

# Complete Single Supply 12-Bit Voltage Output DAC in SO-8

## FEATURES

- **8-Pin SO Package**
- **Buffered Voltage Output**
- **Built-In 2.048V Reference**
- 500 $\mu$ V/LSB with 2.048V Full Scale
- 1/2LSB Max DNL Error
- Guaranteed 12-Bit Monotonic
- 3-Wire Cascadable Serial Interface
- Wide Single Supply Range:  $V_{CC} = 4.75V$  to 15.75V
- Low Power:  $I_{CC}$  Typ = 350 $\mu$ A with 5V Supply

## APPLICATIONS

- Digital Offset/Gain Adjustment
- Industrial Process Control
- Automatic Test Equipment

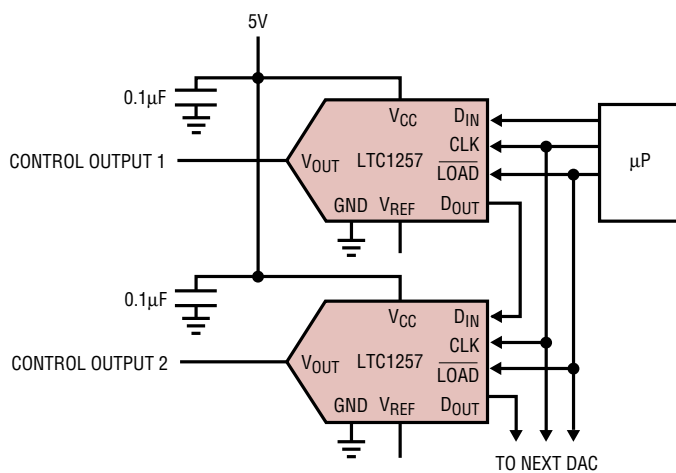
## DESCRIPTION

The LTC<sup>®</sup>1257 is a complete single supply, 12-bit voltage output D/A converter (DAC) in an SO-8 package. The LTC1257 includes an output buffer amplifier, 2.048V voltage reference and an easy to use three-wire cascadable serial interface. An external reference can be used to override the internal reference and extend the output voltage range to 12V. The power supply current is a low 350 $\mu$ A when operating from a 5V supply, making the LTC1257 ideal for battery-powered applications. The space-saving 8-pin SO package and operation with no external components provide the smallest 12-bit D/A system available.

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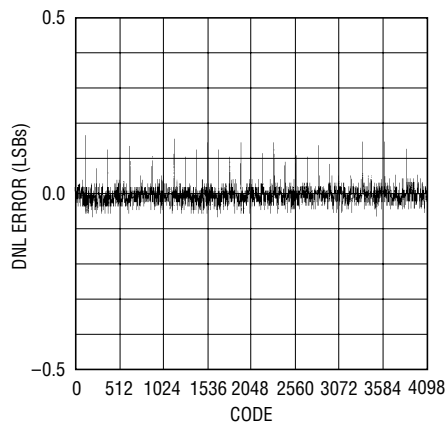
## TYPICAL APPLICATION

Daisy-Chained Control Outputs



1257 TA01

Differential Nonlinearity  
vs Input Code



1257 TA05

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

|   |                          |
|---|--------------------------|
| $V_{CC}$ to GND .....                     | -0.5V to 16.5V           |
| TTL Input Voltage .....                   | -0.5V to $V_{CC} + 0.5V$ |
| $V_{OUT}$ .....                           | -0.5V to $V_{CC} + 0.5V$ |
| REF .....                                 | -0.5V to $V_{CC} + 0.5V$ |
| Operating Temperature Range               |                          |
| LTC1257C .....                            | 0°C to 70°C              |
| LTC1257I .....                            | -40°C to 85°C            |
| Maximum Junction Temperature              |                          |
| Plastic Package .....                     | -65°C to 125°C           |
| Storage Temperature Range .....           | -65°C to 150°C           |
| Lead Temperature (Soldering, 10 sec)..... | 300°C                    |

## PACKAGE/ORDER INFORMATION

|   |                          |
|---|--------------------------|
| <p>TOP VIEW</p> <p>N8 PACKAGE<br/>8-LEAD PDIP</p> <p><math>T_{JMAX} = 125^{\circ}C, \theta_{JA} = 100^{\circ}C/W</math></p>       | ORDER PART NUMBER        |
|   | LTC1257CN8<br>LTC1257IN8 |
| <p>TOP VIEW</p> <p>S8 PACKAGE<br/>8-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 125^{\circ}C, \theta_{JA} = 150^{\circ}C/W</math></p> | LTC1257CS8<br>LTC1257IS8 |
|   | S8 PART MARKING          |
|   | 1257<br>1257I            |

Consult LTC Marketing for parts specified with wider operating temperature ranges.

## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = T_{MIN}$  to  $T_{MAX}$ .  $V_{CC} = 4.75V$  to  $15.75V$ , internal or external reference ( $2.475V \leq V_{REF} \leq V_{CC} - 2.7V$ ), unless otherwise noted.

| SYMBOL            | PARAMETER                   | CONDITIONS                              | MIN | TYP   | MAX    | UNITS  |    |
|-------------------|-----------------------------|---|-----|-------|--------|--------|----|
| <b>DAC</b>        |                             |   |     |       |        |        |    |
|                   | Resolution                  |   | ●   | 12    |        | Bits   |    |
| DNL               | Differential Nonlinearity   | Guaranteed Monotonic (Note 4)           | ●   |       | ±0.5   | LSB    |    |
| INL               | Integral Nonlinearity       | LTC1257C (Note 4)                       | ●   |       | ±3.5   | LSB    |    |
|                   |                             | LTC1257I (Note 4)                       | ●   |       | ±4.0   | LSB    |    |
| OFF               | Offset Error                | When Using Internal Reference, LTC1257C | ●   |       | ±8     | LSB    |    |
|                   |                             | When Using Internal Reference, LTC1257I | ●   |       | ±10    | LSB    |    |
|                   |                             | When Using External Reference, LTC1257C | ●   |       | ±4     | mV     |    |
|                   |                             | When Using External Reference, LTC1257I | ●   |       | ±5     | mV     |    |
| OFF <sub>TC</sub> | Offset Error Tempco         | When Using Internal Reference (Note 2)  | ●   | ±0.02 | ±0.066 | LSB/°C |    |
|                   |                             | When Using External Reference (Note 2)  | ●   | ±15   | ±30    | μV/°C  |    |
|                   | Gain Error                  |   | ●   | 0.5   | ±2     | LSB    |    |
|                   | Gain Error Tempco           | (Note 2)                                | ●   | ±0.01 | ±0.02  | LSB/°C |    |
| <b>Reference</b>  |                             |   |     |       |        |        |    |
|                   | Reference Output Voltage    | $I_{REF} = 0$ , LTC1257C                | ●   | 2.028 | 2.048  | 2.068  | V  |
|                   |                             | $I_{REF} = 0$ , LTC1257I                | ●   | 2.018 |        | 2.078  | V  |
|                   | Reference Output Tempco     | $I_{REF} = 0$                           | ●   |       | ±0.06  | LSB/°C |    |
|                   | Reference Line Regulation   | $I_{REF} = 0$ , LTC1257C                | ●   |       | ±0.4   | LSB/V  |    |
|                   |                             | $I_{REF} = 0$ , LTC1257I                | ●   |       | ±0.7   | LSB/V  |    |
|                   | Reference Load Regulation   | $0 \leq I_{REF} \leq 100\mu A$          | ●   |       | ±1     | LSB    |    |
|                   | Reference Input Range       | $V_{CC} > V_{REF} + 2.7V$               | ●   | 2.475 | 12     | V      |    |
|                   | Reference Input Resistance  |   | ●   | 8     | 14     | 18     | kΩ |
|                   | Reference Input Capacitance | (Note 2)                                |     |       | 15     | pF     |    |
|                   | Short-Circuit Current       | $V_{REF}$ Shorted to GND                | ●   |       | 90     | mA     |    |

## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = T_{MIN}$  to  $T_{MAX}$ .  $V_{CC} = 4.75V$  to  $15.75V$ , internal or external reference ( $2.475V \leq V_{REF} \leq V_{CC} - 2.7V$ ), unless otherwise noted.

| SYMBOL                       | PARAMETER                     | CONDITIONS  |   | MIN          | TYP | MAX      | UNITS      |
|------------------------------|-------------------------------|---|---|--------------|-----|----------|------------|
| <b>Power Supply</b>          |                               |   |   |              |     |          |            |
| $V_{CC}$                     | Positive Supply Voltage       | For Specified Performance   | ● | 4.75         |     | 15.75    | V          |
| $I_{CC}$                     | Supply Current                | $4.75V \leq V_{CC} \leq 5.25V$  | ● |              | 350 | 600      | $\mu A$    |
|                              |                               | $4.75V \leq V_{CC} \leq 15.75V$                                       | ● |              | 800 | 1500     | $\mu A$    |
| <b>Op Amp DC Performance</b> |                               |   |   |              |     |          |            |
|                              | Short-Circuit Current Low     | $V_{OUT}$ Shorted to GND  | ● |              |     | 60       | mA         |
|                              | Short-Circuit Current High    | $V_{OUT}$ Shorted to $V_{CC}$   | ● |              |     | 60       | mA         |
|                              | Output Impedance to GND       | Input Code = 0  | ● |              | 250 | 500      | $\Omega$   |
| <b>AC Performance</b>        |                               |   |   |              |     |          |            |
|                              | Voltage Output Slew Rate      | $5k\Omega$ in Parallel with 100pF                                     | ● | 1.0          |     |          | V/ $\mu s$ |
|                              | Voltage Output Settling Time  | To $\pm 1/2LSB$ , $5k\Omega$ in Parallel with 100pF, $V_{CC} = 4.75V$ | ● |              |     | 6        | $\mu s$    |
|                              | Digital Feedthrough           | (Notes 2,3)   |   |              | 50  |          | nV/s       |
| <b>Digital I/O</b>           |                               |   |   |              |     |          |            |
| $V_{IH}$                     | Digital Input High Voltage    |   | ● | 2.4          |     |          | V          |
| $V_{IL}$                     | Digital Input Low Voltage     |   | ● |              |     | 0.8      | V          |
| $V_{OH}$                     | Digital Output High Voltage   | $I_{OUT} = -1mA$ , $D_{OUT}$ Only                                     | ● | $V_{CC} - 1$ |     |          | V          |
| $V_{OL}$                     | Digital Output Low Voltage    | $I_{OUT} = 1mA$ , $D_{OUT}$ Only                                      | ● | 0.4          |     |          | V          |
| $I_{LEAK}$                   | Digital Input Leakage         | $V_{IN} = GND$ to $V_{CC}$  | ● |              |     | $\pm 10$ | $\mu A$    |
| $C_{IN}$                     | Digital Input Capacitance     | (Note 2)  | ● |              |     | 10       | pF         |
| <b>Switching (Note 2)</b>    |                               |   |   |              |     |          |            |
| t1                           | $D_{IN}$ Valid to CLK Setup   |   | ● | 100          |     |          | ns         |
| t2                           | $D_{IN}$ Valid to CLK Hold    |   | ● | 25           |     |          | ns         |
| t3                           | CLK High Time                 |   | ● | 350          |     |          | ns         |
| t4                           | CLK Low Time                  |   | ● | 350          |     |          | ns         |
| t5                           | $\overline{LOAD}$ Pulse Width |   | ● | 150          |     |          | ns         |
| t6                           | LSB CLK to $\overline{LOAD}$  |   | ● | 0            |     |          | ns         |
| t7                           | $\overline{LOAD}$ High to CLK |   | ● | 0            |     |          | ns         |
| t8                           | $D_{OUT}$ Output Delay        | $C_{LOAD} = 15pF$   | ● | 35           |     | 150      | ns         |
| $f_{CLK}$                    | Maximum Clock Frequency       |   |   |              |     | 1.4      | MHz        |

**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

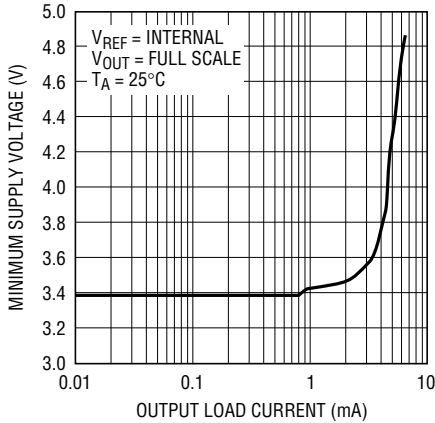
**Note 2:** Guaranteed by design; not subject to test.

**Note 3:** DAC switched from all 1s to all 0s, and all 0s to all 1s code.

**Note 4:** Guaranteed with internal  $V_{REF}$  or with external  $V_{REF}$  range of 2.475V to 12V. Tested at 10V.

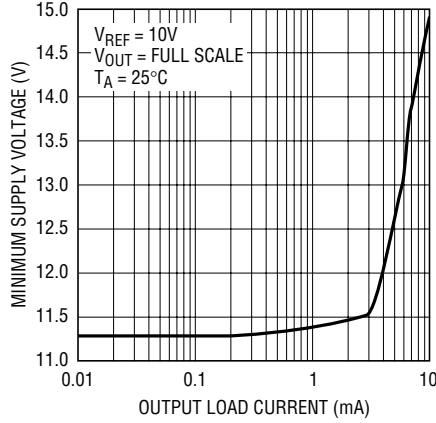
# TYPICAL PERFORMANCE CHARACTERISTICS

**Minimum Supply Voltage vs Load Current #1**



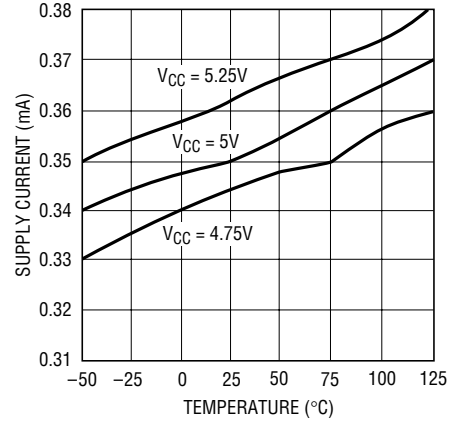
1257 G01

**Minimum Supply Voltage vs Load Current #2**



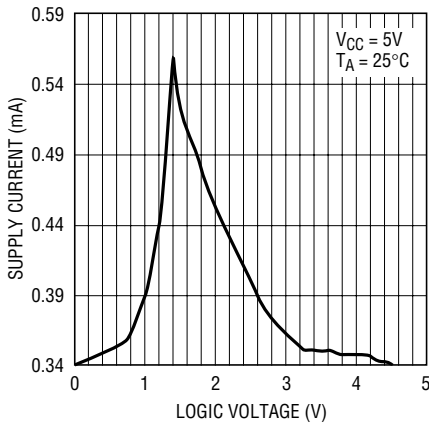
1257 G02

**Supply Current vs Temperature**



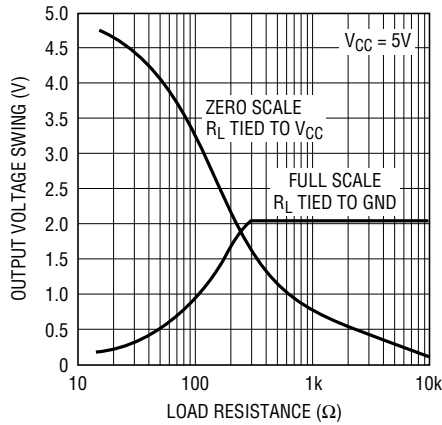
1257 G03

**Supply Current vs Logic Input Voltage**



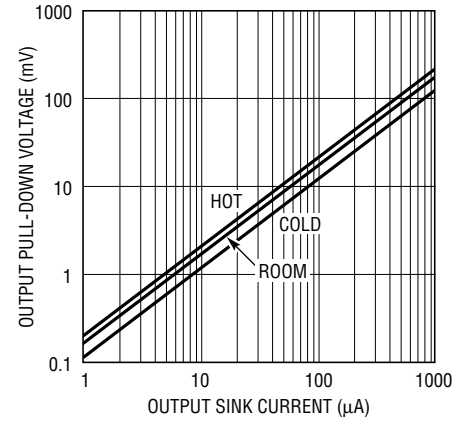
1257 G04

**Output Swing vs Load Resistance**



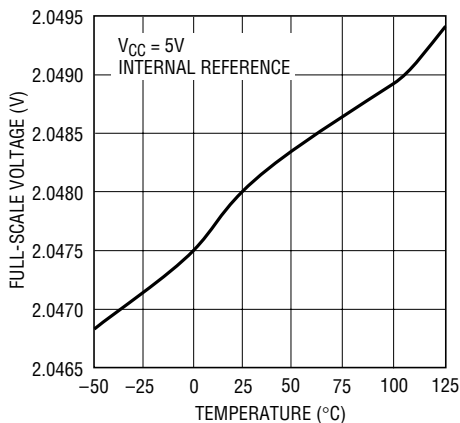
1257 G05

**Pull-Down Voltage vs Output Sink Current Capability**



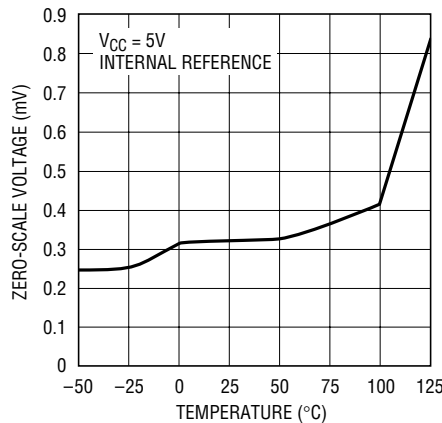
1257 G06

**Full-Scale Voltage vs Temperature**



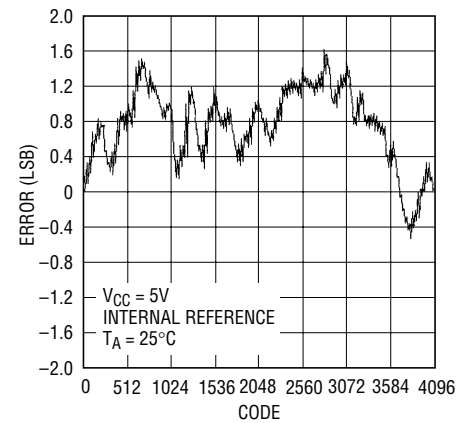
1257 G07

**Zero-Scale Voltage vs Temperature**



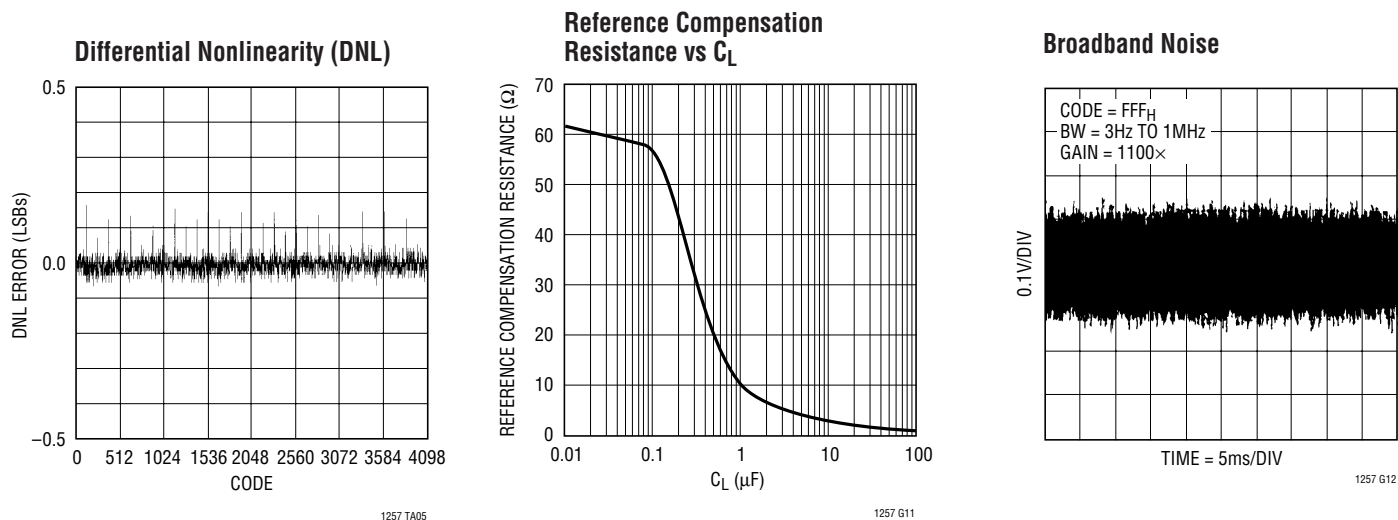
1257 G08

**Integral Nonlinearity (INL)**



1257 G09

## TYPICAL PERFORMANCE CHARACTERISTICS



## PIN FUNCTIONS

**CLK (Pin 1):** The TTL level input for the serial interface clock.

**$D_{IN}$  (Pin 2):** The TTL level input for the serial interface data. Data on the  $D_{IN}$  pin is latched into the shift register on the rising edge of the serial clock.

**LOAD (Pin 3):** The TTL level input for the serial interface load control. Data is loaded from the shift register into the DAC register, thus updating the DAC output when LOAD is pulled low. The DAC register is transparent as long as LOAD is held low.

**$D_{OUT}$  (Pin 4):** The output of the shift register which becomes valid on the rising edge of the serial clock. The  $D_{OUT}$  pin is driven from GND to  $V_{CC}$  by an internal CMOS inverter. Multiple LTC1257s may be cascaded by connecting the  $D_{OUT}$  pin to the  $D_{IN}$  pin of the next chip.

**GND (Pin 5):** Ground.

**REF (Pin 6):** The output of the 2.048V reference and the input to the DAC resistor ladder. An external reference with voltage from 2.475V to  $V_{CC} - 2.7V$  may be used to override the internal reference.

**$V_{OUT}$  (Pin 7):** The buffered DAC output is capable of sourcing 2mA over temperature while pulling within 2.7V of  $V_{CC}$ . The output will pull to ground through an internal 250 $\Omega$  equivalent resistance.

**$V_{CC}$  (Pin 8):** The positive supply input.  $4.75V \leq V_{CC} \leq 15.75V$ . Requires a bypass capacitor to ground.

## DEFINITIONS

**LSB:** The least significant bit or the ideal voltage difference between two successive codes.

$$\text{LSB} = (V_{\text{FS}} - V_{\text{OS}})/2^n - 1$$

$n$  = The number of digital input bits

$V_{\text{OS}}$  = The zero code error or offset of the DAC

$V_{\text{FS}}$  = The full-scale output voltage of the DAC measured when all bits are set to 1

**Resolution:** The resolution is the number of DAC output states ( $2^n$ ) that divide the full-scale range. The resolution does not imply linearity.

**INL:** End-point integral nonlinearity is the maximum deviation from a straight line passing through the end-points of the DAC transfer curve. Because the part operates from a single supply and the output cannot go below ground, the linearity is measured between full-scale and the first code that guarantees a positive output. The INL error at a given input code is calculated as follows:

$$\text{INL} = (V_{\text{OUT}} - V_{\text{IDEAL}})/\text{LSB}$$

$$V_{\text{IDEAL}} = (\text{Code})(\text{LSB}) + V_{\text{OS}}$$

$V_{\text{OUT}}$  = The output voltage of the DAC measured at the given input code

**DNL:** Differential nonlinearity is the difference between the measured change and the ideal 1LSB change between any two adjacent codes. The DNL error between any two codes is calculated as follows:

$$\text{DNL} = (\Delta V_{\text{OUT}} - \text{LSB})/\text{LSB}$$

$\Delta V_{\text{OUT}}$  = The measured voltage difference between two adjacent codes

**Offset Error:** The theoretical voltage at the output when the DAC is loaded with all zeros. The output amplifier can have a true negative offset, but because the part is operated from a single supply, the output cannot go below ground. If the offset is negative, the output will remain near 0V resulting in the transfer curve shown in Figure 1.

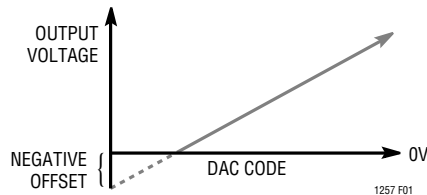


Figure 1. Effect of Negative Offset

The offset of the part is measured at the first code that produces an output voltage 0.5LSB greater than the previous code:

$$V_{\text{OS}} = V_{\text{OUT}} - [(\text{Code})(V_{\text{FS}})/(2^n - 1)]$$

**Full-Scale Error:** Full-scale error is the difference between the ideal and measured DAC output voltages with all bits set to one (Code = 4095). The full-scale error includes the offset error and is calculated as follows:

$$\text{FSE} = (V_{\text{OUT}} - V_{\text{IDEAL}})/\text{LSB}$$

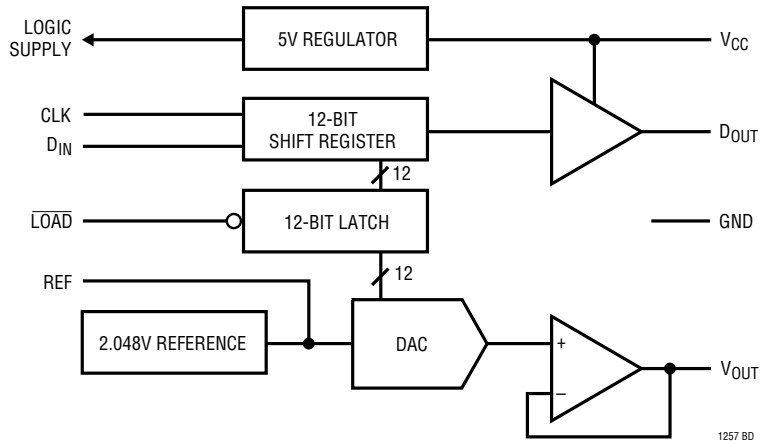
$$V_{\text{IDEAL}} = (V_{\text{REF}})(1 - 2^{-n}) - V_{\text{OS}}$$

$V_{\text{REF}}$  = The reference voltage, either internal or external

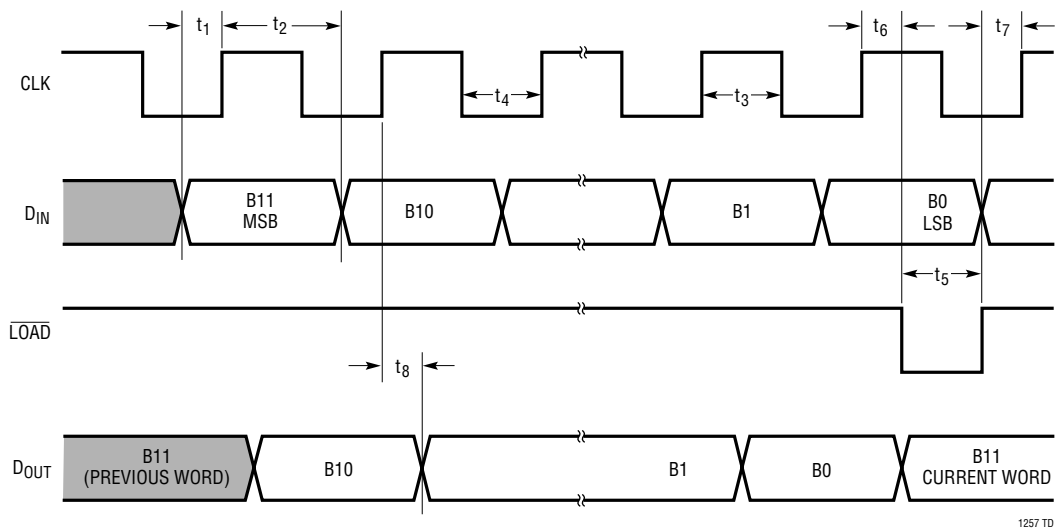
**Gain Error:** Gain error is the difference between the ideal and measured slope of the DAC transfer characteristic. Gain error is equal to full-scale error minus offset error.

**Digital Feedthrough:** The glitch that appears at the analog output caused by AC coupling from the digital inputs when they change state. The area of the glitch is specified in (nV)(sec).

# BLOCK DIAGRAM



# TIMING DIAGRAM



## OPERATION

### Serial Interface

The data on the  $D_{IN}$  input is loaded into the shift register on the rising edge of the clock. The MSB is loaded first and the LSB last. The DAC register loads the data from the shift register when  $\overline{LOAD}$  is pulled low, and remains transparent until  $\overline{LOAD}$  is pulled high and the data is latched.

An internal 5V regulator provides the supply for the digital logic. By limiting the internal digital signal swings to 5V, digital noise is reduced. The buffered output of the 12-bit shift register is available on the  $D_{OUT}$  pin which will swing from GND to  $V_{CC}$ .

Multiple LTC1257s may be daisy chained together by connecting the  $D_{OUT}$  pin to the  $D_{IN}$  pin of the next chip, while the clock and load signals remain common to all chips in the daisy chain. The serial data is clocked to all of the chips, then the  $\overline{LOAD}$  signal is pulled low to update all of them simultaneously. The maximum clocking rate is 1.4MHz.

### Reference

The LTC1257 includes an internal 2.048V reference, making 1LSB equal to  $500\mu V$ . The internal reference output is turned off when the pin is forced above the reference voltage, allowing an external reference to be connected to the reference pin. The external reference must be greater than 2.475V and less than  $V_{CC} - 2.7V$ , and be capable of driving the 10k minimum DAC resistor ladder.

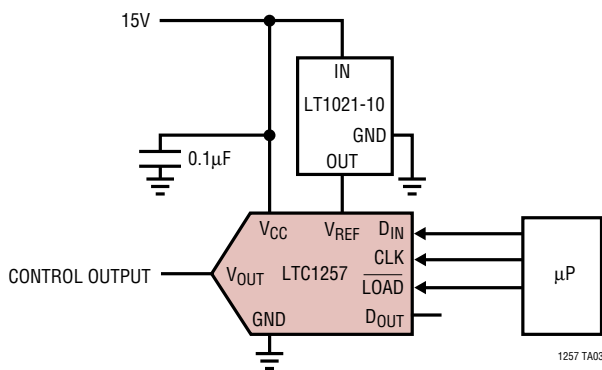
If the reference output is driving a large capacitive load, a series resistor must be added to insure stability. For any capacitive load greater than  $1\mu F$ , a  $10\Omega$  series resistor will suffice.

### Voltage Output

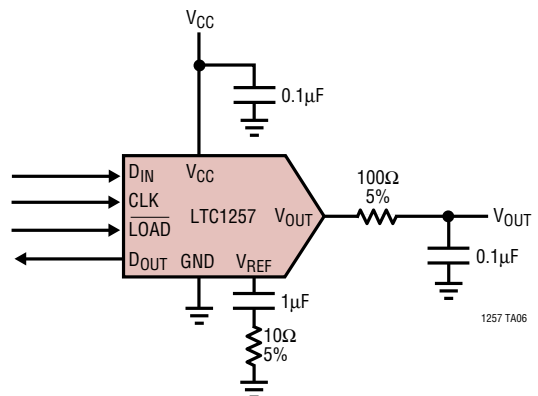
The LTC1257 voltage output is able to pull within 2.7V of  $V_{CC}$  while sourcing 2mA. A internal NMOS transistor with a  $200\Omega$  equivalent impedance pulls the output to ground. The output is protected against short circuits and is able to drive up to a 500pF capacitive load without oscillation. If digital noise on the output causes a problem, a simple  $100\Omega$ ,  $0.1\mu F$  RC circuit can be used to filter the noise.

## TYPICAL APPLICATIONS

DAC with External Reference



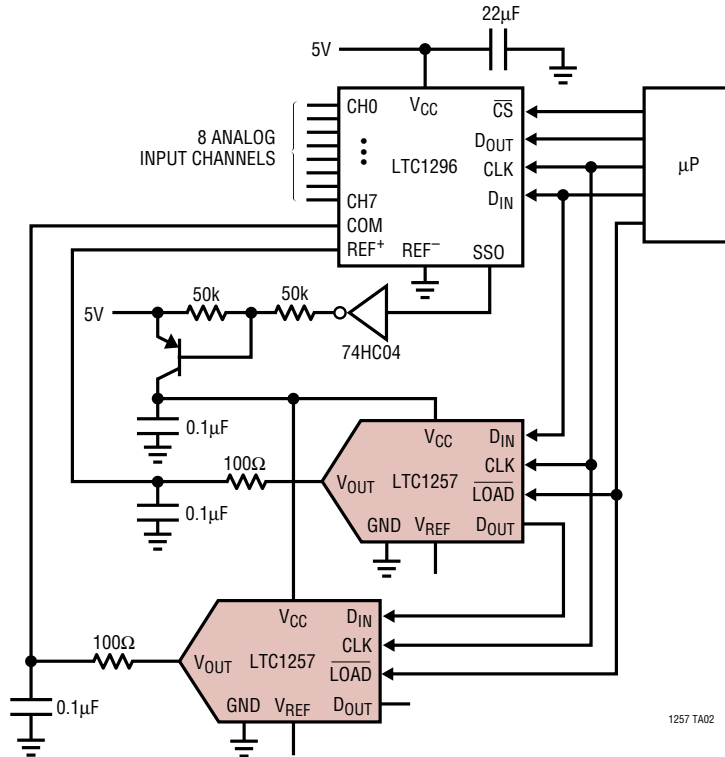
Filtering  $V_{REF}$  and  $V_{OUT}$



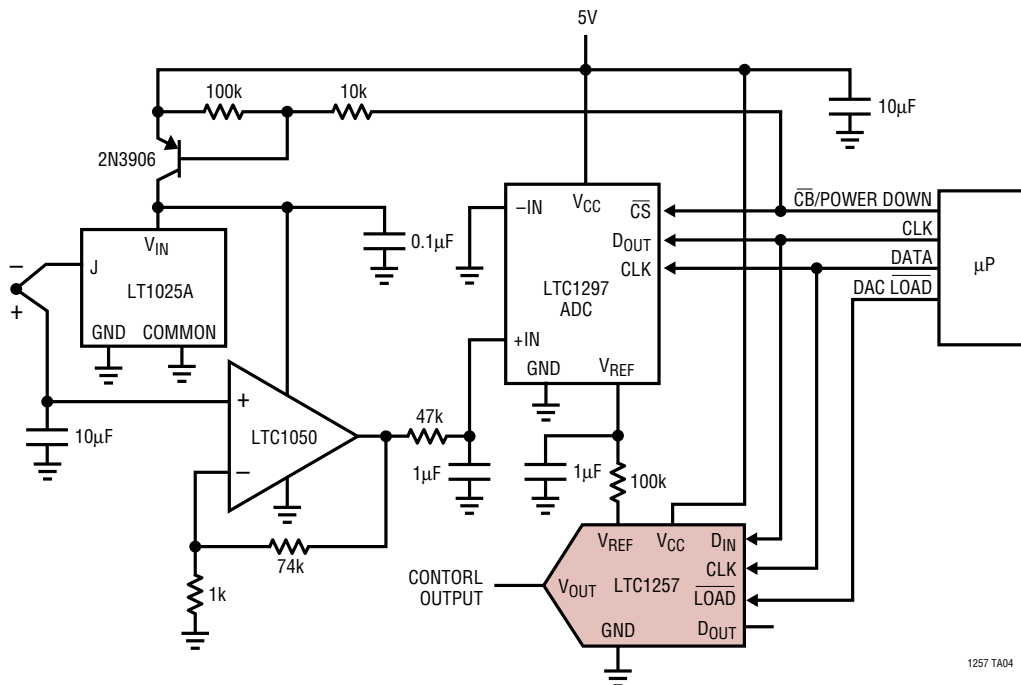


# TYPICAL APPLICATIONS

## Auto Ranging 8-Channel ADC with Shutdown

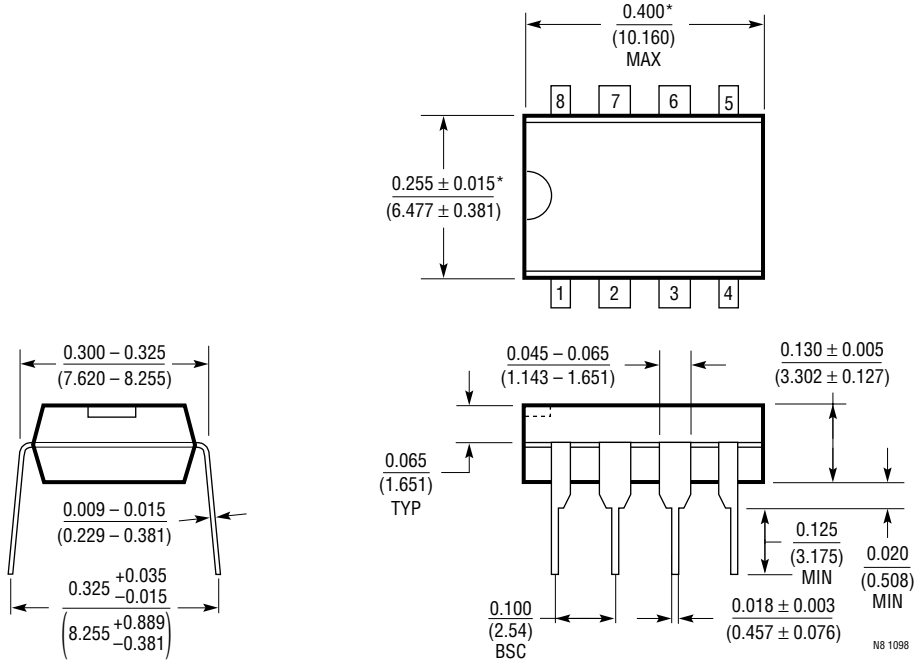


## 12-Bit Single 5V Control System with Shutdown



**PACKAGE DESCRIPTION**

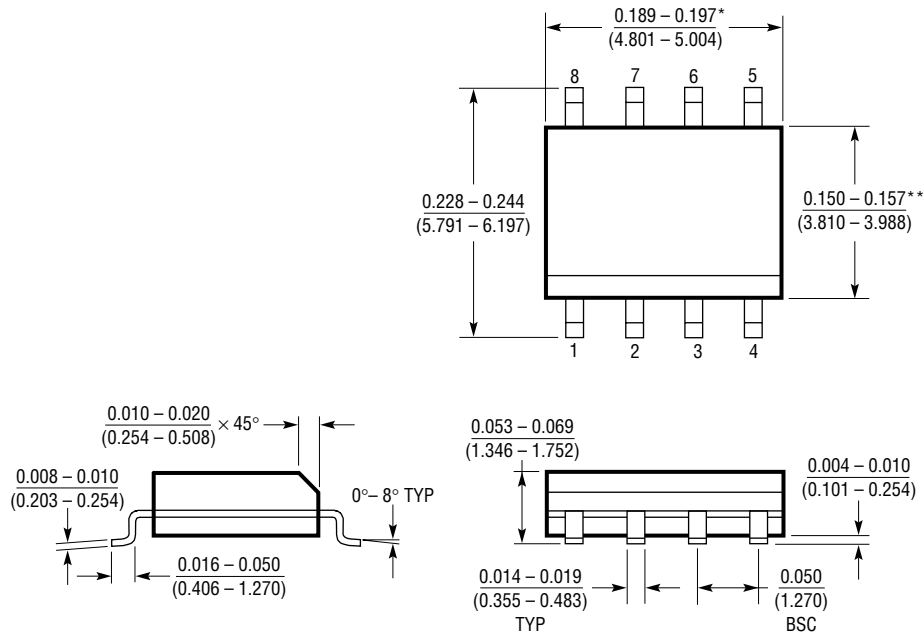
**N8 Package**  
**8-Lead PDIP (Narrow .300 Inch)**  
 (Reference LTC DWG # 05-08-1510)



\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

## PACKAGE DESCRIPTION

**S8 Package**  
**8-Lead Plastic Small Outline (Narrow .150 Inch)**  
 (Reference LTC DWG # 05-08-1610)



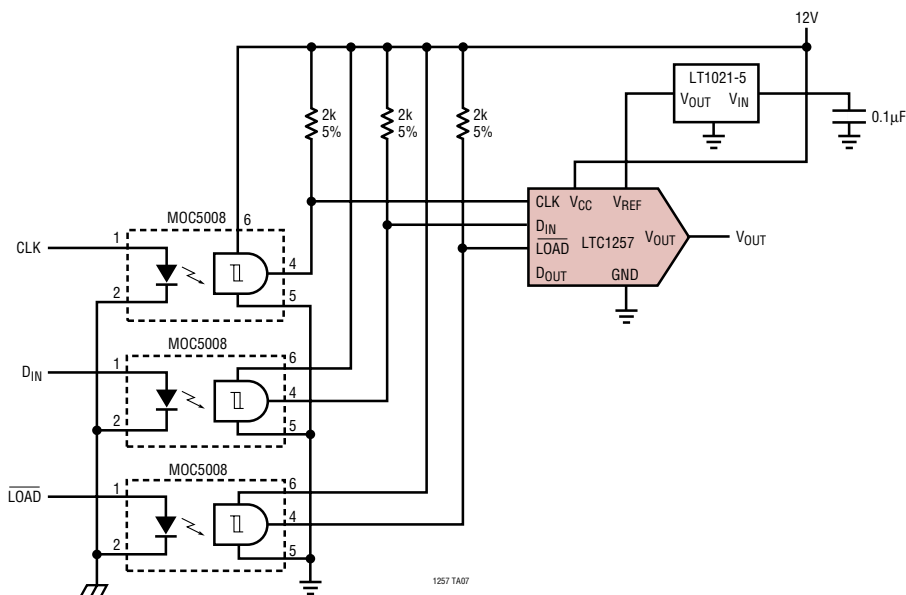
\*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

\*\*DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

S08 1298

## TYPICAL APPLICATION

### Driving LTC1257 with Optoisolators



## RELATED PARTS

| PART NUMBER      | DESCRIPTION   | COMMENTS  |
|------------------|---|---|
| <b>12 Bit</b>    |   |   |
| LTC1446/LTC1446L | Dual 12-Bit $V_{OUT}$ DACs in SO-8 Package  | LTC1446: $V_{CC} = 4.5V$ to $5.5V$ , $V_{OUT} = 0V$ to $4.095V$<br>LTC1446L: $V_{CC} = 2.7V$ to $5.5V$ , $V_{OUT} = 0V$ to $2.5V$ |
| LTC1448          | Dual 12-Bit $V_{OUT}$ DAC in SO-8 Package, $V_{CC} = 2.7V$ to $5.5V$  | Output Swings from GND to REF, REF Input Can Be Tied to $V_{CC}$  |
| LTC1450/LTC1450L | Single 12-Bit $V_{OUT}$ DACs with Parallel Interface  | LTC1450: $V_{CC} = 4.5V$ to $5.5V$ , $V_{OUT} = 0V$ to $4.095V$<br>LTC1450L: $V_{CC} = 2.7V$ to $5.5V$ , $V_{OUT} = 0V$ to $2.5V$ |
| LTC1451          | Single Rail-to-Rail 12-Bit $V_{OUT}$ DAC, Full Scale: $4.095V$ , $V_{CC} = 4.5V$ to $5.5V$ , Internal $2.048V$ Reference Brought Out to Pin | Low Power, Complete $V_{OUT}$ DAC in SO-8 Package   |
| LTC1452          | Single Rail-to-Rail 12-Bit $V_{OUT}$ Multiplying DAC, $V_{CC} = 2.7V$ to $5.5V$   | Low Power, Multiplying $V_{OUT}$ DAC with Rail-to-Rail Buffer Amplifier in SO-8 Package   |
| LTC1453          | Single Rail-to-Rail 12-Bit $V_{OUT}$ DAC, Full Scale: $2.5V$ , $V_{CC} = 2.7V$ to $5.5V$  | $3V$ , Low Power, Complete $V_{OUT}$ DAC in SO-8 Package  |
| LTC1454/LTC1454L | Dual 12-Bit $V_{OUT}$ DACs in SO-16 Package with Added Functionality  | LTC1454: $V_{CC} = 4.5V$ to $5.5V$ , $V_{OUT} = 0V$ to $4.095V$<br>LTC1454L: $V_{CC} = 2.7V$ to $5.5V$ , $V_{OUT} = 0V$ to $2.5V$ |
| LTC1456          | Single Rail-to-Rail Output 12-Bit DAC with Clear Pin, Full Scale: $4.095V$ , $V_{CC} = 4.5V$ to $5.5V$                                      | Low Power, Complete $V_{OUT}$ DAC in SO-8 Package with Clear Pin  |
| LTC1458/LTC1458L | Quad 12 Bit Rail-to-Rail Output DACs with Added Functionality   | LTC1458: $V_{CC} = 4.5V$ to $5.5V$ , $V_{OUT} = 0V$ to $4.095V$<br>LTC1458L: $V_{CC} = 2.7V$ to $5.5V$ , $V_{OUT} = 0V$ to $2.5V$ |
| LTC1659          | Single Rail-to-Rail 12-Bit $V_{OUT}$ DAC in MSOP-8 Package, $V_{CC} = 2.7V$ to $5.5V$   | Output Swings from GND to REF, REF Input Can Be Tied to $V_{CC}$  |
| <b>14 Bit</b>    |   |   |
| LTC1658          | 14-Bit Rail-to-Rail Micropower DAC in MSOP, $V_{CC} = 2.7V$ to $5.5V$   | Output Swings from GND to REF, REF Input Can Be Tied to $V_{CC}$  |
| LTC1654          | Dual 14-Bit $V_{OUT}$ DAC   | Programmable Speed/Power, SO-8 Footprint  |
| <b>16 Bit</b>    |   |   |
| LTC1655(L)       | Single 16-Bit $V_{OUT}$ DAC with Serial Interface in SO-8   | $V_{CC} = 5V$ ( $3V$ ), Low Power, Deglitched, $V_{OUT} = 0V$ to $4.096V$ ( $0V$ to $2.5V$ )                                      |