LTC2400 Differential Bridge Digitizers

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This Design Idea covers two circuits that convert differential signals to single-ended, ground referred signals for input to the LTC2400 delta-sigma ADC. These circuits were designed to have a minimal effect on the LTC2400's 1ppm typical accuracy. The circuit in Figure 1 is ideal for low level differential bridge outputs in applications that have ±5V supplies. The circuit in Figure 2 is ideal for low level differential bridge outputs, typically 2mV/V, in single-supply applications, and features "live at zero" operation. ("Live at zero" refers to a topology with an elevated ground, allowing the amplifier to drive signals below the LTC2400's negative rail.) Both circuits were tested using the LTC2400 demonstration board. The V_{CC} and V_{REF} for the LTC2400 in Figure 1's circuit are generated by an LT1236-5.

The circuit in Figure 2 uses a simple voltage reference (the Schottky diode and NPN transistor) to bias the single-ended signal approximately 270mV above ground. For single-supply applications, this bias voltage and "live at zero" operation allows the LTC1050 and the LTC2400 to amplify and convert signals that include inputs below ground.

Both circuits combine an LTC1043 precision switched capacitor block and an LTC1050 chopper stabilized op amp, creating a differential input, single-ended output bridge amplifier that has a rail-to-rail common mode input range. The LTC1043 samples 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 is set by a 0.01µF capacitor, C1, and when 1µF capacitors are used for C_S and C_H. Using any other value will compromise the accuracy. For example, a C1 value of 0.1µF will typically increase the circuit's overall nonlinearity tenfold. 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. 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 errors are less than 0.001%.

The circuit in Figure 1 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.

The circuit in Figure 2 receives a very low level output from a bridge excited by only 2.5V. It uses bandwidth limiting and an attenuator after the amplifier to reduce input referred noise and autozero commutating noise

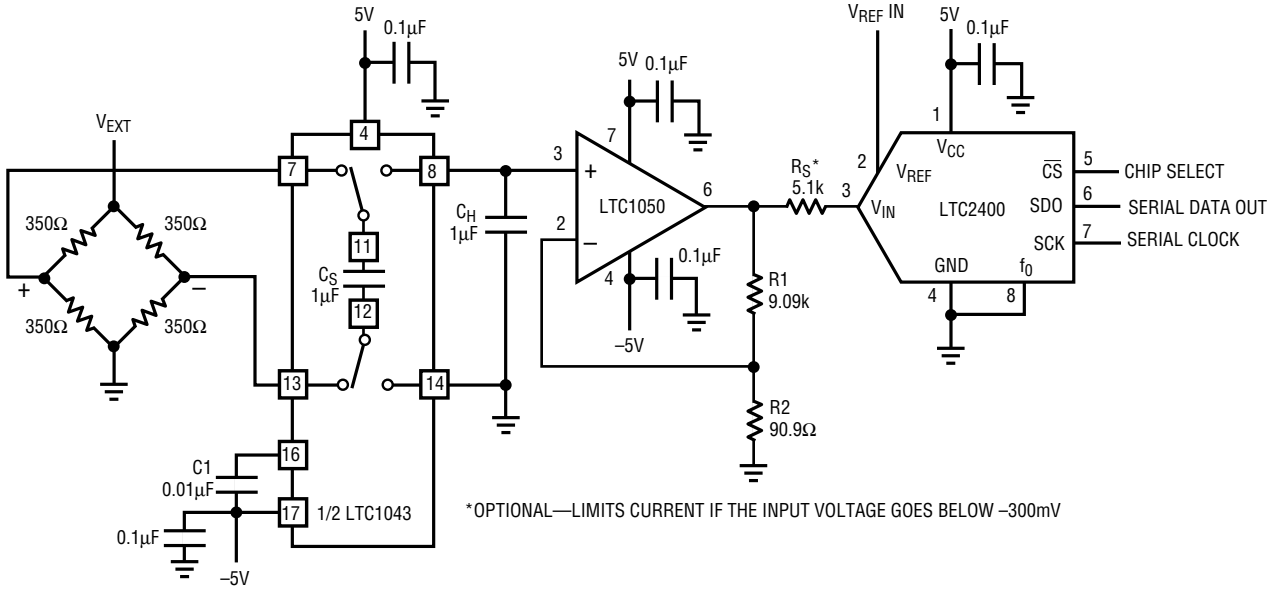

Figure 1. LTC2400 bridge digitizer for ±5V supplies

Table 1. Performance specifications for the circuits in Figures 1 and 2

Parameter	Figure 1	Figure 2	LTC2400	Units
Input Voltage Range	–3 to 40	–0.5 to 5		mV
Zero Error	12.7	2	1.5	µV
Input Current	(See Text)	(See Text)		
Nonlinearity	±1	±5	4	ppm
Noise (without Averaging)	0.3*	0.21*	1.5	μV_{RMS}
Noise (Averaged 64 Readings)	0.05*	0.026*		μV_{RMS}
Resolution (with Averaged Readings)	19.6	17.2		Bits
Overall Accuracy (uncalibrated)	20**	17.6**		Bits
Supply Voltage	±5	5	5	V
Supply Current	1.6	2.6	0.2	mA
CMRR	120	120		dB
Common Mode Range	±5	0 to 5		V

Specifications: $V_{CC} = V_{REF}$ = LTC1236-5 for Figure 1, LT1019-2.5 for Figure 2; V_{FS} = 40mV; R_{SOURCE} = 175Ω(Balanced)

*Input-referred noise with a gain of 101
**Offset and gain error removed

as much as possible. The noise gain shown (101) allows adequate headroom for the expected signal; the attenuator reduces the overall gain to 16.8. This is approximately the point, when using the LTC1050 and the LTC2400, where additional gain produces no additional reduction in input-referred noise.

Another source of error is thermocouple effects that occur in soldered connections. These 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 effect linearity in the final conversion result. These effects can be minimized by balancing the thermocouple connections with reversed redundant connections and by sealing the circuit against moving air.

Each circuit's input current is dependent on the input signal's common mode voltage. The circuit in Figure 1 has an input current of approximately –100nA and 100nA respectively, relative to the limits of the common mode range, dropping to zero at 0V common mode. The circuit in Figure 2 has an input current of approximately 100nA at a common mode input of 5V, dropping to zero at 0V common mode. The input-current values may vary from part to part. The input of each circuit is analogous to a 2µF capacitor in parallel with 25MΩ connected to ground. The LTC1043's nominal 800Ω switch resistance is between the input signal source and the 2µF capacitance.

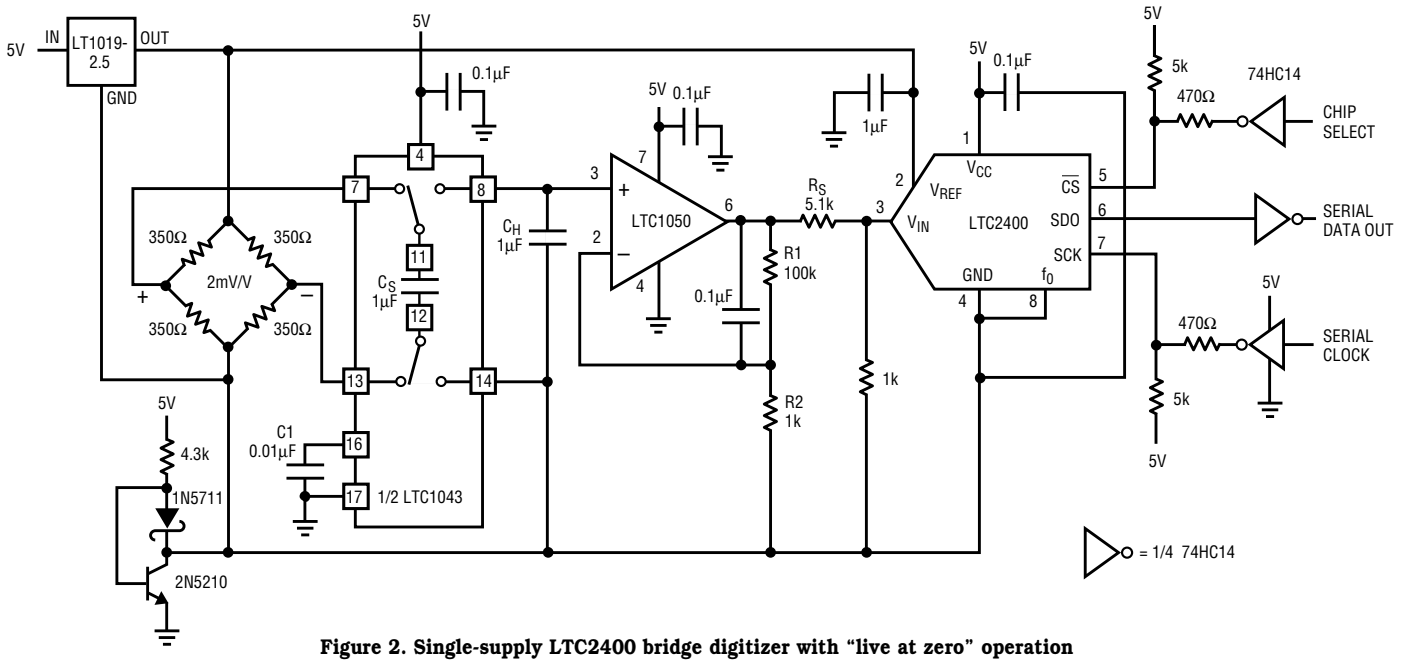

Figure 2. Single-supply LTC2400 bridge digitizer with "live at zero" operation