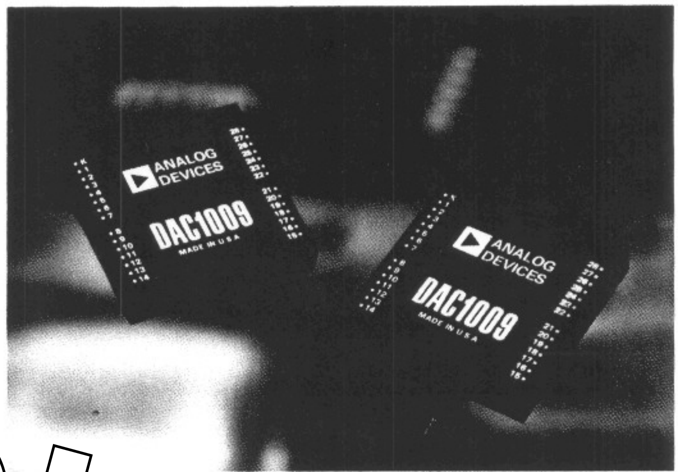
ANALOG DEVICES

Low Cost Multipurpose Digital-to-Analog Converter

DAC1009

FEATURES
12 Bit Resolution
Positive True Logic Inputs
Fixed Reference or Multiplying Operation
TTL/DTL or CMOS Compatible
Current or Voltage Output
User Selected Output Ranges
Small Size – 2" x 2" x 0.4" (51 x 51 x 10mm)



GENERAL DESCRIPTION

The DAC1009 is a low cost, multipurpose digital-to-analog converter which can be readily adapted to a variety of applications. This versatile 12 bit device can be programmed for fixed reference or multiplying operation and for current or voltage output. It will interface with CMOS or DTL/TTL logic systems and it features convenient positive-true logic inputs. Performance specifications include ±½LSB linearity error, 4μsec settling time for a 10V output step, and a gain temperature coefficient of 11ppm/°C.

OUTPUT VERSATILITY

The DAC1009 can be used in either the voltage output or current output mode. When it is used as a voltage output device, any one of the five following output ranges are available:

Unipolar	0 to –5V, 0 to –10V
Bipolar	±2.5V, ±5V, ±10V

External jumpers at the module pins determine the output amplifier feedback resistance. Offset of exactly one-half full scale for bipolar applications is provided by connecting a jumper between an internal reference source and the summing junction of the output amplifier.

As a current output device the DAC1009 can be used to drive an external op amp. Internal feedback resistors can also be used with this external op amp to assure optimum temperature tracking of components.

DIGITAL INPUTS

The DAC1009 uses the positive-true logic convention preferred by many system designers (i.e., 111...1 digital input results in the maximum absolute value analog output). The logic levels of:

$$+2.0V \leqslant \text{Logic "1"} \leqslant +15V$$
$$0V \leqslant \text{Logic "0"} \leqslant +0.8V$$

are compatible with both DTL/TTL and CMOS systems. When used with CMOS logic, the driving gate for each input bit must be capable of sinking at least 1mA.

For unipolar outputs either Binary or BCD code may be used; for bipolar outputs Offset Binary code is available.

MULTIPLYING CAPABILITY

The DAC1009 can be readily configured as either a one or two-quadrant multiplying DAC. When used in this manner the one-quadrant analog input of 0 to –1mA is attenuated by an amount corresponding to the one-quadrant (unipolar) or two-quadrant (bipolar) digital input signal. By appropriate choice of the input resistor value, any input voltage range may be used. The following sections of this data sheet should be consulted to determine whether the multiplying characteristics of this device make it suitable for a given application.

Route 1 Industrial Park; P.O. Box 280; Norwood, Mass. 02062
Tel: 617/329-4700 TWX: 710/394-6577
West Coast 213/595-1783 | Mid-West 312/894-3300 | Texas 214/231-5094

SPECIFICATIONS (typical @ +25°C and rated supply voltages, unless otherwise noted)

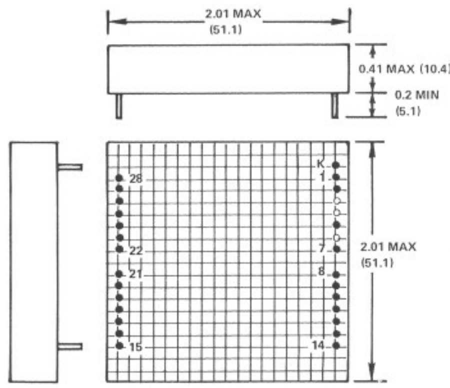
	Voltage Output	Current Output
RESOLUTION		
Binary	12 Bits	*
BCD	3 Digits	*
DIGITAL INPUTS[1]	TTL Compatible	*
0V ≤ Logic "0" ≤ +0.8V	@ -1mA	*
+2V ≤ Logic "1" ≤ +15V	@ +40μA	*
INPUT CODES		
Unipolar	Binary, BCD	*
Bipolar	Offset Binary	*
OUTPUT RANGES		
(User Programmable)	0 to -5V @ 10mA	0 to +2mA
	0 to -10V @ 5mA	
	±2.5V, ±5V @ 10mA	±1mA
	±10V @ 5mA	
Voltage Compliance	—	±400mV
OUTPUT IMPEDANCE	0.02Ω	6.9kΩ
SETTLING TIME[2]	4μs (7μs max)	700ns (1.5μs max)
LINEARITY ERROR	±½LSB max	*
TEMPERATURE COEFFICIENT		
Gain	±11ppm/°C (±40ppm/°C max)	*
Zero		
Unipolar	±12μV/°C (±50μV/°C max)[3]	±1nA/°C max[4]
Bipolar	±50μV/°C (±130μV/°C max)[5]	±7nA/°C (±60nA/°C max)
Differential Linearity Error	±4ppm/°C (±10ppm/°C max)	*
TEMPERATURE RANGE		
Operating	0 to +70°C	*
Storage	-25°C to +85°C	*
POWER REQUIREMENTS	+15V ±5% @ 17mA	*
	-15V ±5% @ 18mA	*
POWER SUPPLY SENSITIVITY[6]		
Gain	0.1ppm/%ΔV_S	*
Zero	1ppm/%ΔV_S	*
ADJUSTMENT RANGE		
Gain	±0.4% of F.S.	*
Zero	±14LSB	*
PRICES		
(1-9)	$84	*
(10-24)	$71	*
(25-99)	$62	*
(100+)	$54	*

*Specification is same as for Voltage Output Mode.
[1] Open input equivalent to Logic "1".
[2] To ±0.01% accuracy for a full scale output step.
[3] For the 0 to -10V range.
[4] Doubles every 10°C.
[5] For the ±5V range.
[6] For the ±15V supplies only, with +15V and -15V supplies tracking.

Specifications subject to change without notice.

OUTLINE DIMENSIONS

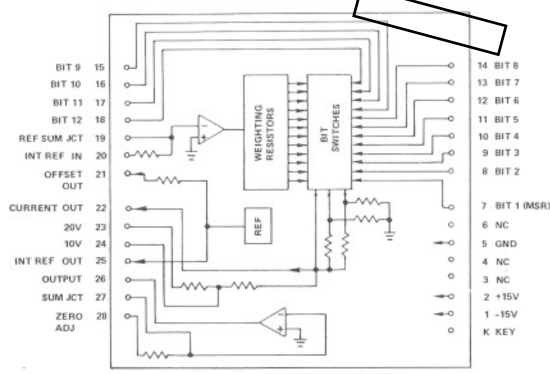
Dimensions shown in inches and (mm).



NOTE:

Terminal pins installed only in shaded hole locations.
Module weight: 1.6 ounces (45 grams)
All pins are gold plated half-hard brass (MIL-G-45204B), 0.019" ±0.001" (0.48 ±0.025mm) diameter.
For plug-in mounting card, order Board No. AC6160 @ $20.00.

BLOCK DIAGRAM AND PIN DESIGNATIONS



NOTE: PINS SHOWN AS HAVING NO CONNECTION (N.C.) ARE DELETED

ORDERING GUIDE:

DAC1009 /XXX

- BIN
- BCD

DIGITAL INPUT DATA

The DAC1009 is fully DTL/TTL compatible with each input bit representing one standard TTL load. The required logic levels of:

$+2.0V \leqslant$ Logic "1" $\leqslant +15V$

$0V \leqslant$ Logic "0" $\leqslant +0.8V$

are also compatible with CMOS logic systems. When driving the DAC1009 with a CMOS gate, standard CMOS/TTL interface rules must be observed to assure that the CMOS gate will adequately sink at least 1mA.

Binary or BCD code can be used for unipolar output; Offset Binary code is used for bipolar output. The following table illustrates the analog outputs associated with various digital input codes for fixed reference operation.

Digital Input	Nominal Analog Output	
	Voltage Output*	Current Output
Binary (12 Bits)		
Unipolar		
111111111111	-9.9976V	+1.9995mA
000000000000	0	0
Bipolar		
111111111111	-9.9951V	+0.9995mA
100000000000	0	0
000000000000	+10V	-1.000mA
BCD (3 digits)		
Unipolar		
1001 1001 1001	-9.9900V	+1.2488mA
0000 0000 0000	0	0

*Voltages shown are for the 0 to -10V and ±10V ranges; outputs are proportionately smaller for other ranges.

VOLTAGE OUTPUT RANGE SELECTION

The following simplified schematic (Figure 1) represents the DAC1009 output circuit.

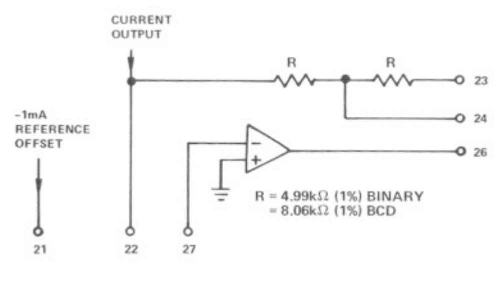


Figure 1. Simplified Output Circuit

The output voltage range is determined by the amount of feedback resistance used with the internal op amp. By connecting external jumpers between module pins, three feedback resistance values can be obtained.

A -1mA current must be applied to the internal op amp's summing junction to produce the half scale offset necessary for bipolar output. The OFFSET OUTPUT (pin 21), derived from the module's internal reference source, provides this current.

The following table shows the external connections used to program the various output ranges.

Output Range	Pins Jumpered Together		
±2.5V	27, 22, 21, 23	26, 24	
±5.0V	27, 22, 21	26, 24	
±10V	27, 22, 21	26, 23	
0 to -5V	27, 22, 23	26, 24	21, 5
0 to -10V	27, 22	26, 24	21, 5

CURRENT OUTPUT APPLICATIONS

The CURRENT OUTPUT terminal (pin 22) provides an output of 0 to +2mA for unipolar operation. When the OFFSET OUTPUT of pin 21 is connected to it, a ±1mA bipolar output results. Because of the ±400mV compliance of the CURRENT OUTPUT terminal, only an external inverting op amp should be used to transform the current output to a voltage output. The proper connection of such an op amp is shown below in Figure 2.

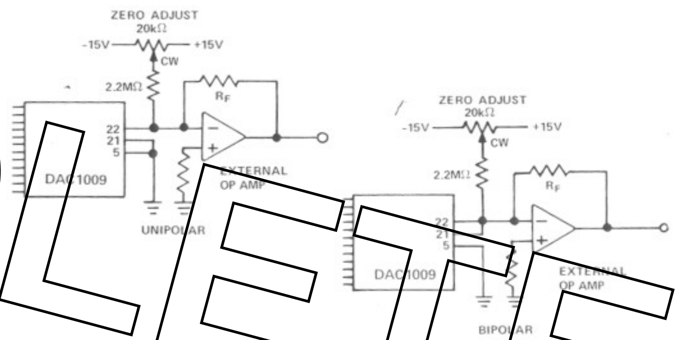


Figure 2. Connection of an External Op Amp (With External Feedback Resistor)

The feedback resistors which are normally used with the internal op amp can also be used with external op amps to provide optimum temperature tracking of the critical gain determining components. The arrangement of these resistors and their connections to the external op amp are shown below in Figure 3.

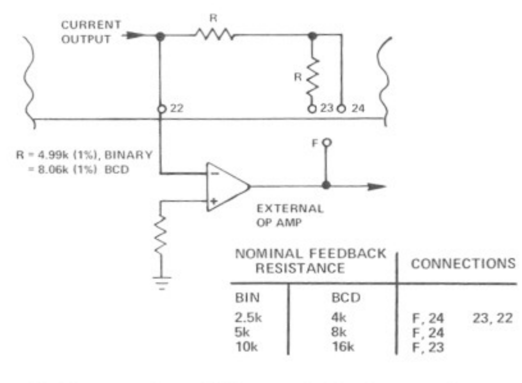


Figure 3. Connection of External Op Amp to Internal Feedback Resistors

In order to prevent the introduction of noise, the lead from the CURRENT OUTPUT terminal to the external op amp summing junction should be made with shielded cable and should be kept as short as possible.

FIXED REFERENCE OPERATION

Each module contains a precision -6.2V (nominal) reference source, the output of which is available at pin 25. When the converter is used in the fixed reference mode, this output is connected via a 50Ω trim pot (supplied by the user) to the reference input terminal (pin 20) as shown in Figure 4.

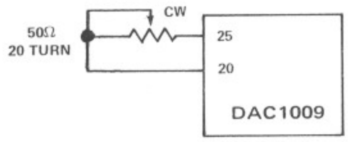


Figure 4. Reference Connection

Since the value of the reference input current ultimately determines the magnitude of the converter's analog output, this trim pot is used to make gain adjustments. An external reference source capable of supplying -6.2 volts at -1mA may be used in place of the internal reference.

MULTIPLYING OPERATION

When used as a multiplying DAC, the fixed reference input is replaced by a signal which can vary in amplitude from 0 to -1mA. The converter's output will then represent the product of the digital and analog inputs. The use of a unipolar input code produces one quadrant multiplication; a bipolar code produces two quadrant multiplication. As a multiplier, the DAC1009 has a small signal bandwidth of 950kHz, a full power bandwidth of 125kHz and a half power bandwidth of 750kHz. With proper external circuitry, maximum feedthrough is less than 1LSB at 50kHz.

The following simplified schematic (Figure 5) represents the analog input circuit configuration.

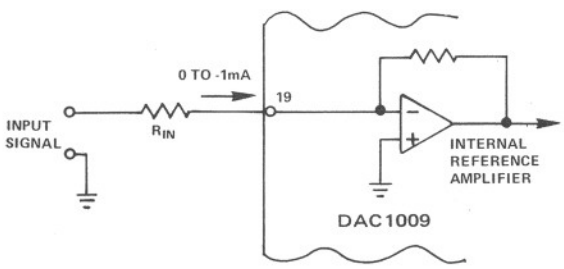


Figure 5. Analog Input Circuit

Pin 19 which is connected to the reference amplifier's summing junction is essentially at ground potential. The input resistance necessary to yield -1mA with the peak input voltage applied can, therefore, be readily calculated. Due to minor variations between units, an initial adjustment of up to ±2% in the value of the input resistor may be necessary to produce the proper overall gain.

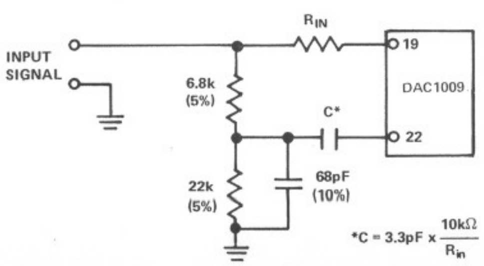


Figure 6. Feedthrough Reduction Circuit

The feedthrough characteristics of the DAC1009 can be greatly enhanced by the addition of the simple external circuit shown in Figure 6.

With this circuit, feedthrough is reduced by a factor of approximately 10:1. The following table lists typical values of feedthrough for a −1mA sine wave input and a digital input code of 000. . .00 for the 0 to −10V output range.

	Feedthrough (mV)	
Input Frequency	w/Circuit	w/o Circuit
10kHz	1.6	6
50kHz	2.0	24
100kHz	4.0	44

With full scale (-1mA) reference applied, each DAC1009 is carefully trimmed to eliminate minor errors in the weighting of individual bits. These errors tend to reappear when the reference level decreases as it does during multiplying operation. The overall effect of these errors is a function of reference input level as shown in Figure 7.

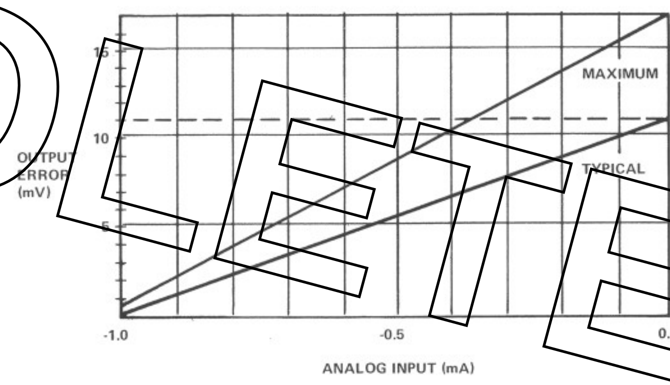


Figure 7. Output Error vs. Analog Input

Maximum linearity is achieved when the analog input signal remains close to full scale.

GAIN AND ZERO ADJUSTMENT

The proper connections of the user-supplied gain and zero adjustment potentiometers are shown below in Figure 8 for fixed reference voltage output operation. For current output operation, the wiper of the zero adjustment potentiometer should be connected via a 2.2MΩ resistor to pin 22 instead of directly to pin 28 as shown in Figure 2.

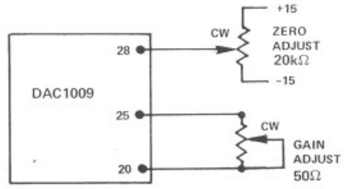


Figure 8. Gain and Zero Adjustments

With a digital code of 000. . .00 applied, adjust the zero pot until the analog output is zero ±1/10LSB for unipolar units or $+V_{FS}$ ±1/10LSB for bipolar units. With a full scale digital code of 111. . .11 (binary) or 1001 1001 1001 (BCD) applied, adjust the gain pot until the analog output is within ±1/10LSB of Full Scale less 1LSB.

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