

June 1999

DAC0800/DAC0802

8-Bit Digital-to-Analog Converters

General Description

The DAC0800 series are monolithic 8-bit high-speed current-output digital-to-analog converters (DAC) featuring typical settling times of 100 ns. When used as a multiplying DAC, monotonic performance over a 40 to 1 reference current range is possible. The DAC0800 series also features high compliance complementary current outputs to allow differential output voltages of 20 Vp-p with simple resistor loads as shown in Figure 1. The reference-to-full-scale current matching of better than ± 1 LSB eliminates the need for full-scale trims in most applications while the nonlinearities of better than $\pm 0.1\%$ over temperature minimizes system error accumulations.

The noise immune inputs of the DAC0800 series will accept TTL levels with the logic threshold pin, V_{LC} , grounded. Changing the V_{LC} potential will allow direct interface to other logic families. The performance and characteristics of the device are essentially unchanged over the full $\pm 4.5V$ to $\pm 18V$ power supply range; power dissipation is only 33 mW with $\pm 5V$ supplies and is independent of the logic input states.

The DAC0800, DAC0802, DAC0800C and DAC0802C are a direct replacement for the DAC-08, DAC-08A, DAC-08C, and DAC-08H, respectively.

Features

- Fast settling output current: 100 ns
- Full scale error: ± 1 LSB
- Nonlinearity over temperature: $\pm 0.1\%$
- Full scale current drift: ± 10 ppm/ $^{\circ}C$
- High output compliance: $-10V$ to $+18V$
- Complementary current outputs
- Interface directly with TTL, CMOS, PMOS and others
- 2 quadrant wide range multiplying capability
- Wide power supply range: $\pm 4.5V$ to $\pm 18V$
- Low power consumption: 33 mW at $\pm 5V$
- Low cost

Typical Applications

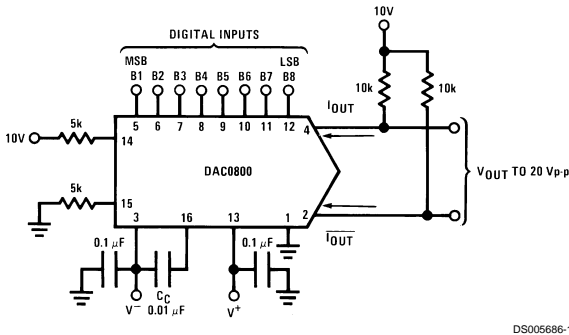


FIGURE 1. ± 20 V_{P-P} Output Digital-to-Analog Converter (Note 5)

Ordering Information

| Non-Linearity | Temperature Range | Order Numbers | | | | |
|---------------|---------------------------------|---------------------------|----------|---------------------------|----------|-------------------|
| | | J Package (J16A) (Note 1) | | N Package (N16E) (Note 1) | | SO Package (M16A) |
| ±0.1% FS | 0°C ≤ T _A ≤ +70°C | DAC0802LCJ | DAC-08HQ | DAC0802LCN | DAC-08HP | DAC0802LCM |
| ±0.19% FS | −55°C ≤ T _A ≤ +125°C | DAC0800LJ | DAC-08Q | | | |
| ±0.19% FS | 0°C ≤ T _A ≤ +70°C | DAC0800LCJ | DAC-08EQ | DAC0800LCN | DAC-08EP | DAC0800LCM |

Note 1: Devices may be ordered by using either order number.

Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

| | |
|--|---------------------------|
| Supply Voltage ($V^+ - V^-$) | $\pm 18V$ or $36V$ |
| Power Dissipation (Note 3) | 500 mW |
| Reference Input Differential Voltage (V14 to V15) | V^- to V^+ |
| Reference Input Common-Mode Range (V14, V15) | V^- to V^+ |
| Reference Input Current | 5 mA |
| Logic Inputs | V^- to V^- plus $36V$ |
| Analog Current Outputs ($V_S = -15V$) | 4.25 mA |
| ESD Susceptibility (Note 4) | TBD V |

Storage Temperature -65°C to $+150^\circ\text{C}$

Lead Temp. (Soldering, 10 seconds)

| | |
|--------------------------------|---------------------|
| Dual-In-Line Package (plastic) | 260°C |
| Dual-In-Line Package (ceramic) | 300°C |
| Surface Mount Package | |
| Vapor Phase (60 seconds) | 215°C |
| Infrared (15 seconds) | 220°C |

Operating Conditions (Note 2)

| | Min | Max | Units |
|-----------------------|-----|------|------------------|
| Temperature (T_A) | | | $^\circ\text{C}$ |
| DAC0800L | -55 | +125 | $^\circ\text{C}$ |
| DAC0800LC | 0 | +70 | $^\circ\text{C}$ |
| DAC0802LC | 0 | +70 | $^\circ\text{C}$ |

Electrical Characteristics

The following specifications apply for $V_S = \pm 15V$, $I_{REF} = 2\text{ mA}$ and $T_{MIN} \leq T_A \leq T_{MAX}$ unless otherwise specified. Output characteristics refer to both I_{OUT} and I_{OUT-} .

| Symbol | Parameter | Conditions | DAC0802LC | | | DAC0800L/ DAC0800LC | | | Units |
|--------------------------|--|---|-----------|---------------|------------|------------------------|---------------|------------|--------------------------------|
| | | | Min | Typ | Max | Min | Typ | Max | |
| | Resolution | | 8 | 8 | 8 | 8 | 8 | 8 | Bits |
| | Monotonicity | | 8 | 8 | 8 | 8 | 8 | 8 | Bits |
| | Nonlinearity | | | | ± 0.1 | | | ± 0.19 | %FS |
| t_s | Settling Time | To $\pm 1/2$ LSB, All Bits Switched "ON" or "OFF", $T_A = 25^\circ\text{C}$ DAC0800L DAC0800LC | | 100 | 135 | | 100 100 | 135 150 | ns ns |
| t_{PLH} , t_{PHL} | Propagation Delay Each Bit All Bits Switched | $T_A = 25^\circ\text{C}$ | | 35 35 | 60 60 | | 35 35 | 60 60 | ns ns |
| TC_{IFS} | Full Scale Tempco | | | ± 10 | ± 50 | | ± 10 | ± 50 | ppm/ $^\circ\text{C}$ |
| V_{OC} | Output Voltage Compliance | Full Scale Current Change $< 1/2$ LSB, $R_{OUT} > 20\text{ M}\Omega$ Typ | -10 | | 18 | -10 | | 18 | V |
| I_{FS4} | Full Scale Current | $V_{REF} = 10.000V$, $R14 = 5.000\text{ k}\Omega$ $R15 = 5.000\text{ k}\Omega$, $T_A = 25^\circ\text{C}$ | 1.984 | 1.992 | 2.000 | 1.94 | 1.99 | 2.04 | mA |
| I_{FSS} | Full Scale Symmetry | $I_{FS4} - I_{FS2}$ | | ± 0.5 | ± 4.0 | | ± 1 | ± 8.0 | μA |
| I_{ZS} | Zero Scale Current | | | 0.1 | 1.0 | | 0.2 | 2.0 | μA |
| I_{FSR} | Output Current Range | $V^- = -5V$ $V^- = -8V$ to $-18V$ | 0 0 | 2.0 2.0 | 2.1 4.2 | 0 0 | 2.0 2.0 | 2.1 4.2 | mA mA |
| V_{IL} V_{IH} | Logic Input Levels Logic "0" Logic "1" | $V_{LC} = 0V$ | | | 0.8 | | | 0.8 | V V |
| I_{IL} I_{IH} | Logic Input Current Logic "0" Logic "1" | $V_{LC} = 0V$ $-10V \leq V_{IN} \leq +0.8V$ $2V \leq V_{IN} \leq +18V$ | | -2.0 0.002 | -10 | | -2.0 0.002 | -10 | μA μA |
| V_{IS} | Logic Input Swing | $V^- = -15V$ | -10 | | 18 | -10 | | 18 | V |
| V_{THR} | Logic Threshold Range | $V_S = \pm 15V$ | -10 | | 13.5 | -10 | | 13.5 | V |
| I_{15} | Reference Bias Current | | | -1.0 | -3.0 | | -1.0 | -3.0 | μA |
| dl/dt | Reference Input Slew Rate | (Figure 11) | 4.0 | 8.0 | | 4.0 | 8.0 | | mA/ μs |
| $PSSI_{FS+}$ | Power Supply Sensitivity | $4.5V \leq V^+ \leq 18V$ | | 0.0001 | 0.01 | | 0.0001 | 0.01 | %/% |
| $PSSI_{FS-}$ | | $-4.5V \leq V^- \leq 18V$ $I_{REF} = 1\text{ mA}$ | | 0.0001 | 0.01 | | 0.0001 | 0.01 | %/% |

Electrical Characteristics (Continued)

The following specifications apply for $V_S = \pm 15V$, $I_{REF} = 2\text{ mA}$ and $T_{MIN} \leq T_A \leq T_{MAX}$ unless otherwise specified. Output characteristics refer to both I_{OUT} and $\overline{I_{OUT}}$.

| Symbol | Parameter | Conditions | DAC0802LC | | | DAC0800L/ DAC0800LC | | | Units |
|--|----------------------|---|-----------|------|------|------------------------|------|------|-------|
| | | | Min | Typ | Max | Min | Typ | Max | |
| I_+ I_- I_+ I_- I_+ I_- | Power Supply Current | $V_S = \pm 5V$, $I_{REF} = 1\text{ mA}$ | | 2.3 | 3.8 | | 2.3 | 3.8 | mA |
| | | | | -4.3 | -5.8 | | -4.3 | -5.8 | mA |
| | | $V_S = 5V$, $-15V$, $I_{REF} = 2\text{ mA}$ | | 2.4 | 3.8 | | 2.4 | 3.8 | mA |
| | | | | -6.4 | -7.8 | | -6.4 | -7.8 | mA |
| | | $V_S = \pm 15V$, $I_{REF} = 2\text{ mA}$ | | 2.5 | 3.8 | | 2.5 | 3.8 | mA |
| | | | | -6.5 | -7.8 | | -6.5 | -7.8 | mA |
| P_D | Power Dissipation | $\pm 5V$, $I_{REF} = 1\text{ mA}$ | | 33 | 48 | | 33 | 48 | mW |
| | | $5V$, $-15V$, $I_{REF} = 2\text{ mA}$ | | 108 | 136 | | 108 | 136 | mW |
| | | $\pm 15V$, $I_{REF} = 2\text{ mA}$ | | 135 | 174 | | 135 | 174 | mW |

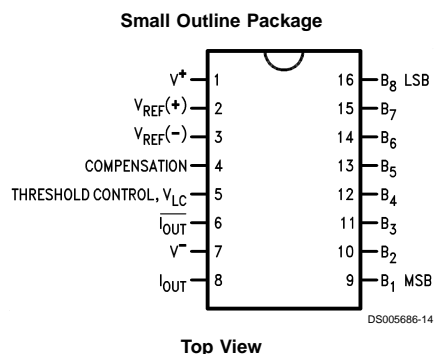
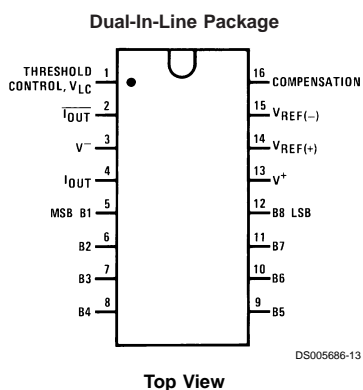
Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its specified operating conditions.

Note 3: The maximum junction temperature of the DAC0800 and DAC0802 is 125°C. For operating at elevated temperatures, devices in the Dual-In-Line J package must be derated based on a thermal resistance of 100°C/W, junction-to-ambient, 175°C/W for the molded Dual-In-Line N package and 100°C/W for the Small Outline M package.

Note 4: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

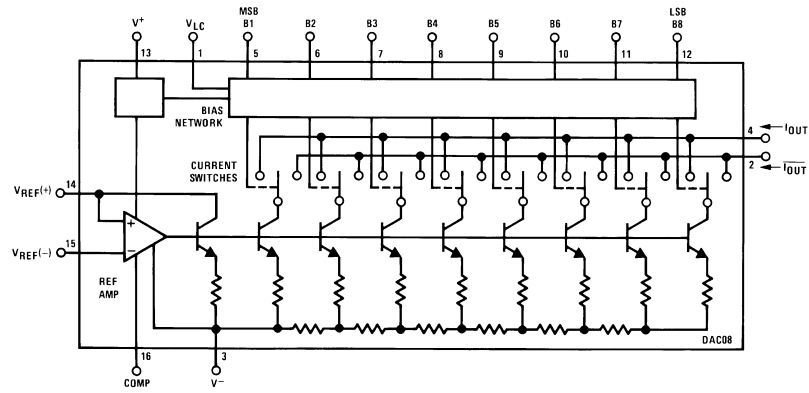
Note 5: Pin-out numbers for the DAC080X represent the Dual-In-Line package. The Small Outline package pin-out differs from the Dual-In-Line package.

Connection Diagrams



See Ordering Information

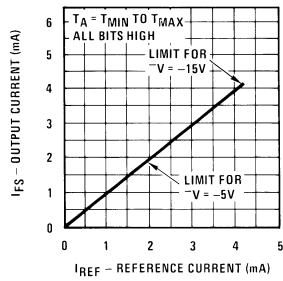
Block Diagram (Note 5)



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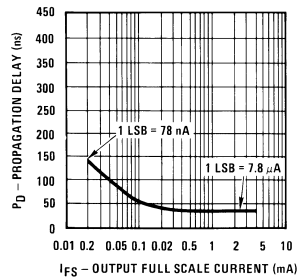
Typical Performance Characteristics

Full Scale Current vs Reference Current



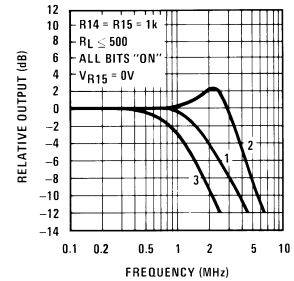
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LSB Propagation Delay vs I_{FS}



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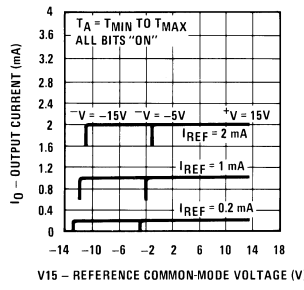
Reference Input Frequency Response



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Curve 1: $C_C = 15$ pF, $V_{IN} = 2$ Vp-p centered at 1V.
Curve 2: $C_C = 15$ pF, $V_{IN} = 50$ mVp-p centered at 200 mV.
Curve 3: $C_C = 0$ pF, $V_{IN} = 100$ mVp-p centered at 0V and applied through 50Ω connected to pin 14.2V applied to R14.

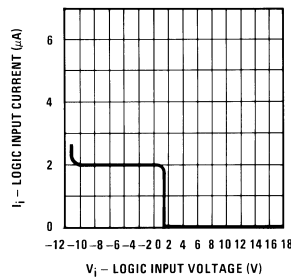
Reference Amp Common-Mode Range



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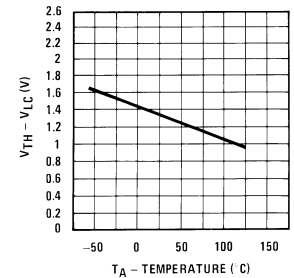
Note. Positive common-mode range is always $(V+) - 1.5V$.

Logic Input Current vs Input Voltage



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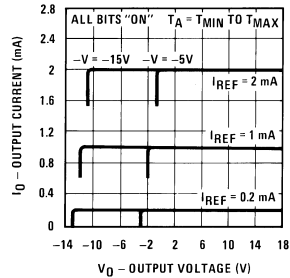
$V_{TH} - V_{LC}$ vs Temperature



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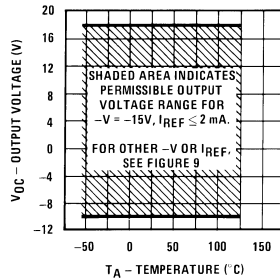
Typical Performance Characteristics (Continued)

Output Current vs Output Voltage (Output Voltage Compliance)



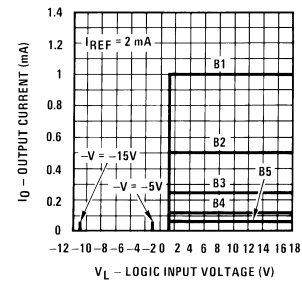
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Output Voltage Compliance vs Temperature



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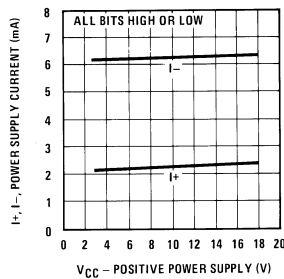
Bit Transfer Characteristics



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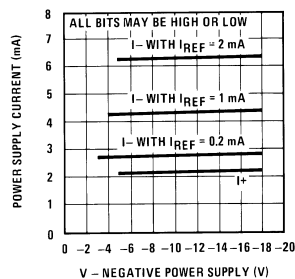
Note. B1-B8 have identical transfer characteristics. Bits are fully switched with less than 1/2 LSB error, at less than ±100 mV from actual threshold. These switching points are guaranteed to lie between 0.8 and 2V over the operating temperature range ($V_{LC} = 0V$).

Power Supply Current vs +V



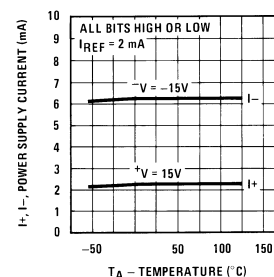
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Power Supply Current vs -V



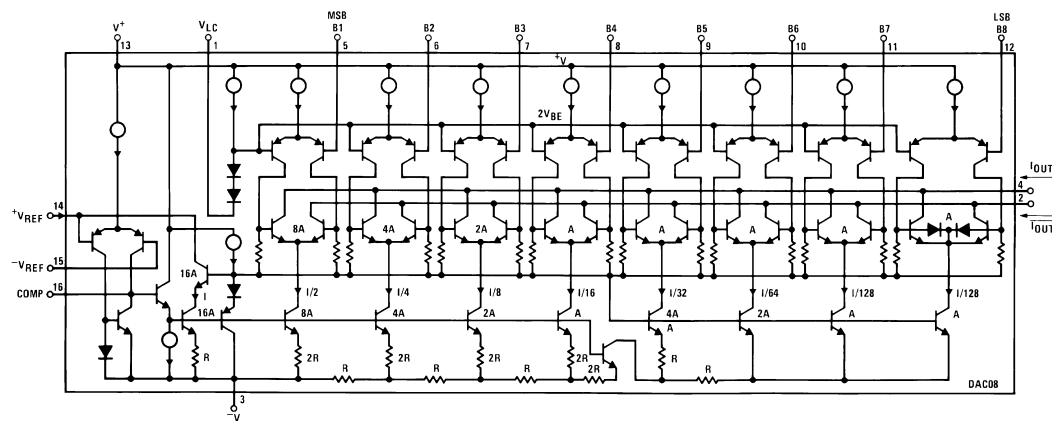
DS005686-32

Power Supply Current vs Temperature



DS005686-33

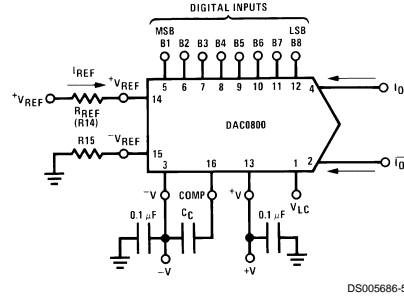
Equivalent Circuit



DS005686-15

FIGURE 2.

Typical Applications



$$I_{FS} \approx \frac{+V_{REF}}{R_{REF}} \times \frac{255}{256}$$

$I_O + \bar{I}_O = I_{FS}$ for all logic states

For fixed reference, TTL operation, typical values are:

$V_{REF} = 10.000V$

$R_{REF} = 5.000k$

$R15 = R_{REF}$

$C_C = 0.01 \mu F$

$V_{LC} = 0V$ (Ground)

FIGURE 3. Basic Positive Reference Operation (Note 5)

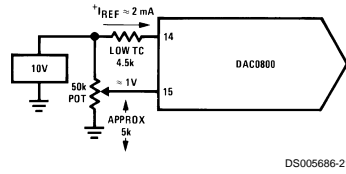
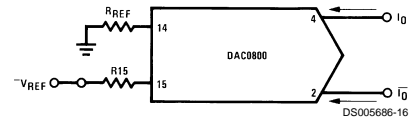


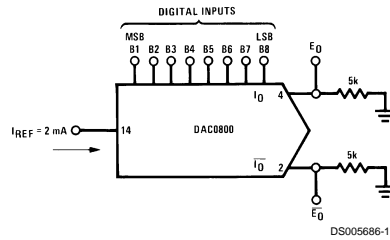
FIGURE 4. Recommended Full Scale Adjustment Circuit (Note 5)



$$I_{FS} \approx \frac{-V_{REF}}{R_{REF}} \times \frac{255}{256}$$

Note. R_{REF} sets I_{FS} ; $R15$ is for bias current cancellation

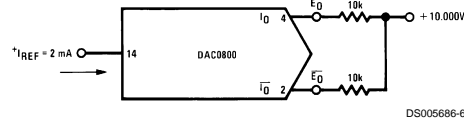
FIGURE 5. Basic Negative Reference Operation (Note 5)



| | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | I_O mA | \bar{I}_O mA | E_O | \bar{E}_O |
|----------------|----|----|----|----|----|----|----|----|----------|----------------|--------|-------------|
| Full Scale | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.992 | 0.000 | -9.960 | 0.000 |
| Full Scale-LSB | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1.984 | 0.008 | -9.920 | -0.040 |
| Half Scale+LSB | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1.008 | 0.984 | -5.040 | -4.920 |
| Half Scale | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.000 | 0.992 | -5.000 | -4.960 |
| Half Scale-LSB | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.992 | 1.000 | -4.960 | -5.000 |
| Zero Scale+LSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.008 | 1.984 | -0.040 | -9.920 |
| Zero Scale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 | 1.992 | 0.000 | -9.960 |

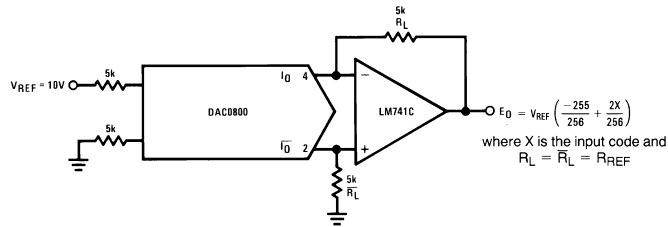
FIGURE 6. Basic Unipolar Negative Operation (Note 5)

Typical Applications (Continued)



| | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | E_O | \bar{E}_O |
|---------------------|----|----|----|----|----|----|----|----|---------|-------------|
| Pos. Full Scale | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | -9.920 | +10.000 |
| Pos. Full Scale-LSB | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | -9.840 | +9.920 |
| Zero Scale+LSB | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | -0.080 | +0.160 |
| Zero Scale | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 | +0.080 |
| Zero Scale-LSB | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | +0.080 | 0.000 |
| Neg. Full Scale+LSB | 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 |

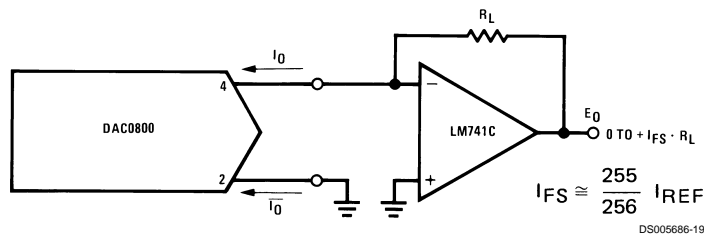
FIGURE 7. Basic Bipolar Output Operation (Note 5)



If $R_L = \bar{R}_L$ within $\pm 0.05\%$, output is symmetrical about ground

| | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | E_O |
|---------------------|----|----|----|----|----|----|----|----|--------|
| Pos. Full Scale | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | +9.960 |
| Pos. Full Scale-LSB | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | +9.880 |
| (+)Zero Scale | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0.040 |
| (-)Zero Scale | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | -0.040 |
| Neg. Full Scale+LSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | -9.880 |
| Neg. Full Scale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -9.960 |

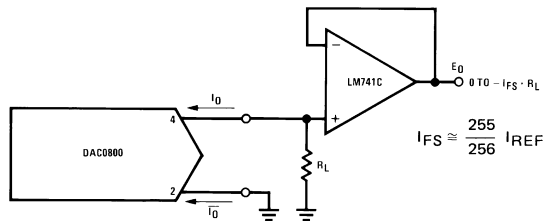
FIGURE 8. Symmetrical Offset Binary Operation (Note 5)



For complementary output (operation as negative logic DAC), connect inverting input of op amp to \bar{I}_O (pin 2), connect I_O (pin 4) to ground.

FIGURE 9. Positive Low Impedance Output Operation (Note 5)

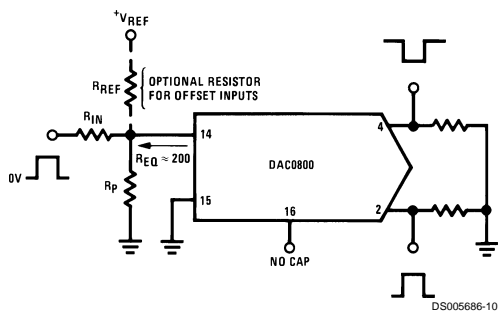
Typical Applications (Continued)



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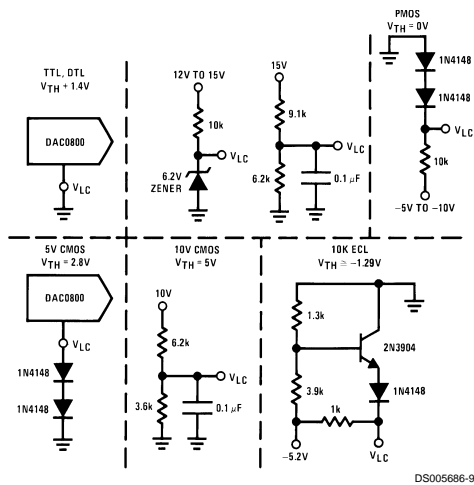
For complementary output (operation as a negative logic DAC) connect non-inverting input of op am to \bar{I}_O (pin 2); connect I_O (pin 4) to ground.

FIGURE 10. Negative Low Impedance Output Operation (Note 5)



Typical values: $R_{IN}=5k, +V_{IN}=10V$

FIGURE 11. Pulsed Reference Operation (Note 5)



DS005686-9

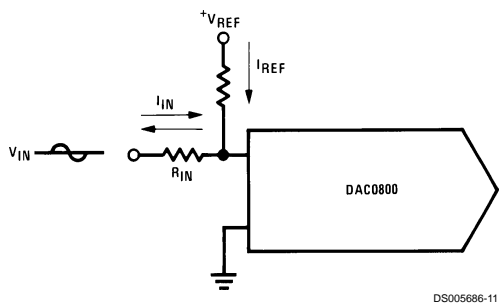
$$V_{TH} = V_{LC} + 1.4V$$

15V CMOS, HTL, HNIL

$$V_{TH} = 7.6V$$

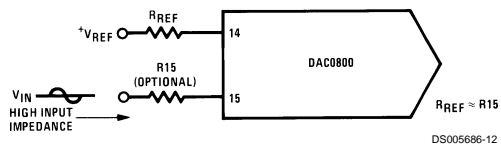
Note. Do not exceed negative logic input range of DAC.

FIGURE 12. Interfacing with Various Logic Families



DS005686-11

(a) $I_{REF} \geq$ peak negative swing of I_{IN}



DS005686-12

(b) $+V_{REF}$ must be above peak positive swing of V_{IN}

FIGURE 13. Accommodating Bipolar References (Note 5)

Typical Applications (Continued)

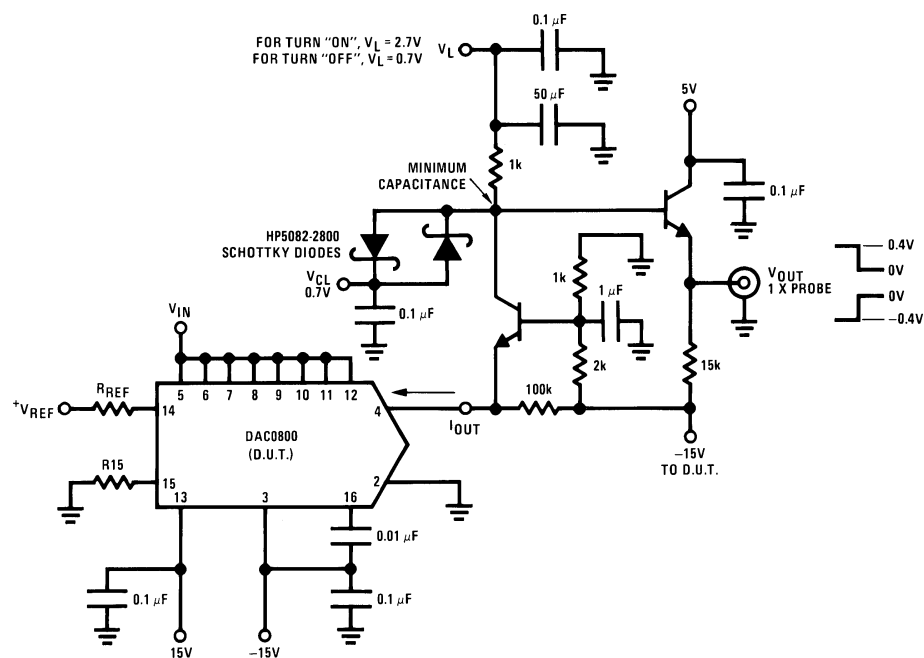
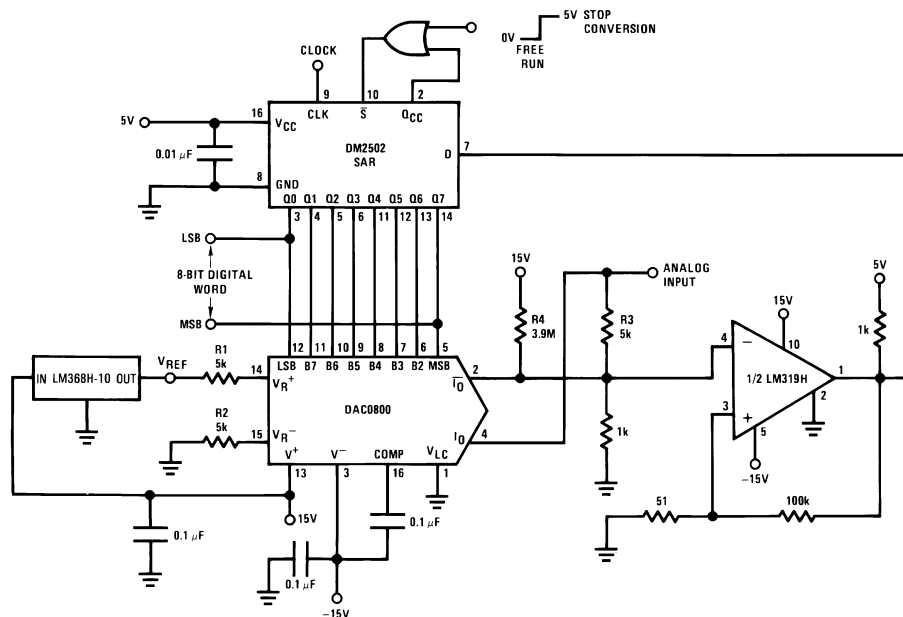


FIGURE 14. Settling Time Measurement (Note 5)

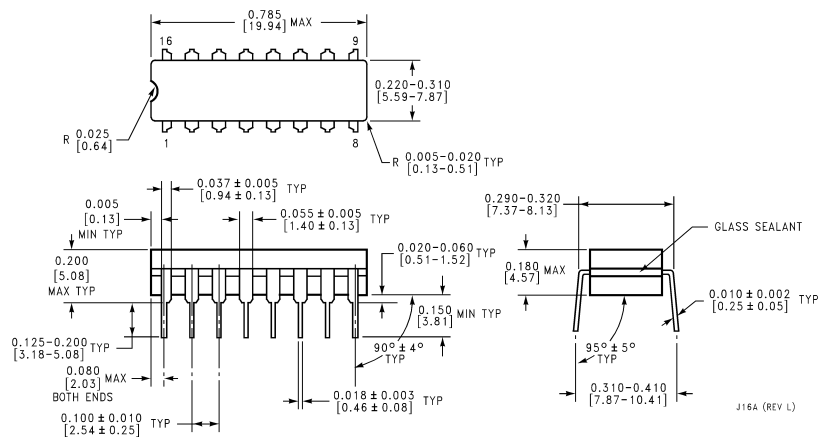
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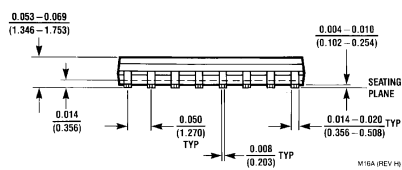
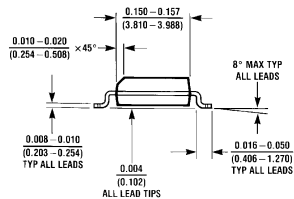
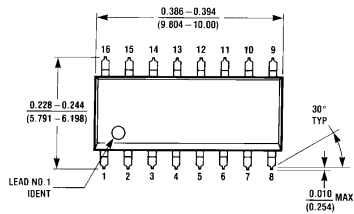
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Note. For 1 µs conversion time with 8-bit resolution and 7-bit accuracy, an LM361 comparator replaces the LM319 and the reference current is doubled by reducing R1, R2 and R3 to 2.5 kΩ and R4 to 2 MΩ.

FIGURE 15. A Complete 2 µs Conversion Time, 8-Bit A/D Converter (Note 5)

Physical Dimensions inches (millimeters) unless otherwise noted

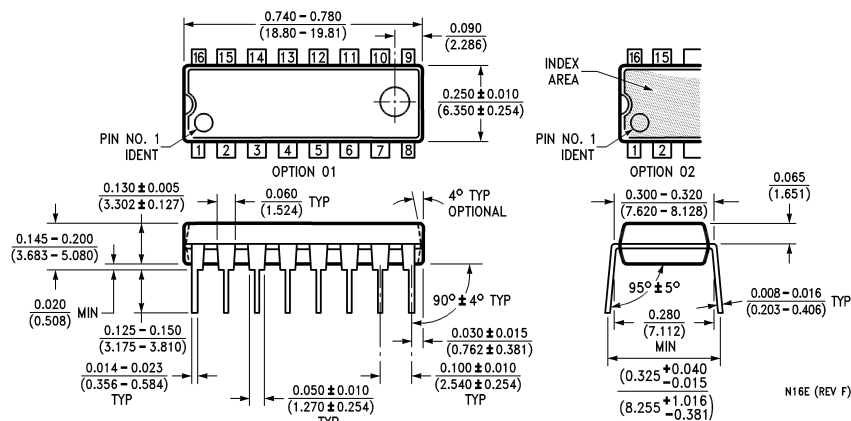
Molded Small Outline Package (SO)
Order Numbers DAC0800LCM,
or DAC0802LCM
NS Package Number M16A



Molded Small Outline Package (SO)
Order Numbers DAC0800LCM,
or DAC0802LCM
NS Package Number M16A

Physical Dimensions

inches (millimeters) unless otherwise noted (Continued)



Molded Dual-In-Line Package
Order Numbers DAC0800, DAC0802
NS Package Number N16E

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



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