INTERSIL

AD7523
8 Bit Monolithic Multiplying D/A Converters

FEATURES

- **8, 9 and 10 bit linearity**
- **Low gain and linearity Tempcos**
- **Full temperature range operation**
- **Full input static protection**
- **DTL/TTL/CMOS compatible**
- **+5 to +15 volts supply range**
- **Fast settling time: 100 nS**
- **Four quadrant multiplication**
- **883B Processed versions available**

GENERAL DESCRIPTION

The Intersil AD7523 is a monolithic, low cost, high performance, 10 bit accurate, multiplying digital-to-analog converter (DAC), in a 16-pin DIP.

Intersil's thin-film resistors on CMOS circuitry provide 8-bit resolution (8, 9 and 10-bit accuracy), with DTL/TTL/CMOS compatible operation.

Intersil AD7523's accurate four quadrant multiplication, full military temperature range operation, full input protection from damage due to static discharge by clamps to V+ and GND and very low power dissipation make it a very versatile converter.

Low noise audio gain control, motor speed control, digitally controlled gain and attenuators are a few of the wide number of applications of the 7523.

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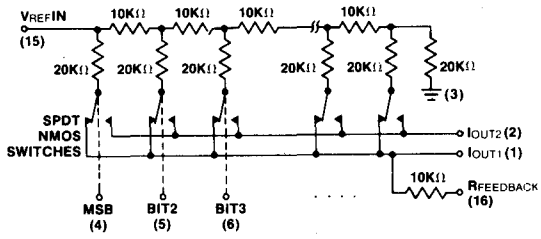
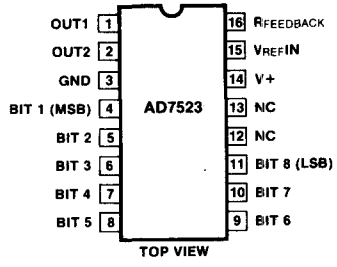
FUNCTIONAL DIAGRAM



(Switches shown for Digital Inputs "High")

PIN CONFIGURATION

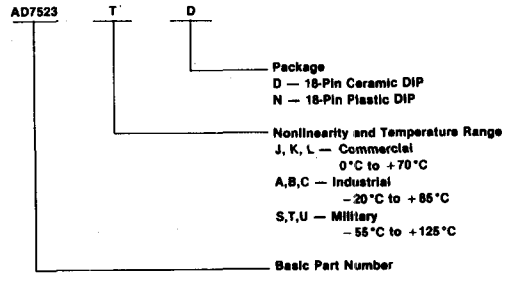


TOP VIEW

OUTLINE DRAWINGS
DE,PE

ORDERING INFORMATION

Nonlinearity	Temperature Range		
	0°C to +70°C	−20°C to +85°C	−55°C to +125°C
0.2% (8 Bit)	AD7523JN	AD7523AD	AD7523SD
0.1% (9 Bit)	AD7523KN	AD7523BD	AD7523TD
0.05% (10 Bit)	AD7523LN	AD7523CD	AD7523UD



ABSOLUTE MAXIMUM RATINGS

(T_A = 25°C unless otherwise noted)

V^+ ..... +17V
V_{REF} ..... ±25V
Digital Input Voltage Range ..... -0.3 to VDD
Output Voltage Compliance ..... -0.3 to VDD
Power Dissipation (package)
Plastic
up to +70°C 670mW
derates above +70°C by ..... 8.3mW/°C
Ceramic
up to 75°C 450mW
derates above 75°C by ..... 6mW/°C
Operating Temperatures
JN, KN, LN Versions ..... 0°C to +70°C
AD, BD, CD Versions ..... -25°C to +85°C
SD, TD, UD Versions ..... -55°C to +125°C
Storage Temperature ..... -65°C to +150°C
Lead Temperature (soldering, 10 seconds) ..... +300°C

CAUTION: 1. The digital control inputs are zener protected; however, permanent damage may occur on unconnected units under high energy electrostatic fields. Keep unused units in conductive foam at all times.
2. Do not apply voltages higher than VDD and lower than GND to any terminal except $V_{REF} + R_{FB}$.

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

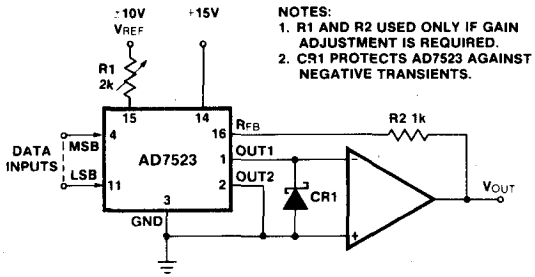
SPECIFICATIONS (V^+ = +15V, V_{REF} = +10V unless otherwise specified)

PARAMETER		TA +25°C	TA MIN-MAX	UNITS	LIMIT	TEST CONDITIONS
DC ACCURACY (Note 1)						
Resolution		8	8	Bits	Min	
Nonlinearity (Note 2)	(±1/2 LSB)	±0.2	±0.2	% of FSR	Max	
	(±1/4 LSB)	±0.1	±0.1	% of FSR	Max	$-10V \le V_{REF} \le +10V$
	(±1/8 LSB)	±0.05	±0.05	% of FSR	Max	$V_{OUT1} = V_{OUT2} = 0V$
Monotonicity		Guaranteed				
Gain Error (Note 2)		±1.5	±1.8	% of FSR	Max	Digital inputs high.
Nonlinearity Tempco (Note 2 and 3)		2		PPM of FSR/°C	Max	$-10V$ V_{REF} $+10V$
Gain Error Tempco (Note 2 and 3)		10		PPM of FSR/°C	Max	
Output Leakage Current (either output)		±50	±200	nA	Max	$V_{OUT1} = V_{OUT2} = 0$
AC ACCURACY (Note 3)						
Power Supply Rejection (Note 2)		0.02	0.03	% of FSR/%	Max	V^+ = 14.0 to 15.0V
Output Current Settling Time		150	200	nS	Max	To 0.2% of FSR, $R_L = 100\Omega$
Feedthrough Error		±1/2	±1	LSB	Max	V_{REF} = 20V pp, 200KHz sine wave. All digital inputs low.
REFERENCE INPUT		5K		Ω	Min	
Input Resistance (Pin 15)		20K		Ω	Max	All digital inputs high. I_{OUT1} at ground.
Temperature Coefficient (Note 3)		-500		ppm/°C	Max	
ANALOG OUTPUT (Note 3)						Both outputs.
Voltage Compliance (Note 4)		-100mV to V^+				See maximum ratings.
Output Capacitance	C_{OUT1}	100		pF	Max	All digital inputs high (VINH)
	C_{OUT2}	30		pF	Max	
	C_{OUT1}	30		pF	Max	All digital inputs low (VINL)
	C_{OUT2}	100		pF	Max	
DIGITAL INPUTS						
Low State Threshold (V_{INL})		0.8		V	Max	Guarantees DTL/TTL and CMOS (0.5
High State Threshold (V_{INH})		2.4		V	Min	max, 14.5 min) levels
Input Current (per input)		±1		μA	Max	V_{IN} = 0V or +15V
Input Coding		Binary/Offset Binary				See Tables 1 & 2
Input Capacitance (Note 3)		4		pF	Max	
POWER REQUIREMENTS						Accuracy is tested and guaranteed at
Power Supply Voltage Range		+5 to +16		V		V^+ = +15V, only.
I^+		100		μA	Max	All digital inputs low or high.

NOTES: 1. Full scale range (FSR) is 10V for unipolar and ±10V for bipolar modes.
2. Using internal feedback resistor, $R_{FEEDBACK}$.
3. Guaranteed by design; not subject to test.
4. Accuracy not guaranteed unless outputs at ground potential.

Specifications subject to change without notice.

APPLICATIONS
UNIPOLAR OPERATION



NOTES:
1. R1 AND R2 USED ONLY IF GAIN ADJUSTMENT IS REQUIRED.
2. CR1 PROTECTS AD7523 AGAINST NEGATIVE TRANSIENTS.

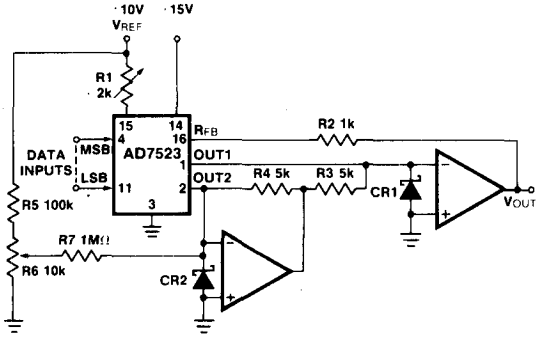
Figure 1. Unipolar Binary Operation (2-Quadrant Multiplication)

DIGITAL INPUT MSB LSB	ANALOG OUTPUT
11111111	$-V_{REF}\left(\frac{255}{256}\right)$
10000001	$-V_{REF}\left(\frac{129}{256}\right)$
10000000	$-V_{REF}\left(\frac{128}{256}\right) = -\frac{V_{REF}}{2}$
01111111	$-V_{REF}\left(\frac{127}{256}\right)$
00000001	$-V_{REF}\left(\frac{1}{256}\right)$
00000000	$-V_{REF}\left(\frac{0}{256}\right) = 0$

Note: 1 LSB = (2^{-8}) (V_{REF})= $\left(\frac{1}{256}\right)$ (V_{REF})

Table 1. Unipolar Binary Code Table

BIPOLAR OPERATION



NOTES:
1. R3/R4 MATCH 0.1% OR BETTER.
2. R1, R2 USED ONLY IF GAIN ADJUSTMENT IS REQUIRED.
3. R5-R7 USED TO ADJUST V_{OUT} = 0V AT INPUT CODE 10000000.
4. CR1 & CR2 PROTECT AD7523 AGAINST NEGATIVE TRANSIENTS.

Figure 2. Bipolar (4-Quadrant) Operation

DIGITAL INPUT MSB LSB	ANALOG OUTPUT
11111111	$-V_{REF}\left(\frac{127}{128}\right)$
10000001	$-V_{REF}\left(\frac{1}{128}\right)$
10000000	0
01111111	$+V_{REF}\left(\frac{1}{128}\right)$
00000001	$+V_{REF}\left(\frac{127}{128}\right)$
00000000	$+V_{REF}\left(\frac{128}{128}\right)$

Note: 1LSB = (2^{-7}) (V_{REF}) = $\left(\frac{1}{128}\right)$ (V_{REF})

Table 2. Bipolar (Offset Binary) Code Table

POWER DAC DESIGN USING AD7523

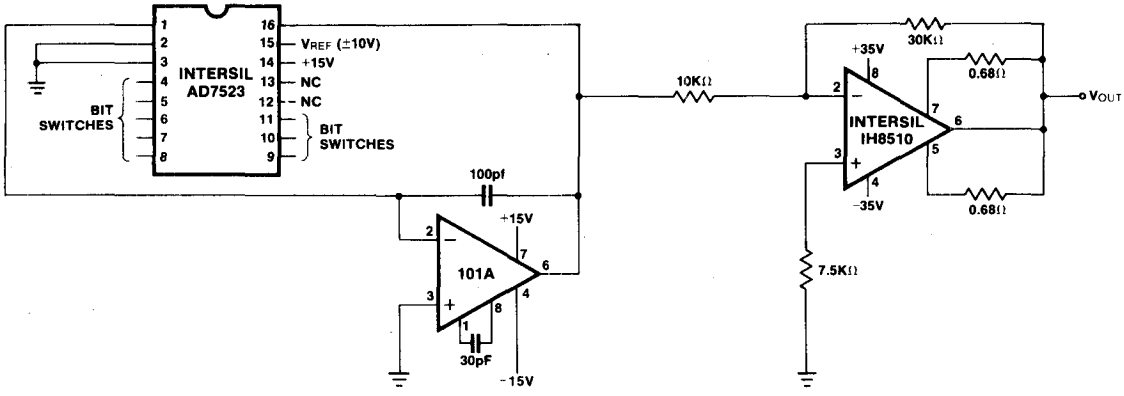


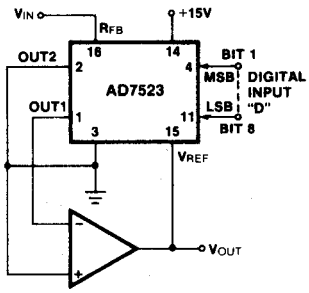
Figure 3. The Basic Power DAC

A typical power DAC designed for 10 bit accuracy and 8 bit resolution is shown in Figure 3. INTERSIL IH8510 power amplifier (1 Amp continuous output with up to +25V) is driven by the AD7523.

A summing amplifier between the AD7523 and the IH8510 is used to separate the gain block containing the AD7520 on-chip resistors from the power amplifier gain stage whose gain is set only by the external resistors. This approach minimizes drift since the resistor pairs will track properly. Otherwise AD7523 can be directly connected to the IH8510, by using a 25 volts reference for the DAC.

APPLICATIONS (continued)

DIVIDER (DIGITALLY CONTROLLED GAIN)



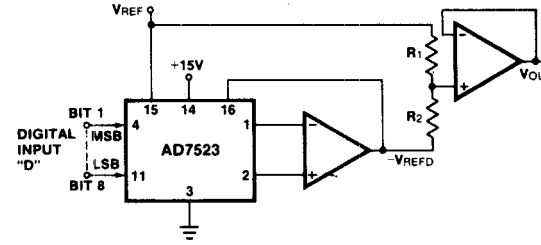
$V_{OUT} = -V_{IN}/D$

WHERE:

$$D = \frac{BIT1}{2^1} + \frac{BIT2}{2^2} + \cdots \frac{BIT8}{2^8}$$

$$\left(0 \le D \le \frac{255}{256}\right)$$

MODIFIED SCALE FACTOR AND OFFSET



$$V_{OUT} = V_{REF}\left[\left(\frac{R_2}{R_1+R_2}\right) - \left(\frac{R_1 D}{R_1+R_2}\right)\right] \quad \text{WHERE:} \quad D = \frac{BIT\ 1}{2^1} + \frac{BIT\ 2}{2^2} + \cdots \frac{BIT\ 8}{2^8}$$

$$\left(0 \le D \le \frac{255}{256}\right)$$

DEFINITION OF TERMS

NONLINEARITY: Error contributed by deviation of the DAC transfer function from a best straight line function. Normally expressed as a percentage of full scale range. For a multiplying DAC, this should hold true over the entire V_{REF} range.

RESOLUTION: Value of the LSB. For example, a unipolar converter with n bits has a resolution of $(2^{-n})(V_{REF})$. A bipolar converter of n bits has a resolution of $[2^{-(n-1)}][V_{REF}]$. Resolution in no way implies linearity.

SETTLING TIME: Time required for the output function of the DAC to settle to within 1/2 LSB for a given digital input stimulus, i.e., 0 to Full Scale.

GAIN: Ratio of the DAC's operational amplifier output voltage to the nominal input voltage value.

FEEDTHROUGH ERROR: Error caused by capacitive coupling from V_{REF} to output with all switches OFF.

OUTPUT CAPACITANCE: Capacity from I_{OUT1} and I_{OUT2} terminals to ground.

OUTPUT LEAKAGE CURRENT: Current which appears on I_{OUT1} terminal with all digital inputs LOW or on I_{OUT2} terminal when all inputs are HIGH.

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For further information on the use of this device, see the following Application Bulletins:

A016 "Selecting A/D Converters," by David Fullagar
A018 "Do's and Don'ts of Applying A/D Converters," by Peter Bradshaw and Skip Osgood
A020 "A Cookbook Approach to High-Speed Data Acquisition and Microprocessor Interfacing" by Ed Sliger
A021 "Power D/A Converters Using the IH8510," by Dick Wilenken
R005 "Interfacing Data Converters & Microprocessors," by Peter Bradshaw et al., Electronics, Dec. 9, 1976