



September 2006

## 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. The reference-to-full-scale current matching of better than  $\pm 1$  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 will accept a variety of logic levels. The performance and characteristics of the device are essentially unchanged over the  $\pm 4.5$ V to  $\pm 18$ V power supply range and power consumption at only 33 mW with  $\pm 5$ V supplies is independent of logic input levels.

The DAC0800, DAC0802, DAC0800C and DAC0802C are a direct replacement for the DAC-08, DAC-08A, DAC-08C, and DAC-08H, respectively. For single supply operation, refer to AN-1525.

#### Features

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

#### Typical Application

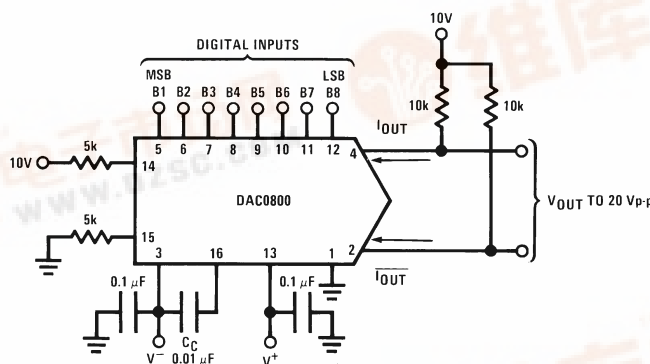


FIGURE 1.  $\pm 20$  V<sub>P-P</sub> Output Digital-to-Analog Converter (Note 4)

#### Ordering Information

| Non-Linearity   | Temperature Range (T <sub>A</sub> )   | Order Numbers      |          |                    |          |                   |
|-----------------|---------------------------------------|--------------------|----------|--------------------|----------|-------------------|
|                 |                                       | J Package (J16A) * |          | N Package (N16E) * |          | SO Package (M16A) |
| $\pm 0.1\%$ FS  | 0 $^{\circ}$ C to +70 $^{\circ}$ C    | DAC0802LCJ         | DAC-08HQ | DAC0802LCN         | DAC-08HP | DAC0802LCM        |
| $\pm 0.19\%$ FS | -55 $^{\circ}$ C to +125 $^{\circ}$ C | DAC0800LJ          | DAC-08Q  |                    |          |                   |
| $\pm 0.19\%$ FS | 0 $^{\circ}$ C to +70 $^{\circ}$ C    | DAC0800LCJ         | DAC-08EQ | DAC0800LCN         | DAC-08EP | DAC0800LCM        |

\* Devices may be ordered by using either order number.

DAC0800/DAC0802 8-Bit Digital-to-Analog Converters

**Absolute Maximum Ratings** (Note 1)

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 2)                           | 500 mW                                      |
| Reference Input Differential Voltage<br>(V14 to V15) | $V^-$ to $V^+$                              |
| Reference Input Common-Mode<br>Range (V14, V15)      | $V^-$ to $V^+$                              |
| Reference Input Current                              | 5 mA                                        |
| Logic Inputs                                         | $V^-$ to $V^-$ plus 36V                     |
| Analog Current Outputs<br>( $V_S = -15V$ )           | 4.25 mA                                     |
| ESD Susceptibility (Note 3)                          | TBD V                                       |
| Storage Temperature                                  | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Lead Temp. (Soldering, 10 seconds)                   |                                             |
| Dual-In-Line Package (plastic)                       | $260^\circ\text{C}$                         |
| Dual-In-Line Package (ceramic)                       | $300^\circ\text{C}$                         |
| Surface Mount Package                                |                                             |
| Vapor Phase (60 seconds)                             | $215^\circ\text{C}$                         |
| Infrared (15 seconds)                                | $220^\circ\text{C}$                         |

**Operating Conditions** (Note 1)

|                            | Min            | Max            | Units            |
|----------------------------|----------------|----------------|------------------|
| Temperature ( $T_A$ )      |                |                |                  |
| DAC0800L                   | -55            | +125           | $^\circ\text{C}$ |
| DAC0800LC                  | 0              | +70            | $^\circ\text{C}$ |
| DAC0802LC                  | 0              | +70            | $^\circ\text{C}$ |
| $V^+$                      | ( $V^-$ ) + 10 | ( $V^-$ ) + 30 | V                |
| $V^-$                      | -15            | -5             | V                |
| $I_{REF}$ ( $V^- = -5V$ )  | 1              | 2              | mA               |
| $I_{REF}$ ( $V^- = -15V$ ) | 1              | 4              | mA               |

**Electrical Characteristics**

The following specifications apply for  $V_S = \pm 15V$ ,  $I_{REF} = 2$  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/<br>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                                       |                                                                                       |           |           | $\pm 0.1$ |                        |          | $\pm 0.19$ | %FS                   |
| $t_s$                    | Settling Time                                      | To $\pm 1/2$ LSB, All Bits Switched "ON" or "OFF",<br>$T_A = 25^\circ\text{C}$        |           | 100       | 135       |                        |          |            | ns                    |
|                          |                                                    | DAC0800L                                                                              |           |           |           | 100                    | 135      |            | ns                    |
|                          |                                                    | DAC0800LC                                                                             |           |           |           | 100                    | 150      |            | ns                    |
| $t_{PLH}$ ,<br>$t_{PHL}$ | Propagation Delay<br>Each Bit<br>All Bits Switched | $T_A = 25^\circ\text{C}$                                                              |           | 35        | 60        |                        | 35       | 60         | ns                    |
|                          |                                                    |                                                                                       |           | 35        | 60        |                        | 35       | 60         | ns                    |
|                          |                                                    |                                                                                       |           |           |           |                        |          |            |                       |
| $TCI_{FS}$               | Full Scale Tempco                                  |                                                                                       |           | $\pm 10$  | $\pm 50$  |                        | $\pm 10$ | $\pm 50$   | ppm/ $^\circ\text{C}$ |
| $V_{OC}$                 | Output Voltage Compliance                          | Full Scale Current Change<br>$< 1/2$ LSB, $R_{OUT} > 20$ M $\Omega$ ,<br>Typical      | -10       |           | 18        | -10                    |          | 18         | V                     |
| $I_{FS4}$                | Full Scale Current                                 | $V_{REF} = 10.000V$ ,<br>$R14 = R15 = 5.000$ k $\Omega$ ,<br>$T_A = 25^\circ\text{C}$ | 1.984     | 1.992     | 2.00      | 1.94                   | 1.99     | 2.04       | mA                    |
| $I_{FSS}$                | Full Scale Symmetry                                | $I_{FS4} - I_{FS2}$                                                                   |           | $\pm 0.5$ | $\pm 4.0$ |                        | $\pm 1$  | $\pm 8.0$  | $\mu\text{A}$         |
| $I_{ZS}$                 | Zero Scale Current                                 |                                                                                       |           | 0.1       | 1.0       |                        | 0.2      | 2.0        | $\mu\text{A}$         |
| $I_{FSR}$                | Output Current Range                               | $V^- = -5V$                                                                           | 0         | 2.0       | 2.1       | 0                      | 2.0      | 2.1        | mA                    |
|                          |                                                    | $V^- = -8V$ to $-18V$                                                                 | 0         | 2.0       | 4.2       | 0                      | 2.0      | 4.2        |                       |

## 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/<br>DAC0800LC |        |      | Units             |
|--------------|-----------------------------------|----------------------------------------------------|-----------|--------|------|------------------------|--------|------|-------------------|
|              |                                   |                                                    | Min       | Typ    | Max  | Min                    | Typ    | Max  |                   |
| $V_{IL}$     | Logic Input Levels                | $V_{LC} = 0V$                                      |           |        | 0.8  |                        |        | 0.8  | V                 |
| $V_{IH}$     | Logic "1"                         |                                                    | 2.0       |        |      | 2.0                    |        |      | V                 |
| $I_{IL}$     | Logic Input Current               | $V_{LC} = 0V$                                      |           |        |      |                        |        |      | $\mu A$           |
|              | Logic "0"                         | $-10V \leq V_{IN} \leq +0.8V$                      |           | -2.0   | -10  |                        | -2.0   | -10  | $\mu A$           |
| $I_{IH}$     | Logic "1"                         | $2V \leq V_{IN} \leq +18V$                         |           | 0.002  | 10   |                        | 0.002  | 10   | $\mu A$           |
| $V_{IS}$     | 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 | $\mu A$           |
| $dl/dt$      | Reference Input Slew Rate         | (Figure 11)                                        | 4.0       | 8.0    |      | 4.0                    | 8.0    |      | $\text{mA}/\mu s$ |
| $PSSI_{FS+}$ | Positive Power Supply Sensitivity | $4.5V \leq V^+ \leq 18V$                           |           | 0.0001 | 0.01 |                        | 0.0001 | 0.01 | %/%               |
| $PSSI_{FS-}$ | Negative Power Supply Sensitivity | $-4.5V \leq V^- \leq 18V$ , $I_{REF} = 1\text{mA}$ |           | 0.0001 | 0.01 |                        | 0.0001 | 0.01 | %/%               |
| $I^+$        | Power Supply Current              | $V_S = \pm 5V$ , $I_{REF} = 1 \text{ mA}$          |           | 2.3    | 3.8  |                        | 2.3    | 3.8  | $\text{mA}$       |
| $I^-$        | Power Supply Current              |                                                    |           | -4.3   | -5.8 |                        | -4.3   | -5.8 | $\text{mA}$       |
| $I^+$        | Power Supply Current              | $V_S = +5V, -15V$ , $I_{REF} = 2 \text{ mA}$       |           | 2.4    | 3.8  |                        | 2.4    | 3.8  | $\text{mA}$       |
| $I^-$        | Power Supply Current              |                                                    |           | -6.4   | -7.8 |                        | -6.4   | -7.8 | $\text{mA}$       |
| $I^+$        | Power Supply Current              | $V_S = \pm 15V$ , $I_{REF} = 2 \text{ mA}$         |           | 2.5    | 3.8  |                        | 2.5    | 3.8  | $\text{mA}$       |
| $I^-$        | Power Supply Current              |                                                    |           | -6.5   | -7.8 |                        | -6.5   | -7.8 | $\text{mA}$       |
| $P_D$        | Power Consumption                 | $\pm 5V$ , $I_{REF} = 1 \text{ mA}$                |           | 33     | 48   |                        | 33     | 48   | $\text{mW}$       |
|              |                                   | $+5V, -15V$ , $I_{REF} = 2 \text{ mA}$             |           | 108    | 136  |                        | 108    | 136  | $\text{mW}$       |
|              |                                   | $\pm 15V$ , $I_{REF} = 2 \text{ mA}$               |           | 135    | 174  |                        | 135    | 174  | $\text{mW}$       |

**Note 1:** 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.

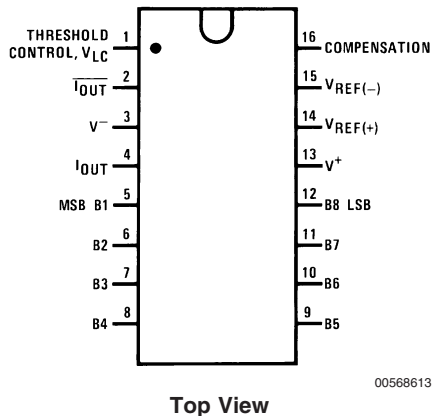
**Note 2:** The maximum junction temperature of the DAC0800 and DAC0802 is  $125^\circ\text{C}$ . For operating at elevated temperatures, devices in the Dual-In-Line J package must be derated based on a thermal resistance of  $100^\circ\text{C}/\text{W}$ , junction-to-ambient,  $175^\circ\text{C}/\text{W}$  for the molded Dual-In-Line N package and  $100^\circ\text{C}/\text{W}$  for the Small Outline M package.

**Note 3:** Human body model, 100 pF discharged through a 1.5 k $\Omega$  resistor.

**Note 4:** Pin numbers represent the Dual-In-Line package. The Small Outline package pin numbers differ from from that of the Dual-In-Line package.

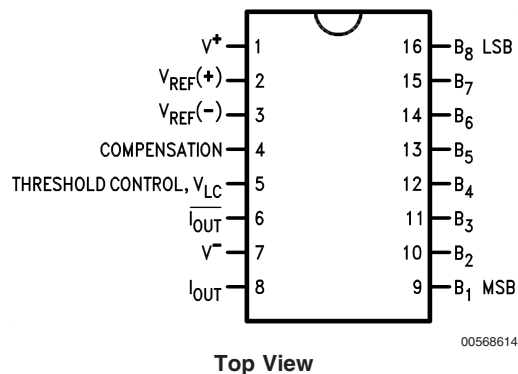
## Connection Diagrams

Dual-In-Line Package



Top View

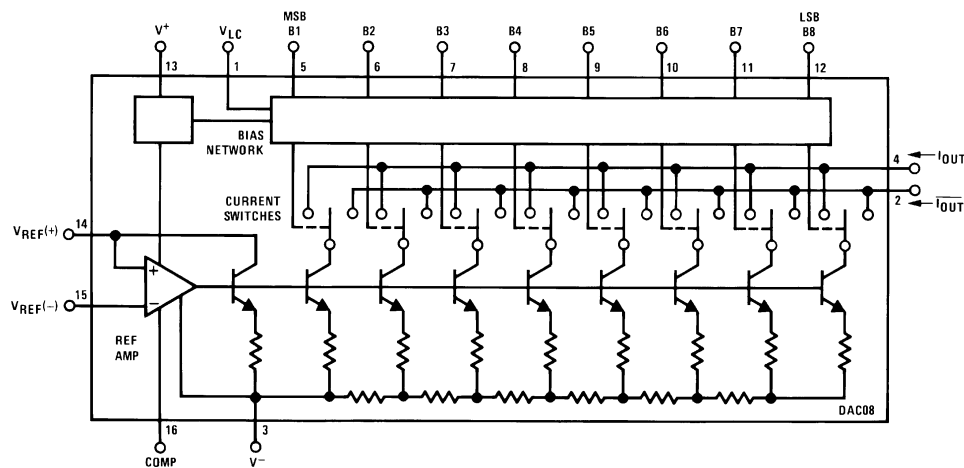
Small Outline Package



Top View

See Ordering Information

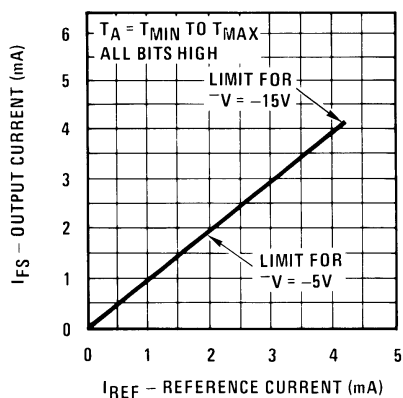
## Block Diagram (Note 4)



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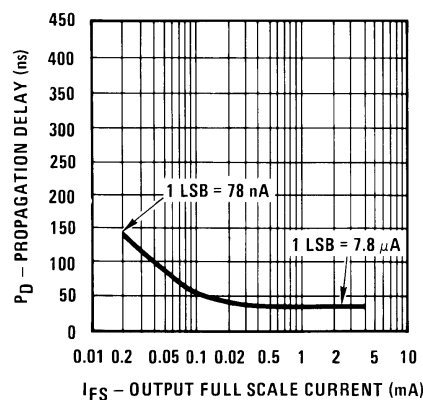
## Typical Performance Characteristics

Full Scale Current vs.  
Reference Current



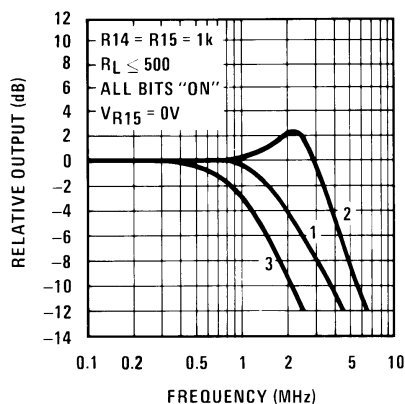
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LSB Propagation Delay vs.  $I_{FS}$



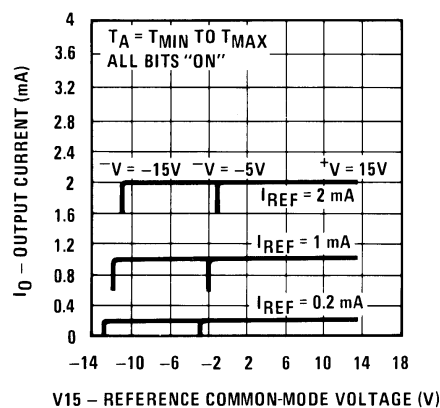
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Reference Input  
Frequency Response



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Reference Amp  
Common-Mode Range



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Curve 1:  $C_C=15$  pF,  $V_{IN}=2$  Vp-p centered at 1V.

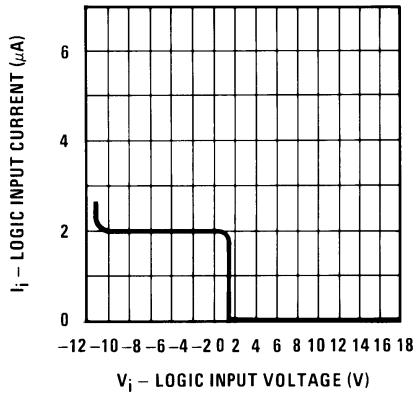
Curve 2:  $C_C=15$  pF,  $V_{IN}=50$  mVp-p centered at 200 mV.

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.

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

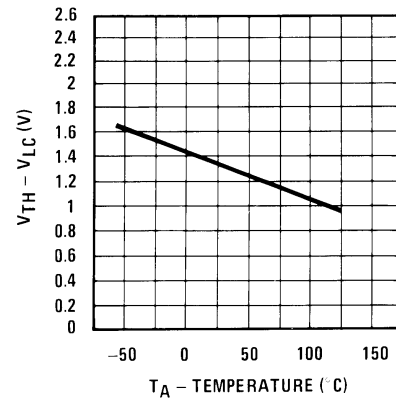
# Typical Performance Characteristics (Continued)

Logic Input Current vs.  
Input Voltage



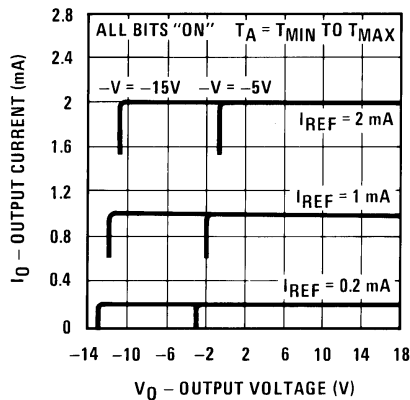
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$V_{TH} - V_{LC}$  vs. Temperature



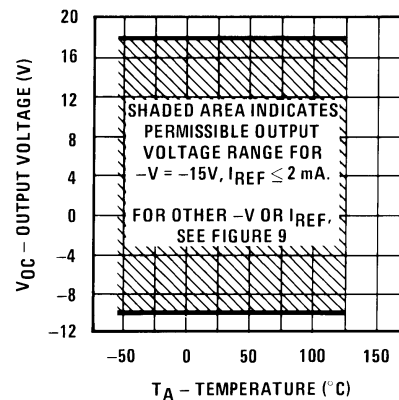
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Output Current vs. Output  
Voltage (Output Voltage  
Compliance)



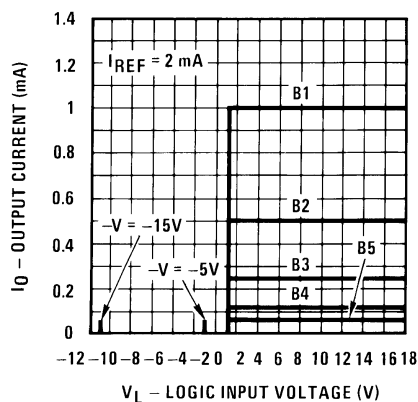
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Output Voltage Compliance vs.  
Temperature



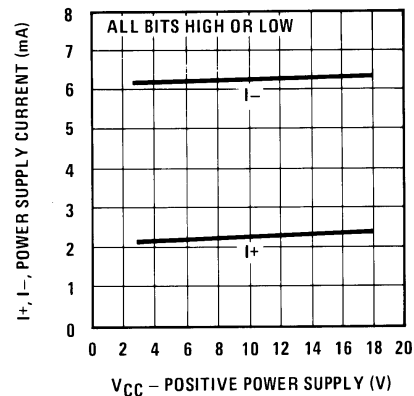
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Bit Transfer  
Characteristics



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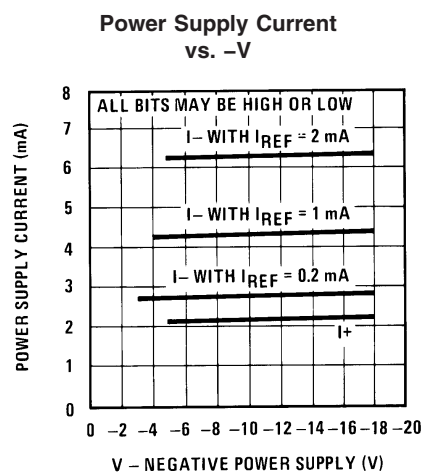
Power Supply Current  
vs. +V



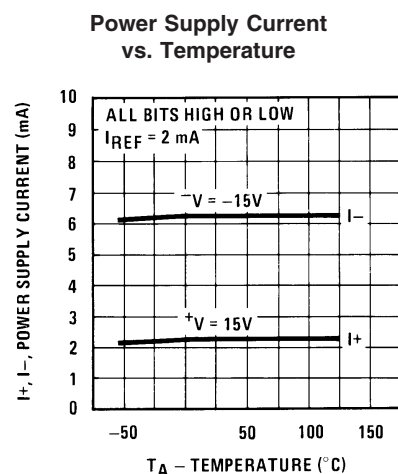
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Note. B1-B8 have identical transfer characteristics. Bits are fully switched with less than 1/2 LSB error, at less than ±100 mV from actual threshold. These switching points are guaranteed to lie between 0.8 and 2V over the operating temperature range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

# Typical Performance Characteristics (Continued)

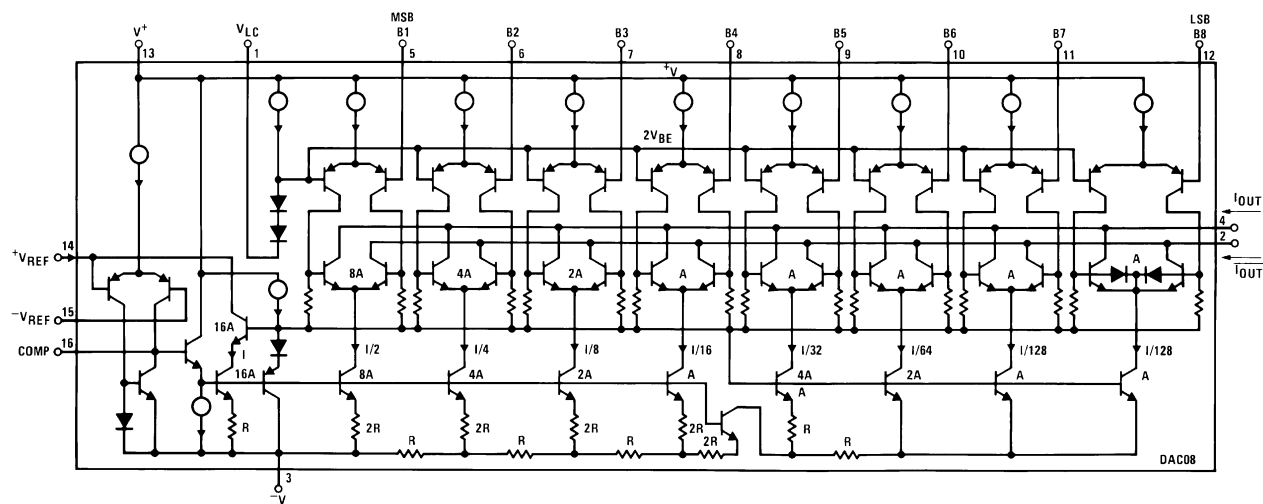


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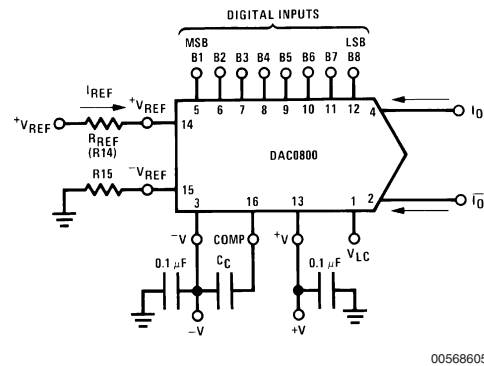
## Equivalent Circuit



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FIGURE 2. Equivalent Circuit

## Typical Applications



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

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

For fixed reference, TTL operation, typical values are:

$V_{REF} = 10.000V$

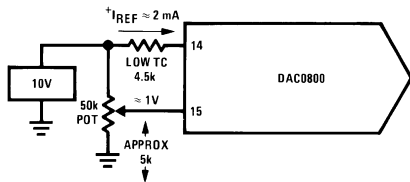
$R_{REF} = 5.000k$

$R15 \approx R_{REF}$

$C_C = 0.01 \mu F$

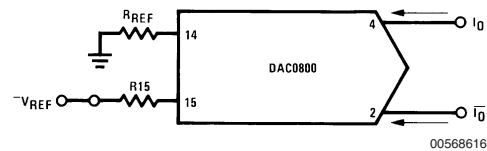
$V_{LC} = 0V$  (Ground)

FIGURE 3. Basic Positive Reference Operation (Note 4)



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



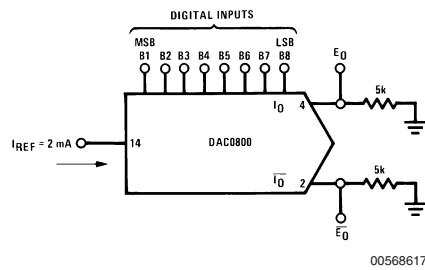
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$$I_{FS} \approx \frac{-V_{REF}}{R_{REF}} \times \frac{255}{256}$$

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

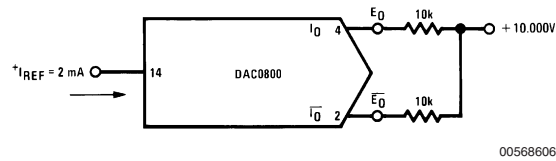
FIGURE 5. Basic Negative Reference Operation (Note 4)

## Typical Applications (Continued)



|                | 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 4)

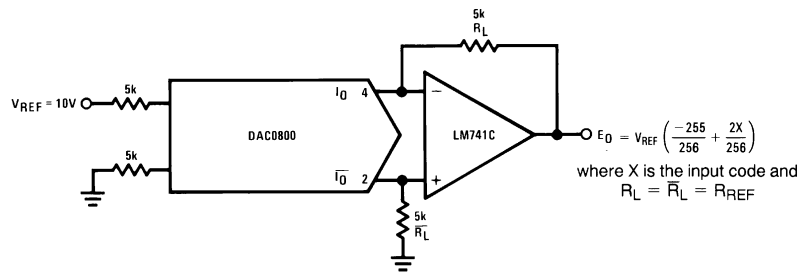


|                     | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | $E_O$   | $\bar{E}_O$ |
|---------------------|----|----|----|----|----|----|----|----|---------|-------------|
| Pos. Full Scale     | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | -9.920  | +10.000     |
| Pos. Full Scale-LSB | 1  | 1  | 1  | 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 4)



## Typical Applications (Continued)

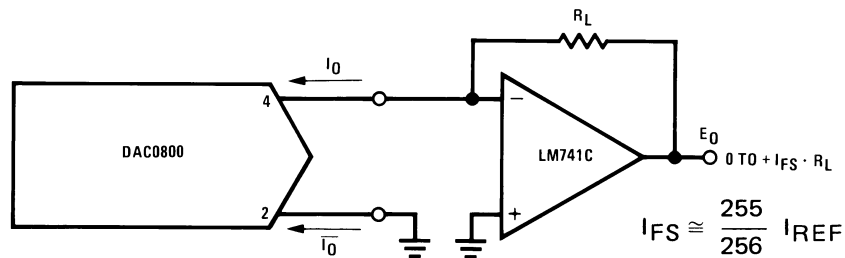


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If  $R_L = \bar{R}_L$  within  $\pm 0.05\%$ , output is symmetrical about ground

|                     | 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 |

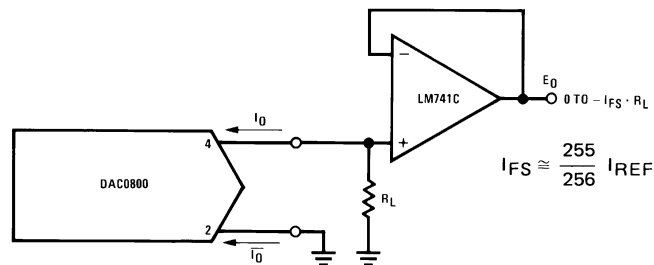
FIGURE 8. Symmetrical Offset Binary Operation (Note 4)



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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 4)

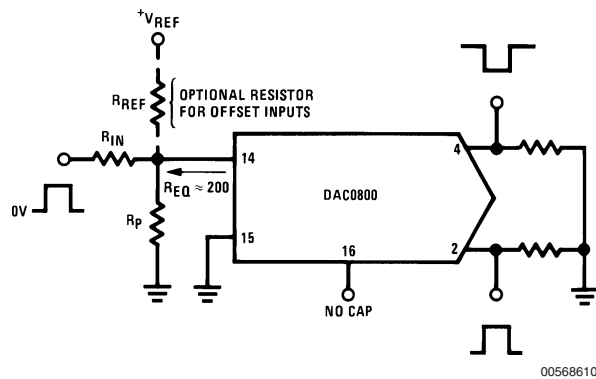


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For complementary output (operation as a negative logic DAC) connect non-inverting input of op am to  $\bar{I}_O$  (pin 2); connect  $I_O$  (pin 4) to ground.

FIGURE 10. Low Impedance Negative Output Operation (Note 4)

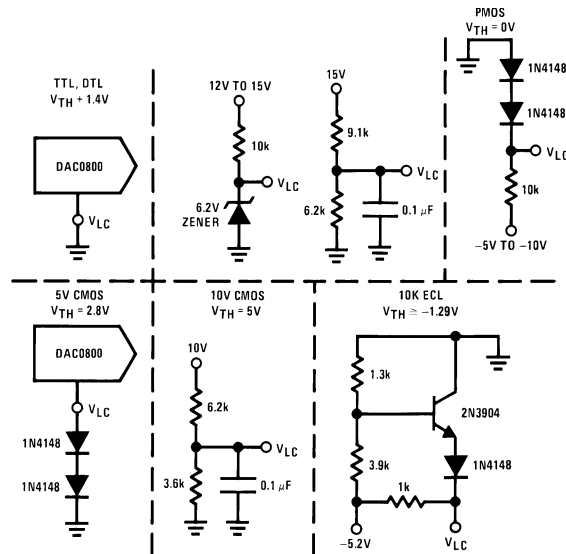
## Typical Applications (Continued)



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

FIGURE 11. Pulsed Reference Operation (Note 4)



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

## Typical Applications (Continued)

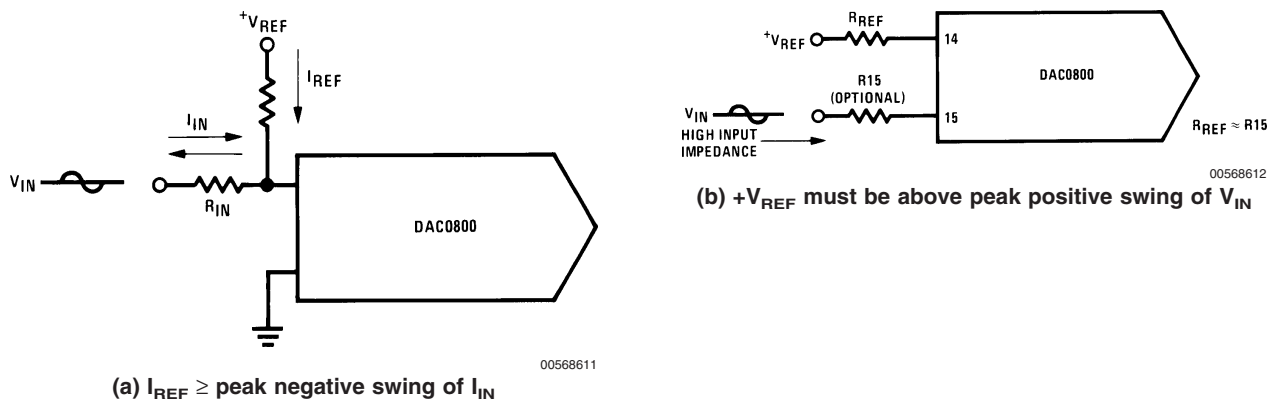


FIGURE 13. Accommodating Bipolar References (Note 4)

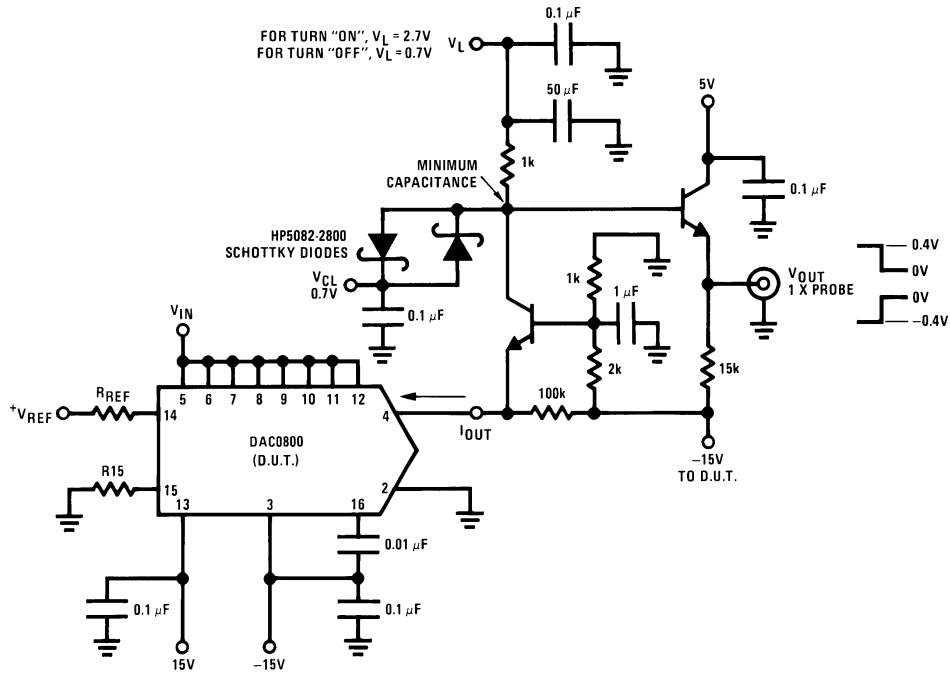
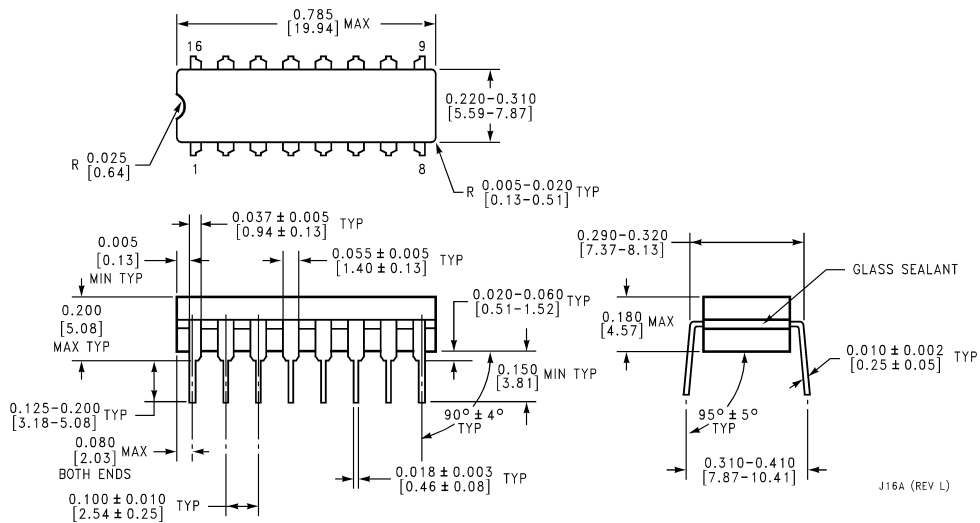


FIGURE 14. Settling Time Measurement (Note 4)

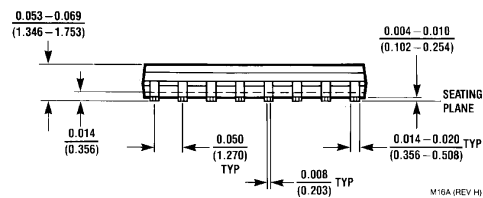
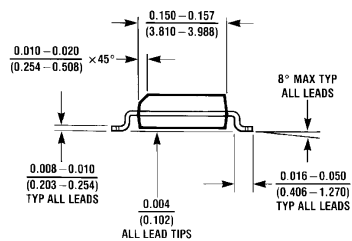
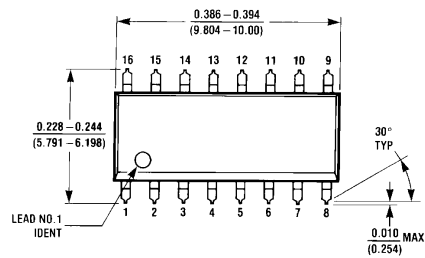


**FIGURE 15. A Complete 2  $\mu$ s Conversion Time, 8-Bit A/D Converter (Note 4)**

# Physical Dimensions inches (millimeters) unless otherwise noted

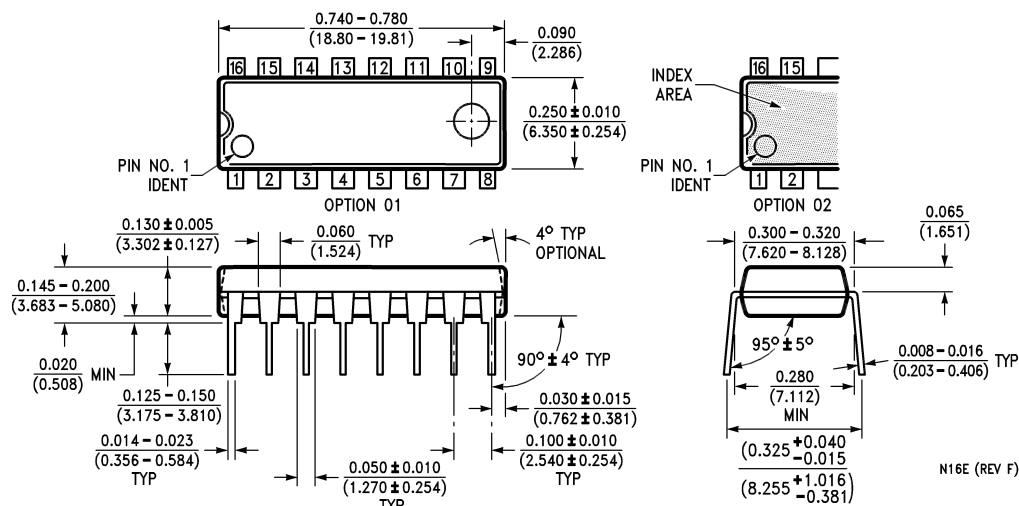


**Molded Small Outline Package (SO)**  
**Order Numbers DAC0800LCM,**  
**or DAC0802LCM**  
**NS Package Number M16A**



**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**

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