Circuit Note
CN-0102

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Devices Connected/Referenced	
AD7190	4.8 kHz, Ultralow Noise, 24-Bit, Σ-Δ ADC with PGA
ADP3303	5 V Low Dropout Linear Regulator
ADP3303	3.3 V Low Dropout Linear Regulator

Precision Weigh Scale Design Using the AD7190 24-Bit Sigma-Delta ADC with Internal PGA

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

AD7190 Evaluation Board (EVAL-AD7190EBZ)

Design and Integration Files

Schematics, Layout Files, Bill of Materials

CIRCUIT FUNCTION AND BENEFITS

This circuit is a weigh scale system that uses the AD7190, an ultralow noise, low drift, 24-bit sigma delta (Σ-Δ) analog-to-digital converter (ADC) with an internal programmable gain amplifier (PGA). The AD7190 simplifies the weigh scale design because most of the system building blocks are included on the chip. The AD7190 maintains good performance over the complete output data rate range, from 4.7 Hz to 4.8 kHz, which allows it to be used in weigh scale systems that operate at low speeds along with higher speed weigh scale systems, such as hopper scales.

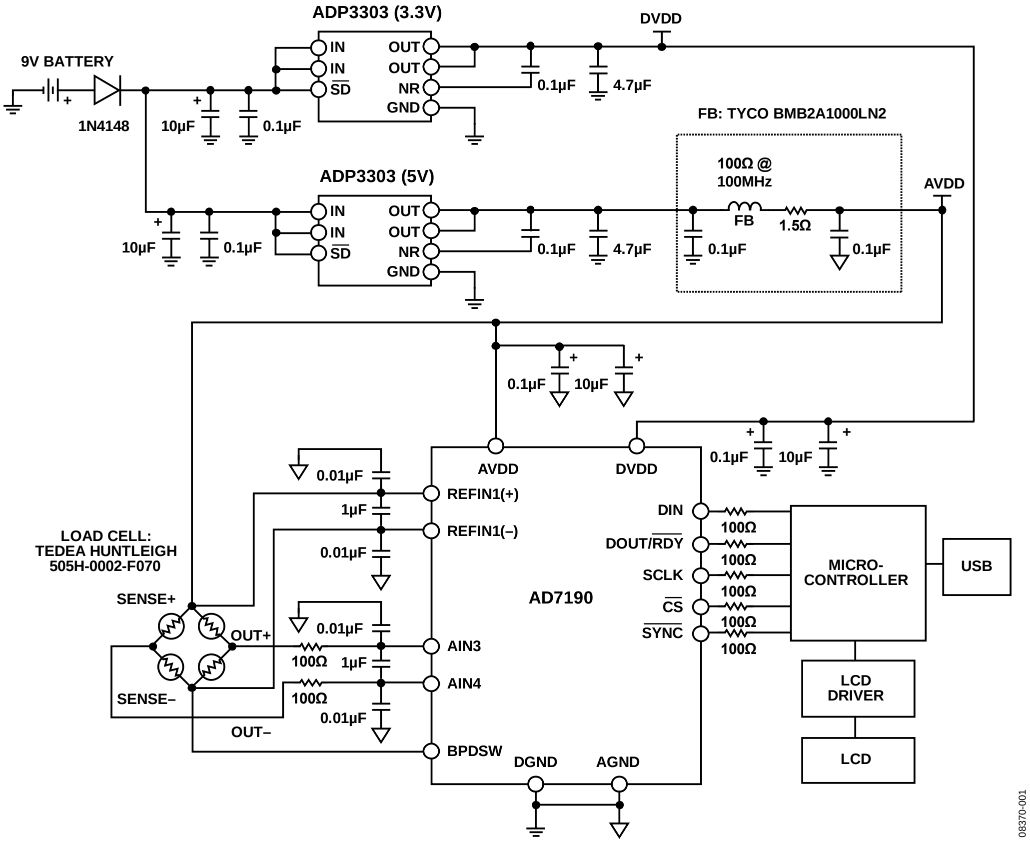

Figure 1. Weigh Scale System Using the AD7190 (Simplified Schematic: All Connections Not Shown)

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CIRCUIT DESCRIPTION

Because the AD7190 provides an integrated solution for weigh scales, it interfaces directly to the load cell. The only external components required are some filters on the analog inputs and capacitors on the reference pins for EMC purposes. The low level signal from the load cell is amplified by the internal PGA of the AD7190. The PGA is programmed to operate with a gain of 128. The conversions from the AD7190 are then sent to the microcontroller where the digital information is converted to weight and displayed on the LCD.

Figure 2 shows the actual test setup. A 6-wire load cell is used, because this gives the optimum system performance. A 6-wire load cell has two sense pins, in addition to the excitation, ground, and two output connections. The sense pins are connected to the high side and low side of the Wheatstone bridge. The voltage developed across the bridge can, therefore, be accurately measured, regardless of the voltage drop due to the wiring resistance. In addition, the AD7190 has differential analog inputs, and it accepts a differential reference. Connection of the load cell differential SENSE lines to the AD7190 reference inputs creates a ratiometric configuration that is immune to low frequency changes in the power supply excitation voltage. In addition, it eliminates the need for a precision reference. With a 4-wire load cell, the sense pins are not present, and the ADC reference pins are connected to the excitation voltage and ground. With this arrangement, the system is not completely ratiometric because there is a voltage drop between the excitation voltage and SENSE+ due to wiring resistance. There is also a voltage drop due to wire resistance on the low side.

Figure 2. Weigh Scale System Setup Using the AD7190

The AD7190 has separate analog and digital power supply pins. The analog section must be powered from 5 V. The digital power supply is independent of the analog power supply and can be any voltage between 2.7 V and 5.25 V. The microcontroller uses a 3.3 V power supply. Therefore, DVDD is also powered from 3.3 V. This simplifies the interface between the ADC and microcontroller because no external level shifting is required.

There are several methods to power the weigh scale system. It can be powered from the main power supply bus or battery powered (as shown in Figure 1). A 5 V low noise regulator is used to ensure that the AD7190 and the load cell receive a low noise supply. The ADP3303 (5 V) is used to generate the 5 V supply and is a low noise regulator. The filter network shown inside the dotted box ensures a low noise AVDD for the system. In addition, noise reduction capacitors are placed on the regulator output as recommended in the ADP3303 (5 V) data sheet. To optimize the EMC performance, the regulator output is filtered ahead of the AD7190 and the load cell. The 3.3 V digital supply is generated using the ADP3303 (3.3 V). It is essential that low noise regulators are used to generate all the power supply voltages to the AD7190 and the load cell, because any noise on the power supply or ground planes introduces noise into the system and degrades the circuit performance.

Figure 3 shows the rms noise of the AD7190 for different output data rates when the gain is equal to 128. Figure 3 shows that the rms noise increases as the output data rate increases. However, the device maintains good noise performance over the complete range of the output data rates.

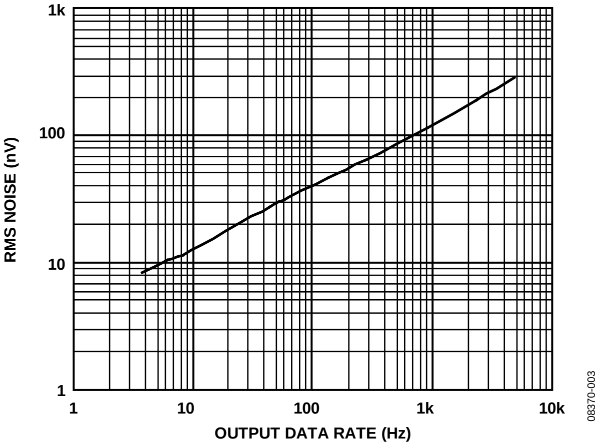

Figure 3. RMS Noise for Different Output Data Rates

If a 2 kg load cell with a sensitivity of 2 mV/V is used, the full-scale signal from the load cell is 10 mV when the excitation voltage is 5 V. A load cell has an offset, or TARE, associated with it. This TARE can have a magnitude that is up to 50% of the load cell full-scale output signal. The load cell also has a gain error that can be up to ±20% of full scale. Some customers use a DAC to remove or null the TARE. When the AD7190 uses a 5 V reference, its analog input range is equal to ±40 mV when the gain is set to 128 and the part is configured for bipolar operation. The wide analog input range of the AD7190 relative to the load cell full-scale signal (10 mV) is beneficial because it ensures that the offset and gain error of the load cell do not overload the front end of the ADC.

The AD7190 has an rms noise of 8.5 nV when the output data rate is 4.7 Hz. The number of noise-free counts is equal to

$$\frac{10\text{ mV}}{6.6 \times 8.5\text{ nV}} = 178{,}250 \qquad (1)$$

where the factor of 6.6 converts the rms voltage into a peak-to-peak voltage.

The resolution in grams is, therefore, equal to

$$\frac{2\text{ kg}}{178{,}250} = 0.01\text{ g} \qquad (2)$$

The noise-free resolution is equal to

$$\log_2(178{,}250) = \frac{\log_{10}(178{,}250)}{\log_{10}(2)} = 17.4\text{ bits} \qquad (3)$$

In practice, the load cell itself introduces some noise. There is also some time and temperature drift due to the load cell along with the drift of the AD7190. To determine the accuracy of the complete system, the weigh scale can be connected to a PC via the USB connector. Using LabVIEW software, the performance of the weigh scale system can be evaluated. Figure 4 shows the measured output performance when a 1 kg weight is placed on the load cell and 500 conversions are gathered. The noise of the system is calculated by the software to be 12 nV rms and 88 nV peak-to-peak. This equates to 113,600 noise-free counts, or 16.8 bits of noise-free code resolution.

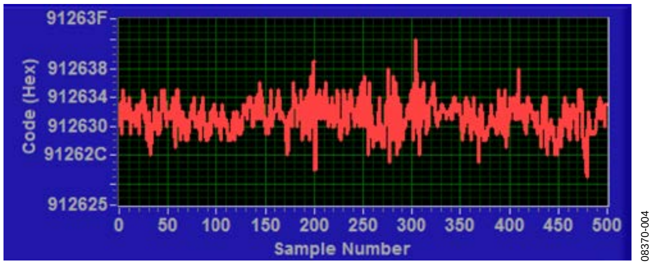

Figure 4. Measured Output Code for 500 Samples Showing the Effects of Noise

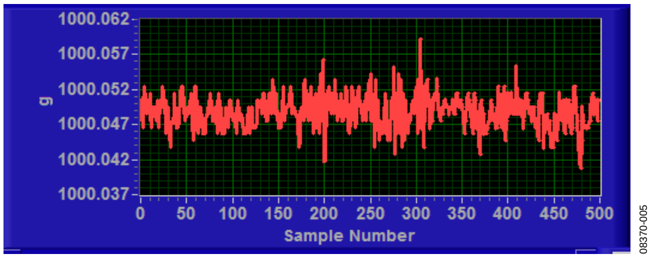

Figure 5. Measured Output in Grams for 500 Samples Showing the Effects of Noise

Figure 5 shows the performance in terms of weight. The peak-to-peak variation in output is 0.02 grams over the 500 codes. Therefore, the weigh scale system achieves an accuracy of 0.02 grams.

Figure 4 and Figure 5 show the actual (raw) conversions read back from the AD7190 when the load cell is attached. In practice, a digital post filter is used in a weigh scale system. The additional averaging that is performed in the post filter further improves the number of noise-free counts at the expense of a reduced data rate.

COMMON VARIATIONS

Note that all noise specifications in this section are given for a PGA gain of 128.

The AD7190 is a high precision ADC for high-end weigh scales. Other suitable ADCs are the AD7192 and AD7191. The AD7192 is pin-for-pin compatible with the AD7190. However, its rms noise is slightly higher. The AD7192 has an rms noise of 11 nV for an output data rate of 4.7 Hz, while the AD7190 has an rms noise of 8.5 nV at this output data rate. The AD7191 is a pin-programmable device. It has four output data rates and four gain settings. Due to its pin programmability and reduced feature set, it is an easy to use device. Its rms noise is the same as the rms noise of the AD7192.

For medium-end weigh scales, the AD7799 is a suitable device. At an output data rate of 4.17 Hz, the AD7799 has an rms noise of 27 nV.

Finally, for low-end weigh scales, the AD7798, AD7781 and AD7780 are suitable devices. The AD7798 has the same feature set as the AD7799. At 4.17 Hz, its rms noise is 40 nV. The AD7780 and AD7781 have one differential analog input and are pin programmable, allowing an output data rate of 10 Hz and 17.6 Hz and a gain of 1 or 128. The rms noise is 44 nV when the output data rate is 10 Hz.

As with any high accuracy circuit, proper layout, grounding, and decoupling techniques must be employed. See Tutorial MT-031, *Grounding Data Converters and Solving the Mystery of AGND and DGND* and Tutorial MT-101, *Decoupling Techniques* for more details.

A complete design support documentation package for this circuit note can be found at http://www.analog.com/CN0102-DesignSupport.

CIRCUIT EVALUATION AND TEST

With the exception of the external load cell and the PC, the circuit shown in Figure 1 is contained on the AD7190 evaluation board (EVAL-AD7190EBZ).

Interface to the evaluation board via a standard USB connector, J1. J1 is used to connect the evaluation board to the USB port of a PC. A standard USB connector cable is included with the AD7190 evaluation board to allow the evaluation board to interface with the USB port of the PC. Because the board is powered via the USB connector, there is no need for an external power supply, although if preferred, one may be connected via J2.

Equipment Needed

The EVAL-AD7190EBZ evaluation board and a PC running Windows® 2000, Windows XP, or Windows Vista (32-bit) are the only items required other than the external load cell. A Tedea Huntleigh 505H-0002-F070 load cell was used to obtain the results presented. The load cell is not shipped with the evaluation board and must be purchased from the manufacturer by the customer.

Getting Starting

The EVAL-AD7190EBZ evaluation board ships with a CD containing software to control the AD7190 that can be installed onto a standard PC. The software communicates with the AD7190 through the USB cable that accompanies the board. The software allows the user to read conversion data from the AD7190. Data can be read from the AD7190 and displayed or stored for later analysis.

Install the AD7190 evaluation board software using the supplied AD7190 evaluation board CD before connecting the board to the PC. For full details on this, refer to the UG-222 User Guide.

Functional Block

Figure 1 shows the basic functional block diagram of the test setup.

Setup and Test

Complete instructions for setup and testing of the AD7190 evaluation board can be found in UG-222 User Guide.

After installing the software, configure the AD7190 evaluation board for use with the external load cell by setting the appropriate links (jumpers) as described in Table 1 of the UG-222 User Guide. Ensure that the links are set before applying power to the evaluation board.

The load cell connects to the evaluation board header, J4. Operation of the **WeighScale Demo** is described in UG-222.

LEARN MORE

CN0102 Design Support Package:
http://www.analog.com/CN0102-DesignSupport

Kester, Walt. 1999. *Sensor Signal Conditioning*. Section 2. Analog Devices.

Kester, Walt. 1999. *Sensor Signal Conditioning*. Section 3. Analog Devices.

Kester, Walt. 1999. *Sensor Signal Conditioning*. Section 4. Analog Devices.

MT-004 Tutorial, *The Good, the Bad, and the Ugly Aspects of ADC Input Noise—Is No Noise Good Noise?* Analog Devices.

MT-022 Tutorial, *ADC Architectures III: Sigma-Delta ADC Basics,* Analog Devices.

MT-023 Tutorial, *ADC Architectures IV: Sigma-Delta ADC Advanced Concepts and Applications*, Analog Devices.

MT-031 Tutorial, *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND"*, Analog Devices.

MT-101 Tutorial, *Decoupling Techniques*, Analog Devices.

Data Sheets and Evaluation Boards

AD7190 Data Sheet

AD7190 Evaluation Board (EVAL-AD7190EBZ)

AD7191 Data Sheet

AD7192 Data Sheet

AD7780 Data Sheet

AD7781 Data Sheet

AD7798 Data Sheet

AD7799 Data Sheet

ADP3303 Data Sheet

REVISION HISTORY

12/12—Rev. 0 to Rev. A

Added Evaluation and Design Support Section 1
Changes to Common Variations Section 3
Added Circuit Evaluation and Test Section, Equipment Needed Section, Getting Started Section, Functional Block Section, and Setup and Test Section 4
Changes to Learn More Section 4

8/09—Revision 0: Initial Version

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