**FEATURES**
- Guaranteed Monotonic
- Buffered True Rail-to-Rail Voltage Output
- 12-Bit Resolution
- 3V Operation (LTC1450L) \(I_{CC}: 250\mu A\) Typ
- 5V Operation (LTC1450) \(I_{CC}: 400\mu A\) Typ
- Parallel 12-Bit or 8 + 4-Bit Double Buffered Digital Input
- Internal Reference
- Output Buffer Configurable to Gain of 1 or 2
- Configurable as a Multiplying DAC
- Internal Power-On Reset
- Maximum DNL Error: 0.5LSB

**APPLICATIONS**
- Digital Calibration
- Industrial Process Control
- Automatic Test Equipment
- Arbitrary Function Generators
- Battery-Powered Data Conversion Products
- Feedback Control Loops and Gain Control

**DESCRIPTION**
The LTC®-1450/LTC1450L are complete single supply, rail-to-rail voltage output, 12-bit digital-to-analog converters (DACs) in a 24-pin SSOP or PDIP package. They include an output buffer amplifier, reference and a double buffered parallel digital interface.

The LTC1450 operates from a 4.5V to 5.5V supply. The output can be pin strapped for 4.095V or 2.048V full-scale. It has a 2.048V internal reference.

The LTC1450L operates from a 2.7V to 5.5V supply. The output can be pin strapped for 2.5V or 1.22V full-scale. It has a 1.22V internal reference.

The LTC1450/LTC1450L offer true stand-alone performance. In addition, the reference output, high and low reference inputs and gain setting resistor are brought to pins for maximum flexibility.

\* LTC and LT are registered trademarks of Linear Technology Corporation.
### ABSOLUTE MAXIMUM RATINGS

- **$V_{CC}$ to GND**: $-0.5V$ to $7.5V$
- **Logic Inputs to GND**: $-0.5V$ to $7.5V$
- **$V_{OUT}$**: $-0.5V$ to $V_{CC} + 0.5V$
- **REFOUT, REFLO, REFHI, X1/X2**: $-0.5V$ to $V_{CC} + 0.5V$
- **Maximum Junction Temperature**: $125°C$

### Operating Temperature Range
- **Commercial**: $0°C$ to $70°C$
- **Industrial**: $-40°C$ to $85°C$

### Storage Temperature Range
- $-65°C$ to $150°C$

### Lead Temperature (Soldering, 10 sec)
- $300°C$

### ELECTRICAL CHARACTERISTICS

- $V_{CC} = 4.5V$ to $5.5V$ (LTC1450), $2.7V$ to $5.5V$ (LTC1450L), $V_{OUT}$ unloaded,
- REFOUT = REFHI, REFLO = GND = X1/X2, $T_{A} = T_{MIN}$ to $T_{MAX}$, unless otherwise noted.

#### SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS
--- | --- | --- | --- | --- | --- | ---
DAC | Resolution | | 12 | | | Bits
DNL | Differential Nonlinearity | Guaranteed Monotonic (Note 1) | | ±0.5 | | LSB
INL | Integral Nonlinearity | $T_{A} = 25°C$ (Note 1) | | ±3.5 | | LSB
| | | | ±4.0 | | LSB
VOS | Offset Error | $T_{A} = 25°C$ | | ±12 | | mV
| | Offset Error Temperature Coefficient | | | ±15 | | µV/°C
VF | Full-Scale Voltage | Using Internal Reference, LTC1450, $T_{A} = 25°C$ | 4.065 | 4.095 | 4.125 | V
| | | | 4.045 | 4.095 | 4.145 | V
| | | Using Internal Reference, LTC1450L | 4.075 | 4.095 | 4.115 | V
| | | | 4.050 | 4.095 | 4.115 | V
| | | Using External 2.048V Reference, LTC1450 | 2.470 | 2.500 | 2.530 | V
| | | | 2.460 | 2.500 | 2.540 | V
| | | Using External Reference, LTC1450L | 2.480 | 2.500 | 2.520 | V
| | | | 2.460 | 2.500 | 2.540 | V
VF | Full-Scale Voltage Temperature Coefficient | | ±0.10 | | | LSB/°C
| | | Using Internal Reference, LTC1450 | ±0.02 | | | LSB/°C
| | | Using External Reference, LTC1450/LTC1450L | ±0.10 | | | LSB/°C
Reference Output (REFOUT) | Reference Output Voltage | LTC1450L | 1.195 | 1.220 | 1.245 | V
| | LTC1450 | | 2.008 | 2.048 | 2.088 | V
| | Reference Output Temperature Coefficient | | | ±0.08 | | LSB/°C
| | Reference Line Regulation | | | 0.7 | ±2 | LSB/V
| | Reference Load Regulation | | | 0 ≤ I_{OUT} ≤ 100µA, LTC1450L | 0.6 | ±3.0 | LSB
| | | | | 0.2 | ±1.5 | LSB
| | Short-Circuit Current | REFOUT Shorted to GND | | 80 | | mA
### ELECTRICAL CHARACTERISTICS

**VCC = 4.5V to 5.5V (LTC1450), 2.7V to 5.5V (LTC1450L), VOUT unloaded, REFOUT = REFHI, REFLO = GND = X1/X2, TA = TMIN to TMAX, unless otherwise noted.**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Input (REFLO = GND)</td>
<td>REFHI Input Range</td>
<td>VREFHI ≤ VCC − 1.5V</td>
<td></td>
<td></td>
<td>VCC/2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>REFHI Input Resistance</td>
<td></td>
<td>8</td>
<td>18</td>
<td>30</td>
<td>kΩ</td>
</tr>
<tr>
<td></td>
<td>REFHI Input Capacitance</td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td>pF</td>
</tr>
<tr>
<td>Power Supply</td>
<td>VCC Positive Supply Voltage</td>
<td>For Specified Performance, LTC1450L</td>
<td></td>
<td>VCC</td>
<td>2.7</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LTC1450</td>
<td>4.5</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ICC Supply Current</td>
<td>4.5V ≤ VCC ≤ 5.5V (Note 4) LTC1450</td>
<td>300</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.7V ≤ VCC ≤ 5.5V (Note 4) LTC1450L</td>
<td>150</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>Op Amp DC Performance</td>
<td>Short-Circuit Current Low</td>
<td>VOUT Shorted to GND</td>
<td>100</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>Short-Circuit Current High</td>
<td>VOUT Shorted to VCC</td>
<td>120</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>Output Impedance to GND</td>
<td>Input Code = 0</td>
<td>40</td>
<td>120</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>AC Performance</td>
<td>Voltage Output Slew Rate</td>
<td>(Note 2)</td>
<td>0.5</td>
<td>1.0</td>
<td></td>
<td>V/µs</td>
</tr>
<tr>
<td></td>
<td>Voltage Output Settling Time</td>
<td>(Notes 2, 3) to ±0.5LSB</td>
<td>14</td>
<td></td>
<td></td>
<td>µs</td>
</tr>
<tr>
<td></td>
<td>Digital Feedthrough</td>
<td>LDAC = 1</td>
<td>5</td>
<td></td>
<td></td>
<td>(nV)/(s)</td>
</tr>
<tr>
<td></td>
<td>AC Feedthrough</td>
<td>REFHI = 1kHz, 2Vp,p</td>
<td>−95</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>SINAD</td>
<td>Signal-to-Noise + Distortion</td>
<td>REFHI = 1kHz, 2Vp,p (Code: All 1’s)</td>
<td>85</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Digital Inputs</td>
<td>VH Digital Input High Voltage</td>
<td>VCC = 3V, LTC1450L</td>
<td>2.2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VCC = 5V, LTC1450</td>
<td>2.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>VL Digital Input Low Voltage</td>
<td>VCC = 3V, LTC1450L</td>
<td></td>
<td>0.8</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VCC = 5V, LTC1450</td>
<td></td>
<td>0.8</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>VLT Threshold Voltage</td>
<td>LTC1450L</td>
<td>VCC/2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>ILEAK Digital Input Leakage</td>
<td>VCC = 5V, VIN = GND to VCC</td>
<td>−10</td>
<td>10</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td>CIN Digital Input Capacitance</td>
<td>Guaranteed by Design. Not Subject to Test</td>
<td>10</td>
<td></td>
<td></td>
<td>pF</td>
</tr>
</tbody>
</table>
ELECTRICAL CHARACTERISTICS

$V_{CC} = 4.5\text{V to } 5.5\text{V (LTC1450), } V_{CC} = 2.7\text{V to } 3.6\text{V (LTC1450L), } T_A = T_{MIN} \text{ to } T_{MAX}$, unless otherwise noted.

### Typical Performance Characteristics

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{CS}$</td>
<td>CS (MSB or LSB) Pulse Width</td>
<td>$V_{CC} = 4.5\text{V to } 5.5\text{V (LTC1450)}$</td>
<td>40</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{WR}$</td>
<td>WR Pulse Width</td>
<td>$V_{CC} = 2.7\text{V to } 3.6\text{V (LTC1450L)}$</td>
<td>40</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{DWH}$</td>
<td>CS to WR Setup</td>
<td>$V_{CC} = 5\text{V (LTC1450L)}$</td>
<td>0</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{DWS}$</td>
<td>Data Valid to WR Setup</td>
<td>$V_{CC} = 4.5\text{V to } 5.5\text{V (LTC1450)}$</td>
<td>40</td>
<td>15</td>
<td>10</td>
<td>ns</td>
</tr>
<tr>
<td>$I_{DWH}$</td>
<td>Data Valid to WR Hold</td>
<td>$V_{CC} = 2.7\text{V to } 3.6\text{V (LTC1450L)}$</td>
<td>0</td>
<td>10</td>
<td>5</td>
<td>ns</td>
</tr>
<tr>
<td>$I_{LDAC}$</td>
<td>LDAC Pulse Width</td>
<td>$V_{CC} = 4.5\text{V to } 5.5\text{V (LTC1450)}$</td>
<td>40</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{CLR}$</td>
<td>CLR Pulse Width</td>
<td>$V_{CC} = 2.7\text{V to } 3.6\text{V (LTC1450L)}$</td>
<td>40</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The $\bullet$ denotes specifications which apply over the full operating temperature range.

**Note 1:** Nonlinearity is defined from the first code that is greater than or equal to the maximum offset specification to code 4095 (full-scale).

**Note 2:** Load is 5k$\Omega$ in parallel with 100pF.

**Note 3:** DAC switched all 1's and the code corresponding to $V_{OS(MAX)}$ for the part.

**Note 4:** Digital inputs at 0V or $V_{CC}$.

**Note 5:** Digital inputs swing 10% to 90% of $V_{CC}$, $t_r = t_f = 5\text{ns}$ and timing measurements are from $V_{CC}/2$.
TYPICAL PERFORMANCE CHARACTERISTICS

LTC1450L Supply Current vs Logic Input Voltage

LTC1450 Output Swing vs Load Resistance

LTC1450 Pull-Down Voltage vs Output Sink Current Capability

LTC1450 Output Offset Voltage vs Temperature

LTC1450 Differential Nonlinearity (DNL)

LTC1450 Integral Nonlinearity (INL)

Power Supply Rejection vs Frequency

LTC1450 Total Harmonic Distortion + Noise vs Frequency

LTC1450 Broadband Output Noise

VCC = 3V
ALL LOGIC INPUTS TIED TOGETHER

FULL SCALE RL TIED TO GND

ZERO SCALE RL TIED TO VCC

VCC = 5V

VREF = 2VP-P

VOUT = 4VP-P

CODE = FFFH

X1/X2 = GND

BW = 3Hz to 1.2MHz

TOTAL = 0.35mVRMS
**PIN FUNCTIONS**

**WR (Pin 1):** Write Input (Active Low). Used with CSMSB and/or CSLSB to load data into the input latches. While WR and CSMSB and/or CSLSB are held low the enabled input latches are transparent. The rising edge of WR will latch data into all input latches.

**CSLSB (Pin 2):** Chip Select Least Significant Byte (Active Low). Used with WR to load data into the eight LSB input latches. While WR and CSLSB are held low the eight LSB input latches are transparent. The rising edge will latch data into the eight LSB input latches. Can be connected to CSMSB for simultaneous loading of both sets of input latches on a 12-bit bus.

**CSMSB (Pin 3):** Chip Select Most Significant Byte (Active Low). Used with WR to load data into the four MSB input latches. While WR and CSMSB are held low the four MSB input latches are transparent. The rising edge will latch data into the four MSB input latches. Can be connected to CSLSB for simultaneous loading of both sets of input latches on a 12-bit bus.

**D0 to D7 (Pins 4 to 11):** Input data for the Least Significant Byte. Loaded into LSB input latch when WR = 0 and CSLSB = 0.

**D8, D9, D10, D11 (Pins 12, 13, 14, 15):** Input data for the Most Significant Byte. Loaded into MSB input latch when WR = 0 and CSMSB = 0. Can be connected to D0 to D3 for multiplexed operation on an 8-bit bus.

**GND (Pin 16):** Ground.

**REFL0 (Pin 17):** Lower input terminal of the DAC’s internal resistor string. Typically connected to Analog Ground.

An input code of (000H) will connect the positive input of the output buffer to this end. Can be used to offset the zero scale above ground.

**REFHI (Pin 18):** Upper input terminal of the DAC’s internal resistor string. Typically connected to REFOUT. An input code of (FFFH) will connect the positive input of the output buffer to 1LSB from this end.

**REFOUT (Pin 19):** Output of the internal 2.048V/1.22V reference. Typically connected to REFHI to drive internal DAC resistor string.

**VCC (Pin 20):** Positive Power Supply Input. $4.5V \leq V_{CC} \leq 5.5V$ (LTC1450) and $2.7V \leq V_{CC} \leq 5.5V$ (LTC1450L). Requires a bypass capacitor to ground.

**VOUT (Pin 21):** Buffered DAC Output.

**X1/X2 (Pin 22):** Gain Setting Resistor Pin. Connect to GND for $G = 2$ or to VOUT for $G = 1$. Should always be tied to a low impedance source, such as ground or VOUT, to ensure stability of the output buffer when driving capacitive loads.

**CLR (Pin 23):** Clear Input (Asynchronous Active Low). A low on this pin asynchronously resets all internal latches to 0s.

**LDAC (Pin 24):** Load DAC (Asynchronous Active Low). Used to asynchronously transfer the contents of the input latches to the DAC latches which updates the output voltage. The rising edge latches the data into the DAC latches. If held low the DAC latches are transparent and data from the input latches will immediately update VOUT.
## Digital Interface Truth Table

<table>
<thead>
<tr>
<th>CLR</th>
<th>CSMSB</th>
<th>CSLSB</th>
<th>WR</th>
<th>LDAC</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>Loads the eight LSBs into the input latch</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
<td>↑</td>
<td>H</td>
<td>Latches the eight LSBs into the input latch</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>Latches the eight MSBs into the input latch</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>H</td>
<td>↑</td>
<td>H</td>
<td>Latches the four MSBs into the input latch</td>
</tr>
<tr>
<td>H</td>
<td>↑</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>Latches the four MSBs into the input latch</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>Loads the input latch data into the DAC latch</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>Loads input data into DAC latches (latches transparent)</td>
</tr>
<tr>
<td>L</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>All zeros loaded into input and DAC latches</td>
</tr>
</tbody>
</table>

## Timing Diagram

![Timing Diagram](image_url)

## Block Diagram

![Block Diagram](image_url)
DEFINITIONS

Resolution (n): Resolution is defined as the number of digital input bits (n). It defines the number of DAC output states (2^n) that divide the full-scale range. The resolution does not imply linearity.

Full-Scale Voltage (V_{FS}): This is the output of the DAC when all bits are set to 1.

Voltage Offset Error (V_{OS}): 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 zero. If the offset is negative, the output will remain near 0V resulting in the transfer curve shown in Figure 1.

The offset of the part is measured at the code that corresponds to the maximum offset specification:

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

Least Significant Bit (LSB): One LSB is the ideal voltage difference between two successive codes.

\[ \text{LSB} = (V_{FS} - V_{OS})/(2^n - 1) = (V_{FS} - V_{OS})/4095 \]

Nominal LSBs:

LTC1450  \quad \text{LSB} = 4.095V/4095 = 1mV
LTC1450L \quad \text{LSB} = 2.5V/4095 = 0.610mV

Integral Nonlinearity (INL): End-point INL 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 zero, the linearity is measured between full scale and the code corresponding to the maximum offset specification. The INL error at a given input code is calculated as follows:

\[ \text{INL} = \frac{[V_{OUT} - V_{OS} - (V_{FS} - V_{OS})(\text{code}/4095)]}{\text{LSB}} \]

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

Differential Nonlinearity (DNL): DNL is the difference between the measured change and the ideal one LSB change between any two adjacent codes. The DNL error between any two codes is calculated as follows:

\[ \text{DNL} = \frac{(\Delta V_{OUT} - \text{LSB})}{\text{LSB}} \]

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

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)(s).

Figure 1. Effect of Negative Offset
Parallel Interface

The data on the input of the DAC is loaded into the DAC’s input latches when Chip Select (CSLSB and/or CSMSB) and WR are at a logic low. The data that is loaded into the input latches will depend on which of the Chip Selects are at a logic low (see Digital Interface Truth Table). If WR and CSLSB are both low and CSMSB is high, then only data on the eight LSBs (D0 to D7) is loaded into the input latches. Similarly if WR and CSMSB are both low and CSLSB is high then only data on the four MSBs (D8 to D11) is loaded into the input latches. Data is loaded into both the Least Significant Data Bits (D0 to D7) and the Most Significant Bits (D8 to D11) at the same time if WR, CSLSB and CSMSB are low.

The input data is latched into the input latches on the rising edge of either the WR or one of the Chip Selects. The WR transition high will latch the data in both input latches. A rising edge on CSMSB will latch data bits D8 to D11. A rising edge on CSLSB will latch data bits D0 to D7.

Once data is loaded into the input latches, it can be loaded into the DAC latch. This will update the analog voltage output of the DAC. The DAC latch is loaded by a logic low on LDAC. The data that is loaded into the DAC latch will be latched on the rising edge of LDAC.

Power-On Reset

The LTC1450/LTC1450L have an internal power-on reset that resets all internal latches to 0’s on power-up (equivalent to the CLR pin function).

Reference

The LTC1450 includes an internal 2.048V reference, giving the LTC1450 a full-scale range of 4.095V in the gain of 2 configuration. The LTC1450L has an internal 1.22V reference with a full-scale range of 2.5V and a gain of 2.05 in the gain of 2 configuration. The onboard reference in the LTC1450 and LTC1450L is not internally connected to the DAC’s reference resistor string but is provided on an adjacent pin for flexibility. Because the internal reference is not internally connected to the DAC resistor string, an external reference can be used or the resistor string can be driven with an external source in multiplying configuration. The external reference or source must be capable of driving the 8k minimum DAC ladder resistance.

The reference output noise can be reduced with a bypass capacitor to ground. (Note: The reference does not require a bypass capacitor to ground for proper operation.) When bypassing the reference a small value resistor in series with the capacitor is recommended to help reduce peaking on the output. A 10Ω resistor in series with a 4.7µF capacitor is optimum for reducing reference generated noise.

DAC Ladder Resistor String

The high and low end of the DAC ladder resistor string (REFHI and REFLO respectively) are not connected internally on this part. Typically REFHI will be connected to REFOUT and REFLO will be connected to GND. This will give the LTC1450 a full-scale range of 4.095V. The full-scale range for the LTC1450L will be 2.5V.

Either of these pins can be driven up to VCC – 1.5V when using the buffer in the gain of 1 configuration. The resistor string pins can be driven to VCC/2 when the buffer is in the gain of 2 configuration (2.05 for the LTC1450L). The resistance between these two pins is typically 18k (8k min).

Voltage Output

The output buffer for the LTC1450/LTC1450L can be configured for two different gain settings. By tying the X1/X2 pin to GND the gain is set to 2 (2.05 for the LTC1450L). By tying the X1/X2 pin to VOUT the gain is set to one.

The LTC1450 family’s rail-to-rail buffered output can source or sink 5mA over the entire operating temperature range while pulling to within 300mV of the positive supply voltage or GND. The output swings to within a few millivolts of either supply rail when unloaded and has an equivalent output resistance of 40Ω when driving a load to the rails.
**TYPICAL APPLICATIONS**

Filter $V_{REF}$ to Lower Output Noise (0.18mV$_{RMS}$ at $V_{OUT}$)

![Diagram of LTC1450/LTC1450L](image)

**Digitally Programmable Noninverting Amplifier**

LTC1450: $V_{IN} = 0V$ TO 2.048V ($V_{CC} = 4.5V$ TO 5V)
LTC1450L: $V_{IN} = 0V$ TO 2.048V ($V_{CC} = 4.5V$ TO 5.5V)

$V_{OUT} = \frac{D_{IN}}{4096} \times 2 | V_{IN}$

LTC1450L: $V_{OUT} = \frac{D_{IN}}{4096} \times 2.05 | V_{IN}$

---

LTC1450/LTC1450L

DATA (0:11) VCC REFOUT REFHI
CSELB CMSELB WR LDAC CLR
GND VCC REFLO X1/X2

VCC

0.1µF

5V

10Ω

4.7µF
Bipolar Output 12-Bit DAC

\[ V_{OUT} = 2.048 + \left( \frac{D_{IN} - 4096}{4096} \right) \times 4.096 \]

*REFLO is tied to REFOUT and REFHI is tied to GND. Tying REFLO to REFOUT and REFHI to GND in this application overcomes the need for a pull-down resistor on the REFOUT pin. REFOUT sees a constant load to GND independent of \( V_{OUT} \).

Digitally Programmable Bilateral Current Source/Sink

\[ I_{OUT} = \frac{D_{IN}}{4096} \times 4.096 - V_{REF} \left( \frac{R_2}{R_1} \right) \]

\[ I_{OUT} = \frac{2.047mA}{4096} - \frac{2.048mA}{4096} \]

\[ \frac{R_2}{R_1} \times (R_3 + R_4) \]

\[ \frac{R_2}{R_1} \times R_3 \]

\[ \frac{R_2}{R_1} \times R_4 \]
4-Quadrant Multiplying DAC Application

This application shows the LTC1450L configured as a single supply 4-quadrant multiplying DAC. It uses a 5V supply and only one external component, a 5k resistor tied from REFOUT to ground. (The LTC1450 can be used in a similar fashion.) The multiplying DAC allows the user to digitally change the amplitude and polarity of an AC input signal whose voltage is centered around an offset signal ground provided by the 1.22V reference voltage. The transfer function is shown in the following equations.

\[
V_{OUT} = (V_{IN} - V_{REF}) \left( \frac{D_{IN}}{4096} + 1 \right) + V_{REF}
\]

For the LTC1450L Gain = 2.05 and \( V_{REF} = 1.22V \)

\[
V_{OUT} = (V_{IN} - 1.22V) \left( 2.05 \left( \frac{D_{IN}}{4096} \right) - 1.05 \right) + 1.22V
\]

Table 1 shows the expressions for \( V_{OUT} \) as a function of \( V_{IN}, V_{REF} \) and \( D_{IN} \). The scope photo shows a 12.5kHz, 2.3VP-P triangle wave input signal and the corresponding output waveforms for zero-scale and full-scale DAC codes.
G Package
24-Lead Plastic SSOP (0.209)
(LTC DWG # 05-08-1640)

Dimensions in Inches (millimeters) unless otherwise noted.

*DIMENSIONS DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE
**DIMENSIONS DO NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE
PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

N Package
24-Lead PDIP (Narrow 0.300)
(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)**

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Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.
## LTC1450/LTC1450L

### RELATED PARTS

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<td>5V to 15V Single Supply in 8-Pin SO and PDIP</td>
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<td>LTC1451/LTC1452/LTC1453</td>
<td>Complete Serial I/O V&lt;sub&gt;OUT&lt;/sub&gt; 12-Bit DACs</td>
<td>3V/5V Single Supply, Rail-to-Rail in 8-Pin SO and PDIP</td>
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<td>Dual 12-Bit V&lt;sub&gt;OUT&lt;/sub&gt; DACs in SO-8 Package</td>
<td>LTC1446: V&lt;sub&gt;CC&lt;/sub&gt; = 4.5V to 5.5V, V&lt;sub&gt;OUT&lt;/sub&gt; = 0V to 4.095V LTC1446L: V&lt;sub&gt;CC&lt;/sub&gt; = 2.7V to 5.5V, V&lt;sub&gt;OUT&lt;/sub&gt; = 0V to 2.5V</td>
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<td>LTC1454: V&lt;sub&gt;CC&lt;/sub&gt; = 4.5V to 5.5V, V&lt;sub&gt;OUT&lt;/sub&gt; = 0V to 4.095V LTC1454L: V&lt;sub&gt;CC&lt;/sub&gt; = 2.7V to 5.5V, V&lt;sub&gt;OUT&lt;/sub&gt; = 0V to 2.5V</td>
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<td>Quad 12-Bit V&lt;sub&gt;OUT&lt;/sub&gt; DACs in 28-Lead SW and SSOP Packages</td>
<td>LTC1458: V&lt;sub&gt;CC&lt;/sub&gt; = 4.5V to 5.5V, V&lt;sub&gt;OUT&lt;/sub&gt; = 0V to 4.095V LTC1458L: V&lt;sub&gt;CC&lt;/sub&gt; = 2.7V to 5.5V, V&lt;sub&gt;OUT&lt;/sub&gt; = 0V to 2.5V</td>
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