{1}{4096} \right)$
0000 0000 0000	0V

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

**BIPOLAR OPERATION
(4-QUADRANT MULTIPLICATION)**

The recommended circuit diagram for bipolar operation is shown in Figure 5. Offset binary coding is used.

With the appropriate DAC register loaded to 1000 0000 0000, adjust R1 (R3) so that V_{OUTA} (V_{OUTB}) = 0V. Alternatively, R1, R2 (R3, R4) may be omitted and the ratios of R6, R7 (R9, R10) varied for V_{OUTA} (V_{OUTB}) = 0V. Full-scale trimming can be accomplished by adjusting the amplitude of V_{IN} or by varying the value of R5 (R8).

If R1, R2 (R3, R4) are not used, then resistors R5, R6, R7 (R8, R9, R10) should be ratio matched to 0.01% to ensure gain error performance to the data sheet specification. When operating over a wide temperature range, it is important that the resistors be of the same type so that their temperature coefficients match.

The code table for Figure 5 is given in Table III.

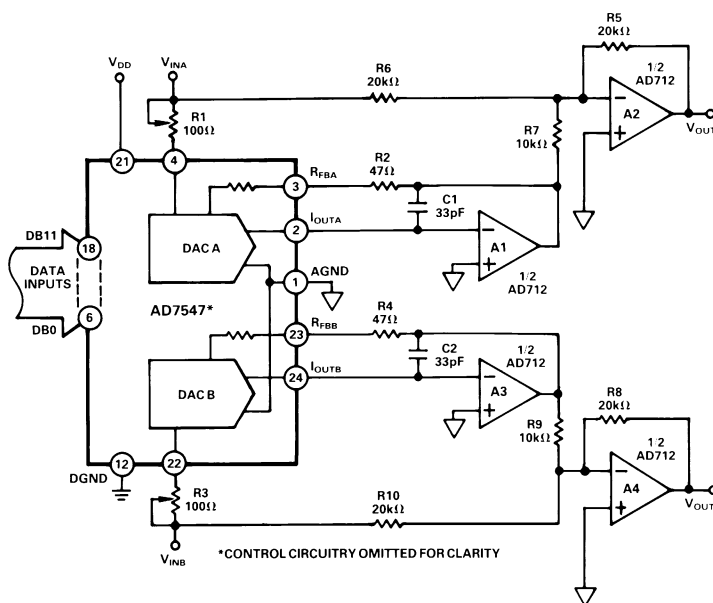


Figure 5. Bipolar Operation (Offset Binary Coding)

Binary Number in DAC Register MSB LSB	Analog Output, V_{OUTA} or V_{OUTB}
1111 1111 1111	$+V_{IN} \left(\frac{2047}{2048} \right)$
1000 0000 0001	$+V_{IN} \left(\frac{1}{2048} \right)$
1000 0000 0000	0V
0111 1111 1111	$-V_{IN} \left(\frac{1}{2048} \right)$
0000 0000 0000	$-V_{IN} \left(\frac{2048}{2048} \right) = -V_{IN}$

Table III. Bipolar Code Table for Offset Binary Circuit of Figure 5.

AD7547 — Applications

PROGRAMMABLE STATE VARIABLE FILTER

The circuit shown in Figure 6 provides three filter outputs: low pass, high pass and bandpass. It is called a State Variable Filter and the particular version shown in Figure 6 uses two AD7547s to control the critical parameters f_0 , Q and A_0 . Instead of several fixed resistors, the circuit uses the DAC equivalent resistances as circuit elements. Thus, R_1 in Figure 6 is controlled by the 12-bit digital word loaded to DAC A of the AD7547. This is also the case with R_2 , R_3 and R_4 . The fixed resistor R_5 is the feedback resistor, R_{FBB} .

$$\text{DAC Equivalent Resistance, } R_{eq} = \frac{4096 \times R_{LAD}}{N}$$

where R_{LAD} = DAC Ladder Resistance

N = DAC Digital Code in Decimal. ($0 < N < 4095$)

In the circuit of Figure 6:

$C_1 = C_2$, $R_7 = R_8$, $R_3 = R_4$ (i.e., the same code is in each DAC)

$$\text{Resonant frequency, } f_0 = \frac{1}{2\pi R_3 C_1}$$

$$\text{Quality Factor, } Q = \frac{R_6 \cdot R_2}{R_8 \cdot R_5}$$

$$\text{Bandpass Gain, } A_0 = \frac{-R_2}{R_1}$$

Using the values shown in Figure 6 the Q range is 0.3 to 5 and f_0 range is 0 to 12kHz.

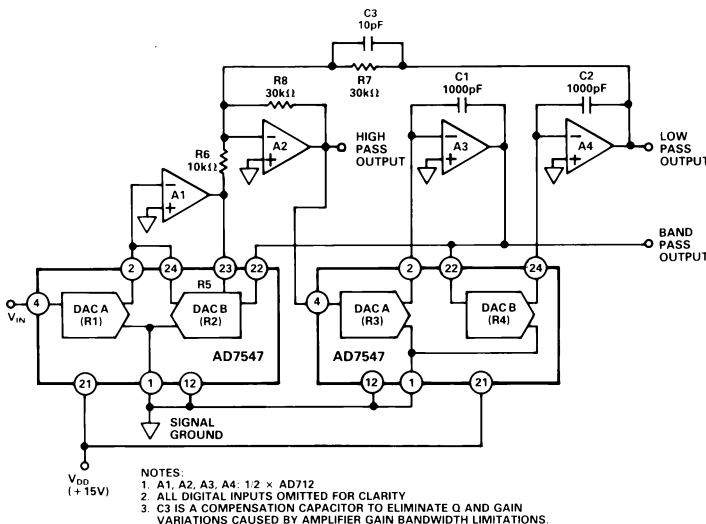


Figure 6. Programmable State Variable Filter

SINGLE SUPPLY APPLICATIONS

DAC A and DAC B of the AD7547 have termination resistors which are tied to the AGND line within the device. This arrangement is ideal for single supply operation because AGND may be biased at any voltage between DGND and V_{DD} . Figure 7 shows a circuit which provides two +5V to +10V analog

outputs by biasing AGND to +5V with respect to DGND, which in this case is also the system ground. The two DAC reference inputs are also tied to system ground.

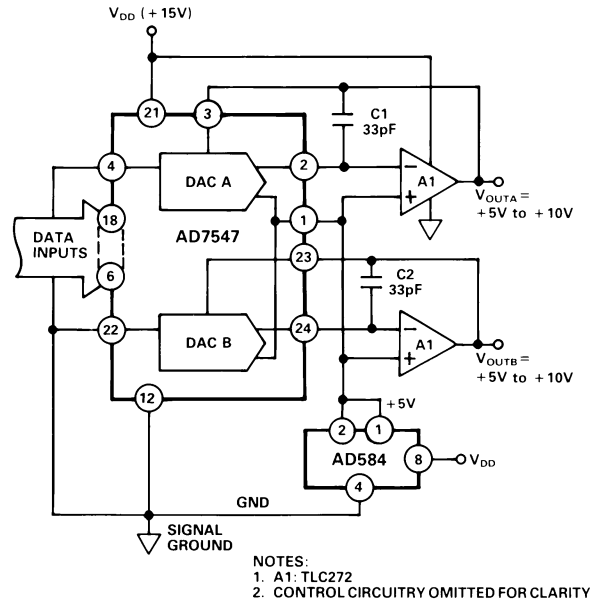


Figure 7. AD7547 Single Supply Operation

The transfer function for each channel is:

$$V_{OUT} = 5V \left(1 + \frac{R_{FB}}{R_{EQ}} \right)$$

With all 0's loaded to the DAC, $R_{EQ} = \infty$ and $V_{OUT} = +5V$. With all 1's loaded $R_{EQ} = R_{LADDER} = R_{FB}$ and $V_{OUT} = +10V$.

Figure 8 shows both DACs of the AD7547 connected in the voltage switching mode. For further information on this mode of operation see the CMOS DAC Application Guide from Analog Devices, publication number G872a-15-4/86. To optimize performance when using this circuit, V_{IN} must be in the range 0 to +1.25V and the output buffered. V_{IN} must be driven from a low impedance source (e.g. a buffer amplifier). Figure 9 shows how differential linearity degrades with increasing V_{IN} .

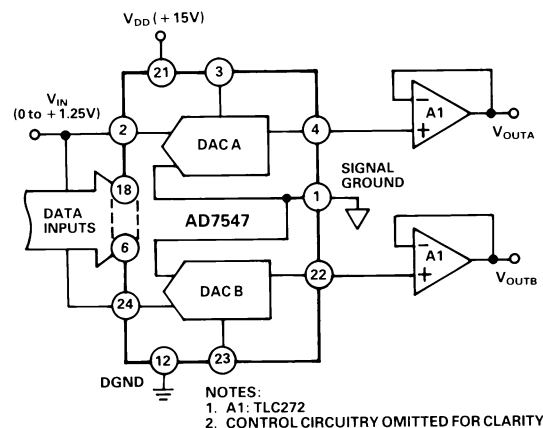
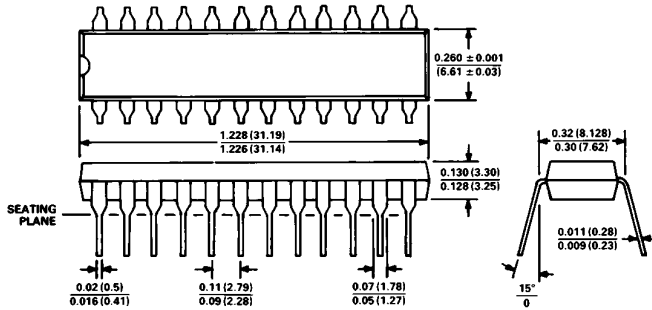


Figure 8. AD7547 Operated in Single Supply, Voltage Switching Mode

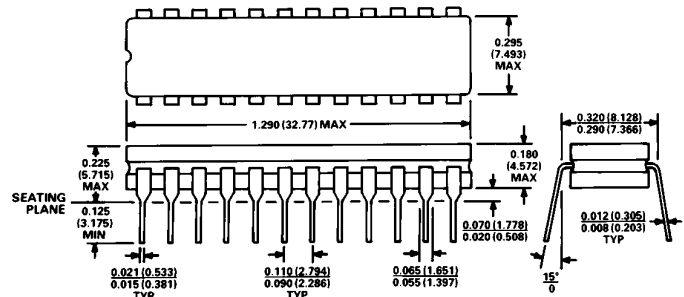
OUTLINE DIMENSIONS
Dimensions shown in inches and (mm).

24-Pin Plastic DIP (N-24)



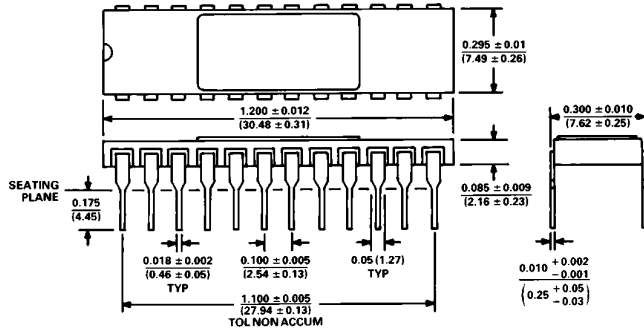
- NOTES
1. LEAD NO. 1 IDENTIFIED BY DOT OR NOTCH.
2. PLASTIC LEADS WILL BE EITHER SOLDER DIPPED OR TIN LEAD PLATED IN ACCORDANCE WITH MIL-M-38510 REQUIREMENTS.

24-Pin Cerdip (Q-24)



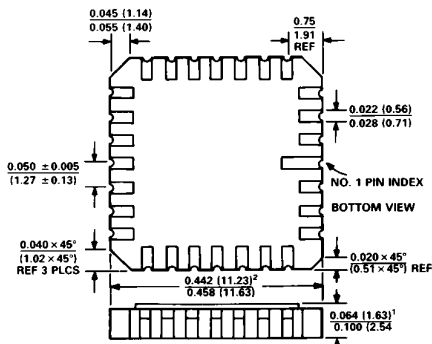
- NOTES
1. LEAD NO. 1 IDENTIFIED BY DOT OR NOTCH.
2. CERDIP LEADS WILL BE EITHER TIN PLATED OR SOLDER DIPPED IN ACCORDANCE WITH MIL-M-38510 REQUIREMENTS.

24-Pin Ceramic DIP (D-24A)



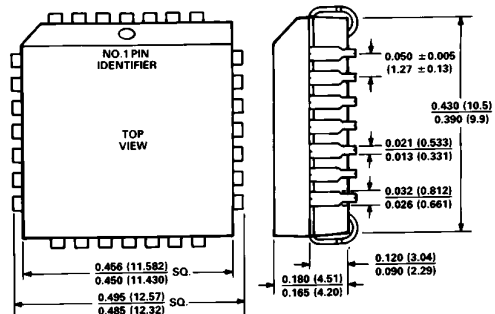
- NOTES
1. LEAD NO. 1 IDENTIFIED BY DOT OR NOTCH.
2. CERAMIC DIP LEADS WILL BE EITHER GOLD OR TIN PLATED IN ACCORDANCE WITH MIL-M-385 TO REQUIREMENTS.
3. METAL LID IS CONNECTED TO DGND.

28-Terminal Leadless Ceramic Chip Carrier (E-28A)



- NOTES
1. THIS DIMENSION CONTROLS THE OVERALL PACKAGE THICKNESS.
2. APPLIES TO ALL FOUR SIDES.
3. ALL TERMINALS ARE GOLD PLATED.

28-Terminal Plastic Leaded Chip Carrier (P-28A)



PRICING (100+) \$

AD7547JN \$14.50	AD7547AQ \$19.80	AD7547SQ \$60.00
AD7547KN \$17.00	AD7547BQ \$22.30	AD7547TQ \$70.00
AD7547LN \$23.00	AD7547CQ \$28.30	AD7547UQ \$85.00

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