DATEL

DAC-IC10B Series
Low Cost, 10-Bit Monolithic Digital-to-Analog Converter

FEATURES

- **10-Bit resolution**
- **Straight binary coding**
- **Current output**
- **250 Nanosecond settling time**
- **TTL/CMOS-compatible**
- **Low cost**

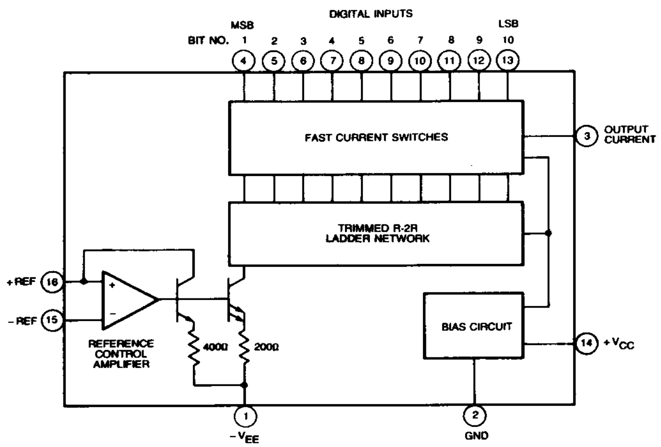
GENERAL DESCRIPTION

The DAC-IC10B is a low cost, 10-bit monolithic DAC with fast output current settling time. It is packaged in a 16-pin ceramic DIP and requires only an external reference and operational amplifier for voltage output operation. A full-scale change in output current settles in 250 nanoseconds, and with a fast I.C. operational amplifier (such as DATEL's AM-452) a 10V output change can settle within 1 microsecond. Digital input coding is straight binary for unipolar operation, and offset binary for bipolar operation; the logic inputs are compatible with TTL or CMOS.

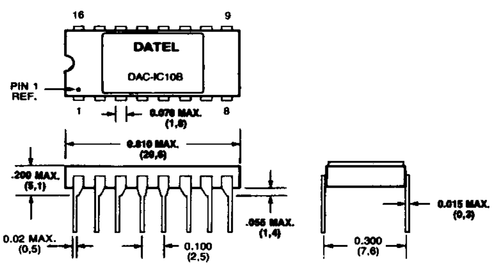
This converter is manufactured with monolithic bipolar technology. The circuit incorporates 10 fast switching current sources which drive a diffused resistor R-2R network. The ladder network is laser trimmed by cutting aluminum links. The circuit also contains a reference control amplifier and a bias circuit. An external reference current of 2 mA is required at the + Reference input terminal; this is accomplished by an external voltage reference and a metal film resistor.

Other characteristics of the DAC-IC10B include linearity to ± ½ LSB and guaranteed monotonic performance. The gain temperature coefficient of this unit is typically −20 ppm/°C. Output voltage compliance is −2.5V to +0.2V, permitting direct driving of a 625Ω resistor for a voltage output. The reference input current can be varied from 0.5 mA to 2.5 mA to give monotonic operation as a one- or two-quadrant multiplier.

Power supply requirement is +5V dc and −15V dc. The DAC-IC10B is available in three models covering two temperature ranges, 0°C to +70°C and −55°C to +125°C.



MECHANICAL DIMENSIONS INCHES (MM)



INPUT/OUTPUT CONNECTIONS

PIN	FUNCTION
1	−VEE
2	GROUND
3	OUTPUT CURRENT
4	BIT 1 IN (MSB)
5	BIT 2 IN
6	BIT 3 IN
7	BIT 4 IN
8	BIT 5 IN
9	BIT 6 IN
10	BIT 7 IN
11	BIT 8 IN
12	BIT 9 IN
13	BIT 10 IN
14	+VCC
15	−REFERENCE
16	+REFERENCE

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ABSOLUTE MAXIMUM RATINGS	
V_{CC}	+7.0V
V_{EE}	+18.0V
Digital Input Voltage	+15V
Output Voltage, Pin 3	+0.5, −5.0V
Reference Current	2.5 mA
Different Reference Voltage	0.7V

FUNCTIONAL SPECIFICATIONS

Typical at 25°C, V_{CC} = +5V, V_{EE} = −15V, I_{REF} = 2.0 mA.

INPUTS	
Resolution	10 Bits
Coding, Unipolar Output	Straight Binary
Coding, Bipolar Output	Offset Binary
Input Level, Logic "1"	+2.0 to +15V at +20 μA
Input Level, Logic "0"	0 to +0.8V at −.02 mA
Nominal Reference Current, Pin 16	2.0 mA
Reference Current Range	0.5 mA to 2.5 mA
Reference Bias Current, Pin 15	−5 μA maximum
OUTPUTS	
Output Current	4.0 mA ±0.2 mA
Output Current Range	0 to 5.0 mA
Output Current, All Bits "0"	2.0 μA maximum[1]
Output Voltage Compliance	−2.5 to +0.2V
Output Capacitance	25 pF
PERFORMANCE	
Linearity Error, B, BM	±½ LSB, maximum
BC	±1 LSB, maximum
Differential Linearity Error	±½ LSB
Monotonicity, B, BM	Full Temperature Range[2]
BC	At 25°C
Gain Tempco	−20 ppm/°C, 60 ppm/°C maximum[3]
Reference Current, Slew Rate	20 mA/microseconds
Reference Current Settling	2.0 microseconds[4]
Output Current Settling	250 nanoseconds[5]
Update Rate	4 MHz
Power Supply Sensitivity	02%/% maximum
POWER REQUIREMENTS	
V_{CC} Voltage	+5V dc ±0.25V
V_{CC} Current	+4 mA maximum
V_{EE} Voltage	−15V dc ±0.75V
V_{EE} Current	−18 mA maximum
PHYSICAL/ENVIRONMENTAL	
Operating Temperature Range	
DAC-IC10B, BC	0°C to +70°C
DAC-IC10BM	−55°C to +125°C
Storage Temperature Range	−65°C to +125°C
Package	16-Pin Ceramic DIP

FOOTNOTES:

1. 4.0 μA maximum for DAC-IC10BC only.
2. All converters in this series typically retain rated monotonicity for values of input reference current from 0.5 mA to 2.5 mA.
3. 70 ppm/°C maximum for DAC-IC10BM only.
4. Zero to 4 mA output change to rated accuracy.
5. Full scale change to ½ LSB.

TECHNICAL NOTES

1. The *General Connection Diagram* shows the basic connections for the converter. The scale factor is set by a reference current injected into pin 16. Pins 15 and 16 are the input terminals to the reference control amplifier. When connected as shown, pin 15 is grounded through R_{15} and pin 16 is at virtual ground. Therefore, the reference current is determined by the external voltage reference and R_{16}: $I_{REF} = V_{REF}/R_{16}$. R_{16} should be a stable metal film resistor. R_{15} is used only to compensate for the input bias current into pin 15 (1 μA typical). R_{15}, if used, should be equal to R_{16} and may be a carbon composition type. An I_{REF} of 2.0 mA is recommended for most applications.
2. There is a second method of connecting the reference shown in *Two Ways to Connect Reference*. A negative reference can be applied to pin 15. In this case only the bias current must be supplied from the reference since pin 15 is a high impedance input. Pin 16 is at the negative voltage and I_{REF} still flows into pin 16. Again, R_{15} is used only to compensate for bias current. There is an important requirement for this connection: **the negative reference voltage must always be 3 volts above V_{EE}.**
3. I_{OUT} is inversely proportional to the reference input current (I_{REF}) times the digital word. Scaling of the applied reference can be represented as follows:

$$I_{OUT} = -2 \frac{V_{REF}}{R_{REF}} \frac{A_n}{2^n}$$

where n = 10 (10-bit DAC)
A_n = digital code

Note: 1) The largest digital code for a 10 bit DAC is 1023.
2) The reference current is scaled by a factor of 2 within the DAC.

Example:

$$I_{OUT}(FS) = -2 \frac{2.5V}{1.25K} \frac{1023}{1024}$$
$$= -3.996 \text{ mA (nominal)}$$

$$I_{OUT}(ZERO) = -2 \frac{2.5V}{1.25K} \frac{0}{1024}$$
$$= 0 \text{ mA (nominal)}$$

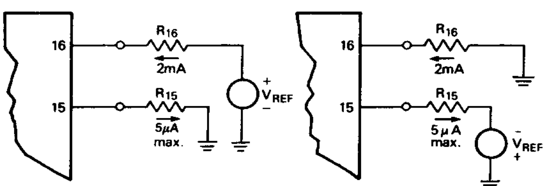
4. The reference amplifier is internally compensated. The minimum reference current supplied from a current source is 0.5 mA for stability.
5. The voltage on pin 3 is restricted to a range of −2.5V to +0.2V. This compliance voltage is guaranteed at 25°C and nearly constant over temperature.
6. Full-scale output current of 3.996 mA is guaranteed for input reference currents to pin 16 between 1.9 and 2.1 mA.
7. It is recommended that pin 14 (V_{CC}) and pin 1 V_{EE}) always be bypassed to ground with at least 0.1 μF capacitors located close to the pins.
8. The accuracy of the converter is specified for a reference current of 2.0 mA; the accuracy, however, is essentially constant for reference currents from 1.5 mA to 2.5 mA. Typically, this device is monotonic for all values of reference current above 0.5 mA.

TECHNICAL NOTES (Cont'd.)

9. For fastest voltage output settling times in either unipolar or bipolar modes, two circuits using DATEL AM-452 monolithic operational amplifiers are recommended. These circuits, with the compensation shown, result in output settling times of typically 550 nanoseconds for a 10V change to 1 LSB. This is the worst case settling time which occurs when all bits are turned on. For current output and R_L less than 500 ohms, this time is 250 nanoseconds; when all bits are turned off the time is shorter, typically 100 nanoseconds. The two circuits shown also illustrate a simple method of deriving both reference current and offset current from a precision 6.4V Zener reference diode.

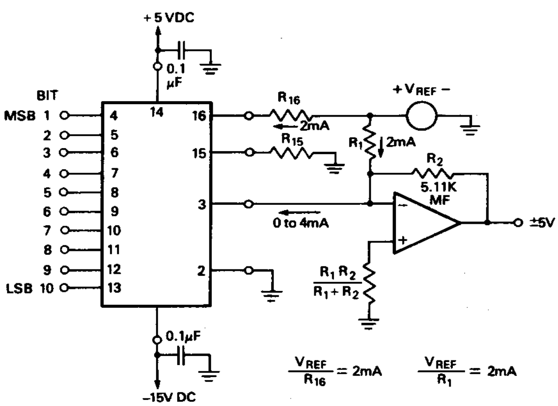
10. Both one and two quadrant multiplication are also possible with the converter as shown in the two diagrams. V_{IN} is shown operating into pin 16; this results in an input impedance of 2.5K. Alternatively, V_{IN} can be applied to pin 15 for a high impedance input as explained previously. The range of V_{IN} is then 0 to − 10V. For two quadrant multiplication V_{IN} is unipolar and the digital input is bipolar with offset binary coding. V_{OUT} then varies over the bipolar range of ± 5V. In multiplication applications, it is recommended that full scale I_{REF} be set to 2.0 mA; the output is then monotonic as the reference current varies over 0.5 mA to 2.0 mA.

TWO WAYS TO CONNECT REFERENCE

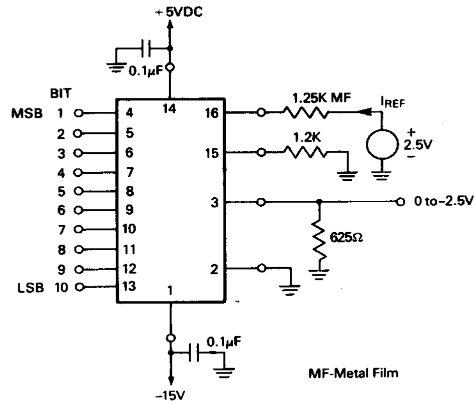


$R_{15} = R_{16}$ $\frac{V_{REF}}{R_{16}} = 2mA$

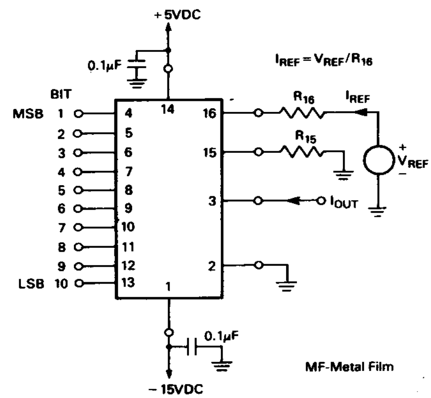
CONNECTION FOR BIPOLAR VOLTAGE OUT



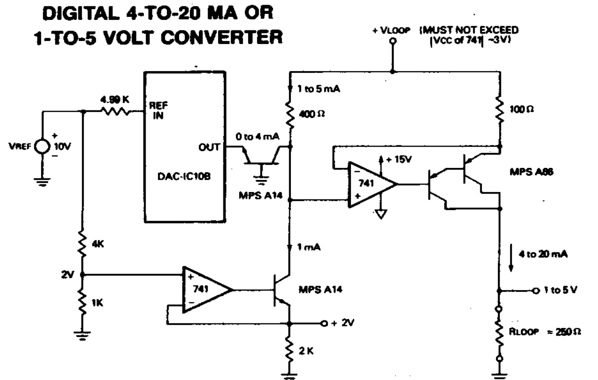
CONNECTION FOR DIRECT VOLTAGE OUTPUT



GENERAL CONNECTION DIAGRAM

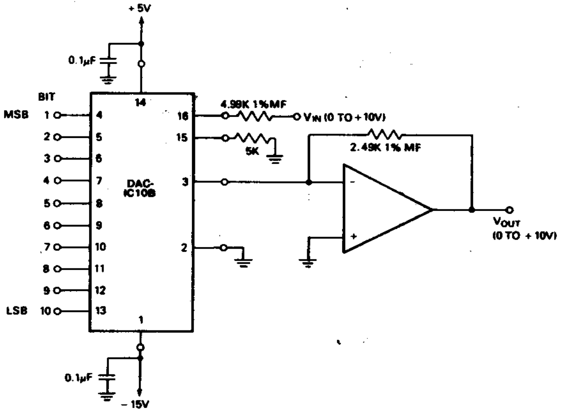


DIGITAL 4-TO-20 MA OR 1-TO-5 VOLT CONVERTER

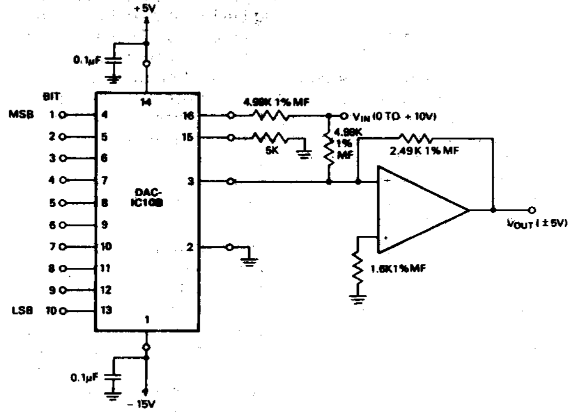


APPLICATION DIAGRAMS

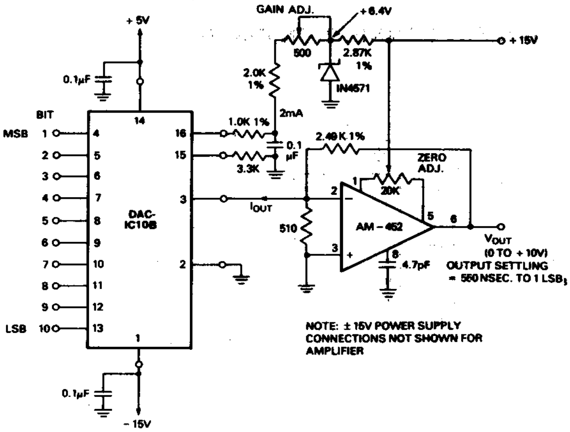
ONE QUADRANT MULTIPLICATION



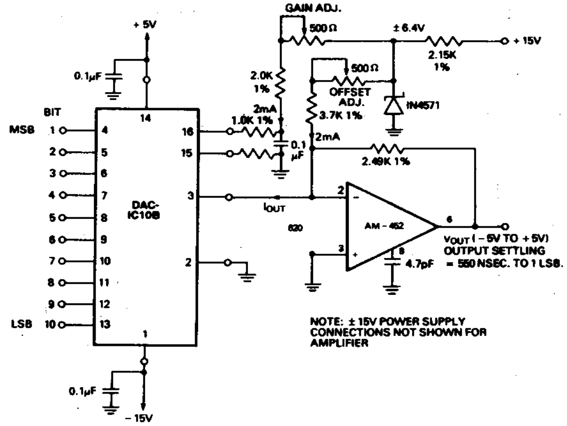
TWO QUADRANT MULTIPLICATION



FAST, UNIPOLAR VOLTAGE OUTPUT



FAST, BIPOLAR VOLTAGE OUTPUT



CALIBRATION AND CODING TABLE

1. Select the desired output range by means of the feedback resistor of the external operational amplifier and the externally programmed reference current.
2. *Zero and Offset Adjustments*/For unipolar operation, set all digital inputs to "0" (0V to +0.8V) and adjust the output amplifier ZERO ADJUSTMENT for zero output voltage. For bipolar operation, set all digital inputs to "0" (0 to +0.8V) and adjust the OFFSET ADJUSTMENT for the negative full-scale voltage shown in the Coding Table.
3. *Gain Adjustment*/For either unipolar or bipolar operation, set all digital inputs to "1" (+2.0 to +5.5V) and adjust the GAIN ADJUSTMENT for the positive full-scale voltage shown in the Coding Table.

INPUT CODE	UNIPOLAR OPERATION—STRAIGHT BINARY			
MSB LSB	0 TO +5V	0 TO +10V	0 TO −2 mA	0 to −4 mA
11 1111 1111	+4.995V	+9.990	−1.998 mA	−3.996
11 1000 0000	+4.375	+8.750	−1.750	−3.500
11 0000 0000	+3.750	+7.500	−1.500	−3.000
10 0000 0000	+2.500	+5.000	−1.000	−2.000
01 0000 0000	+1.250	+2.500	−0.500	−0.100
00 0000 0001	+0.005	+0.010	−0.002	−0.004
00 0000 0000	0.000	0.000	0.000	0.000

INPUT CODE	BIPOLAR OPERATION—OFFSET BINARY CODING			
MSB LSB	±5V	±10V	±1 mA	±2 mA
11 1111 1111	+4.990V	+ 9.980V	−0.998 mA	−1.996 mA
11 1000 0000	+3.750	+ 7.500	−0.750	−1.500
11 0000 0000	+2.500	+ 5.000	−0.500	−1.000
10 0000 0000	0.000	0.000	0.000	0.000
01 0000 0000	−2.500	− 5.000	+0.500	+1.000
00 0000 0001	−4.990	− 9.980	+0.998	+1.996
00 0000 0000	−5.000	−10.000	+1.000	+2.000

ORDERING INFORMATION

MODEL NO.	OPERATING TEMP. RANGE
DAC-IC10BC	0°C to +70°C
DAC-IC10B	0°C to +70°C
DAC-IC10BM	−55°C to +125°C

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