

## DAC0800/DAC0801/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 V<sub>p-p</sub> with simple resistor loads as shown in *Figure 1*. 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.

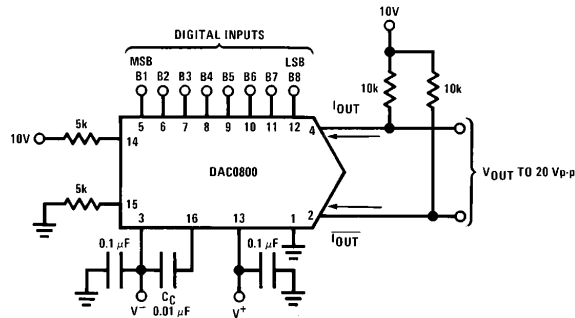
The noise immune inputs of the DAC0800 series will accept TTL levels with the logic threshold pin,  $V_{LC}$ , grounded. Changing the  $V_{LC}$  potential will allow direct interface to other logic families. The performance and characteristics of the device are essentially unchanged over the full  $\pm 4.5V$  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, DAC0801C and DAC0802C are a direct replacement for the DAC-08, DAC-08A, DAC-08C, DAC-08E and DAC-08H, respectively.

### 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  $-10V$  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



TL/H/5686-1

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

### Ordering Information

| Non-Linearity   | Temperature Range                          | Order Numbers     |          |                   |          |                   |
|-----------------|--------------------------------------------|-------------------|----------|-------------------|----------|-------------------|
|                 |                                            | J Package (J16A)* |          | N Package (N16A)* |          | SO Package (M16A) |
| $\pm 0.1\%$ FS  | $0^{\circ}C \leq T_A \leq +70^{\circ}C$    | DAC0802LCJ        | DAC-08HQ | DAC0802LCN        | DAC-08HP | DAC0802LCM        |
| $\pm 0.19\%$ FS | $-55^{\circ}C \leq T_A \leq +125^{\circ}C$ | DAC0800LJ         | DAC-08Q  |                   |          |                   |
| $\pm 0.19\%$ FS | $0^{\circ}C \leq T_A \leq +70^{\circ}C$    | DAC0800LCJ        | DAC-08EQ | DAC0800LCN        | DAC-08EP | DAC0800LCM        |
| $\pm 0.39\%$ FS | $0^{\circ}C \leq T_A \leq +70^{\circ}C$    |                   |          | DAC0801LCN        | DAC-08CP | DAC0801LCM        |

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

## 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 (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 3)                       | TBD V                           |
| Storage Temperature                               | $-65^\circ C$ to $+150^\circ C$ |

Lead Temp. (Soldering, 10 seconds)

Dual-In-Line Package (plastic)  $260^\circ C$

Dual-In-Line Package (ceramic)  $300^\circ C$

Surface Mount Package

Vapor Phase (60 seconds)  $215^\circ C$

Infrared (15 seconds)  $220^\circ C$

## Operating Conditions (Note 1)

|                       | Min   | Max    | Units      |
|-----------------------|-------|--------|------------|
| Temperature ( $T_A$ ) |       |        |            |
| DAC0800L              | $-55$ | $+125$ | $^\circ C$ |
| DAC0800LC             | 0     | $+70$  | $^\circ C$ |
| DAC0801LC             | 0     | $+70$  | $^\circ C$ |
| DAC0802LC             | 0     | $+70$  | $^\circ C$ |

**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 |                 |               | DAC0801LC |                 |               | Units              |
|--------------------------|----------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------|-----------------|---------------|------------------------|-----------------|---------------|-----------|-----------------|---------------|--------------------|
|                          |                                                    |                                                                                                       | 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               |
|                          | Nonlinearity                                       |                                                                                                       |           |                 | $\pm 0.1$     |                        |                 | $\pm 0.19$    |           |                 | $\pm 0.39$    | %FS                |
| $t_s$                    | Settling Time                                      | To $\pm 1/2$ LSB, All Bits Switched "ON" or "OFF", $T_A = 25^\circ C$<br>DAC0800L<br>DAC0800LC        |           | 100             | 135           |                        |                 |               |           | 100             | 150           | ns                 |
|                          |                                                    |                                                                                                       |           |                 |               |                        | 100             | 135           |           |                 |               | ns                 |
|                          |                                                    |                                                                                                       |           |                 |               |                        | 100             | 150           |           |                 |               | ns                 |
| $t_{PLH}$ ,<br>$t_{PHL}$ | Propagation Delay<br>Each Bit<br>All Bits Switched | $T_A = 25^\circ C$                                                                                    |           | 35              | 60            |                        | 35              | 60            |           | 35              | 60            | ns                 |
|                          |                                                    |                                                                                                       |           | 35              | 60            |                        | 35              | 60            |           | 35              | 60            | ns                 |
| $TC_{IFS}$               | Full Scale Tempco                                  |                                                                                                       |           | $\pm 10$        | $\pm 50$      |                        | $\pm 10$        | $\pm 50$      |           | $\pm 10$        | $\pm 80$      | ppm/ $^\circ C$    |
| $V_{OC}$                 | Output Voltage Compliance                          | Full Scale Current Change $< 1/2$ LSB, $R_{OUT} > 20$ M $\Omega$ Typ                                  | $-10$     |                 | 18            | $-10$                  |                 | 18            | $-10$     |                 | 18            | V                  |
| $I_{FS4}$                | Full Scale Current                                 | $V_{REF} = 10.000V$ , $R_{14} = 5.000$ k $\Omega$<br>$R_{15} = 5.000$ k $\Omega$ , $T_A = 25^\circ C$ | 1.984     | 1.992           | 2.000         | 1.94                   | 1.99            | 2.04          | 1.94      | 1.99            | 2.04          | mA                 |
| $I_{FSS}$                | Full Scale Symmetry                                | $I_{FS4} - I_{FS2}$                                                                                   |           | $\pm 0.5$       | $\pm 4.0$     |                        | $\pm 1$         | $\pm 8.0$     |           | $\pm 2$         | $\pm 16$      | $\mu A$            |
| $I_{ZS}$                 | Zero Scale Current                                 |                                                                                                       |           | 0.1             | 1.0           |                        | 0.2             | 2.0           |           | 0.2             | 4.0           | $\mu A$            |
| $I_{FSR}$                | Output Current Range                               | $V^- = -5V$                                                                                           | 0         | 2.0             | 2.1           | 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           | 0         | 2.0             | 4.2           | mA                 |
| $V_{IL}$<br>$V_{IH}$     | Logic Input Levels<br>Logic "0"<br>Logic "1"       | $V_{LC} = 0V$                                                                                         | 2.0       |                 | 0.8           | 2.0                    |                 | 0.8           | 2.0       |                 | 0.8           | V                  |
| $I_{IL}$<br>$I_{IH}$     | Logic Input Current<br>Logic "0"<br>Logic "1"      | $V_{LC} = 0V$<br>$-10V \leq V_{IN} \leq +0.8V$<br>$2V \leq V_{IN} \leq +18V$                          |           | $-2.0$<br>0.002 | $-10$<br>10   |                        | $-2.0$<br>0.002 | $-10$<br>10   |           | $-2.0$<br>0.002 | $-10$<br>10   | $\mu A$<br>$\mu A$ |
| $V_{IS}$                 | Logic Input Swing                                  | $V^- = -15V$                                                                                          | $-10$     |                 | 18            | $-10$                  |                 | 18            | $-10$     |                 | 18            | V                  |
| $V_{THR}$                | Logic Threshold Range                              | $V_S = \pm 15V$                                                                                       | $-10$     |                 | 13.5          | $-10$                  |                 | 13.5          | $-10$     |                 | 13.5          | V                  |
| $I_{15}$                 | Reference Bias Current                             |                                                                                                       |           | $-1.0$          | $-3.0$        |                        | $-1.0$          | $-3.0$        |           | $-1.0$          | $-3.0$        | $\mu A$            |
| $dl/dt$                  | Reference Input Slew Rate                          | (Figure 12)                                                                                           | 4.0       | 8.0             |               | 4.0                    | 8.0             |               | 4.0       | 8.0             |               | mA/ $\mu s$        |
| $PSSI_{FS+}$             | Power Supply Sensitivity                           | $4.5V \leq V^+ \leq 18V$                                                                              |           | 0.0001          | 0.01          |                        | 0.0001          | 0.01          |           | 0.0001          | 0.01          | %/%                |
| $PSSI_{FS-}$             |                                                    | $-4.5V \leq V^- \leq 18V$<br>$I_{REF} = 1mA$                                                          |           | 0.0001          | 0.01          |                        | 0.0001          | 0.01          |           | 0.0001          | 0.01          | %/%                |
| $I^+$<br>$I^-$           | Power Supply Current                               | $V_S = \pm 5V$ , $I_{REF} = 1$ mA                                                                     |           | 2.3<br>$-4.3$   | 3.8<br>$-5.8$ |                        | 2.3<br>$-4.3$   | 3.8<br>$-5.8$ |           | 2.3<br>$-4.3$   | 3.8<br>$-5.8$ | mA<br>mA           |
|                          |                                                    | $V_S = 5V$ , $-15V$ , $I_{REF} = 2$ mA                                                                |           | 2.4<br>$-6.4$   | 3.8<br>$-7.8$ |                        | 2.4<br>$-6.4$   | 3.8<br>$-7.8$ |           | 2.4<br>$-6.4$   | 3.8<br>$-7.8$ | mA<br>mA           |
| $I^+$<br>$I^-$           |                                                    | $V_S = \pm 15V$ , $I_{REF} = 2$ mA                                                                    |           | 2.5<br>$-6.5$   | 3.8<br>$-7.8$ |                        | 2.5<br>$-6.5$   | 3.8<br>$-7.8$ |           | 2.5<br>$-6.5$   | 3.8<br>$-7.8$ | mA<br>mA           |

## 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  $\bar{I}_{OUT}$ .

| Symbol | Parameter         | Conditions                              | DAC0802LC |     |     | DAC0800L/<br>DAC0800LC |     |     | DAC0801LC |     |     | Units |
|--------|-------------------|-----------------------------------------|-----------|-----|-----|------------------------|-----|-----|-----------|-----|-----|-------|
|        |                   |                                         | Min       | Typ | Max | Min                    | Typ | Max | Min       | Typ | Max |       |
| $P_D$  | Power Dissipation | $\pm 5V$ , $I_{REF} = 1\text{ mA}$      |           | 33  | 48  |                        | 33  | 48  |           | 33  | 48  | mW    |
|        |                   | $5V$ , $-15V$ , $I_{REF} = 2\text{ mA}$ |           | 108 | 136 |                        | 108 | 136 |           | 108 | 136 | mW    |
|        |                   | $\pm 15V$ , $I_{REF} = 2\text{ mA}$     |           | 135 | 174 |                        | 135 | 174 |           | 135 | 174 | mW    |

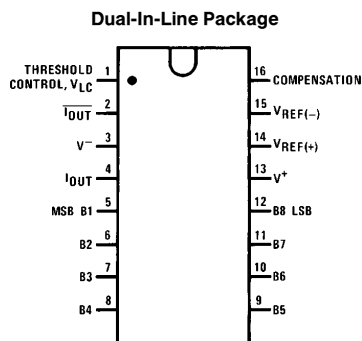
**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its specified operating conditions.

**Note 2:** The maximum junction temperature of the DAC0800, DAC0801 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  $100^\circ\text{C/W}$ , junction-to-ambient,  $175^\circ\text{C/W}$  for the molded Dual-In-Line N package and  $100^\circ\text{C/W}$  for the Small Outline M package.

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

**Note 4:** 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.

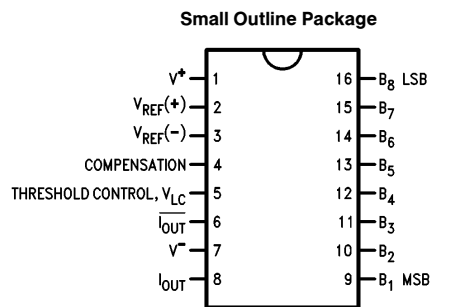
## Connection Diagrams



Top View

TL/H/5686-13

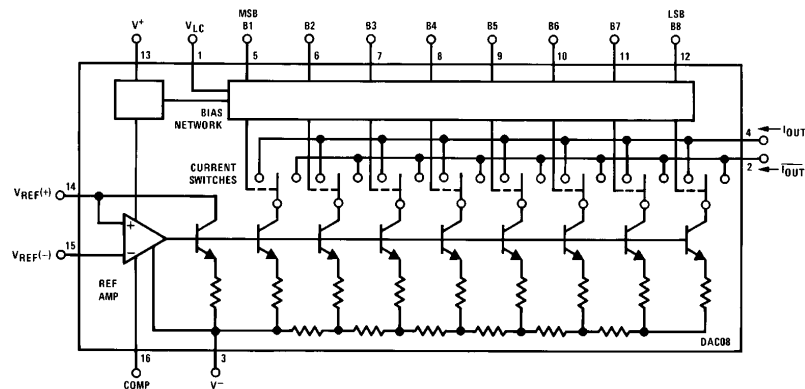
See Ordering Information



Top View

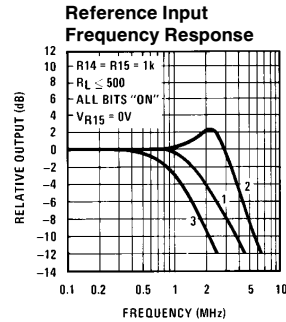
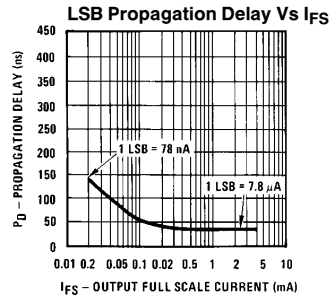
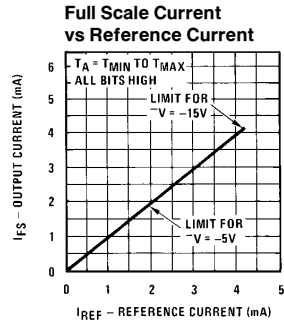
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## Block Diagram (Note 4)



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## Typical Performance Characteristics

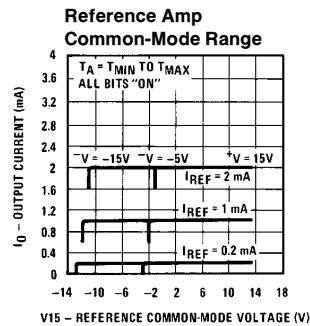


Curve 1:  $C_C = 15$  pF,  $V_{IN} = 2$  Vp-p

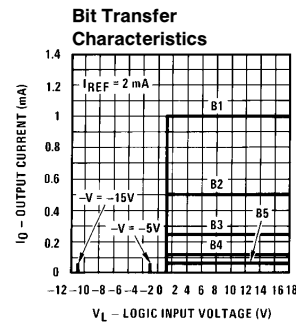
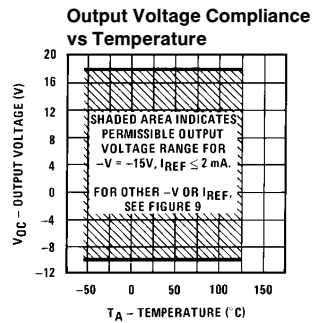
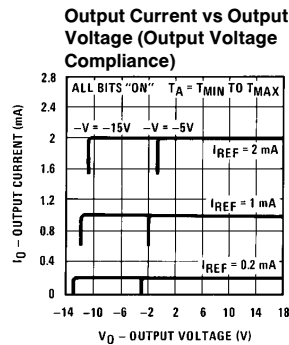
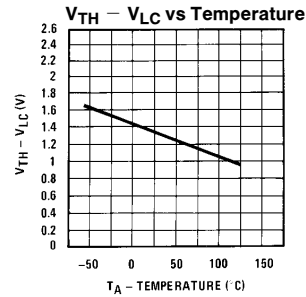
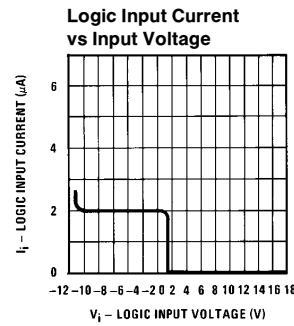
centered at 1V.

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 at 0V and applied through 50  $\Omega$  connected to pin 14.2V applied to R14.



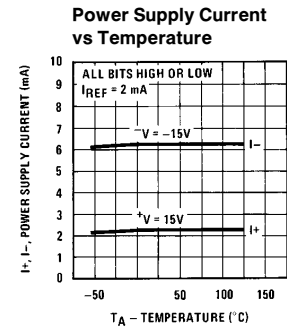
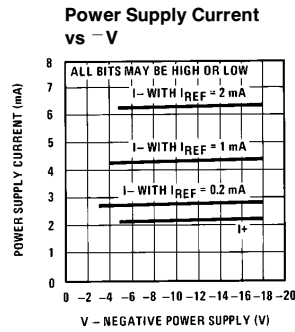
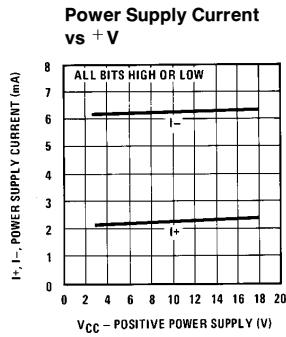
Note. Positive common-mode range is always  $(V+) - 1.5V$



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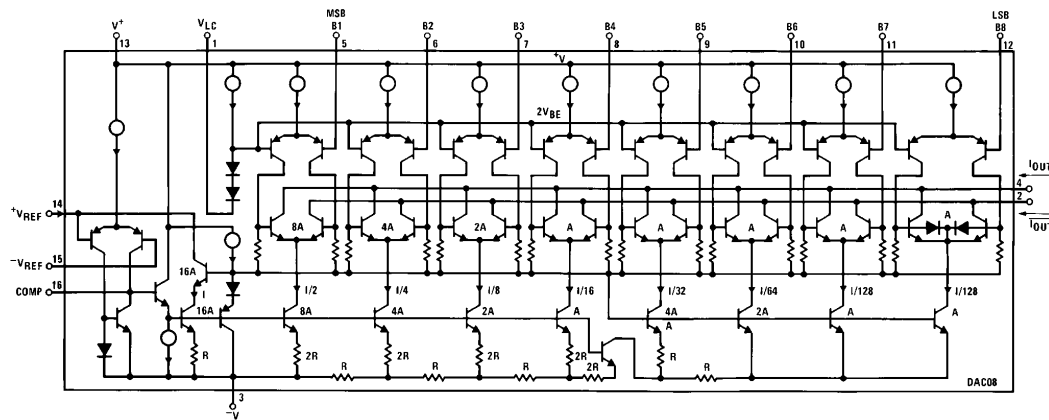
Note. B1-B8 have identical transfer characteristics. Bits are fully switched with less than  $\frac{1}{2}$  LSB error, at less than  $\pm 100$  mV from actual threshold. These switching points are guaranteed to lie between 0.8 and 2V over the operating temperature range ( $V_{LC} = 0V$ ).

## Typical Performance Characteristics (Continued)



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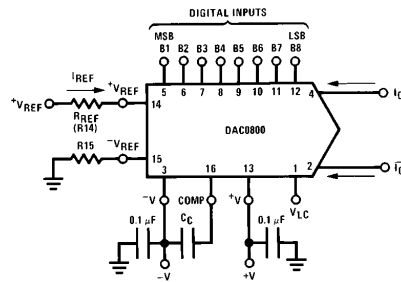
## Equivalent Circuit



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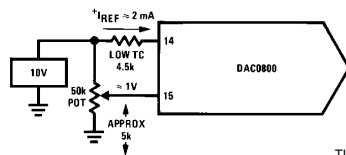
FIGURE 2

## Typical Applications (Continued)



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FIGURE 3. Basic Positive Reference Operation (Note 4)



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

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

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

For fixed reference, TTL operation, typical values are:

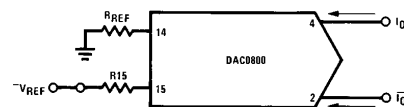
$$V_{REF} = 10.000V$$

$$R_{REF} = 5.000k$$

$$R_{15} \approx R_{REF}$$

$$C_C = 0.01 \mu F$$

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



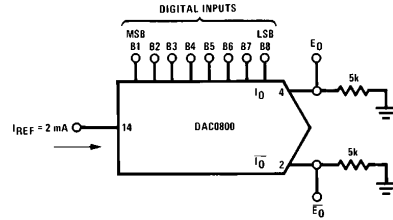
TL/H/5686-16

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

Note:  $R_{REF}$  sets  $I_{FS}$ ;  $R_{15}$  is for bias current cancellation

FIGURE 5. Basic Negative Reference Operation (Note 4)

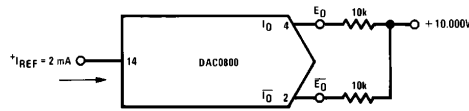
## Typical Applications (Continued)



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|                  | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | I <sub>0</sub> mA | I <sub>0</sub> mA | E <sub>0</sub> | E <sub>0</sub> |
|------------------|----|----|----|----|----|----|----|----|-------------------|-------------------|----------------|----------------|
| 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         |

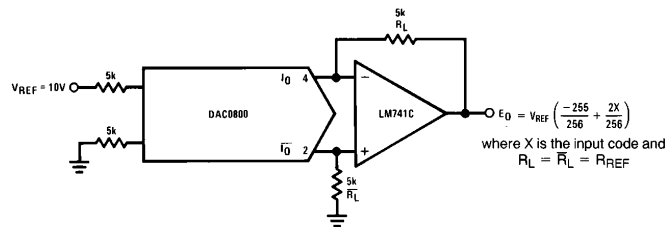
FIGURE 6. Basic Unipolar Negative Operation (Note 4)



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|                       | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | E <sub>0</sub> | E <sub>0</sub> |
|-----------------------|----|----|----|----|----|----|----|----|----------------|----------------|
| 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)



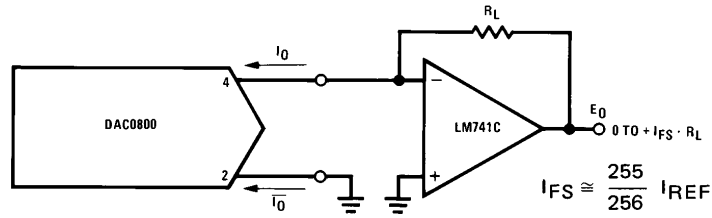
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If  $R_L = \bar{R}_L$  within  $\pm 0.05\%$ , output is symmetrical about ground

|                       | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | E <sub>0</sub> |
|-----------------------|----|----|----|----|----|----|----|----|----------------|
| 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)

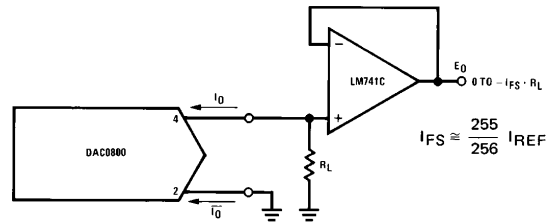
## Typical Applications (Continued)



TL/H/5686-19

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

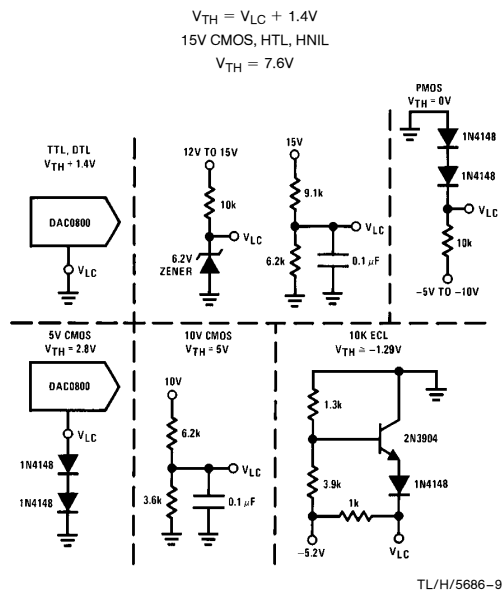
**FIGURE 9. Positive Low Impedance Output Operation (Note 4)**



TL/H/5686-20

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

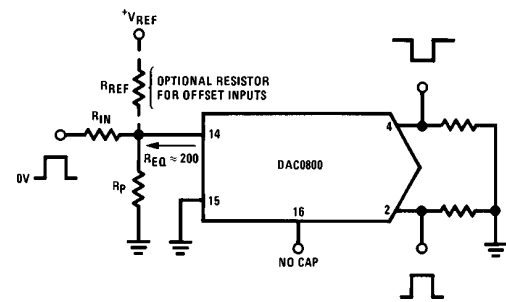
**FIGURE 10. Negative Low Impedance Output Operation (Note 4)**



TL/H/5686-9

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

**FIGURE 11. Interfacing with Various Logic Families**



TL/H/5686-10

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

**FIGURE 12. Pulsed Reference Operation (Note 4)**

## Typical Applications (Continued)

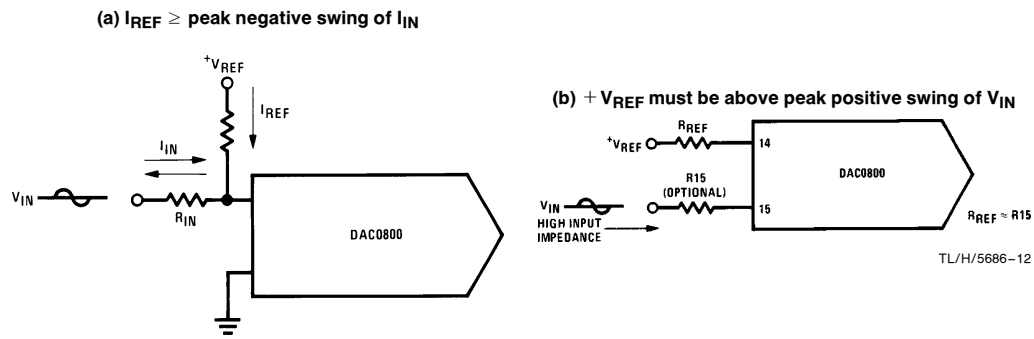


FIGURE 13. Accommodating Bipolar References (Note 4)

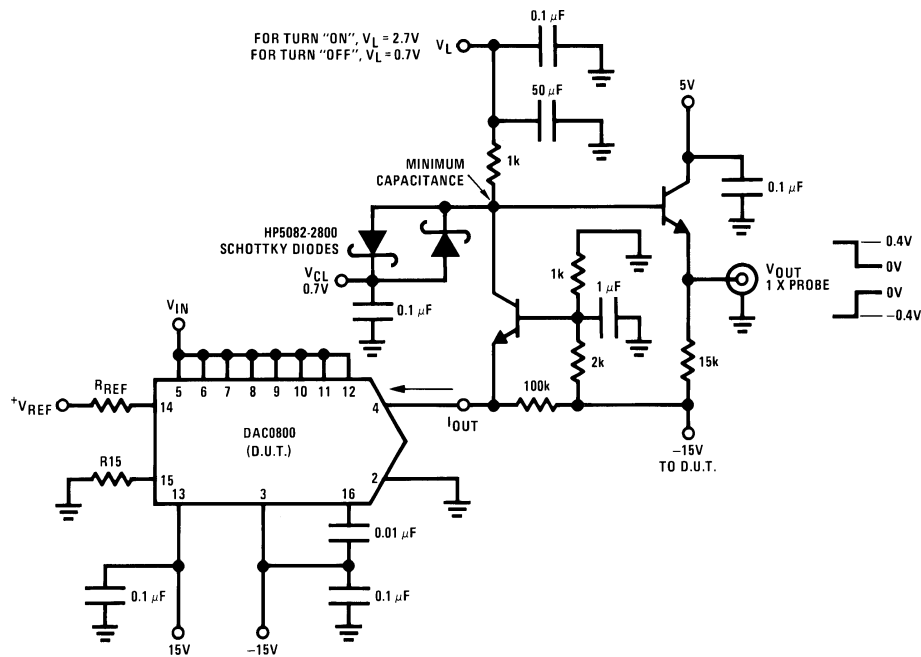


FIGURE 14. Settling Time Measurement (Note 4)

[illegible]

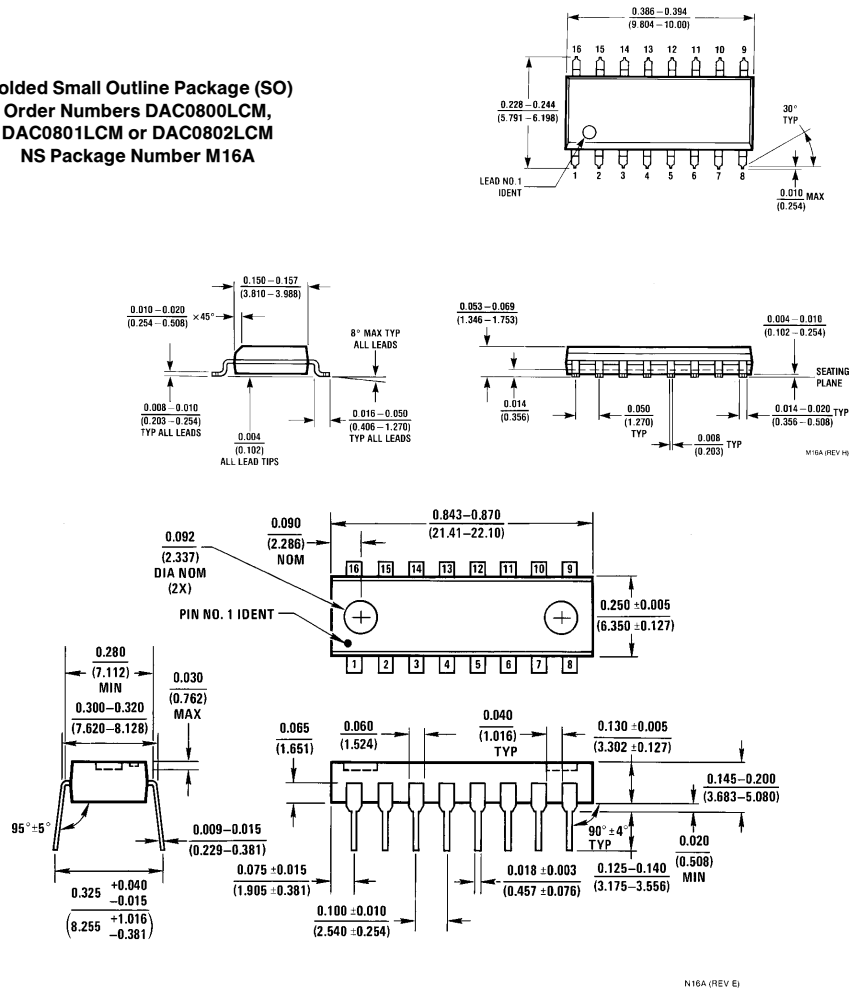
TL/H/5686-8

[illegible]

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# Physical Dimensions inches (millimeters) (Continued)

**Molded Small Outline Package (SO)**  
**Order Numbers DAC0800LCM,**  
**DAC0801LCM or DAC0802LCM**  
**NS Package Number M16A**



**Molded Dual-In-Line Package**  
**Order Numbers DAC0800, DAC0801, DAC0802**  
**NS Package Number N16A**

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