September 2006

National Semiconductor

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 ±1 LSB eliminates the need for full-scale trims in most applications, while the nonlinearities of better than ±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 ±4.5V to ±18V power supply range and power consumption at only 33 mW with ±5V 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: ±1 LSB
- Nonlinearity over temperature: ±0.1%
- Full scale current drift: ±10 ppm/˚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: ±4.5V to ±18V
- Low power consumption: 33 mW at ±5V
- Low cost

Typical Application

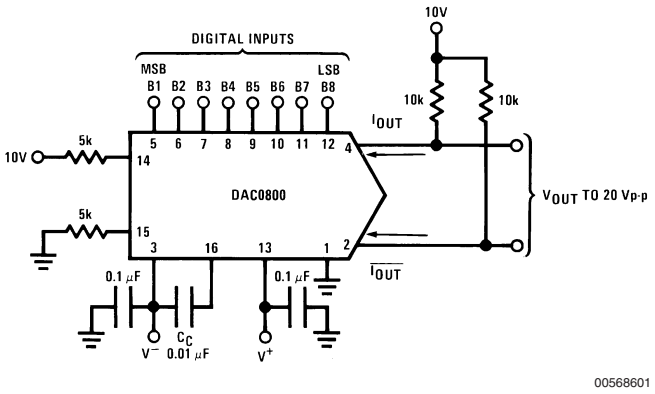


FIGURE 1. ±20 V_{P-P} Output Digital-to-Analog Converter (Note 4)

Ordering Information

Non-Linearity	Temperature Range (T_A)	Order Numbers				
		J Package (J16A) *		N Package (N16E) *		SO Package (M16A)
±0.1% FS	0˚C to +70˚C	DAC0802LCJ	DAC-08HQ	DAC0802LCN	DAC-08HP	DAC0802LCM
±0.19% FS	−55˚C to +125˚C	DAC0800LJ	DAC-08Q			
±0.19% FS	0˚C to +70˚C	DAC0800LCJ	DAC-08EQ	DAC0800LCN	DAC-08EP	DAC0800LCM

* 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 ($V^+ - V^-$)	±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˚C to +150˚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 1)

	Min	Max	Units
Temperature (T_A)			
DAC0800L	−55	+125	˚C
DAC0800LC	0	+70	˚C
DAC0802LC	0	+70	˚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 = ±15V, I_{REF} = 2 mA and $T_{MIN} \le T_A \le T_{MAX}$ 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	
	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 ±½ LSB, All Bits Switched "ON" or "OFF", T_A=25˚C		100	135				ns
		DAC0800L					100	135	ns
		DAC0800LC					100	150	ns
t_{PLH}, t_{PHL}	Propagation Delay	T_A=25˚C							
	Each Bit			35	60		35	60	ns
	All Bits Switched			35	60		35	60	ns
TCI_{FS}	Full Scale Tempco			±10	±50		±10	±50	ppm/˚C
V_{OC}	Output Voltage Compliance	Full Scale Current Change <½ LSB, R_{OUT}>20 MΩ, Typical	−10		18	−10		18	V
I_{FS4}	Full Scale Current	V_{REF} = 10.000V, R14 = R15 = 5.000 kΩ, T_A=25˚C	1.984	1.992	2.00	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	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 = ±15V, I_{REF} = 2 mA and $T_{MIN} \le T_A \le T_{MAX}$ 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	
	Logic Input Levels	V_{LC} = 0V							
V_{IL}	Logic "0"				0.8			0.8	V
V_{IH}	Logic "1"		2.0			2.0			V
	Logic Input Current	V_{LC} = 0V							
I_{IL}	Logic "0"	$-10V \le V_{IN} \le +0.8V$		−2.0	−10		−2.0	−10	µA
I_{IH}	Logic "1"	$2V \le V_{IN} \le +18V$		0.002	10		0.002	10	µA
V_{IS}	Logic Input Swing	V^- = −15V	−10		18	−10		18	V
V_{THR}	Logic Threshold Range	V_S = ±15V	−10		13.5	−10		13.5	V
I_{15}	Reference Bias Current			−1.0	−3.0		−1.0	−3.0	µA
dI/dt	Reference Input Slew Rate	(*Figure 11*)	4.0	8.0		4.0	8.0		mA/µs
$PSSI_{FS+}$	Positive Power Supply Sensitivity	$4.5V \le V^+ \le 18V$		0.0001	0.01		0.0001	0.01	%/%
$PSSI_{FS-}$	Negative Power Supply Sensitivity	$-4.5V \le V^- \le 18V$, I_{REF} = 1mA		0.0001	0.01		0.0001	0.01	%/%
I+	Power Supply Current	V_S = ±5V, I_{REF} = 1 mA		2.3	3.8		2.3	3.8	mA
I−				−4.3	−5.8		−4.3	−5.8	mA
I+	Power Supply Current	V_S = +5V, −15V, I_{REF} = 2 mA		2.4	3.8		2.4	3.8	mA
I−				−6.4	−7.8		−6.4	−7.8	mA
I+	Power Supply Current	V_S = ±15V, I_{REF} = 2 mA		2.5	3.8		2.5	3.8	mA
I−				−6.5	−7.8		−6.5	−7.8	mA
P_D	Power Consumption	±5V, I_{REF} = 1 mA		33	48		33	48	mW
		+5V, −15V, I_{REF} = 2 mA		108	136		108	136	mW
		±15V, I_{REF} = 2 mA		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.

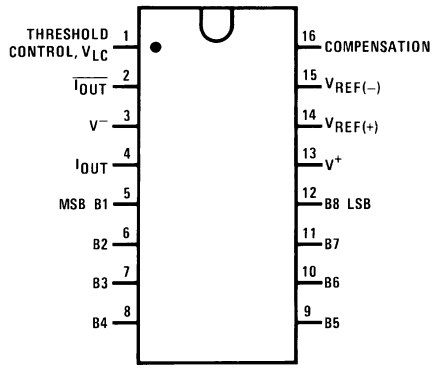
Note 2: The maximum junction temperature of the DAC0800 and DAC0802 is 125˚C. For operating at elevated temperatures, devices in the Dual-In-Line J package must be derated based on a thermal resistance of 100˚C/W, junction-to-ambient, 175˚C/W for the molded Dual-In-Line N package and 100˚C/W for the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

Note 3: Human body model, 100 pF discharged through a 1.5 kΩ 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



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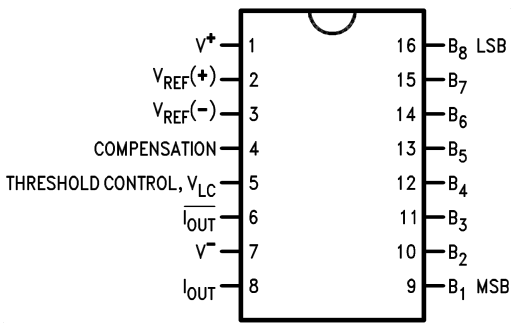
Top View

Small Outline Package



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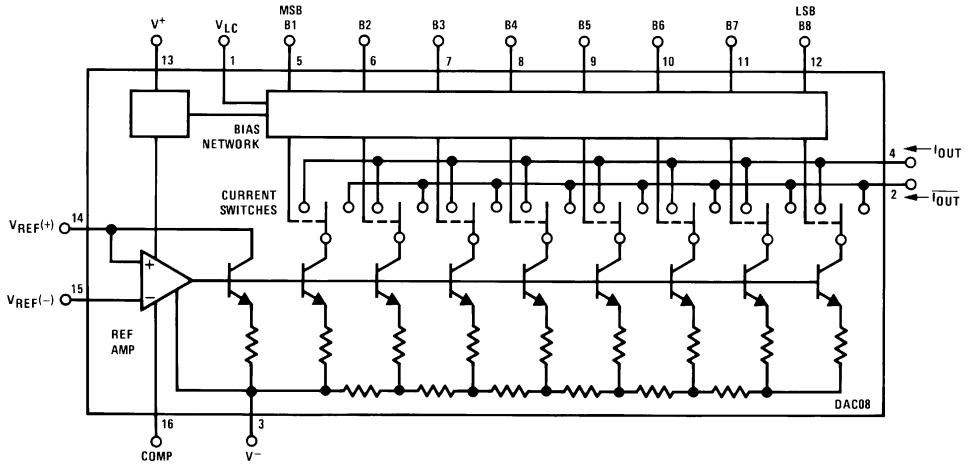
Top View

See Ordering Information

Block Diagram (Note 4)



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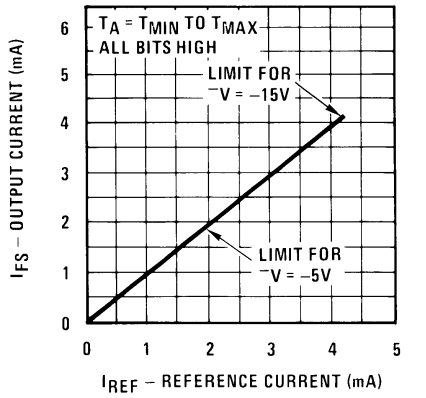
Typical Performance Characteristics

Full Scale Current vs. Reference Current



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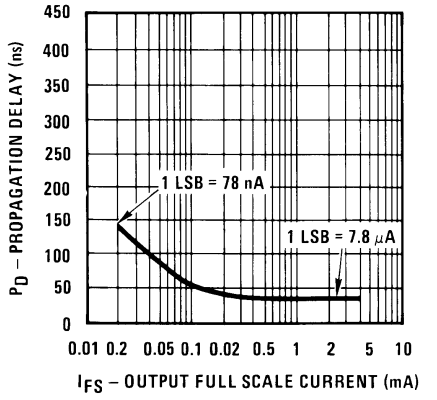
LSB Propagation Delay vs. I_{FS}



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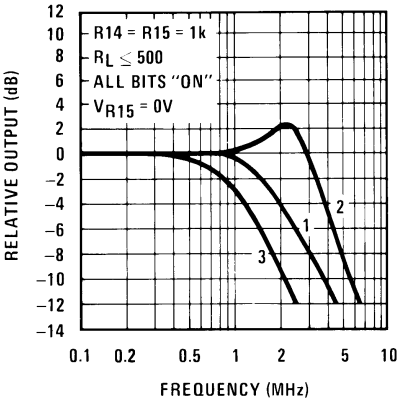
Reference Input Frequency Response



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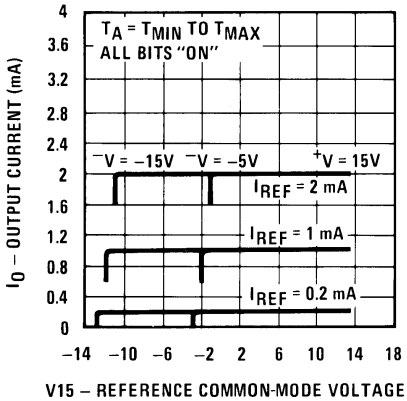
Curve 1: C_C=15 pF, V_{IN}=2 Vp-p centered at 1V.

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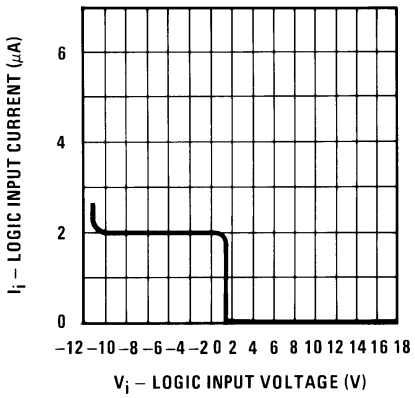
Note. Positive common-mode range is always (V+) – 1.5V.

Typical Performance Characteristics (Continued)

Logic Input Current vs. Input Voltage



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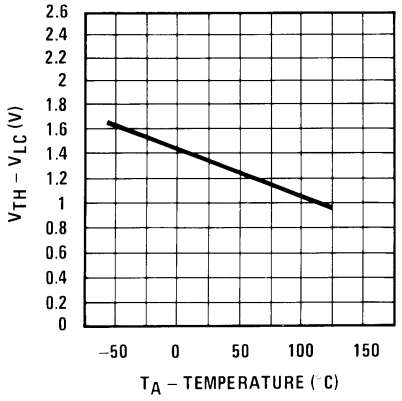
V_{TH} — V_{LC} vs. Temperature



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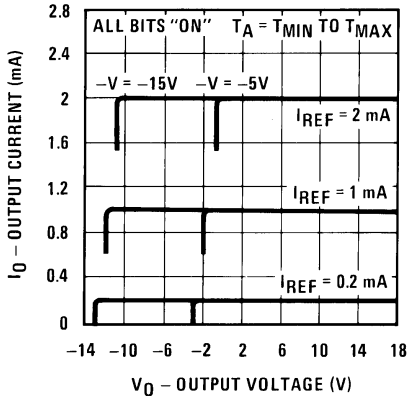
Output Current vs. Output Voltage (Output Voltage Compliance)



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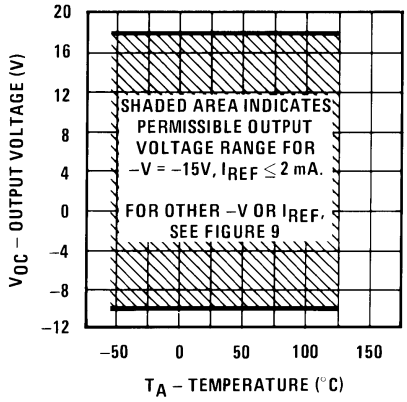
Output Voltage Compliance vs. Temperature



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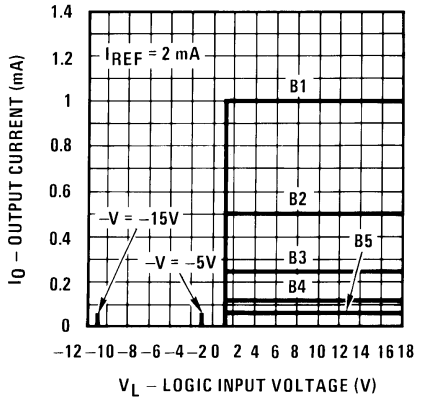
Bit Transfer Characteristics



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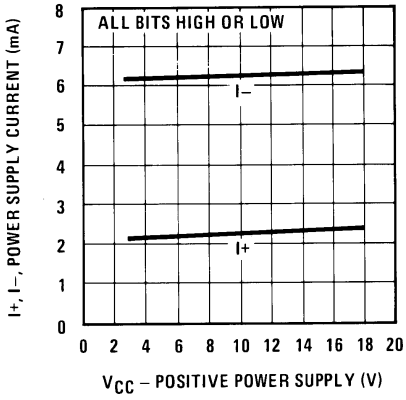
Power Supply Current vs. +V



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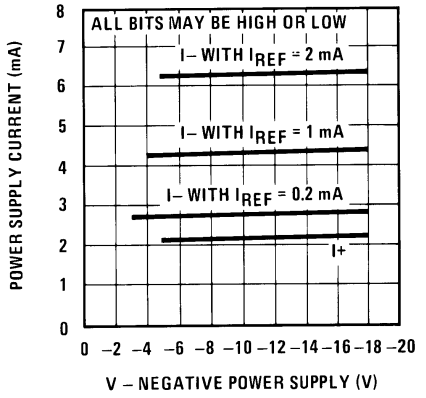
Note. B1–B8 have identical transfer characteristics. Bits are fully switched with less than ½ LSB error, at less than ±100 mV from actual threshold. These switching points are guaranteed to lie between 0.8 and 2V over the operating temperature range (V_{LC} = 0V).

Typical Performance Characteristics (Continued)

Power Supply Current vs. –V



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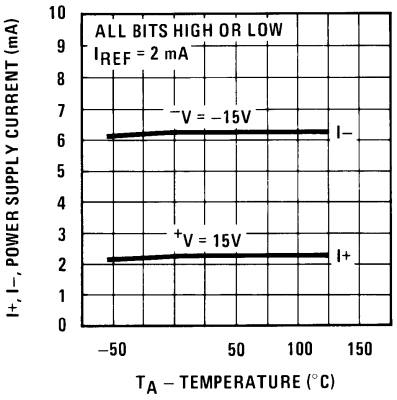
Power Supply Current vs. Temperature



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Equivalent Circuit

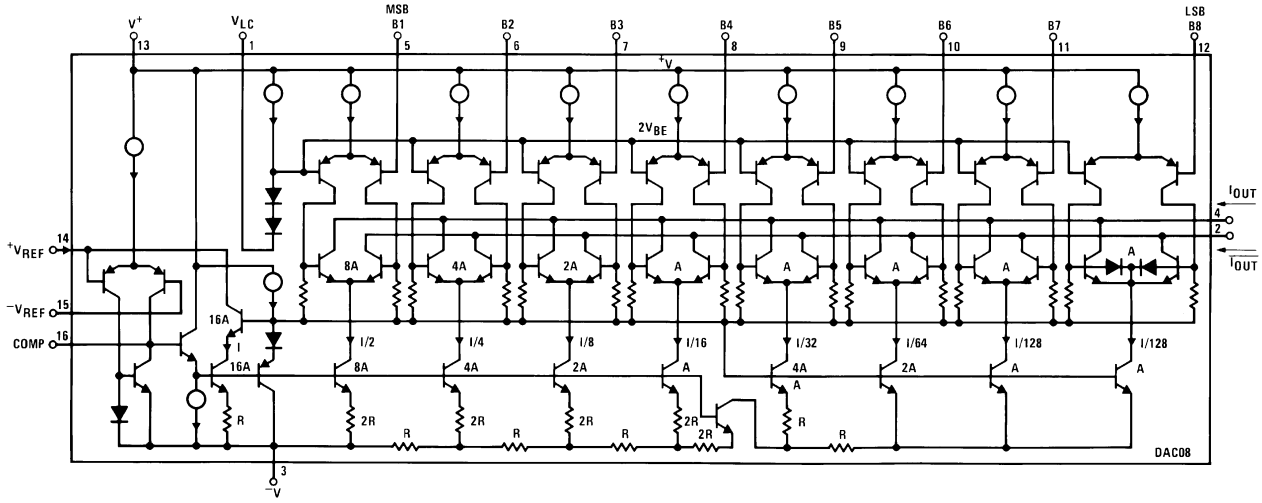

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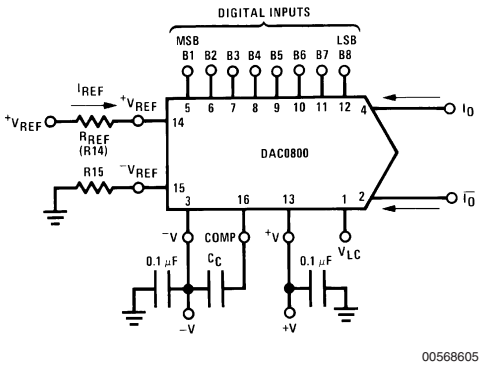
FIGURE 2. Equivalent Circuit

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:

$V_{REF} = 10.000V$

$R_{REF} = 5.000k$

$R15 \approx R_{REF}$

$C_C = 0.01\ \mu F$

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

FIGURE 3. Basic Positive Reference Operation (Note 4)

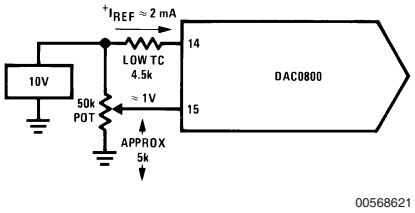
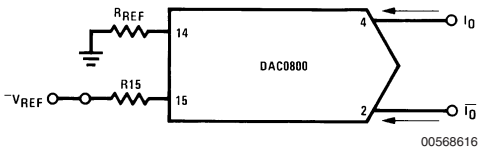


FIGURE 4. Recommended Full Scale Adjustment Circuit (Note 4)

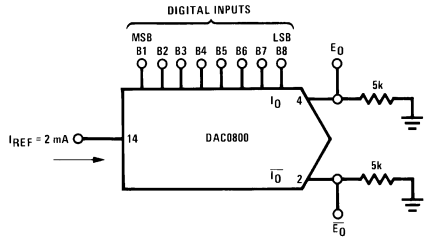


$$I_{FS} \approx \frac{-V_{REF}}{R_{REF}} \times \frac{255}{256}$$

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

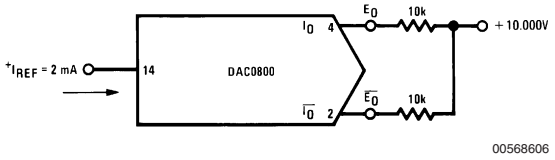
FIGURE 5. Basic Negative Reference Operation (Note 4)

Typical Applications (Continued)



	B1	B2	B3	B4	B5	B6	B7	B8	I_O mA	$\overline{I}_O$mA	E_O	$\overline{E}_O$
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

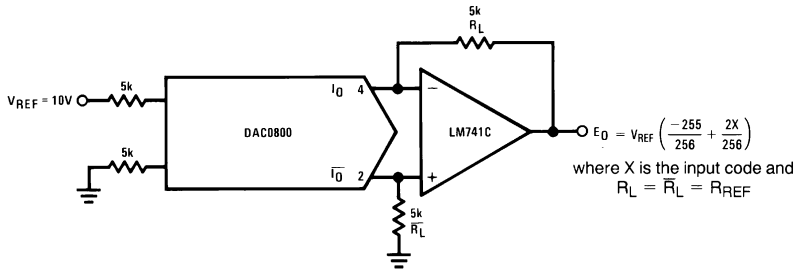
FIGURE 6. Basic Unipolar Negative Operation (Note 4)



	B1	B2	B3	B4	B5	B6	B7	B8	E_O	$\overline{E}_O$
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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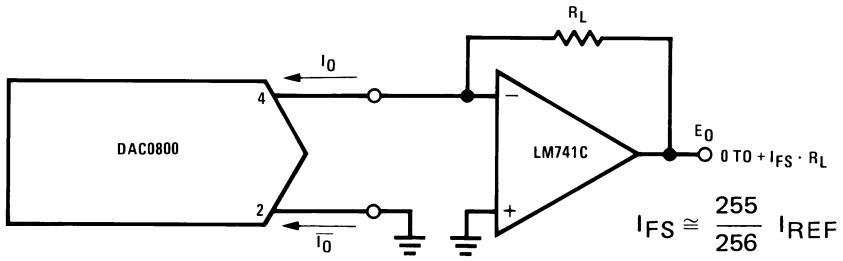
If $R_L = \overline{R}_L$ within ±0.05%, output is symmetrical about ground

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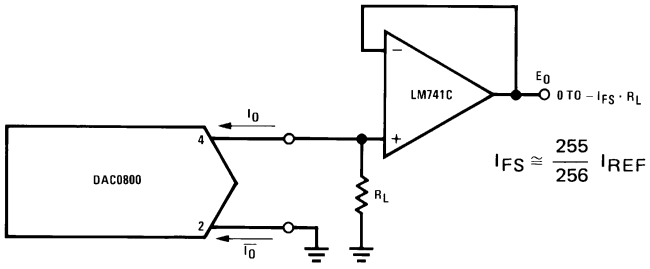
For complementary output (operation as negative logic DAC), connect inverting input of op amp to $\overline{I}_O$ (pin 2), connect I_O (pin 4) to ground.

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



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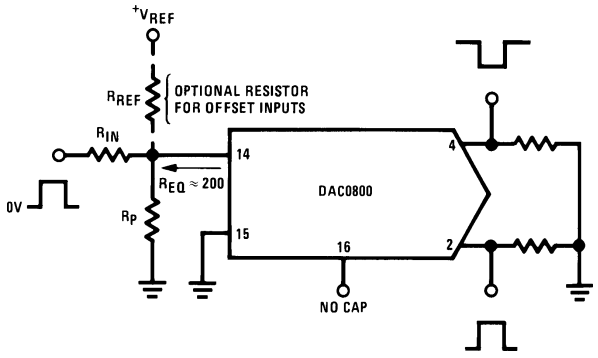
For complementary output (operation as a negative logic DAC) connect non-inverting input of op am to $\overline{I}_O$ (pin 2); connect I_O (pin 4) to ground.

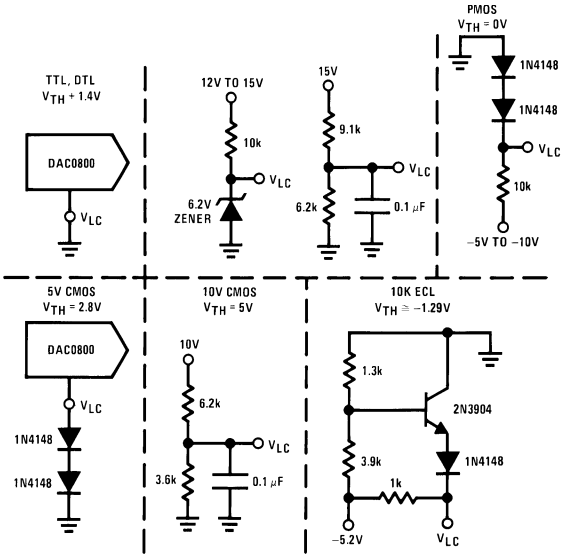
FIGURE 10. Low Impedance Negative Output Operation (Note 4)

Typical Applications (Continued)



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

FIGURE 11. Pulsed Reference Operation (Note 4)



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

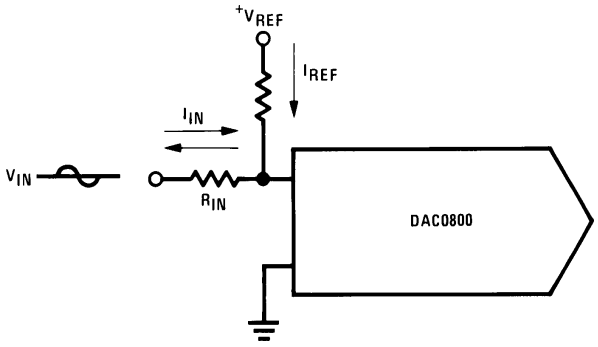
15V CMOS, HTL, HNIL

V_{TH} = 7.6V

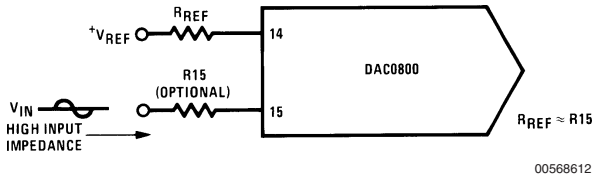
Note. Do not exceed negative logic input range of DAC.

FIGURE 12. Interfacing with Various Logic Families

Typical Applications (Continued)



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



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

FIGURE 13. Accommodating Bipolar References (Note 4)

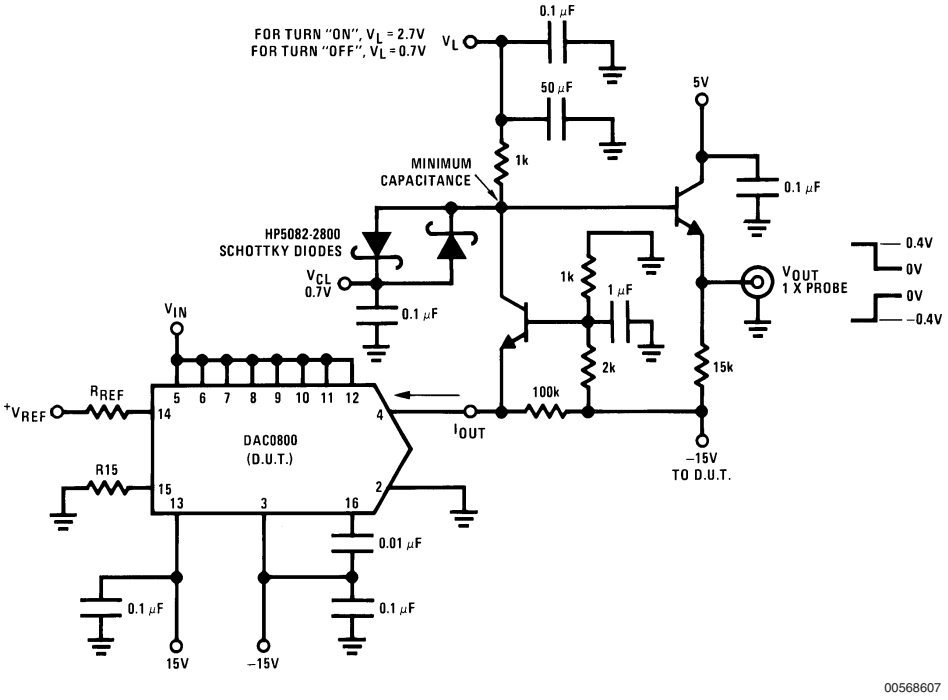
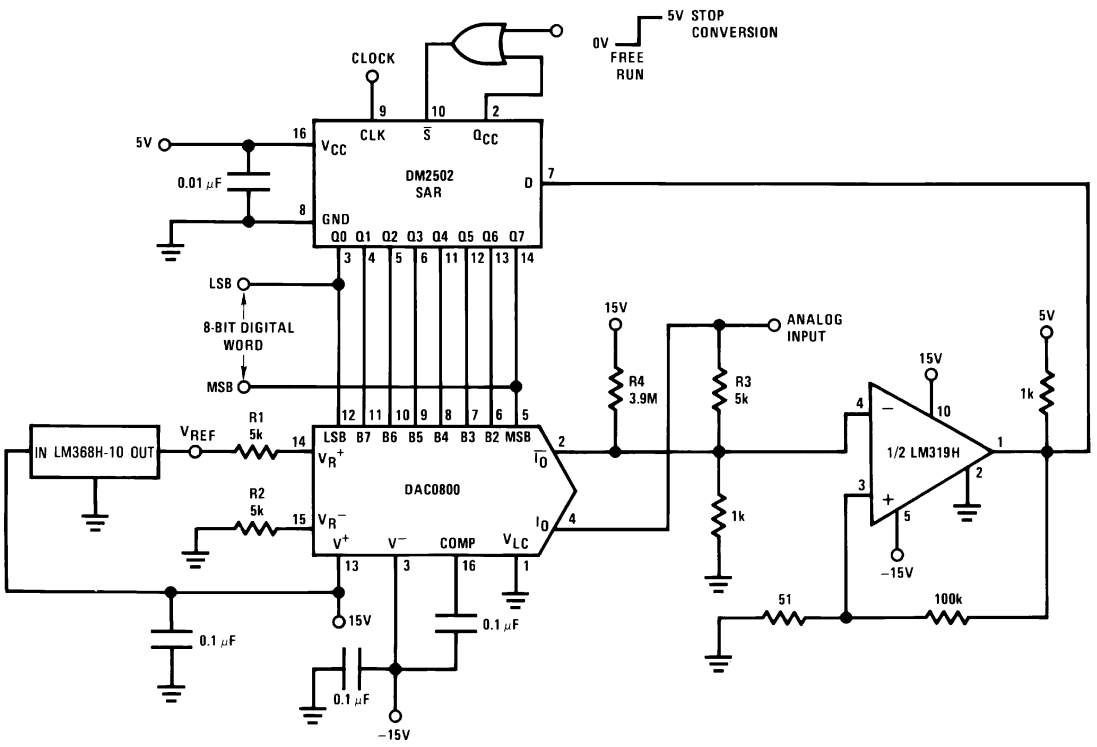


FIGURE 14. Settling Time Measurement (Note 4)

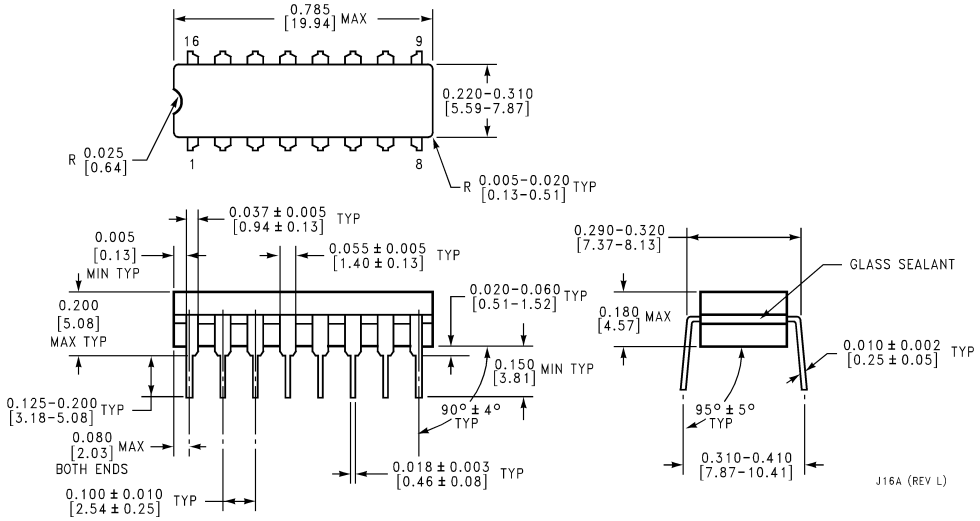
Typical Applications (Continued)



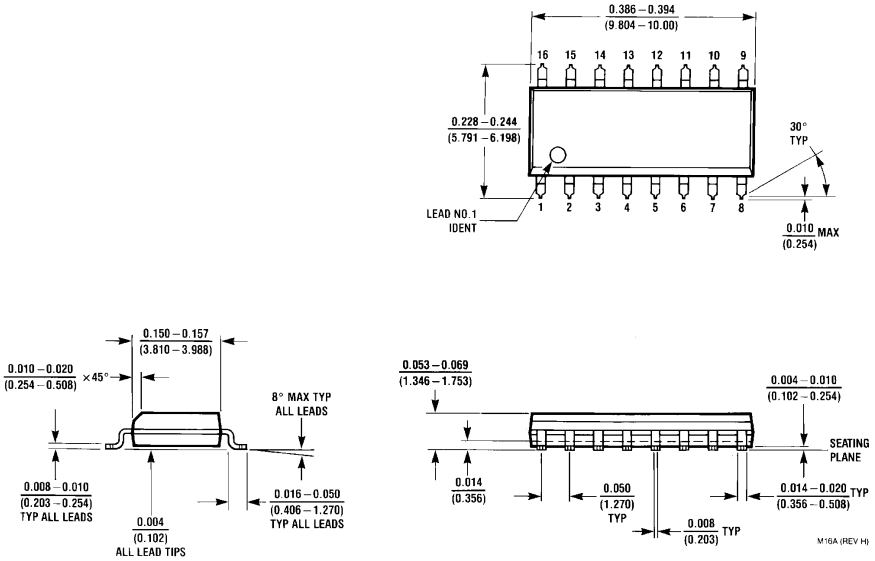
Note. For 1 µs conversion time with 8-bit resolution and 7-bit accuracy, an LM361 comparator replaces the LM319 and the reference current is doubled by reducing R1, R2 and R3 to 2.5 kΩ and R4 to 2 MΩ.

FIGURE 15. A Complete 2 µs Conversion Time, 8-Bit A/D Converter (Note 4)

Physical Dimensions inches (millimeters) unless otherwise noted

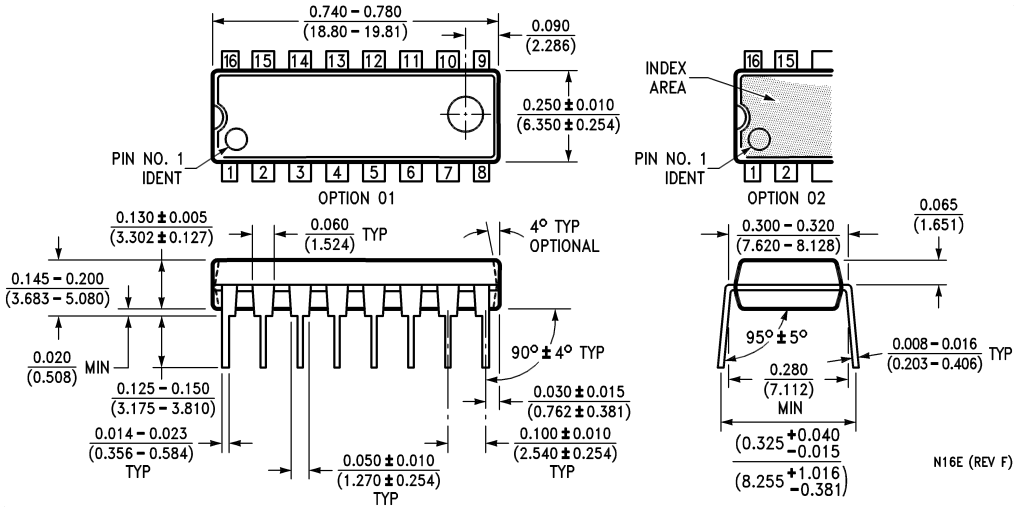


Molded Small Outline Package (SO)
Order Numbers DAC0800LCM,
or DAC0802LCM
NS Package Number M16A



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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