



## LTC1454/LTC1454L

### Dual 12-Bit Rail-to-Rail Micropower DACs

## FEATURES

- 12-Bit Resolution
- **Buffered True Rail-to-Rail Voltage Output**
- 5V Operation,  $I_{CC}$ : 700 $\mu$ A Typ (LTC1454)
- 3V Operation,  $I_{CC}$ : 450 $\mu$ A Typ (LTC1454L)
- Built-In Reference: 2.048V (LTC1454)  
1.220V (LTC1454L)
- CLR Pin
- Power-On Reset
- **16-Lead SO Package**
- 3-Wire Cascadable Serial Interface
- **Maximum DNL Error: 0.5LSB**
- Low Cost

## APPLICATIONS

- Digital Calibration
- Industrial Process Control
- Automatic Test Equipment
- Cellular Telephones

## DESCRIPTION

The LTC<sup>®</sup>1454/LTC1454L are complete single supply, dual rail-to-rail voltage output, 12-bit digital-to-analog converters (DACs) in a 16-lead SO package. They include an output buffer amplifier with variable gain ( $\times 1$  or  $\times 2$ ) and an easy-to-use 3-wire cascadable serial interface.

The LTC1454 has an onboard reference of 2.048V and a full-scale output of 4.095V in a  $\times 2$  gain configuration. It operates from a single 4.5V to 5.5V supply.

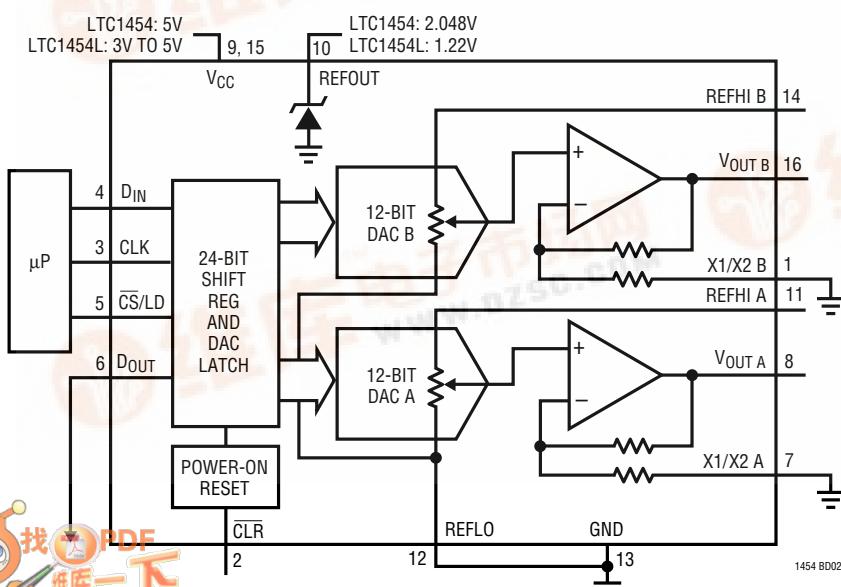
The LTC1454L has an onboard 1.22V reference and a full-scale output of 2.5V in a  $\times 2$  gain configuration. It operates from a single 2.7V to 5.5V supply.

Low power supply current, excellent DNL and small size allow these parts to be used in a host of applications where size, DNL and single supply operation are important.

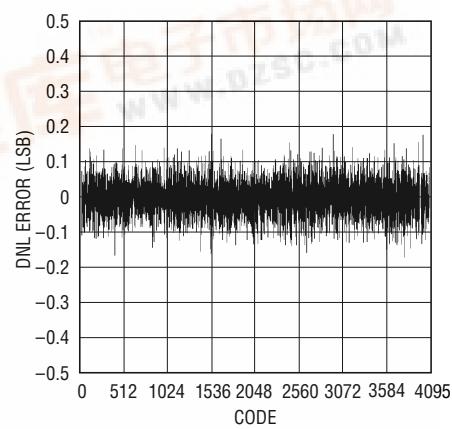
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## TYPICAL APPLICATION

Functional Block Diagram: Dual 12-Bit Rail-to-Rail DAC



Differential Nonlinearity vs Input Code



1454 GD8

## LTC1454/LTC1454L

## ABSOLUTE MAXIMUM RATINGS

$V_{CC}$ to GND .....	-0.5V to 7.5V
Logic Inputs to GND .....	-0.5V to 7.5V
$V_{OUT\ A}, V_{OUT\ B}, X1/X2\ A,$ $X1/X2\ B$ .....	-0.5V to $V_{CC} + 0.5V$
REFHI A, REFHI B, REFLO .....	-0.5V to $V_{CC} + 0.5V$
Maximum Junction Temperature .....	125°C
Operating Temperature Range	
LTC1454C/LTC1454LC .....	0°C to 70°C
LTC1454I/LTC1454LI .....	-40°C to 85°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 sec) .....	300°C

## PACKAGE/ORDER INFORMATION

TOP VIEW		ORDER PART NUMBER
X1/X2 B	1	V <sub>OUT</sub> B
CLR	2	V <sub>CC</sub>
CLK	3	REFHI B
DIN	4	GND
CS/LD	5	REFLO
D <sub>OUT</sub>	6	REFHI A
X1/X2 A	7	REFOUT
V <sub>OUT</sub> A	8	V <sub>CC</sub>
N PACKAGE		S PACKAGE
16-LEAD PDIP		16-LEAD PLASTIC SO
T <sub>JMAX</sub> = 125°C, θ <sub>JA</sub> = 100°C/W (N)		
T <sub>JMAX</sub> = 125°C, θ <sub>JA</sub> = 150°C/W (S)		

Consult factory for Military grade parts.

## **ELECTRICAL CHARACTERISTICS**

$V_{CC} = 4.5V$  to  $5.5V$  (LTC1454),  $2.7V$  to  $5.5V$  (LTC1454L),  $X1/X2 = \text{REFLO} = \text{GND}$ ,  $\text{REFHI} = \text{REFOUT}$ ,  $V_{OUT}$  and  $\text{REFOUT}$  unloaded,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Units	
<b>DAC</b>							
	Resolution		●	12		Bits	
DNL	Differential Nonlinearity	Guaranteed Monotonic (Note 1)	●		±0.5	LSB	
INL	Integral Nonlinearity	$T_A = 25^\circ\text{C}$ (Note 1)		±2.0	±4.0	LSB	
			●	±2.5	±4.5	LSB	
$V_{OS}$	Offset Error	$T_A = 25^\circ\text{C}$		±2.0	±12	mV	
			●	±4.0	±18	mV	
$V_{OS}TC$	Offset Error Temperature Coefficient				±15	$\mu\text{V}/^\circ\text{C}$	
$V_{FS}$	Full-Scale Voltage	When Using Internal Reference, $LTC1454$ , $T_A = 25^\circ\text{C}$ $LTC1454$	●	4.065	4.095	4.125	V
		When Using Internal Reference, $LTC1454L$ , $T_A = 25^\circ\text{C}$ $LTC1454L$	●	4.045	4.095	4.145	V
				2.470	2.500	2.530	V
$V_{FS}TC$	Full-Scale Voltage Temperature Coefficient	When Using Internal Reference		2.460	2.500	2.540	V
					±24		ppm/ $^\circ\text{C}$

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## Reference

	Reference Output Voltage	LTC1454 LTC1454L	● ●	2.008 1.195	2.048 1.220	2.088 1.245	V V	
	Reference Output Temperature Coefficient			±20		ppm/°C		
	Reference Line Regulation			●	0.7	±2.0	LSB/V	
	Reference Load Regulation	0 ≤ $I_{OUT}$ ≤ 100µA, LTC1454 LTC1454L		● ●	0.2 0.6	1.5 3.0	LSB LSB	
	Reference Input Range	$V_{REFHI} \leq V_{CC} - 1.5V$		$V_{CC}/2$		V		
	Reference Input Resistance			●	15	24	40	kΩ
	Reference Input Capacitance			15		pF		
	Short-Circuit Current	REFOUT Shorted to GND		●	40	120	mA	

# LTC1454/LTC1454L

## ELECTRICAL CHARACTERISTICS

$V_{CC} = 4.5V$  to  $5.5V$  (LTC1454),  $2.7V$  to  $5.5V$  (LTC1454L),  $X1/X2 = \text{REFLO} = \text{GND}$ ,  $\text{REFHI} = \text{REFOUT}$ ,  $V_{OUT}$  and  $\text{REFOUT}$  unloaded,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
<b>Power Supply</b>							
$V_{CC}$	Positive Supply Voltage	For Specified Performance, LTC1454 LTC1454L	● ●	4.5 2.7		5.5 5.5	V V
$I_{CC}$	Supply Current	$4.5V \leq V_{CC} \leq 5.5V$ (Note 4), LTC1454 $2.7V \leq V_{CC} \leq 5.5V$ (Note 4), LTC1454L	● ●		700 450	1250 1100	$\mu A$ $\mu A$
<b>Op Amp DC Performance</b>							
	Short-Circuit Current Low	$V_{OUT}$ Shorted to GND	●		70	120	mA
	Short-Circuit Current High	$V_{OUT}$ Shorted to $V_{CC}$	●		80	120	mA
	Output Impedance to GND	Input Code = 0	●		40		$\Omega$
<b>AC Performance</b>							
	Voltage Output Slew Rate	(Note 2)	●	0.5	1.0		$V/\mu s$
	Voltage Output Settling Time	(Notes 2, 3) to $\pm 0.5\text{LSB}$			14		$\mu s$
	Digital Feedthrough				0.3		$nV \cdot s$
	AC Feedthrough	$\text{REFHI} = 1\text{kHz}$ , $2V_{P-P}$ , (Code: All 0s)			-95		dB
SINAD	Signal-to-Noise + Distortion	$\text{REFHI} = 1\text{kHz}$ , $2V_{P-P}$ , (Code: All 1s)			85		dB

$V_{CC} = 5V$  (LTC1454),  $3V$  (LTC1454L),  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	LTC1454			LTC1454L			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
<b>Digital I/O</b>									
$V_{IH}$	Digital Input High Voltage		●	2.4		2.0			V
$V_{IL}$	Digital Input Low Voltage		●		0.8		0.6		V
$V_{OH}$	Digital Output High Voltage	$I_{OUT} = -1\text{mA}$	●	$V_{CC} - 1.0$		$V_{CC} - 0.7$			V
$V_{OL}$	Digital Output Low Voltage	$I_{OUT} = 1\text{mA}$	●		0.4		0.4		V
$I_{LEAK}$	Digital Input Leakage	$V_{IN} = \text{GND}$ to $V_{CC}$	●		$\pm 10$		$\pm 10$		$\mu A$
$C_{IN}$	Digital Input Capacitance	Guaranteed by Design	●		10		10		$\text{pF}$
<b>Switching</b>									
$t_1$	$D_{IN}$ Valid to CLK Setup		●	40		60			ns
$t_2$	$D_{IN}$ Valid to CLK Hold		●	0		0			ns
$t_3$	CLK High Time		●	40		60			ns
$t_4$	CLK Low Time		●	40		60			ns
$t_5$	$\bar{CS}/LD$ Pulse Width		●	50		80			ns
$t_6$	LSB CLK to $\bar{CS}/LD$		●	40		60			ns
$t_7$	$\bar{CS}/LD$ Low to CLK		●	20		30			ns
$t_8$	$D_{OUT}$ Output Delay	$C_{LOAD} = 15\text{pF}$	●		150		220		ns
$t_9$	CLK Low to $\bar{CS}/LD$ Low		●	20		30			ns

The ● 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  $5\text{k}\Omega$  in parallel with  $100\text{pF}$ .

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

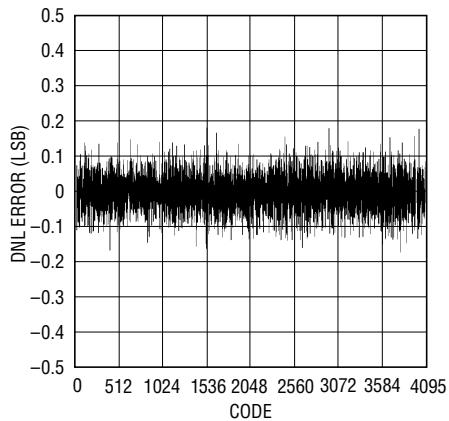
**Note 4:** Digital inputs at 0V or  $V_{CC}$ .

# LTC1454/LTC1454L

## TYPICAL PERFORMANCE CHARACTERISTICS

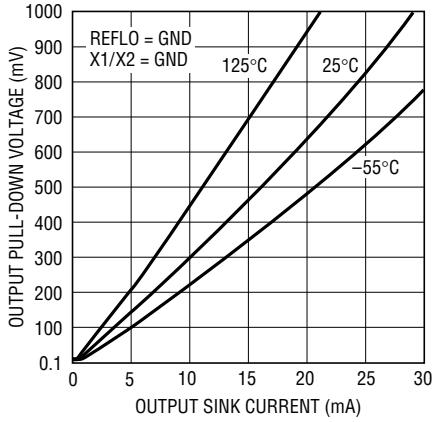
**LTC1454**

Differential Nonlinearity



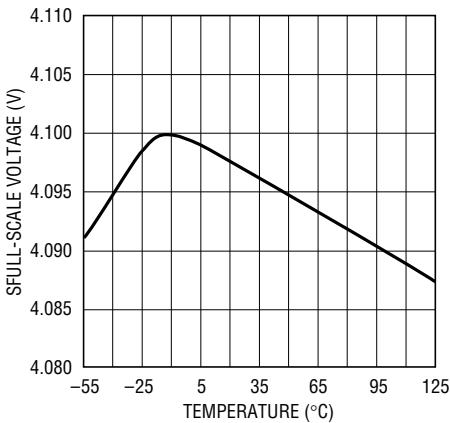
1454 G08

**LTC1454 Minimum Output Voltage vs Output Sink Current**



1454 G04

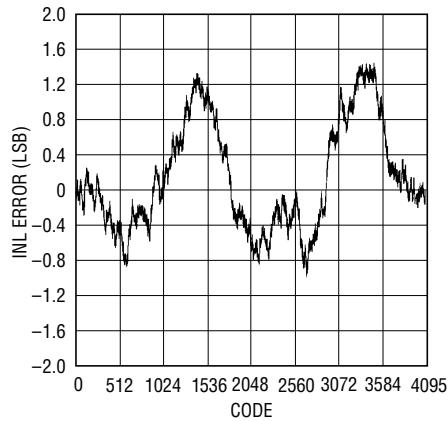
**LTC1454 Full-Scale Voltage vs Temperature**



1454 G02

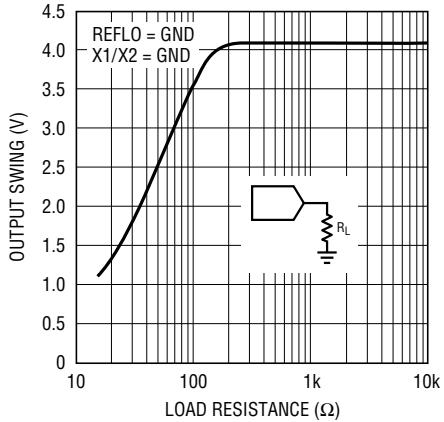
**LTC1454**

Integral Nonlinearity



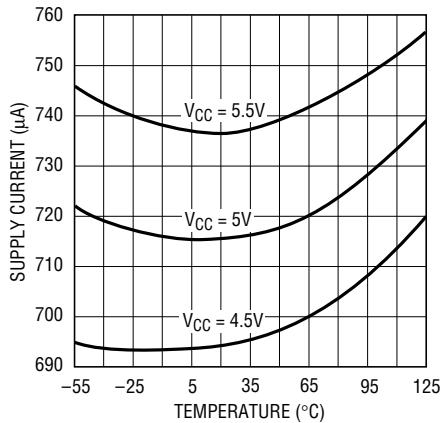
1454 G07

**LTC1454 Output Swing vs Load Resistance**



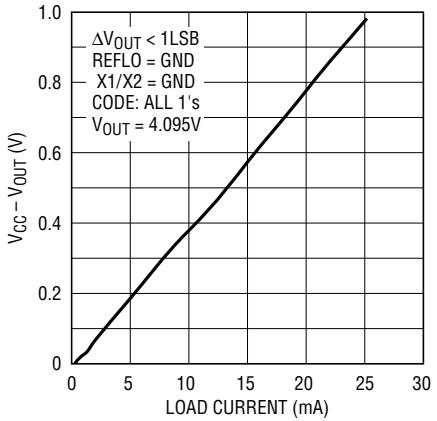
1454 G05

**LTC1454 Supply Current vs Temperature**



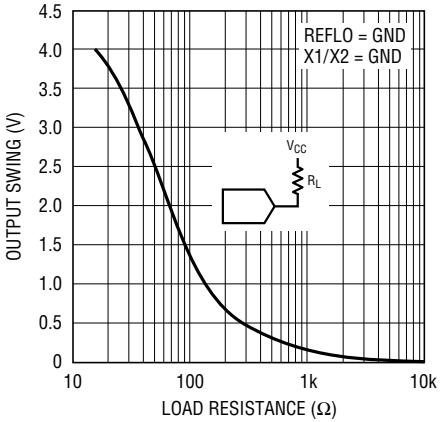
1454 G01

**Minimum Supply Headroom for Full Output Swing vs Load Current**



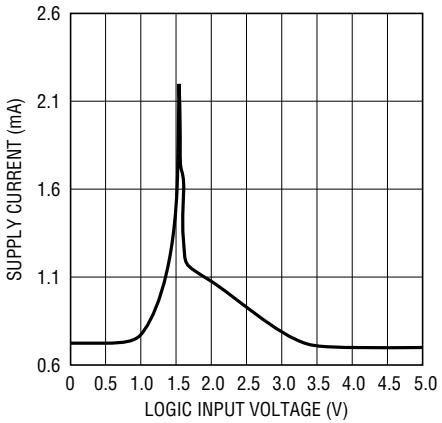
1454 G03

**LTC1454 Output Swing vs Load Resistance**



1458 G06

**LTC1454 Supply Current vs Logic Input Voltage**



1454 G09

## PIN FUNCTIONS

**X1/X2 B, X1/X2 A (Pins 1, 7):** The Input Pin that Sets the Gain for DAC A/B. When grounded the gain will be 2, i.e., output full scale will be  $\times 2$  REFHI. When connected to  $V_{OUT}$  the gain will be 1, i.e., output full scale will be equal to REFHI.

**CLR (Pin 2):** The Clear Pin for the DAC. Clears both DACs to zero scale when pulled low. This pin should be tied to  $V_{CC}$  for normal operation.

**CLK (Pin 3):** The Serial Interface Clock Input.

**D<sub>IN</sub> (Pin 4):** The Serial Data Input. Data on the D<sub>IN</sub> pin is latched into the shift register on the rising edge of the serial clock. Data is loaded as one 24-bit word. The first 12 bits are for DAC A, MSB-first and the second 12 bits are for DAC B, MSB-first.

**CS/LD (Pin 5):** The Serial Interface Enable and Load Control Input. When CS/LD is low the CLK signal is enabled so the data can be clocked in. When CS/LD is

pulled high, data is loaded from the shift register into the DAC register, updating the DAC output.

**D<sub>OUT</sub> (Pin 6):** The Output of the Shift Register which Becomes Valid on the Rising Edge of the Serial Clock.

**V<sub>OUT A</sub>, V<sub>OUT B</sub> (Pins 8, 16):** The Buffered DAC Outputs.

**V<sub>CC</sub> (Pins 9, 15):** The Positive Supply Input.  $4.5 \leq V_{CC} \leq 5.5V$  (LTC1454),  $2.7V \leq V_{CC} \leq 5.5V$  (LTC1454L). Requires a bypass capacitor to ground.

**REFOUT (Pin 10):** The Output of the Internal Reference.

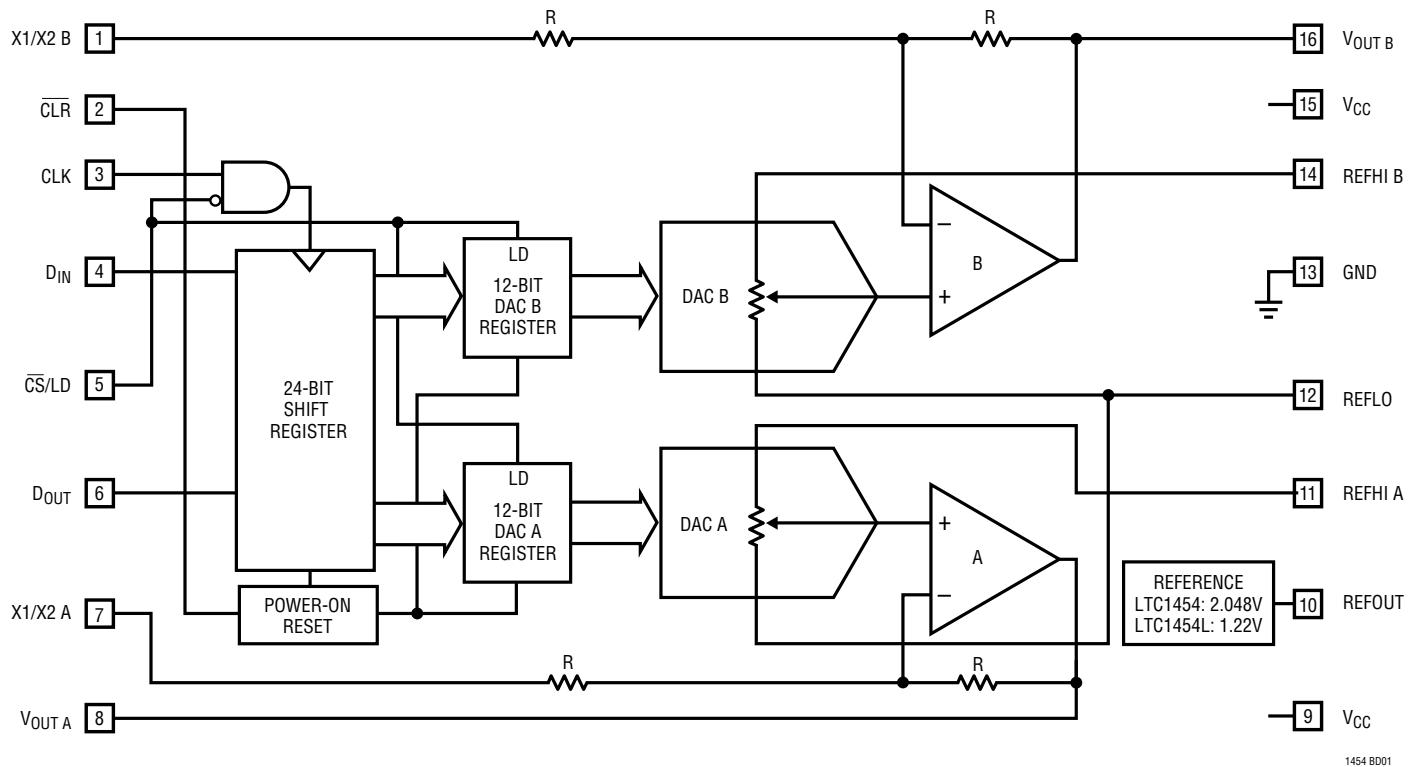
**REFHI A , REFHI B (Pins 11,14):** The Inputs to the DAC Resistor Ladder for DAC A/B.

**REFLO (Pin 12):** The Bottom of the DAC Resistor Ladder for Both DACs. This can be used to offset zero-scale above ground. REFLO should be connected to ground when no offset is required.

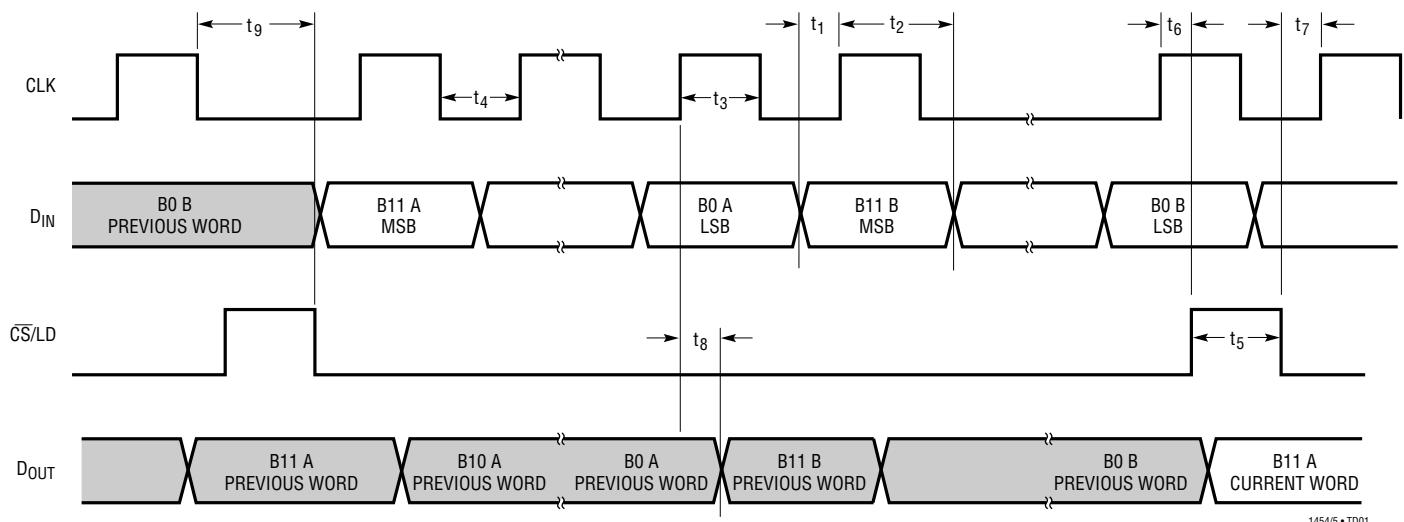
**GND (Pin 13):** Ground.

# LTC1454/LTC1454L

## BLOCK DIAGRAM



## TIMING DIAGRAM



## 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.

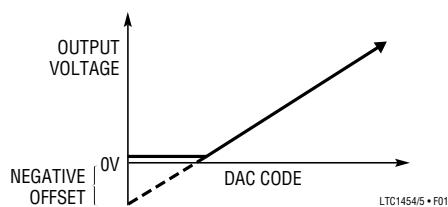


Figure 1. Effect of Negative Offset

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

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

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

$$LSB = (V_{FS} - V_{OS})/(2^n - 1) = (V_{FS} - V_{OS})/4095$$

Nominal LSBs:

$$\begin{aligned} LTC1454 \quad LSB &= 4.095V/4095 = 1mV \\ LTC1454L \quad LSB &= 2.5V/4095 = 0.610mV \end{aligned}$$

**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:

$$\begin{aligned} INL &= [V_{OUT} - V_{OS} - (V_{FS} - V_{OS})(Code/4095)]/LSB \\ V_{OUT} &= \text{The output voltage of the DAC measured at the given input code} \end{aligned}$$

**Differential Nonlinearity (DNL):** DNL 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:

$$\begin{aligned} DNL &= (\Delta V_{OUT} - LSB)/LSB \\ \Delta V_{OUT} &= \text{The measured voltage difference between two adjacent codes} \end{aligned}$$

**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).

# LTC1454/LTC1454L

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## OPERATION

### Serial Interface

The data on the  $D_{IN}$  input is loaded into the shift register on the rising edge of the clock. Data is loaded as one 24-bit word, DAC A first, then DAC B. The MSB is loaded first for each DAC. The DAC registers load the data from the shift register when  $\overline{CS/LD}$  is pulled high. The CLK is disabled internally when  $\overline{CS/LD}$  is high. Note: CLK must be low before  $\overline{CS/LD}$  is pulled low to avoid an extra internal clock pulse.

The buffered output of the 24-bit shift register is available on the  $D_{OUT}$  pin which swings from ground to  $V_{CC}$ .

Multiple LTC1454/LTC1454Ls may be daisy-chained together by connecting the  $D_{OUT}$  pin to the  $D_{IN}$  pin of the next chip, while the CLK and  $\overline{CS/LD}$  signals remain common to all chips in the daisy-chain. The serial data is clocked to all of the chips, then the  $\overline{CS/LD}$  signal is pulled high to update all of them simultaneously.

### Reference

The LTC1454L has an internal reference of 1.22V with a full scale of 2.5V (gain of 2 configuration). The LTC1454 includes an internal 2.048V reference, making 1LSB equal to 1mV (gain of 2 configuration). When the buffer gain is 2, the external reference must be less than  $V_{CC}/2$  and be capable of driving the 15k minimum DAC resistor ladder. With a gain of 1 configuration the external reference must be less than  $V_{CC} - 1.5V$ .

### Voltage Output

The rail-to-rail buffered output of the LTC1454 family can source or sink 5mA when operating with a 5V supply while pulling to within 300mV of the positive supply voltage or ground. The output swings to within a few millivolts of either supply rail when unloaded and has an equivalent output resistance of  $40\Omega$  when driving a load to the rails. The output can drive 1000pF without going into oscillation.

## APPLICATIONS INFORMATION

### A Single Supply, 4-Quadrant Multiplying DAC

The LTC1454 can also be used for 4-quadrant multiplying with an offset signal ground of 1.22V. This application is shown in Figure 2. The inputs are connected to REFHI B or REFHI A and have a 1.22V amplitude around a signal

ground of 1.22V. The outputs will swing from 0V to 2.44V, as shown by the equation with the figure. Since the signal ground is around 1.22V, REFLO is offset above ground by using an LT1034CS8-1.2 as shown.

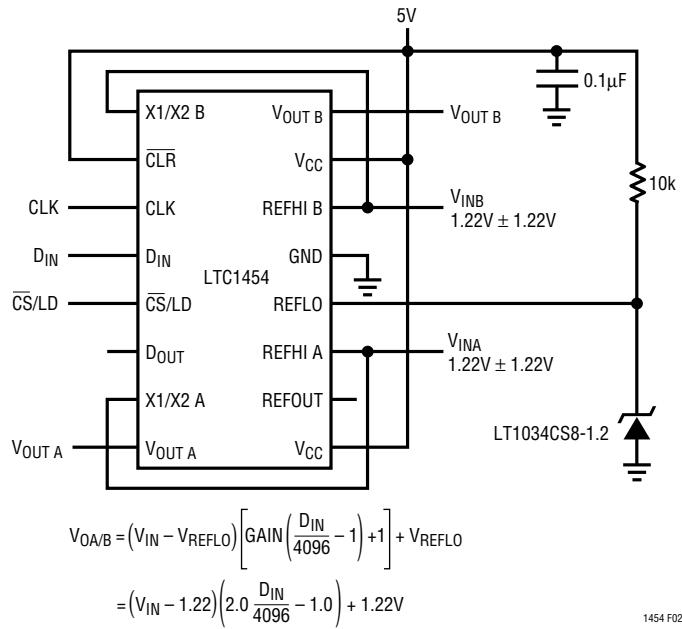


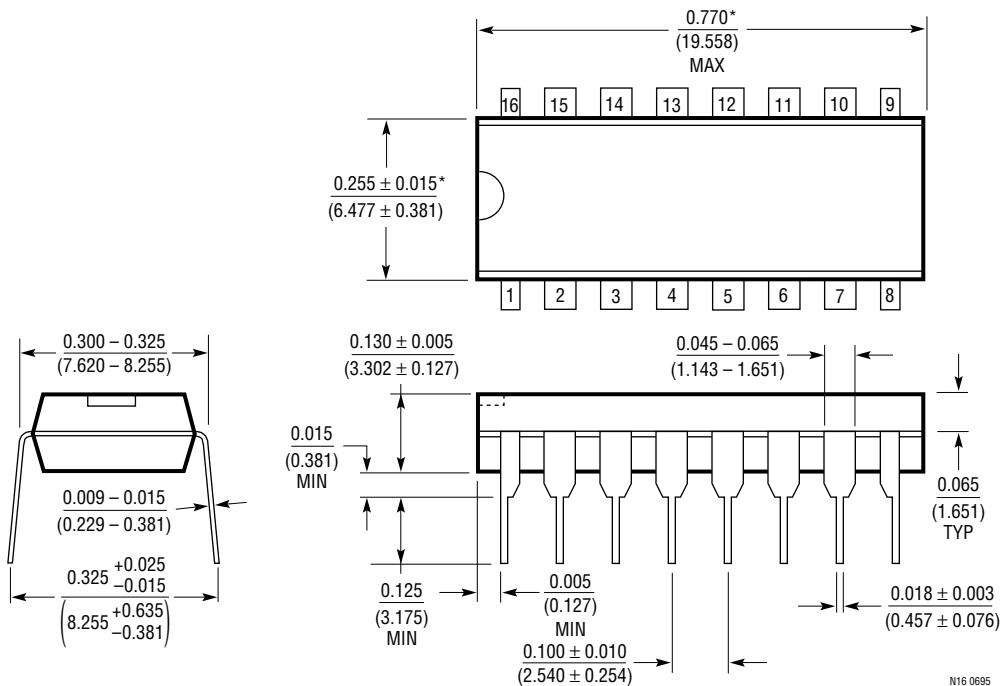
Figure 2

# LTC1454/LTC1454L

## PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

**N Package**  
**16-Lead PDIP (Narrow 0.300)**  
(LTC DWG # 05-08-1510)



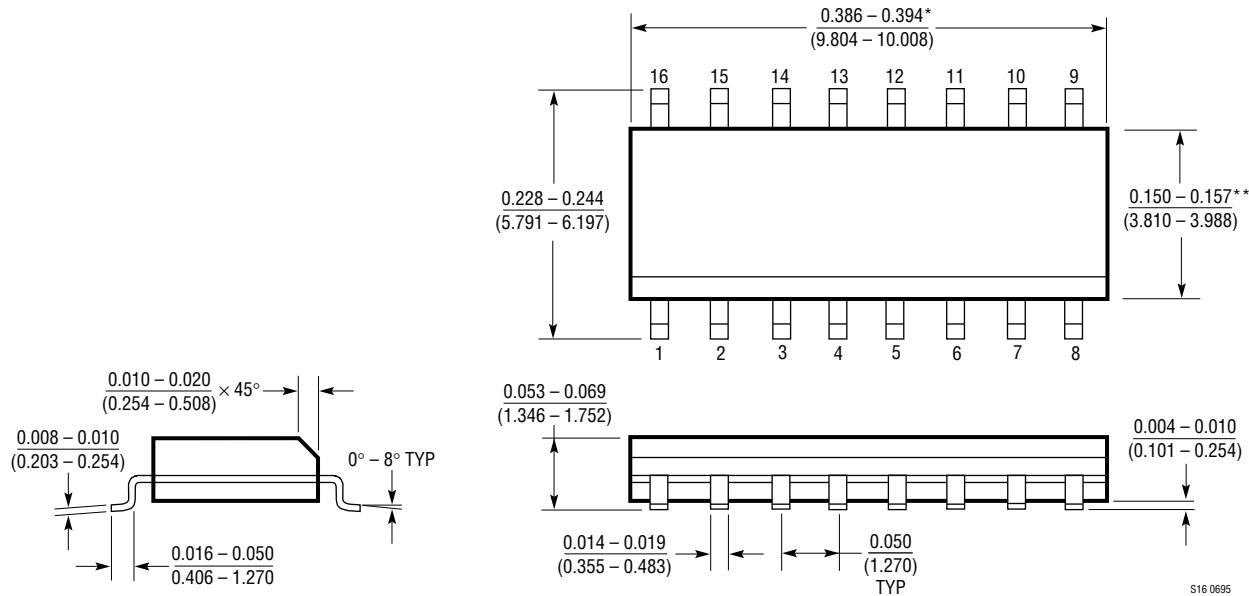
\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

N16 0695

## PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

**S Package**  
**16-Lead Plastic Small Outline (Narrow 0.150)**  
(LTC DWG # 05-08-1610)

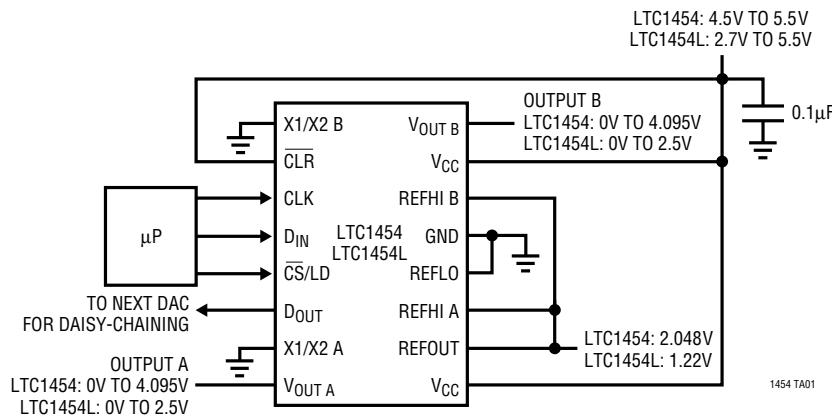


\*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

# LTC1454/LTC1454L

## TYPICAL APPLICATION



## RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1257	Single 12-Bit $V_{OUT}$ DAC, Full Scale: 2.048V, $V_{CC}$ : 4.75V to 15.75V, Reference Can Be Overdriven up to 12V, i.e., $FS_{MAX} = 12V$	5V to 15V Single Supply, Complete $V_{OUT}$ DAC in SO-8 Package
LTC1446/LTC1446L	Dual 12-Bit Rail-to-Rail Output DACs in an SO-8 Package	LTC1446: $V_{CC} = 4.5V$ to 5.5V, $V_{OUT} = 0V$ to 4.095V LTC1446L: $V_{CC} = 2.7V$ to 5.5V, $V_{OUT} = 0V$ to 2.5V
LTC1450/LTC1450L	Single 12-Bit Rail-to-Rail Output DACs with Parallel Interface	LTC1450: $V_{CC} = 4.5V$ to 5.5V, $V_{OUT} = 0V$ to 4.095V LTC1450L: $V_{CC} = 2.7V$ to 5.5V, $V_{OUT} = 0V$ to 2.5V
LTC1451	Single 12-Bit DAC, Full Scale: 4.095V, $V_{CC}$ : 4.5V to 5.5V	Low Power, Complete $V_{OUT}$ DAC in SO-8 Package
LTC1452	Single 12-Bit Rail-to-Rail Output $V_{OUT}$ 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 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
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	LTC1458: $V_{CC} = 4.5V$ to 5.5V, $V_{OUT} = 0V$ to 4.095V LTC1458L: $V_{CC} = 2.7V$ to 5.5V, $V_{OUT} = 0V$ to 2.5V