

## Low Level, High Accuracy, Bipolar Input Differential to Single-Ended Signal Conversion for 24-Bit A/D

Single Supply Differential to Single-Ended Conversion Circuit Amplifies Low Level Bipolar Signals and Maintains the LTC2400's High Accuracy

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### SPECIFICATIONS

$V_{CC} = V_{REF} = LT^{\circ}1236-5$ ;  $V_{FS} = \pm 125mV$ ;  
 $R_{SOURCE} = 175\Omega$  (Balanced)

PARAMETER	CIRCUIT (MEASURED)	LTC2400 ONLY	TOTAL (UNITS)
Input Voltage Range	$\pm 125$		mV
Zero Error	25	1.5	$\mu V$
Input Current	See Text		
Nonlinearity	$\pm 2.5$	4	ppm
Input-Referred Noise (without averaging)	1*	1.5	$\mu V$
Input-Referred Noise (averaged 64 readings)	0.12*		$\mu V$
Resolution (with averaged readings)	21.0		Bits
Overall Accuracy (uncalibrated)**	17.0		Bits
Supply Voltage	5	5	V
Supply Current	1.2	0.2	mA
CMRR	118		dB
Common Mode Range	0 to 5		V

\* Input-referred noise with a gain of 20.

\*\* Does not include gain setting resistors.

### OPERATION

The circuit in Figure 1 is ideal for wide dynamic range differential bridge outputs in applications that have a 5V supply. The circuit uses one-half of an LTC<sup>®</sup>1043 to perform a differential to single-ended conversion over an input common mode range that includes the power supplies. This half of the LTC1043 samples a differential input voltage, holds it on  $C_{S1}$  and transfers it to capacitor  $C_{H1}$ . The voltage on  $C_{H1}$  is buffered, applied to the LTC2400's input and converted to a digital value.

A reference voltage is applied to the LTC2400's  $V_{REF}$  pin and the LTC1043's Pin 6. The remaining half of the LTC1043 divides the reference voltage by two with a high degree of accuracy. This  $V_{REF}/2$  voltage is applied to the


bottom of  $C_{H1}$ , centering the LTC1043's output voltage at midscale. This allows the converter to accept bipolar input voltages that swing about a  $V_{REF}/2$  point when operating on a single supply.

The LTC1043 achieves its best differential to single-ended conversion when its internal switching frequency operates at a nominal 300Hz, as set by the 0.01 $\mu F$  capacitor C1 and when 1 $\mu F$  capacitors are used for  $C_{S1}$ ,  $C_{S2}$ ,  $C_{H1}$  and  $C_{H2}$ . Each of these four resistors should be a film type such as mylar or polypropylene. Conversion accuracy is enhanced by placing a guard shield around  $C_{S1}$  and connecting the shield to Pin 10 of the LTC1043. This minimizes nonlinearity that results from stray capacitance transfer errors associated with  $C_{S1}$ . Consult the LTC1043 data sheet for more information. As is good practice in all high precision circuits, keep all lead lengths as short as possible to minimize stray capacitance and noise pickup.

The circuit in Figure 1 improves on unbuffered LTC1043 circuits, providing an order of magnitude improvement in linearity ( $\pm 2.5ppm$ ) by buffering the voltage on  $C_{H1}$ . One-half of an LTC1051 is used, with its gain set by R1 and R2 ( $A_V = 1 + R1/R2$ ). The remaining half of the LTC1051 buffers the voltage on the bottom of  $C_{H1}$  before it is applied to R2.

As stated above, the LTC1043 has the highest transfer accuracy when using 1 $\mu F$  capacitors. Using any other value will compromise the accuracy. For example, 0.1 $\mu F$  will typically increase the circuit's overall nonlinearity by an order of magnitude.

Another source of error is thermocouple effects that occur in soldered connections starting with the LTC1043's input traces and ending with the connection at the LTC2400's input and ground pins. Any temperature changes in any of

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the low level circuitry's connections will cause perturbations in the final conversion result. Their effects can be minimized by ensuring uniform temperature at pairs of junctions between dissimilar metals and by sealing the circuit against moving air.

The circuit's input current is dependent on the input signal's common mode voltage. The input current is approximately  $-100\text{nA}$  at  $-2.5\text{V}$ ,  $100\text{nA}$  at  $2.5\text{V}$  and  $0\mu\text{A}$  at midscale ( $0\text{V}$ ). The values may vary from part to part. Figure 1's input is analogous to a  $2\mu\text{F}$  capacitor in parallel with a  $25\text{M}\Omega$  connected to ground. The LTC1043's nominal  $800\Omega$  switch resistance is between the source and the  $2\mu\text{F}$  capacitance.

Resistors R1 and R2 set the gain of the op amp that drives the LTC2400. The practical gain range with this topology

as shown is from 5 to 100 unless the op amp supply voltage is increased. At a gain of less than five, the common mode input range of the LTC1051 becomes a constraint, which prevents using the A/D's full dynamic range.

The use of a higher supply voltage for the LTC1051 allows a higher common mode input voltage and, therefore, is suitable for lower gain and greater differential input voltage. The higher supply voltage is not necessary if the rail-to-rail LTC1152 is used.

Lower reference voltage provides an additional benefit of increased LTC2400 linearity. Whereas the linearity error is  $\pm 4\text{ppm}$  with a  $5\text{V}$  reference, it drops to  $\pm 2\text{ppm}$  with a  $2.5\text{V}$  reference. This translates to a lower offset when using midscale as the zero point.

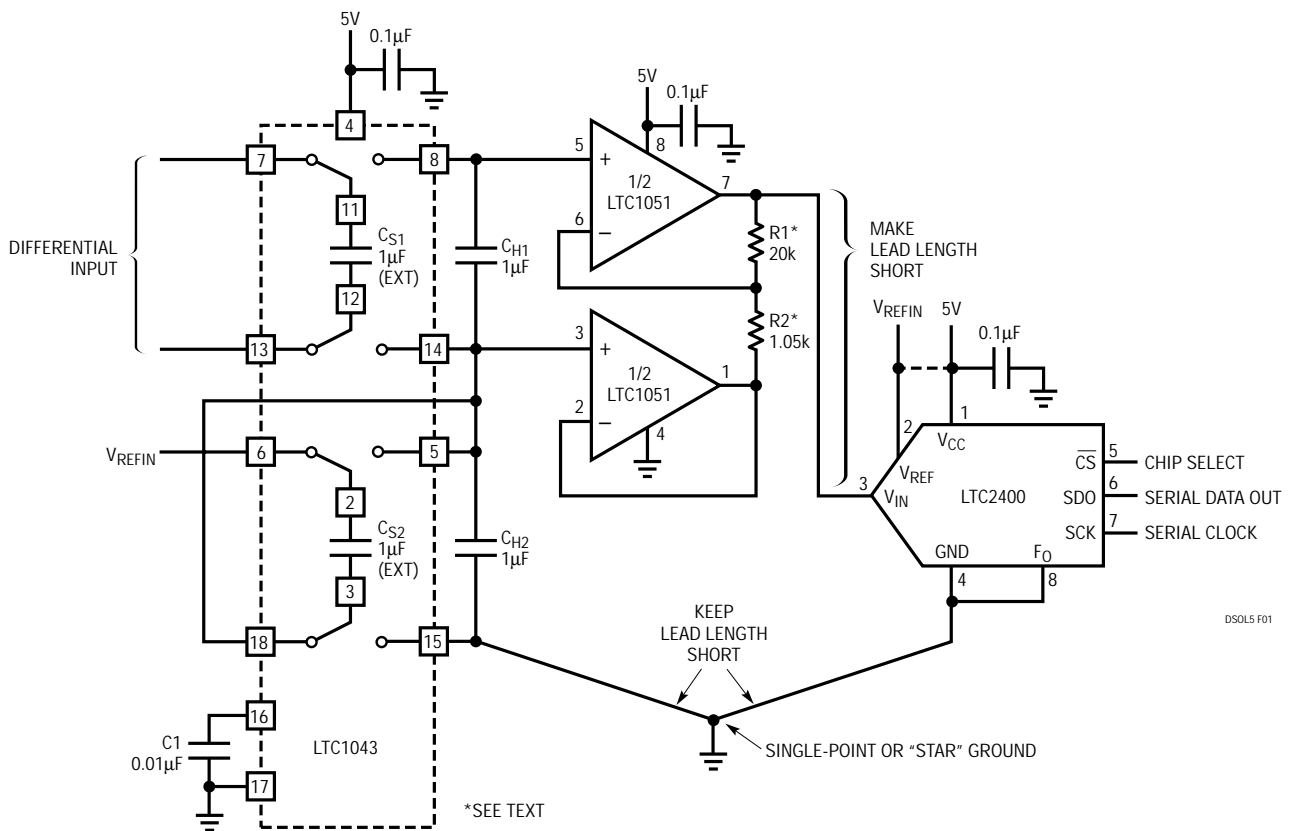


Figure 1. This Single Supply Differential to Single-Ended Conversion Circuit Amplifies Low Level Bipolar Signals and Maintains the LTC2400's High Accuracy