8-BIT HIGH SPEED MULTIPLYING D/A CONVERTER — DAC-08 SERIES

FORMERLY: NE5007/5008-F,N
SE5008-F

DESCRIPTION

The DAC-08 series of 8-bit monolithic multiplying Digital-to-Analog Converters provide very high speed performance coupled with low cost and outstanding applications flexibility.

Advanced circuit design achieves 70ns settling times with very low glitch and at low power consumption. Monotonic multiplying performance is attained over a wide 20 to 1 reference current range. Matching to within 1 LSB between reference and full scale currents eliminates the need for full scale trimming in most applications. Direct interface to all popular logic families with full noise immunity is provided by the high swing, adjustable threshold logic inputs.

Dual complementary outputs are provided, increasing versatility and enabling differential operation to effectively double the peak-to-peak output swing. True high voltage compliance outputs allow direct output voltage conversion and eliminate output op amps in many applications.

All DAC-08 series models guarantee full 8-bit monotonicity and linearities as tight as 0.1% over the entire operating temperature range are available. Device performance is essentially unchanged over the $\pm 4.5V$ to $\pm 18V$ power supply range, with 37mW power consumption attainable at $\pm 5V$ supplies.

The compact size and low power consumption make the DAC-08 attractive for portable and military aerospace applications.

FEATURES

- **Fast settling output current—70ns**
- **Full scale current prematched to ±1 LSB**
- **Direct interface to TTL, CMOS, ECL, HTL, PMOS**
- **Relative accuracy to 0.1% maximum over temperature range**
- **High output compliance −10V to +18V**
- **True and complemented outputs**
- **Wide range multiplying capability**
- **Low FS current drift—±10ppm/°C**
- **Wide power supply range—±4.5V to ±18V**
- **Low power consumption—37mW at ±5V**

APPLICATIONS

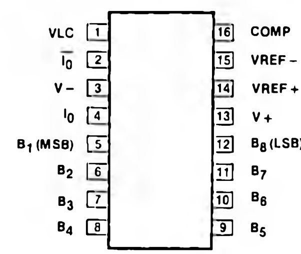
- **8-bit, 1μs A-to-D converters**
- **Servo-motor and pen drivers**
- **Waveform generators**
- **Audio encoders and attenuators**
- **Analog meter drivers**
- **Programmable power supplies**
- **CRT display drivers**
- **High speed modems**
- **Other applications where low cost, high speed and complete input/output versatility are required**
- **Programmable gain and attentuation**
- **Analog-Digital Multiplication**
- **Stepping motor drive**

ORDERING INFORMATION

RELATIVE ACCURACY	0 to 70°C	−55 to 125°C
0.39% FS	DAC-08CN	
	DAC-08CF	
0.19% FS	DAC-08EN	
	DAC-08EF	DAC-08F
	DAC-08ED	
0.1% FS	DAC-08HF	DAC-08AF
	DAC-08HN	

PIN CONFIGURATION

F,N PACKAGE

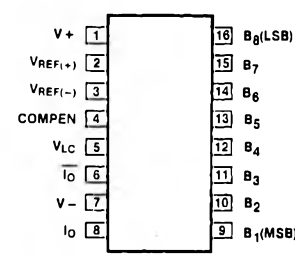


TOP VIEW

ORDER NUMBER

DAC-08AF	SE5009F
DAC-08F	SE5008F
DAC-08HF,N	NE5009F,N
DAC-08CF,N	NE5007F,N

D[3] PACKAGE



TOP VIEW

ORDER NUMBER

DAC-08ED

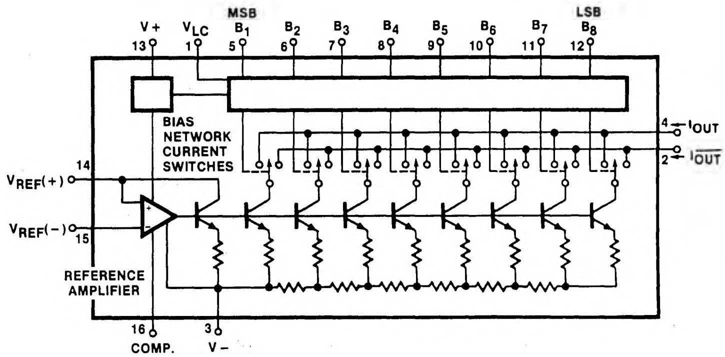
NOTES:
1. SOL - Released in Large SO package only.
2. SOL and non-standard pinout.
3. SO and non-standard pinouts.

DAC-08 ABSOLUTE MAXIMUM RATINGS

	PARAMETER	RATING	UNIT
	Power Supply Voltage, V+ to V−	36	V
V_5-V_{12}	Digital Input Voltage	V− to V− plus 36V	
V_{LC}	Logic Threshold Control	V− to V+	
V_0	Applied Output Voltage	V− to +18	V
I_{14}	Reference Current	5.0	mA
V_{14}, V_{15}	Reference Amplifier Inputs	V_{EE} to V_{CC}	
P_D	Power Dissipation (Package Limitation)		
	Ceramic Package	1000	mW
	Plastic Package	800	mW
	Lead Soldering Temperature (60 sec)	300	°C
T_A	Operating Temperature Range		
	DAC-08, DAC-08A	−55 to +125	°C
	DAC-08C, E, H	0 to +75	°C
T_{STG}	Storage Temperature Range	−65 to +150	°C

8-BIT HIGH SPEED MULTIPLYING D/A CONVERTER — DAC-08 SERIES

BLOCK DIAGRAM



TEST CIRCUIT

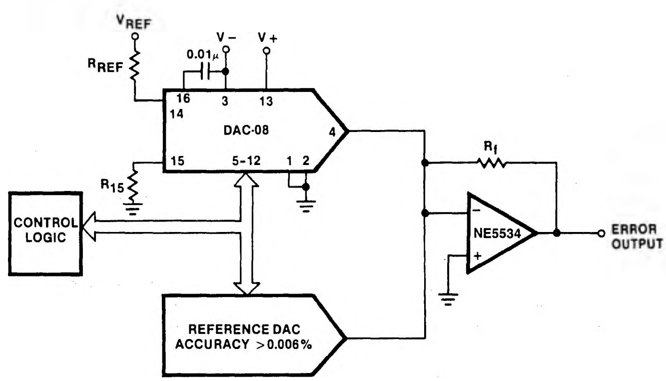


Figure 1. Relative Accuracy Test Circuit

8-BIT MULTIPLYING D/A CONVERTER — DAC-08 SERIES

TEST CIRCUITS (Cont'd)

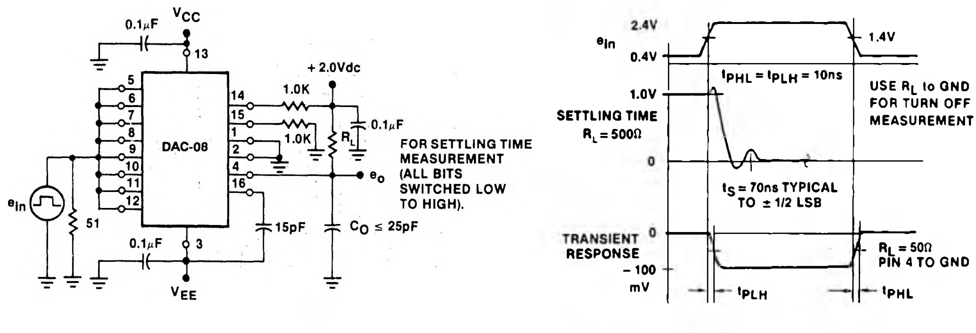


Figure 2. Transient Response and Settling Time

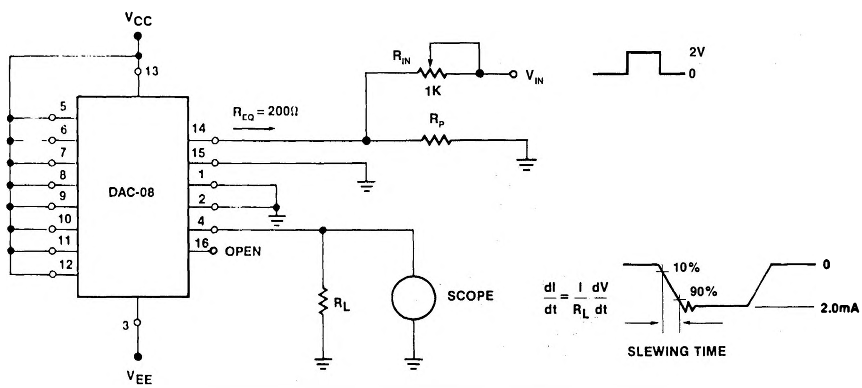
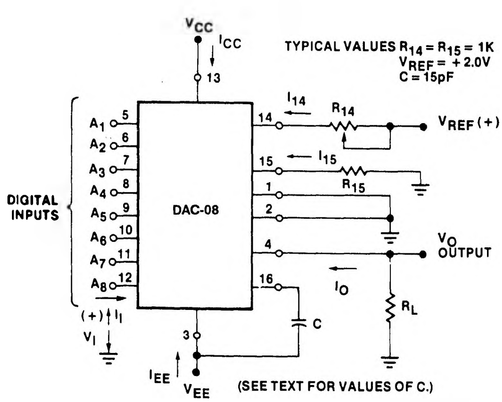


Figure 3. Reference Current Slew Rate Measurement



V_I AND I_I APPLY TO INPUTS A_1 THROUGH A_8

THE RESISTOR TIED TO PIN 15 IS TO TEMPERATURE COMPENSATE THE BIAS CURRENT AND MAY NOT BE NECESSARY FOR ALL APPLICATIONS.

$$I_O = K\left\{\frac{A_1}{2}+\frac{A_2}{4}+\frac{A_3}{8}+\frac{A_4}{16}+\frac{A_5}{32}+\frac{A_6}{64}+\frac{A_7}{128}+\frac{A_8}{256}\right\}$$

where $K \approx \frac{V_{REF}}{R_{14}}$

and A_N = "1" IF A_N IS AT HIGH LEVEL
A_N = "0" IF A_N IS AT LOW LEVEL

Figure 4. Notation Definitions

8-BIT HIGH SPEED MULTIPLYING D/A CONVERTER — DAC-08 SERIES

ELECTRICAL CHARACTERISTICS Pin 3 must be at least 3V more negative than the potential to which R_{15} is returned. $V_{CC} = \pm 15V$, $I_{REF} = 2.0mA$, Output characteristics refer to both IOUT and IOUT unless otherwise noted. DAC-08C, E, H: $T_A = 0°C$ to $70°C$. DAC-08/08A: $T_A = -55°C$ to $125°C$.

	PARAMETER	TEST CONDITIONS	DAC-08C			DAC-08E DAC-08			DAC-08H DAC-08A			UNIT
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
	Resolution		8	8	8	8	8	8	8	8	8	Bits
	Monotonicity*		8	8	8	8	8	8	8	8	8	Bits
	Relative accuracy	Over temperature range			±0.39			±0.19			±0.1	%FS
	Differential nonlinearity				±0.39			±0.19			±0.19	%FS
t_S	Settling time	To ±1/2 LSB, all bits switched on or off, $T_A = 0°C$		70	135		70	135		70	135	ns
t_{PLH} t_{PHL}	Propagation delay Low-to-high High-to-low	T_A=25°C, each bit. All bits switched		35	60		35	60		35	60	ns
TCI_{FS}	Full scale tempco			±10			±10			±10	±50	ppm/°C
V_{OC}	Output voltage compliance	Full scale current change <½ LSB	-10		+18	-10		+18	-10		+18	V
I_{FS4}	Full scale current	V_{REF}=10.000V, R_{14}, R_{15}=5.000kΩ,	1.94	1.99	2.04	1.94	1.99	2.04	1.984	1.992	2.000	mA
I_{FSS}	Full scale symmetry	$I_{FS4}-I_{FS2}$		±2.0	±16		±1.0	±8.0		±1.0	±4.0	μA
I_{ZS}	Zero scale current			0.2	4.0		0.2	2.0		0.2	1.0	μA
I_{FSR}	Full scale output current range	R_{14} R_{15} = 5.000kΩ V_{REF} = +15.0V, V− = −10V V_{REF} = +25.0V, V− = −12V	2.1 4.2			2.1 4.2			2.1 4.2			mA
V_{IL} V_{IH}	Logic input levels Low High	V_{LC}=0V	 2.0		0.8	 2.0		0.8	 2.0		0.8	V
I_{IL} I_{IH}	Logic input current Low High	V_{LC}=0V V_{IN}=-10V to +0.8V V_{IN}=2.0V to 18V		-2.0 0.002	-10 10		-2.0 0.002	-10 10		-2.0 0.002	-10 10	μA
V_{IS}	Logic input swing	V−=-15V	-10		+18	-10		+18	-10		+18	V
V_{THR}	Logic threshold range	V_S=±15V	-10		+13.5	-10		+13.5	-10		+13.5	V
I_{15}	Reference bias current			-1.0	-3.0		-1.0	-3.0		-1.0	-3.0	μA
dI/dt	Reference input slew rate		4.0	8.0		4.0	8.0		4.0	8.0		mA/μs
	Power supply sensitivity	I_{REF}=1mA										%FS/%VS
$PSSI_{FS+}$	Positive	V+=4.5 to 5.5V, V−=-15V; V+=13.5 to 16.5V, V−=-15V		0.0003	0.01		0.0003	0.01		0.0003	0.01	
$PSSI_{FS-}$	Negative	V−=-4.5 to -5.5V, V+=+15V; V−=-13.5 to -16.5, V+=+15V		0.002	0.01		0.002	0.01		0.002	0.01	
	Power supply current											mA
I+ I−	Positive Negative	V_S=±5V, IREF=1.0mA		3.1 -4.3	3.8 -5.8		3.1 -4.3	3.8 -5.8		3.1 -4.3	3.8 -5.8	
I+ I−	Positive Negative	V_S=+5V, -15V, I_{REF}=2.0mA		3.1 −7.1	3.8 -7.8		3.1 −7.1	3.8 -7.8		3.1 −7.1	3.8 -7.8	
I+ I−	Positive Negative	V_S=±15V, I_{REF}=2.0mA		3.2 −7.2	3.8 -7.8		3.2 −7.2	3.8 -7.8		3.2 −7.2	3.8 -7.8	
P_D	Power dissipation	±5V, I_{REF}=1.0mA +5V, -15V, I_{REF}=2.0mA ±15V, I_{REF}=2.0mA		37 122 156	48 136 174		37 122 156	48 136 174		37 122 156	48 136 174	mW

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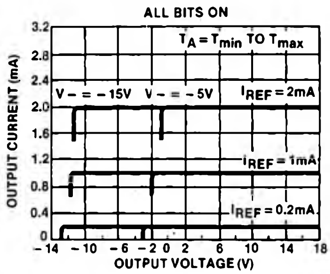
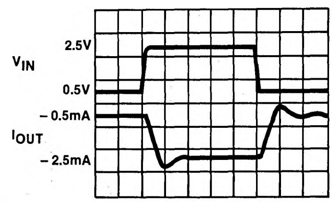
TYPICAL PERFORMANCE CHARACTERISTICS

OUTPUT CURRENT vs OUTPUT VOLTAGE (OUTPUT VOLTAGE COMPLIANCE)



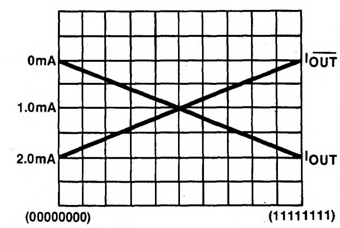
FAST PULSED REFERENCE OPERATION



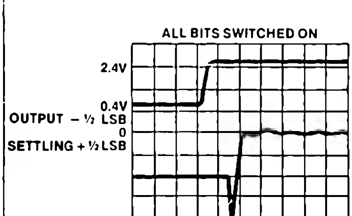
200ns/division

R_{EQ} = 200Ω, R_L = 100Ω, CC = 0

TRUE AND COMPLEMENTARY OUTPUT OPERATION



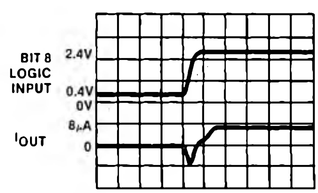
FULL SCALE SETTLING TIME



50ns/DIVISION

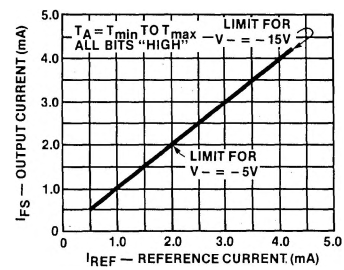
I_{FS} = 2mA, R_L = 1kΩ ½LSB = 4μA

LSB SWITCHING

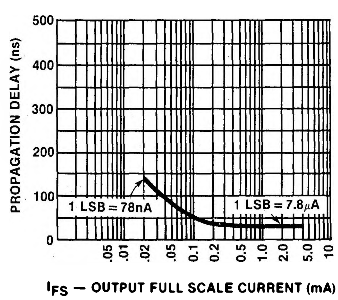


50ns/division

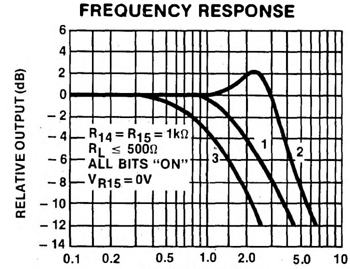
FULL SCALE CURRENT vs REFERENCE CURRENT



LSB PROPAGATION DELAY vs IFS



REFERENCE INPUT FREQUENCY RESPONSE



Curve 1: CC = 15pF, V_{IN} = 2.0V p-p centered at +1.0V.

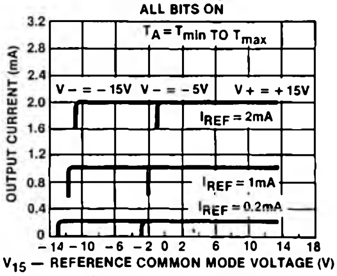
Curve 2: CC = 15pF, V_{IN} = 50mV p-p centered at +200mV.

Curve 3: CC = 0pF, V_{IN} = 100mV p-p centered at 0V and applied thru 50Ω connected to pin 14, +2.0V applied to R_{14}.

TYPICAL PERFORMANCE CHARACTERISTICS (Cont'd)

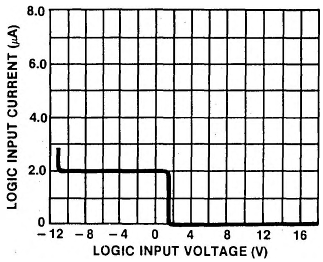
REFERENCE AMP COMMON MODE RANGE

ALL BITS ON

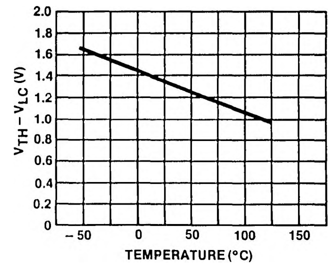


Positive common mode range is always (V+) - 1.5V

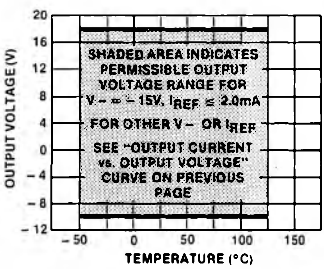
LOGIC INPUT CURRENT vs INPUT VOLTAGE



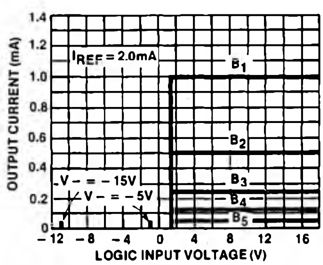
V_{TH} - V_{LC} vs TEMPERATURE



OUTPUT VOLTAGE COMPLIANCE vs TEMPERATURE



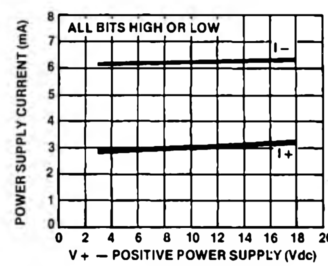
BIT TRANSFER CHARACTERISTICS



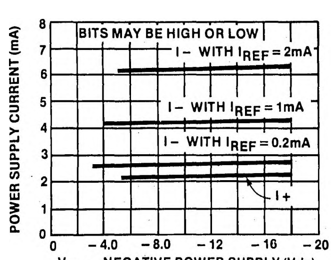
NOTE

B_1 through B_8 have identical transfer characteristics. Bits are fully switched, with less than ½ LSB error, at less than ±100mV from actual threshold. These switching points are guaranteed to lie between 0.8 and 2.0 volts over the operating temperature range (VLC = 0.0V).

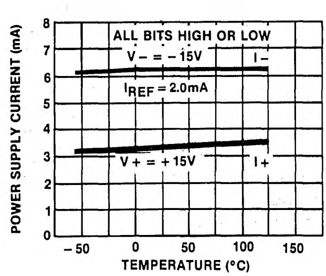
POWER SUPPLY CURRENT vs V+



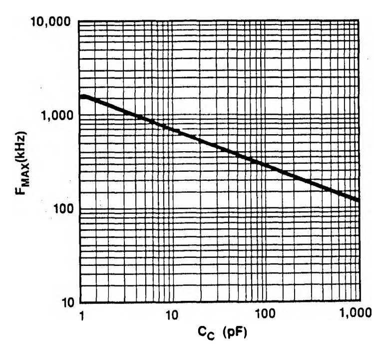
POWER SUPPLY CURRENT vs V-



POWER SUPPLY CURRENT vs TEMPERATURE



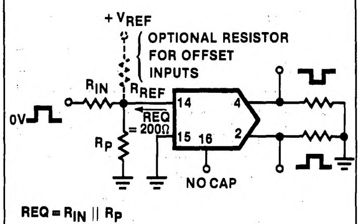
MAXIMUM REFERENCE INPUT FREQUENCY VS. COMPENSATION CAPACITOR VALUE



8-BIT HIGH SPEED MULTIPLYING D/A CONVERTER — DAC-08 SERIES

TYPICAL APPLICATION

PULSED REFERENCE OPERATION



TYPICAL VALUES
R_{IN} = 5K
$+V_{IN}$ = 10V

FUNCTIONAL DESCRIPTION

Reference Amplifier Drive and Compensation

The reference amplifier input current must always flow into pin 14 regardless of the setup method or reference supply voltage polarity.

Connections for a positive reference voltage are shown in Figure 1. The reference voltage source supplies the full reference current. For bipolar reference signals, as in the multiplying mode, R15 can be tied to a negative voltage corresponding to the minimum input level. R15 may be eliminated with only a small sacrifice in accuracy and temperature drift.

The compensation capacitor value must be increased as R14 value is increased. This is in order to maintain proper phase margin. For R14 values of 1.0, 2.5, and 5.0K ohms, minimum capacitor values are 15, 37, and 75pF, respectively. The capacitor may be tied to either V_{EE} or ground, but using V_{EE} increases negative supply rejection. (Fluctuations in the negative supply have more effect on accuracy than do any changes in the positive supply.)

A negative reference voltage may be used if R14 is grounded and the reference voltage is applied to R15, as shown. A high input impedance is the main advantage of this method. The negative reference votage must be at least 3.0V above the V_{EE} supply. Bipolar input signals may be handled by connecting R14 to a positive reference voltage equal to the peak positive input level at pin 15.

When using a DC reference voltage, capacitive bypass to ground is recommended. The 5.0V logic supply is not recommended as a reference voltage, but if a well regulated 5.0V supply which drives logic is to be used as the reference, R14 should be formed of two series resistors with the junction of the two resistors bypassed with 0.1μF to ground. For reference voltages greater than 5.0V, a clamp diode is recommended between pin 14 and ground.

If pin 14 is driven by a high impedance such as a transistor current source, none of the above compensation methods apply and the amplifier must be heavily compensated, decreasing the overall bandwidth.

Output Voltage Range

The voltage at pin 4 must always be at least 4.5 volts more positive than the voltage of the negative supply (pin 3) when the reference current is 2mA or less, and at least 8 volts more positive than the negative supply when the reference current is between 2mA and 4mA. This is necessary to avoid saturation of the output transistors, which would cause serious accuracy degradation.

Output Current Range

Any time the full scale current exceeds 2mA, the negative supply must be at least 8 volts more negative than the output voltage. This is due to the increased internal voltage drops between the negative supply and the outputs with higher reference currents.

Accuracy

Absolute accuracy is the measure of each output current level with respect to its intended value, and is dependent upon relative accuracy, full scale accuracy and full scale current drift. Relative accuracy is the measure of each output current level as a fraction of the full scale current after zero scale current has been nulled out. The relative accuracy of the DAC08 series is essentially constant over the operating temperature range due to the excellent temperature tracking of the monolithic resistor ladder. The reference current may drift with temperature, causing a change in the absolute accuracy of output current. However, the DAC08 series has a very low full scale current drift over the operating temperature range.

The DAC08 series is guaranteed accurate to within ±1/2 LSB at +25°C at a full scale output current of 1.992mA. The relative accuracy test circuit is shown in Figure 1. The 12-bit converter is calibrated to a full scale output current of 1.99219mA, then the DAC08 full scale current is trimmed to the same value with R14 so that a zero value appears at the error amplifier output. The counter is activated and the error band may be displayed on the oscilloscope, detected by comparators, or stored in a peak detector.

Two 8-bit D-to-A converters may not be used to construct a 16-bit accurate D-to-A converter. Sixteen-bit accuracy implies a total of ±1/2 part in 65,536, or ±0.00076%, which is much more accurate than the ±0.19% specification of the DAC08 series.

Monotonicity

A monotonic converter is one which always provides analog output greater than or equal to the preceding value for a corresponding increment in the digital input code. The DAC08 series is monotonic for all values of reference current above 0.5mA. The recommended range for operation is a DC reference current between 0.5mA and 4.0mA.

Settling Time

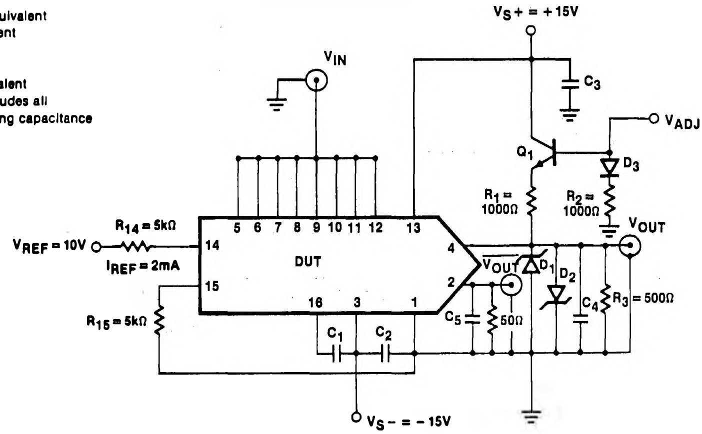
The worst case switching condition occurs when all bits are switched on, which corresponds to a low-to-high transition for all input bits. This time is typically 70ns for settling to within 1/2 LSB for 8-bit accuracy. This time applies when $R_L < 500$ ohms and $C_O < 25$pF. The slowest single switch is the least significant bit, which typically turns on and settles in 65ns. In applications where the DAC functions in a positive going ramp mode, the worst case condition does not occur and settling times less than 70ns may be realized.

Extra care must be taken in board layout since this usually is the dominant factor in satisfactory test results when measuring settling time. Short leads, 100μF supply bypassing for low frequencies, minimum scope lead length, and avoidance of ground loops are all mandatory.

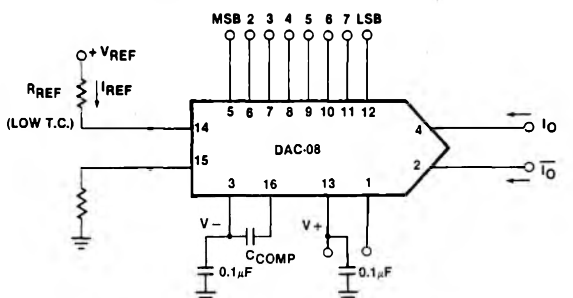
8-BIT HIGH SPEED MULTIPLYING D/A CONVERTER — DAC-08 SERIES

SETTLING TIME AND PROPAGATION DELAY

D_1, D_2 = IN6263 or equivalent
D_3 = IN914 or equivalent
C_1 = 0.01μf
C_2, C_3 = 0.1μf
Q_1 = 2N3904 or equivalent
C_4, C_5 = 15pf and includes all probe and fixturing capacitance

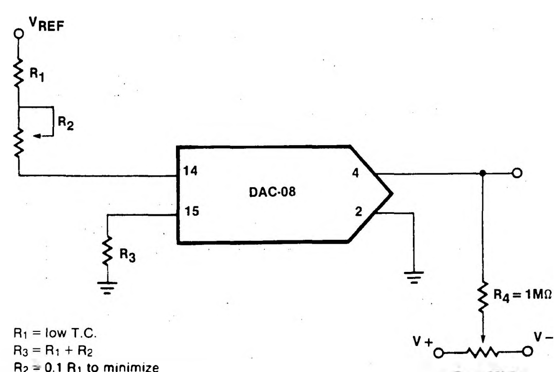


BASIC DAC-08 CONFIGURATION



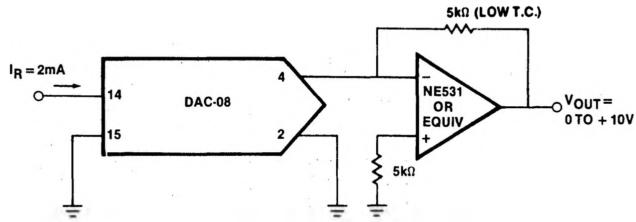
$I_{FS} \approx \frac{+V_{Ref}}{R_{Ref}} \times \frac{255}{256}$; $I_O + \bar{I}_O = I_{FS}$ for all logic states

RECOMMENDED FULL SCALE AND ZERO SCALE ADJUST



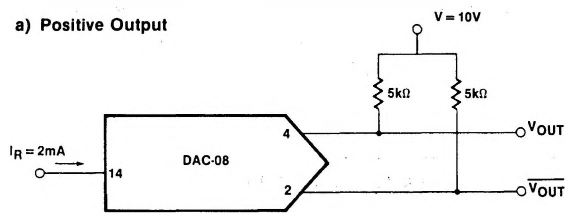
R_1 = low T.C.
$R_3 = R_1 + R_2$
$R_2 \approx 0.1\ R_1$ to minimize pot. contribution to full scale drift

UNIPOLAR VOLTAGE OUTPUT FOR LOW IMPEDANCE OUTPUT

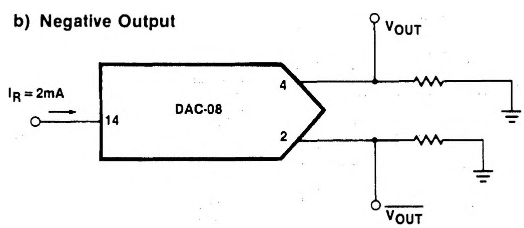


UNIPOLAR VOLT OUTPUT FOR HIGH IMPEDANCE OUTPUT

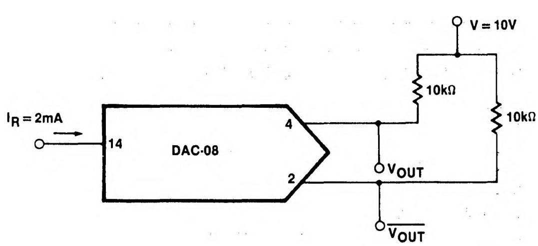
a) Positive Output



b) Negative Output



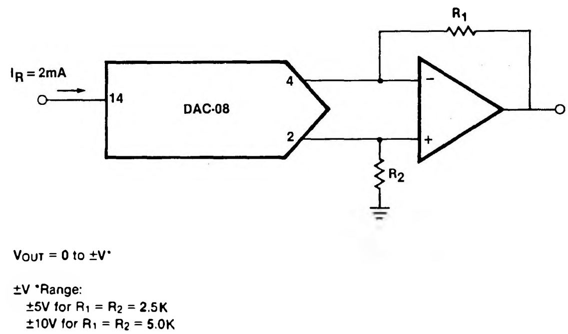
BASIC BIPOLAR OUTPUT OPERATION (OFFSET BINARY)



CODE CHART

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	V_{OUT}	$\overline{V_{OUT}}$
POS full scale	1	1	1	1	1	1	1	1	-9.920V	+10.000
POS f.s. - 1LSB	1	1	1	1	1	1	1	0	-9.840V	+9.920
+ Zero scale + 1LSB	1	0	0	0	0	0	0	1	-0.080V	+0.160
Zero scale	1	0	0	0	0	0	0	0	0.000	+0.080
Zero scale - 1LSB	0	1	1	1	1	1	1	1	0.080	0.000
Neg full scale - 1LSB	0	0	0	0	0	0	0	1	+ 9.920	-9.840
Neg full scale	0	0	0	0	0	0	0	0	+10.000	-9.920

SYMMETRICAL OFFSET BINARY (BIPOLAR)



3 DIGIT BCD CONVERTER

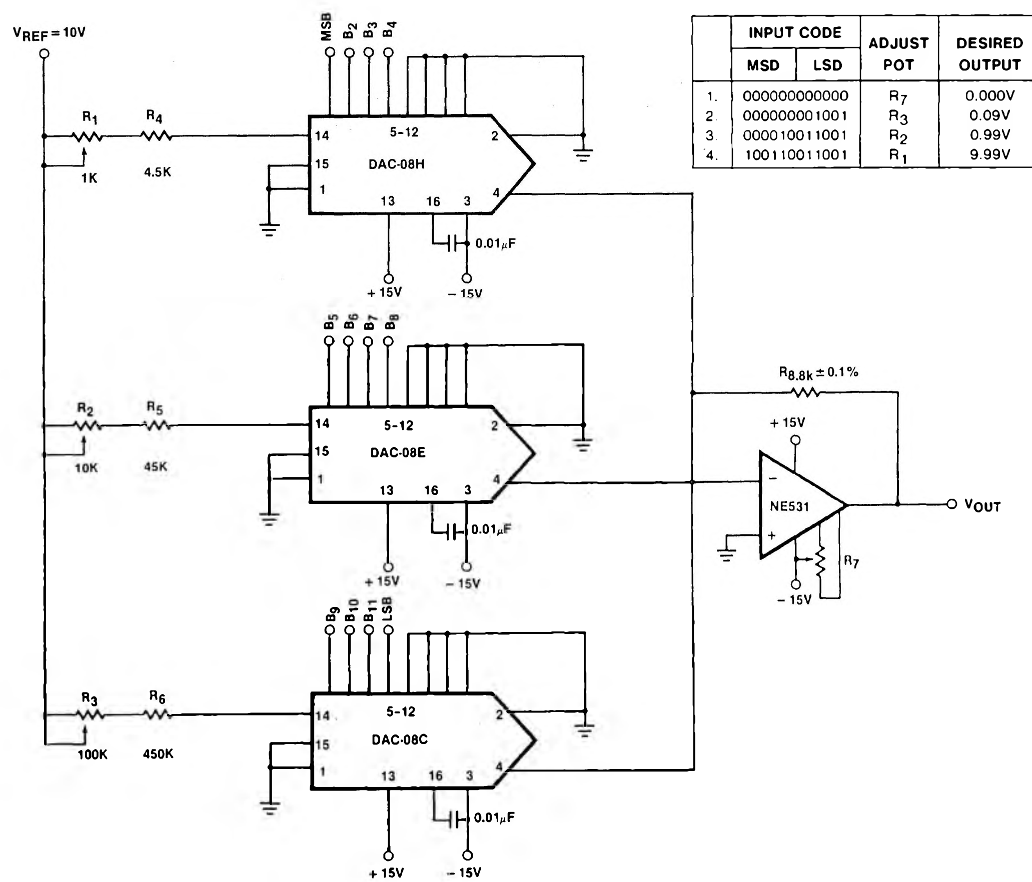
A 3 digit BCD converter, using inexpensive 8-bit binary DACs, can achieve ±0.1% accuracy. The circuit shown in Figure 20 utilizes three DACs, one for each decade, to provide 0 to 999 output steps. DAC 1 contains the first four significant digits controlling the hundreds digit; DAC 2 controls the tens digit and DAC 3 steps 0 to 9. The feedback resistor (R_7) sets the zero scale at 0.00V.

The input coding is the popular 8-4-2-1 coding; i.e. the weighting ratios are 8, 4, 2 and 1. The full scale (999) BCD code is input code 100110011001.

Full scale adjustment procedure.

In the sequence below, switch on the following code combinations and adjust the indicated potentiometer for the proper output.

3 DIGIT BCD CONVERTER WITH ±0.1% ACCURACY



	INPUT CODE MSD	LSD	ADJUST POT	DESIRED OUTPUT
1.	000000000000		R_7	0.000V
2.	000000001001		R_3	0.09V
3.	000010011001		R_2	0.99V
4.	100110011001		R_1	9.99V