Circuit compensates system offset of a load-cell-based balance

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It's a challenge to interface a resistive bridge sensor with an ADC receiving its power from a 5V single-supply power source. Some applications require output-voltage swings from 0V to a full-scale voltage, such as 4.096V, with excellent accuracy. With most single-supply instrumentation amplifiers, problems arise when the output signal approaches 0V, near the lower output-swing limit of a single-supply instrumentation amp. A good single-supply instrumentation amp may swing close to single-supply ground but does not reach ground even if it has a true rail-to-rail output.

In this application, the sensor is a precision load cell with a nominal load of 5 kg, or about 11 lbs, to weigh objects on an aluminum pan weighing approximately 150g, or approximately 5 oz. Because of the pan's weight, the instrumentation amplifier's output signal can never go down to 0V, even if there are no objects to weigh. Now, the problem arises of how to compensate the instrumentation amp's output-offset voltage and the voltage that the pan itself produces.

A software approach is the simplest way to compensate the system offset. During power-up, there are no objects to weigh on the pan, and the system can thus acquire the offset voltage and hold the data in the microcontroller's memory, subsequently subtracting it from the data it acquired when there was an object to weigh. This approach, however, does not reach the 5-kg full-scale of the balance, reaching only 5−0.15 kg, or 4.85 kg.

This Design Idea shows how to achieve hardware compensation us-

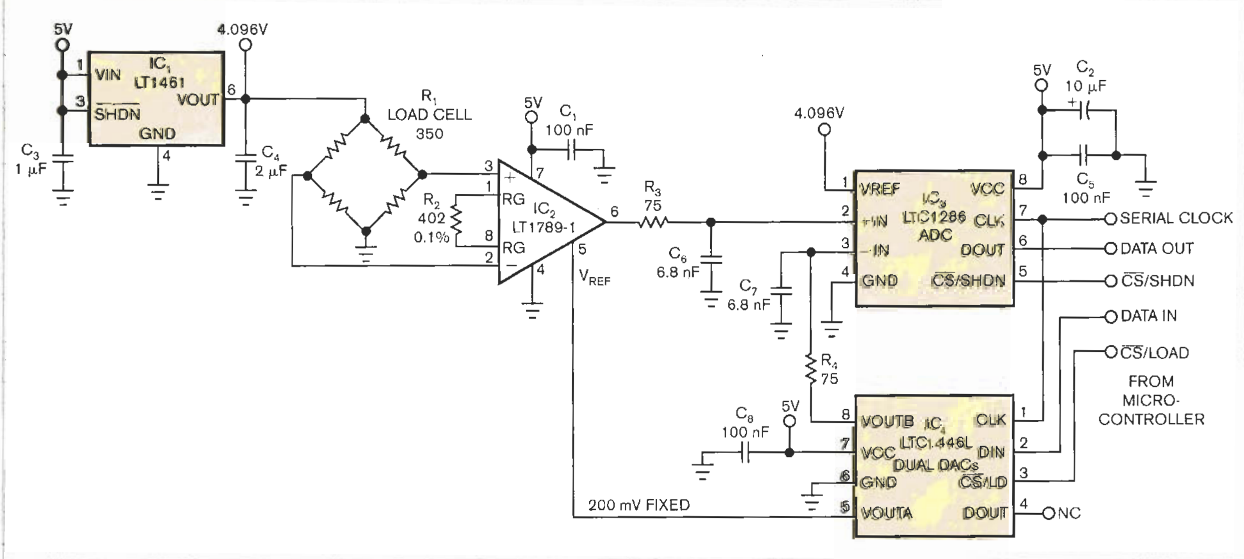

Figure 1 The serial dual DAC in this circuit gets an offset voltage from the microprocessor (not shown) during a power-on-calibration routine.

ing a microcontroller that, on power-up, starts a software routine to reset the system offset. The solution is a simple circuit based on four ICs from Linear Technology (www.linear.com) in **Figure 1**. A precision voltage reference, IC_1, has a high minimum output current of 50 mA. It provides an output voltage of 4.096V to power the load cell and to set the full-scale of the 12-bit ADC, IC_3. The highly accurate LT1789-1 instrumentation amplifier, IC_2, features maximum input-offset voltage of 150 μV over the temperature range of 0 to 70°C and maximum input-drift-offset voltage of 0.5 μV/°C over the temperature range of 0 to 70°C with rail-to-rail output that swings within 110 mV of ground. You set the gain through precision resistor R_2 to a nominal value of 500Ω to give an output span of 4.096V when the load is 5 kg and its maximum input signal is $V_{CC}\times S=4.096\text{V}\times 2\text{ mV/V}=8.192\text{ mV}$, where S is the sensor's sensitivity.

The output of DAC_A of dual-DAC IC_4 provides a reference voltage of 200 mV at the reference pin of the instrumentation amp to avoid saturation near ground of the amplifier itself, where its transfer characteristic is not quite linear. The amplifier's total worst-case output offset is: $V_{REF}+V_{PAN}\pm V_{OFFSET}=200\text{ mV}+125\text{ mV}\pm 500\times 150\ \mu\text{V}=325\text{ mV}\pm 75\text{ mV}=250\text{ mV}/400\text{ mV}$, where $V_{PAN}=125$ mV and is the voltage that the pan's weight produces.

The system-output offset is thus 250 to 400 mV. On power-up, the microcontroller starts a routine that sets the output of the DAC_A equal to 200 mV, while it increases the output of the DAC_B of dual-DAC IC_4 until it is equal to the system offset on Pin 2 of ADC IC_3, and the result of the conversion is 000h. This result is possible because IC_4 contains two 12-bit DACs with the same full-scale voltage of 2.5V, making 1 LSB equal to 0.61 mV, which is smaller than IC_3's resolution of 1 mV. This figure corresponds to the resolution of the balance: 5000g/4096=1.22g. The maximum output voltage of the instrumentation amp with a maximum load of 5 kg is $4.096\text{V}+V_{OUT\_TOTAL\_OFFSET\_INA}=4.346\text{V}/4.496\text{V}$, which is less than the minimum worst case over temperature of 4.62V high saturation.

IC_3 has a single unipolar differential input, so you can subtract from the +IN input voltage a constant voltage of value equal to the system offset that that DAC_B of IC_4 provides. During the first one and a half clock cycles, the ADC samples and holds the positive input. At the end of this phase, or acquisition time, the input capacitor switches to the negative input, and the conversion starts. The RC-input filters on the inputs of IC_3 have a time constant of 0.5 μsec to permit the negative and positive input voltages to settle to a 12-bit accuracy during the first clock cycle of the conversion time, using the maximum clock frequency, which is 200 kHz. If you want to increase the time constant, then you must use a lower clock frequency.

Furthermore, the DAC and ADC have a three-wire serial interface that easily permits transferring data to a wide range of microcontrollers with a maximum sampling rate of 12.5k samples/sec. When the ADC performs no conversions, it automatically powers down to 1 nA of supply current, and, if the microcontroller shuts down IC_1 through its Pin 3, the circuit draws a worst-case supply current of just 1 mA, because all the ICs are micropower. **EDN**