Model DAC-IC8B
Low Cost, 8-Bit Monolithic Digital-to-Analog Converters

FEATURES

- **Low cost**
- **8-Bit resolution**
- **Fast settling—300 nanoseconds**
- **1- or 2-quadrant multiplication**
- **±½ LSB linearity**
- **DTL/TTL compatible inputs**

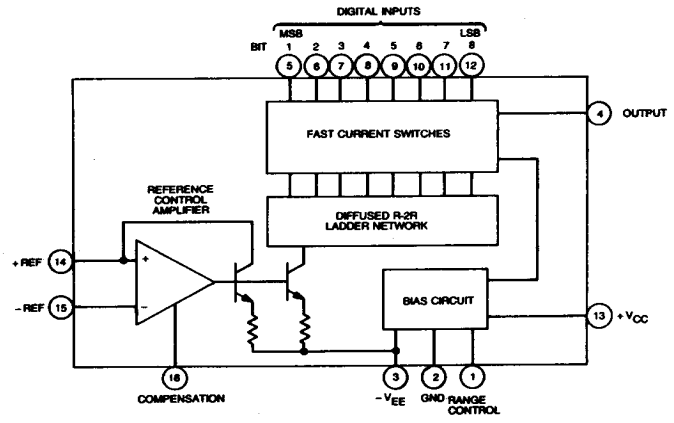
GENERAL DESCRIPTION

The DAC-IC8BC and DAC-IC8BM are 8-bit monolithic DAC's with fast settling current outputs. The units are housed in a 16 pin ceramic DIP and require only an external reference and output amplifier for fast voltage output operation. A full scale output change settles in only 300 nanoseconds for current output operation and 600 nanoseconds for voltage output operation using a fast monolithic output amplifier (DATEL's AM-452). Digital input coding is straight binary for unipolar operation and offset binary for bipolar operation and is compatible with standard DTL/TTL logic.

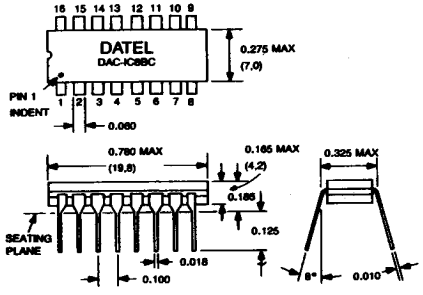
The DAC-IC8B converters consist of 8 fast-switching current sources, a diffused R-2R resistor ladder network, a bias circuit, and a reference control amplifier. The diffused resistor ladder gives excellent temperature tracking resulting in a gain temperature coefficient of −20 ppm/°C. The monolithic fabrication results in excellent linearity and tempco, fast output settling, and low cost. Linearity is ±½ LSB.

An external reference current of 2 mA nominal programs the scale factor for the DAC; this is done by means of an external voltage reference source (such as Zener diode) and a resistor. This reference current can also be varied, resulting in one or two quadrant multiplying operation. The output voltage can be unipolar or bipolar depending on whether an external offsetting current (derived from the reference) is used. Output voltage compliance of the DAC is −0.6V to +0.5V; this can be made as large as −5V to +0.5V by external pin connection for cases where direct voltage output from a load resistor is desired.

Power supply requirement is +5V dc and −5V to −15V dc. Model DAC-IC8BC has an operating temperature range of 0°C to 70°C while DAC-IC8BM operates over −55°C to +125°C. The two models are pin compatible with industry standard devices 1408L-8 and 1508L-8 respectively.



MECHANICAL DIMENSIONS
INCHES (MM)



INPUT/OUTPUT CONNECTIONS

PIN	FUNCTION
1	RANGE CONTROL
2	GROUND
3	V_{EE}
4	OUTPUT
5	BIT 1 IN (MSB)
6	BIT 2 IN
7	BIT 3 IN
8	BIT 4 IN
9	BIT 5 IN
10	BIT 6 IN
11	BIT 7 IN
12	BIT 8 IN (LSB)
13	V_{CC}
14	+REFERENCE
15	−REFERENCE
16	COMPENSATION

ABSOLUTE MAXIMUM RATINGS	
Power Supply Voltage, V_{CC}	+5.5V
V_{EE}	−16.5V
Digital Input Voltage	+5.5V
Reference Current	5.0 mA
Reference Amp. Inputs	$+V_{CC}$, $-V_{EE}$
Power Dissipation	1.0 watt

FUNCTIONAL SPECIFICATIONS

Typical at 25°C, V_{CC} = +5V, V_{EE} = −15V, and I_{REF} = 2 mA unless otherwise specified.

INPUTS	
Resolution	8 bits
Coding, unipolar output	Straight Binary
Coding, bipolar output	Offset Binary
Input Logic Level, bit ON ("1")	+2.0V to +5.5V at 40 μA
Input Logic Level, bit OFF ("0")	0V to +0.8V at −0.8 mA
Logic Loading	1 TTL load
Nominal Reference Current (+ Reference)	2.0 mA
Reference Current Range (+ Reference)	0 to 4.2 mA
Reference Bias Current (− Reference)	−3 μA max.

OUTPUTS	
Output Current, I_{REF} = 2.0 mA	2.0 mA ±0.1 mA
Output Current Range, V_{EE} = −5V	0 to 2.1 mA
Output Current Range, V_{EE} = −6 to −15V	0 to 4.2 mA
Output Current, all bits OFF	4 μA max.
Output Voltage Compliance, pin 1 grnded	−0.6 to +0.5V
Output Voltage Comp., pin 1 open, $V_{EE} \leq -10V$	−5.0V to +0.5V

PERFORMANCE	
Relative Accuracy[1]	±½ LSB (±0.19%) max.
Nonlinearity	±½ LSB (±0.19%) max.
Differential Nonlinearity	±½ LSB (±0.19%)
Temp. Coefficient of Gain	−20 ppm/°C
Power Supply Rejection (V_{EE})	2.7 μA/V max.
Settling Time, 2 mA to ½ LSB	300 nsec.
Update Rate	3.3 MHz
Reference Current Slew Rate	4.0 mA/μsec.

POWER REQUIREMENTS	
V_{CC} Voltage	+5V dc ±0.5V
V_{CC} Current	22 mA max.
V_{EE} Voltage	−4.5V to −16.5V dc
V_{EE} Current	13 mA max.

PHYSICAL/ENVIRONMENTAL	
Operating Temp. Range, DAC-IC8BC	0°C to 70°C
Operating Temp. Range, DAC-IC8BM	−55°C to +125°C
Storage Temp. Range, either model	−65°C to +150°C
Package, DAC-IC8BC	16 Pin Plastic DIP
Package, DAC-IC8BM	16 Pin Ceramic DIP

FOOTNOTE:

1. With zero and full scale adjustments made.

TECHNICAL NOTES

1. The General Connection Diagram shows the basic connections for the DAC-IC8B converter. The scale factor is set by a reference current injected into pin 14. Pins 14 and 15 are the input terminals to the reference control amplifier. When connected as shown, pin 15 is grounded through R_{15} and pin 14 is at virtual ground. Therefore, the reference current is determined by the external voltage reference and R_{14}: $I_{REF} = V_{REF}/R_{14}$. R_{14} 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) and can be shorted out with negligible effect. R_{15}, if used, should be equal to R_{14} and may be 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 14 is at the negative voltage and I_{REF} still flows into pin 14. Again, R_{15} is used only to compensate for bias current and may be omitted. There is an important requirement for this connection: *the negative reference voltage must always be 3 volts above V_{EE}.*
3. The reference amplifier must be externally compensated, and this is done by capacitor C_c, connected from pin 16 to pin 3 (V_{EE}). C_c may also be connected from pin 16 to ground, but connection to pin 3 improves the negative supply rejection. The value of C_c depends on R_{14}, and typical values are given in the compensation table. Compensation is particularly important when the DAC-IC8B is used as a multiplying D/A converter. Proper compensation assures that output peaking does not occur when the reference voltage steps to a new value. If pin 14 is driven from a high impedance current source such as a transistor collector, then much larger values of C_c must be used and the bandwidth of the reference amplifier is significantly reduced.
4. The Alternative Compensation Diagram shows another way of achieving the desired compensation. Here a 1.0K resistor is always used at pin 14, but it is in series with another R to the reference voltage. The junction of the two resistors is bypassed to ground by a 0.1 μF capacitor. For high frequencies pin 14 always "sees" a 1K resistance, thus allowing a 15 pF capacitor for C_c. R_{15}, if used, should be the sum of 1.0K and R. This compensation scheme is useful with voltage references such as 6.2 or 6.4 volt Zener diodes.
5. It is recommended that pin 13 (V_{CC}) and pin 3 (V_{EE}) always be bypassed to ground with at least 0.1 μF capacitors located close to the pins.
6. As shown in the General Connection Diagram, pin 1 may be either connected to ground or left open. This connection determines the voltage compliance at pin 4 (I_{OUT}). For pin 1 grounded, the output compliance is −0.6 to +0.5 volt. This is satisfactory when pin 4 is used to drive a current to voltage converter and pin 4 is held at virtual ground. It is also satisfactory for low values of R_L connected to pin 4 to directly convert the output current to a voltage. The voltage compliance may be extended to −5.0 volts by leaving pin 1 open and using a V_{EE} more negative than −10 volts. In this way a 2.5K load resistor may be used at pin 14 to give an output voltage range of 0 to −5 volts (with reference current of 2 mA). As shown in the table of *Settling Time vs R_L*, the output settling time is constant (300 nseconds) for R_L values from 0 to 500 ohms; thereafter it increases to 1.2 μseconds for R_L = 2.5K.

TECHNICAL NOTES (Con't)

7. The accuracy of the DAC-IC8B 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. Reference currents up to 4.2 mA may be used. *When using a 4 mA reference current, V_{EE} must be more negative than −6 volts.*
8. For fastest voltage output settling times in either unipolar or bipolar modes, two circuits using DATEL's AM-452 monolithic operational amplifiers are recommended. These circuits, with the compensation shown, result in output settling times of typically 600 nanoseconds for a 10 volt 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 300 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 6.4 volt Zener reference diode.
9. Both one and two quadrant multiplication are also possible with the DAC-IC8B as shown in the two diagrams. V_{IN} is shown operating into pin 14; 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 ±5 volts. In multiplication applications, it is recommended that full scale I_{REF} be set to 4.0 mA; the output is then monotonic as the reference current varies over 0.5 mA to 4.0 mA.

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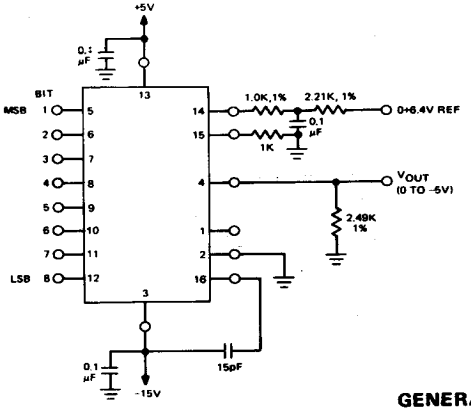
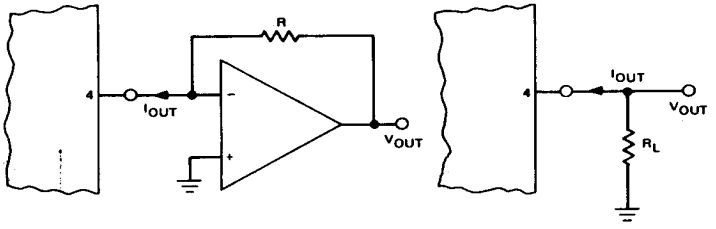
CONNECTION DIAGRAMS

HIGH COMPLIANCE OUTPUT



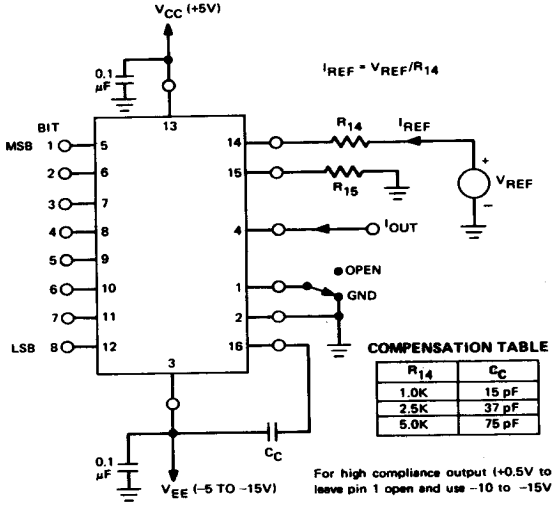
OUTPUT CONNECTIONS



SETTLING TIME VS. R_L

R_L	S.T.
0	300 nsec.
500	300 nsec.
1 K	400 nsec.
2.5 K	1.2 µsec.

GENERAL CONNECTION DIAGRAM



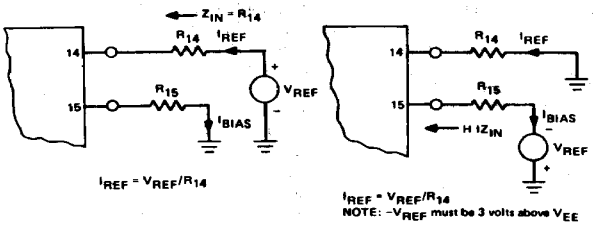
COMPENSATION TABLE

R_{14}	C_C
1.0K	15 pF
2.5K	37 pF
5.0K	75 pF

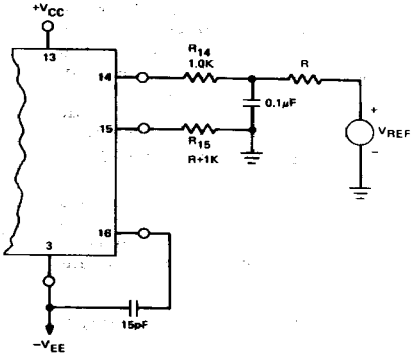
For high compliance output (+0.5V to −5.0V) leave pin 1 open and use −10 to −15V for V_{EE}.

CONNECTION DIAGRAMS

TWO WAYS TO CONNECT REFERENCE

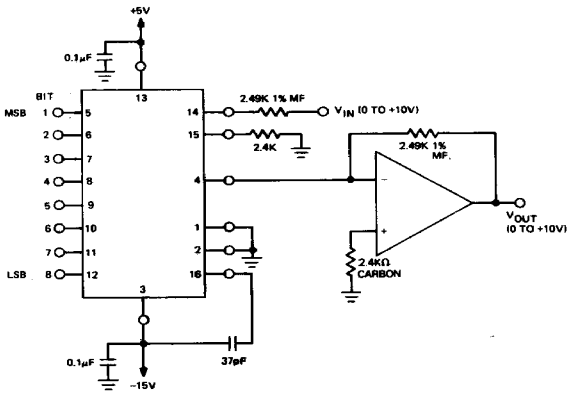


ALTERNATIVE COMPENSATION

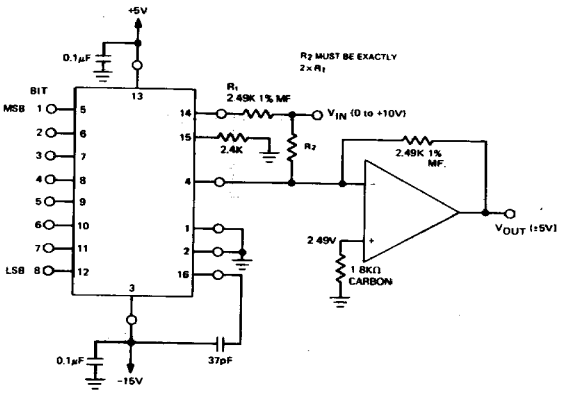


APPLICATION DIAGRAMS

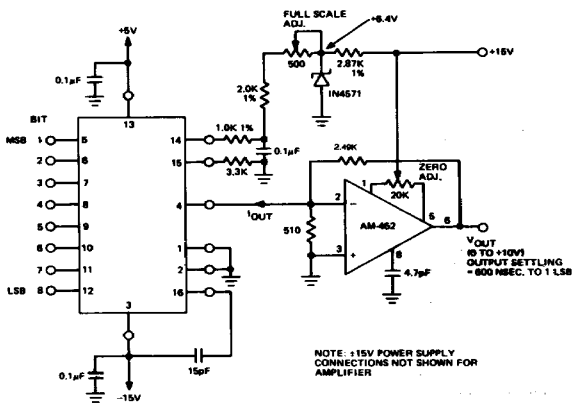
ONE QUADRANT MULTIPLICATION



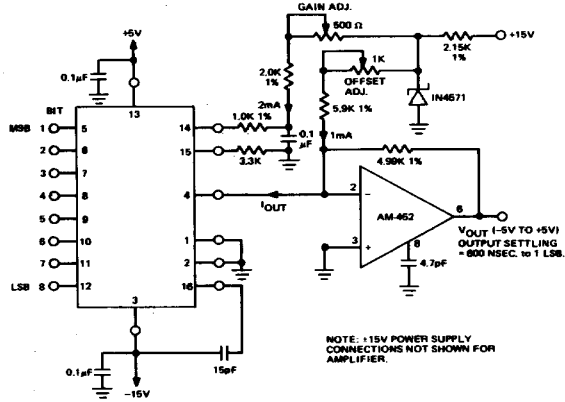
TWO QUADRANT MULTIPLICATION



FAST, UNIPOLAR VOLTAGE OUTPUT



FAST, BIPOLAR VOLTAGE OUTPUT



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CALIBRATION AND CODING TABLES

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.

UNIPOLAR OPERATION—STRAIGHT BINARY CODING

INPUT CODE		UNIPOLAR OUTPUT RANGES			
MSB	LSB	0 TO +5V	0 TO +10V	0 TO −2 mA	0 TO −4 mA
1111	1111	+4.980	+9.961V	−1.992 mA	−3.984 mA
1110	0000	+4.375	+8.750	−1.750	−3.500
1100	0000	+3.750	+7.500	−1.500	−3.000
1000	0000	+2.500	+5.000	−1.000	−2.000
0100	0000	+1.250	+2.500	−0.500	−1.000
0000	0001	+0.020	+0.039	−0.008	−0.016
0000	0000	0.000	0.000	0.000	0.000

BIPOLAR OPERATION—OFFSET BINARY CODING

INPUT CODE		BIPOLAR OUTPUT RANGES			
MSB	LSB	±5V	±10V	±1 mA	±2 mA
1111	1111	+4.961V	+9.922V	−0.992 mA	−1.984 mA
1110	0000	+3.750	+7.500	−0.750	−1.500
1100	0000	+2.500	+5.000	−0.500	−1.000
1000	0000	0.000	0.000	0.000	0.000
0100	0000	−2.500	−5.000	+0.500	+1.000
0000	0001	−4.961	−9.922	+0.992	+1.984
0000	0000	−5.000	−10.000	+1.000	+2.000

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ORDERING INFORMATION

DAC-IC8B ____

OPER. TEMP. RANGE
- C = 0°C TO +70°C
- M = −55°C TO +125°C

ACCESSORIES

Part Number	Description
TP500, TP1K, and TP20K are available from DATEL	Trimming Potentiometers