

DESIGN NOTES

LTC2400 High Accuracy Differential to Single-Ended Converter for $\pm 5V$ Supplies – Design Note 207

Differential to Single-Ended Converter Has Very High Uncalibrated Accuracy and Low Offset and Drift

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Introduction

The circuit in Figure 1 is ideal for low level differential signals in applications that have a $\pm 5V$ supply and need high accuracy without calibration. The circuit achieves 19.6-bit resolution and 18.1-bit accuracy. These and other specifications are summarized in Table 1.

Operation

The circuit in Figure 1 combines an LTC[®]1043 and LTC1050 as a differential to single-ended amplifier that has an input common mode range that includes the power supplies. It uses the LTC1043 to sample a differential input voltage, holds it on C_S and transfers it to a ground-referred capacitor, C_H . The voltage on C_H is applied to the LTC1050's noninverting input and amplified by the gain set by

resistors R1 and R2 (101 for the values shown). The amplifier's output is then converted to a digital value by the LTC2400.

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_S and C_H . C_S and C_H should be a film type such as mylar or polypropylene. Conversion accuracy is enhanced by placing a guard shield around C_S and connecting the shield to Pin 10 of the LTC1043. This minimizes nonlinearity that results from stray capacitance transfer errors associated with C_S . To minimize the possibility of PCB leakage

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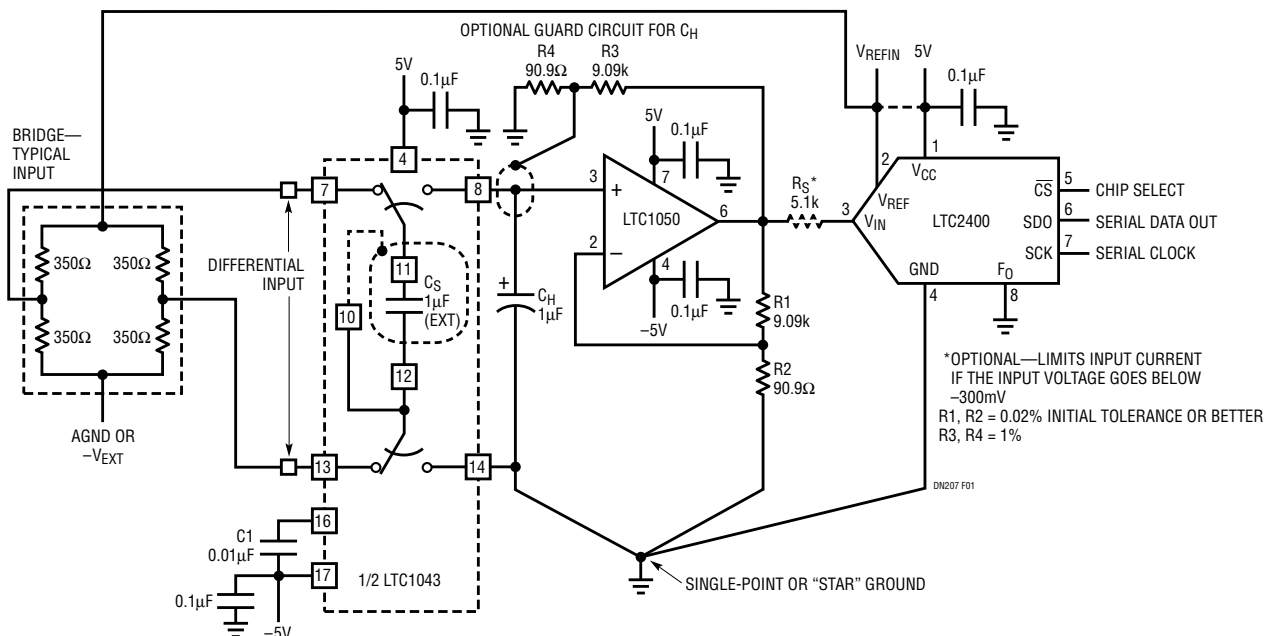


Figure 1. Differential to Single-Ended Converter for Low Level Inputs, Such as Bridges, Maintains the LTC2400's High Accuracy

currents introducing an error source into C_H , an optional guard circuit could be added as shown. The common point of these two resistors produces the potential for the guard ring. 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 LTC1050's closed-loop gain accuracy is affected by the tolerance of the ratio of the gain-setting resistors. If cost considerations preclude using low tolerance resistors (0.02% or better), the processor to which the LTC2400 is connected can be used to perform software correction. Operated as a follower, the LTC1050's gain and linearity error is less than 0.001%.

As stated above, the LTC1043 has the highest transfer accuracy when using 1.0 μ F capacitors. For example, 0.1 μ F will typically increase the circuit's overall nonlinearity tenfold to 0.001% or 10ppm.

A source of errors is thermocouple effects that occur in soldered connections. Their effects are most pronounced in the circuit's low level portion, before the LTC1050's output. Any temperature changes in any of the low level circuitry's connections will cause linearity perturbations in the final conversion result. Their effects can be minimized by balancing the thermocouple connections with reversed redundant connections and by sealing the circuit against moving air.

A subtle source of error arises from ground lead impedance differences between the LTC1043 circuit, the LTC1050 preamplifier and the LTC2400. This error can be avoided by connecting Pin 14 of the LTC1043, the bottom end of R2 and Pin 4 of the LTC2400 to a single-point "star" ground.

The circuit's input current consists of common mode and differential mode components. The differential mode input current can be as much as ± 25 nA when $V_{IN(CM)}$ is equal to the + or -5V common mode limit, and V_{DIFF} is 40mV (typ). The ratio of common mode to differential input current is nominally 3:1. Under balanced input conditions ($V_{IN(CM)} = 0$), the total input current is typically

1nA. The values may vary from part to part. Figure 1's input is analogous to a 2 μ F capacitor in parallel with a 25M Ω connected to ground. The LTC1043's nominal 800 Ω switch resistance is between the source and the 2 μ F capacitance.

The circuit schematic shows an optional resistor, R_S . This resistor can be placed in series with the LTC2400's input to limit current if the input goes below -300mV. The resistor does not degrade the converter's performance as long as any capacitance, stray or otherwise, connected between the LTC2400's input and ground is less than 100pF. Higher capacitance will increase offset and full-scale errors.

Other differential to single-ended conditioning circuits for the LTC2400 are available on LTC's web site. Refer to the URL at the bottom of this page.

Table 1. Performance Specifications for Figure 1's Circuit.
 $V_{CC} = V_{REF} = LT^{\circ}1236-5$; $V_{FS} = 40$ mV, $R_{SOURCE} = 175\Omega$
 (Balanced)

PARAMETER	CIRCUIT (MEASURED)	LTC2400	TOTAL (UNITS)
Input Voltage Range	-3 to 40		mV
Zero Error	12.7	1.5	μ V
Input Current	See Text		
Nonlinearity	± 1	4	ppm
Input-Referred Noise (without averaging)	0.3*	1.5	μ V _{RMS}
Input-Referred Noise (averaged 64 readings)	0.05*		μ V _{RMS}
Resolution (with averaged readings)	19.6		Bits
Overall Accuracy (uncalibrated**)	18.1		Bits
Supply Voltage	± 5	5	V
Supply Current	1.6	0.2	mA
CMRR	120		dB
Common Mode Range	± 5		V

*Input-referred noise with a gain of 101.

**Does not include gain setting resistors.

Data Sheet Download

<http://www.linear-tech.com/go/dnLTC2400>

For literature on our A/D Converters,
 call **1-800-4-LINEAR**. For applications help,
 call (408) 432-1900, Ext. 2453