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MSP430 Ultra-Low-Power MCU Applications BRIEF

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Designing single-chip portable applications for full-bridge sensor data acquisition using a low-power MCU with integrated sigma-delta ADC and PGA

When designing battery-powered applications for weight, force, torque and pressure measurement, resistive full-bridge sensors are widely used. After signal conditioning, the differential voltage that is output by the bridge sensors is provided to a microcontroller with an analog-to-digital converter (ADC) for further processing and display. Most of the bridge sensors require a high excitation voltage (typically in the 10V range), while still outputting a rather low, full-scale differential voltage in the range of 2mV/V excitation voltage.

In general, for portable applications, the system power consumption needs to be considered carefully. Low power consumption enables the use of smaller batteries and results in a longer application lifetime. Coin cells or small alkaline batteries are a common power source for delivering 3V for direct connection of low-power microcontrollers such as the MSP430 from Texas Instruments.

The conventional approach of using a bridge sensor excitation voltage of 10V and an operational amplifier to achieve a full-scale ADC input voltage increases chip count and power consumption. An additional external voltage regulator is also needed to be able to excite the bridge sensor and supply the microcontroller from the same voltage source. A more energy-efficient and cost-effective solution is to use a microcontroller with an integrated high-resolution ADC and integrated programmable gain amplifier (PGA). The entire application can then be powered from a 3V battery.

Design example – single-chip weigh scale

A portable weigh scale that uses a full-bridge, thin-beam sensor for small load measurement is shown. This entire weigh scale, including the sensor excitation, is powered by a 3V battery and displays measurement results on an LCD. A calibration algorithm is provided to compensate for the various systems errors.

The sensor used has a rated output voltage of 2mV/V when loaded with its maximum load capacity of 20lbs. The sensor signal should now be resolved with a resolution of 0.001lbs resulting in a total of 20,000 counts and shown on an LCD display. If the bridge sensor gets excited with 3V, it delivers a full-scale output voltage of 3V x 2mV/V = 6mV. This also means that 0.001lbs equals a voltage of 6mV / 20lbs x 0.001lbs = 0.3µV. In order to resolve 0.001lbs, the LSB voltage of the ADC needs to be less than 0.3µV / 2 = 0.15µV.

Using a fully integrated MCU solution

To address the outlined application requirements, an integrated MCU solution is used. The MSP430F42x family of ultra-low-power, Flash-based microcontrollers is equipped with three integrated 16-bit, sigma-delta ADCs (SD16). These data converters also feature an on-chip PGA that allows the amplification of incoming signals up to 32 times. The bridge sensor is connected directly to the microcontroller (see Figure 1). An on-chip LCD driver enables direct interfacing to common LCD modules.

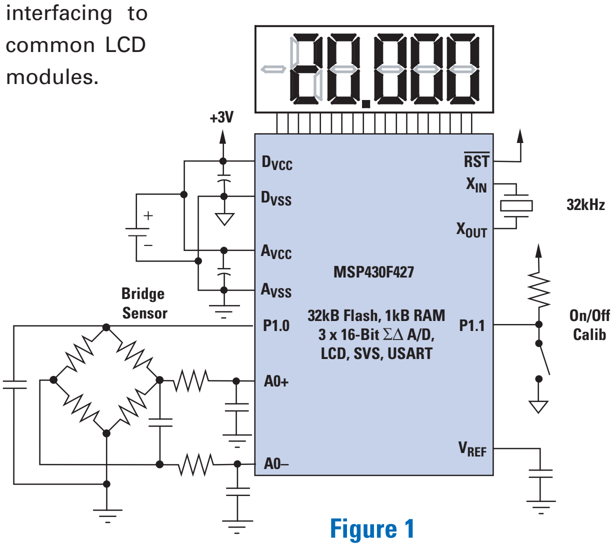

Figure 1

In-system self-programmable Flash memory is used to keep calibration constants for 2- or 3-point calibration algorithms for error compensation.

The SD16 has a built-in voltage reference that determines the full-scale differential input voltage. As the data converter is bipolar, the ADC LSB voltage is 1.2V / 2^{15} = 36.62µV. Using the maximum PGA gain of 32, the LSB voltage decreases to 1.14µV. This is still about eight times higher than the design goal of 0.15µV. An external op amp could be used to provide additional amplification. Another approach without adding external components is using oversampling techniques to provide three additional bits of resolution. The SD16 module is a true 16-bit ADC, but it provides access to a total of 24-bits from its internal digital filter. By adding three more bits from the digital filter output to the 16-bit conversion result, and implementing additional oversampling in software by averaging multiple results, the LSB voltage now reduces to 1.2V / 2^{18} / 32 = 0.143µV. With this voltage, the resolution requirement can be fulfilled, even though the full-scale sensor output voltage is only 6mV and the full input range of the sigma-delta converter is not used. Come see this live demonstration and further, in-depth 16-bit sigma-delta ADC technical training at the 2004 Advanced Technical Conference. **Register today at www.ti.com/msp430apps**.