White Paper
SBAA154–June 2007

The ADS1232 and ADS1234: Complete Front End Solutions for Weigh Scales

Data Acquisition Products

The ADS1232 and ADS1234 are bridge-sensor, analog-to-digital converters (ADCs) from Texas Instruments (TI). To better understand these ADCs, it first helps to review the target application: electronic weigh scales. These scales are used in ever-increasing numbers in an expanding range of applications. For example, electronic commerce scales record the price of merchandise by weight. In shipping, scales verify the weight of cargo to be transported. Counting scales monitor a container's weight for packaging assembly lines to determine when they are full, and scientific scales provide precision analysis of weight during experimentation.

Regardless of the application, at the heart of each of these different types of scales is a precision digitizing process that converts the weight of the object being measured into a digital value for display or data logging. While there are multiple techniques for converting weight into an electrical signal, perhaps the most common is to use a resistive load cell configured as a Wheatstone bridge. Figure 1 shows a bridge configuration where one of the resistors in the bridge changes value as weight is applied. Depending on the construction of the bridge, more resistors may change value as weight is applied. Either way, an excitation voltage is applied across the top and bottom of the bridge. The output signal is measured as the differential voltage across the middle nodes.

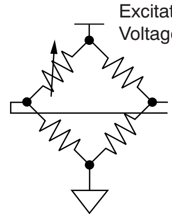


Figure 1. Wheatstone Bridge Resistive Load Cell

The challenge in designing a weigh scale is how to make accurate measurements of the signal produced by the resistor bridge, because this signal is usually very small. Load cells are often specified by the output voltage they produce for a 1V excitation voltage with the load cell maximum rated weight applied. The specification is given in units of mV/V. For example, a 4mV/V load cell excited with 5V will have a full-scale output voltage of only 20mV. Remember, this is the maximum output voltage. To determine the accuracy required by the digitizer, the full-scale voltage of the bridge must be divided by the desired scale resolution. This is typically specified in *counts*. Assume the same 4mV/V load cell excited by 5V and a scale requirement of 20,000 counts of resolution. This in turn requires the digitizer to be able to repeatedly measure signals of (4mV/V)(5V)/20,000 = 1000nV.

And now, to make the design even more challenging! For a good scale design, the readings must be perfectly stable. That is, it should not flicker or toggle between codes because of noise. This requirement in turn places additional demands on the digitizer, resulting in the need for internal resolution much better than what the scale reports to the user. It is not uncommon for the internal precision to be 10 times better than the displayed value. In the case of the previous load cell example, this would require internal resolution of 100nV!

Given the very small signal nature of bridge sensors, and the need for very high resolution measurements, scale manufacturers traditionally have used a very low noise gain stage to amplify the signal from the bridge before digitizing. Bandwidth of the gain stage is not usually a significant concern, given that weight changes relatively slowly on many scales. What is critical, however, is that the gain stage be extremely stable over temperature and time. Most scales are calibrated only periodically, either at the factory or by the customer. Any change in the gain resulting from time or temperature drift of the PGA will adversely affect the accuracy of the scale. In fact, in some high-end scale designs, the gain stage stability over time and temperature is what sets the overall scale specifications. Typically, a high-resolution analog-to-digital converter (ADC) then follows the PGA to digitize the amplified voltage. Given that the signals being measured usually are changing slowly, and that very high resolution is required, delta-sigma topologies are often used to implement the ADC. As with the gain stage, the stability of the ADC over time and temperature is very important so as not to limit overall performance.

Additionally, the ADC should be able to make *ratiometric* measurements by supporting use of the bridge excitation voltage as the reference voltage (see Figure 2). The output signal from the bridge is directly proportional to the excitation voltage with an attenuation factor that is determined by the weight applied to the load cell. By measuring the load cell signal with the ADC ratiometrically—that is, with the excitation voltage serving as the ADC reference voltage—variations in the absolute value of the excitation voltage are cancelled out. This, in turn, makes for a less sensitive and more robust scale design.

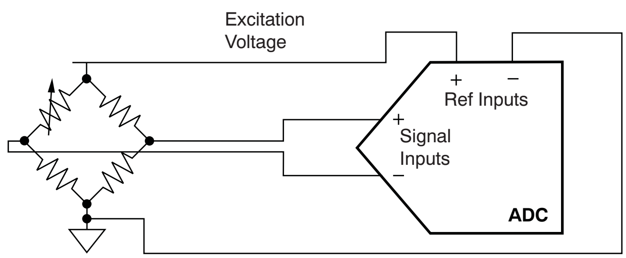
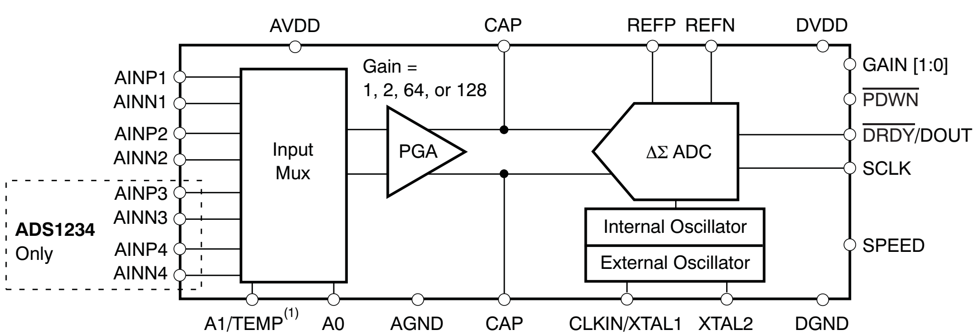


Figure 2. Ratiometric Measurement of Load Cell with an ADC

With these requirements in mind, TI developed the ADS1232 (two channels of input) and the ADS1234 (four channels of input) to provide scale designers with a simple high-performance, low-cost, single-chip solution for digitizing the outputs for bridge sensors. The ADS1232 and ADS1234 incorporate all of the key blocks in a weigh scale front end (see Figure 3), and differ only in the number of input channels they support. A programmable gain amplifier (PGA) allows the user to select gains of 1, 2, 64 or 128. The gains of 64 and 128 are used when the bridge is directly connected to the ADS1232/4. Gains of one and two allow an optional external gain stage to be used between the bridge and the ADS1232/4. Manufactured on TI's new advanced high-performance, sub-micron mixed signal CMOS process, the ADS1232/4 PGA features a novel scheme to minimize low frequency noise and improve offset drift over temperature. Precision onboard resistors used in the PGA provide outstanding gain stability over temperature and time.



NOTE: (1) A1 for ADS1234, TEMP for ADS1232.

Figure 3. ADS1232/4 Block Diagram

Following the PGA is an onboard 24-bit, delta-sigma ADC to permit the use of 5V references to support ratiometric measurements. The onboard digital filter for this ADC provides a selectable data rate of 10 samples-per-second (SPS) or 80 SPS. The 10 SPS operation rejects both 50 and 60 Hz line-cycle interference, while the higher speed provides faster updates. This is useful for scales needing faster response or for post-processing algorithms that require high data rates.

The precision onboard oscillator of the ADS1232/4 eliminates the need for an external oscillator or crystal, although an external clock source can be used if desired. All control of the ADS1232/4 is done with dedicated pins. This architecture greatly simplifies software development by eliminating the need to program any registers. Finally, a simple read-only interface allows for easy retrieval of the ADC data output. Thanks to the high-density capability of TI's mixed signal process, the ADS1232 can fit into a 24-pin thin shrink small outline package (TSSOP), while the ADS1234 uses a 28-pin TSSOP.

To help illustrate the performance of the ADS1232/4, Figure 4 shows the output readings over a 10-second interval with the data rate set to 10 samples per second (SPS), the PGA set to 128, and a 5V bridge excitation used as reference. The left axis shows the ADS1232/4 output readings in units of least-significant bits (LSBs), while the right axis shows the output readings in units of nV. The root mean square (rms) noise is only 17nV, and the peak-to-peak noise is only 110nV. Referring back to the earlier example with the 4mV/V load cell excited with 5V, the ADS1232, when used with this load cell, would provide over 180,000 counts of internal resolution with no additional components or post-processing of output data. It is important to note that the noise of the ADS1232/4 will change as a function of data rate, PGA and reference voltage. The ADS1232/4 production data sheet available at www.ti.com provides noise tables to show performance in the different settings.

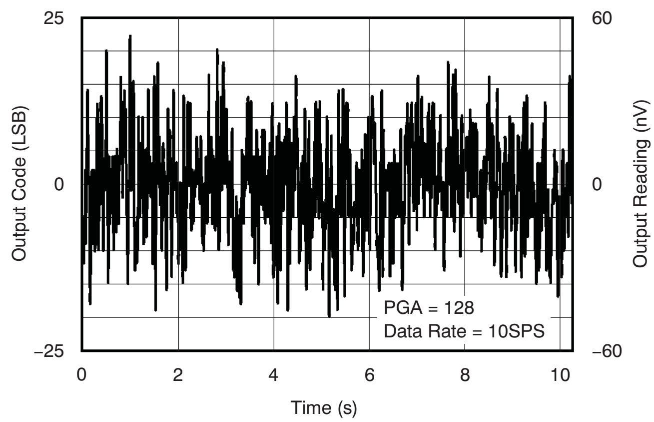


Figure 4. ADS1232 Noise Performance

As an aid for weigh scale designers, TI also developed the ADS1232REF, a weigh scale reference design using the ADS1232. Figure 5 shows the block diagram. The ADS1232 serves as the heart of the design and directly digitizes the weigh scale load cell signals. The MSP430 microcontroller collects the ADS1232 data, drives the LCD display, interprets user inputs from the switches, and communicates with an optional PC via a USB connection. Figure 6 highlights key elements on the board. The user connects the load cell to the indicated connector. Jumpers allow the optional RC filter to be bypassed in front of the ADS1232 input. The reference voltage can be switched between an external excitation voltage or the analog power supply. Power is supplied from an external dc supply. In *standalone* mode, the main control switches control overall operation. The user-selected data are then displayed by the MSP430 on the LCD. In *PC* mode, the USB interface allows a PC to control operation with data output on the PC monitor. For more information on the ADS1232REF, please visit the TI website to download the User's Guide.

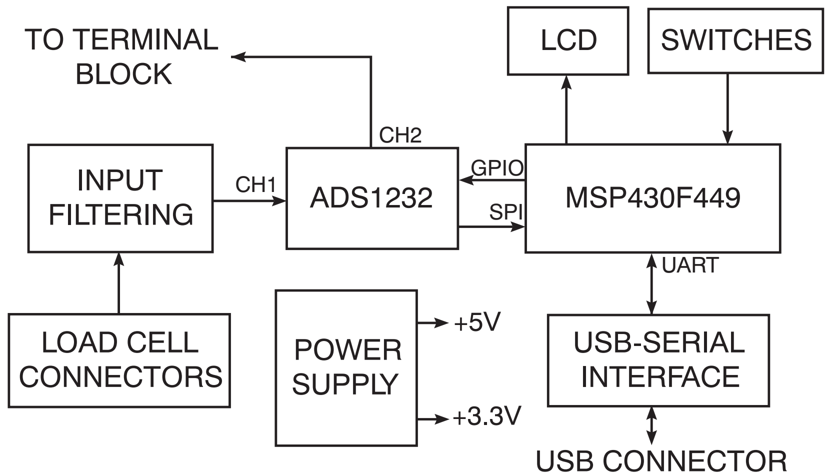


Figure 5. Block Diagram of the ADS1232REF Weigh Scale Reference Design

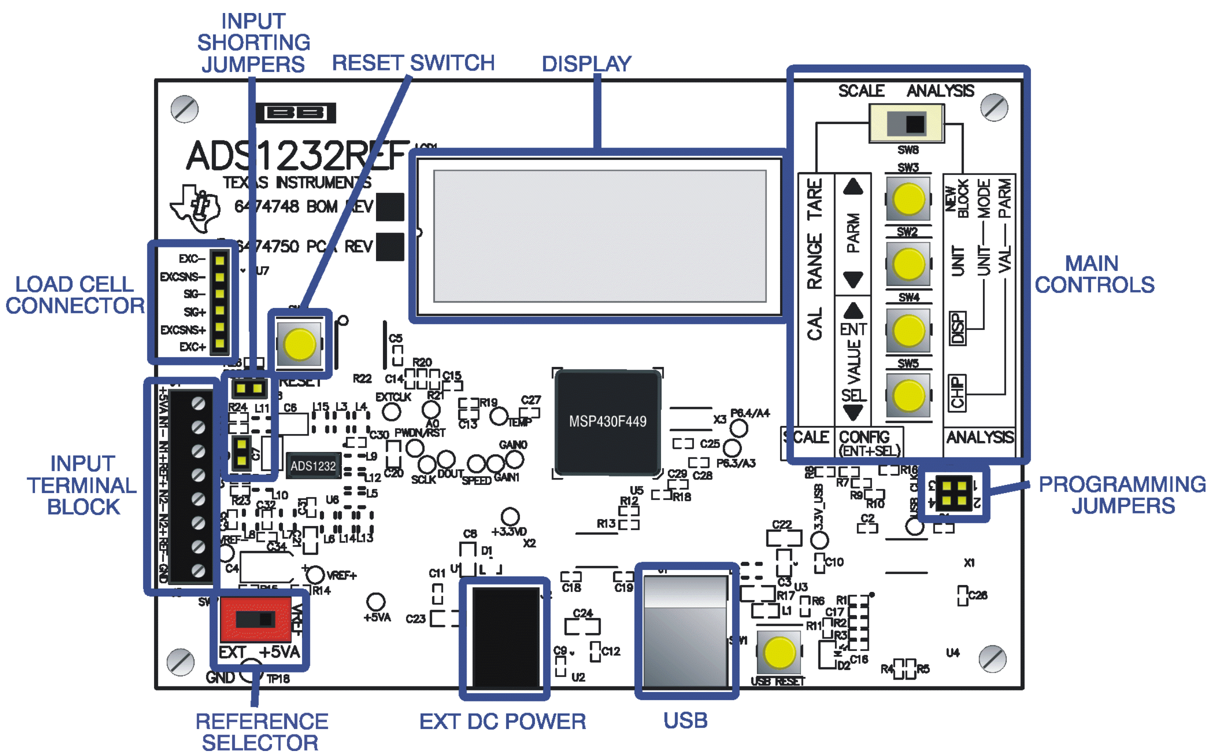


Figure 6. ADS1232REF Weigh Scale Reference Design Layout

In summary, electronic weigh scales are increasingly becoming popular in a wide variety of applications. Load cells, perhaps the most common weight sensor, output extremely small signals that are a difficult challenge to measure accurately. The ADS1232 and ADS1234 provide single-chip solutions that allow a weigh scale designer to easily and quickly develop a small, very low cost and high-performance weigh scale. The ADS1232REF reference design allows performance evaluation of the ADS1232 with the user's own load cell, and can serve as the basis for a complete weigh scale design.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Clocks and Timers	www.ti.com/clocks	Digital Control	www.ti.com/digitalcontrol
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265