Using the ADS1261's Integrated AC Excitation Mode to Remove System Offset and Offset Drift

TEXAS INSTRUMENTS

Introduction

Many types of industrial end-equipment employ resistive bridges to sense changes in physical variables such as strain, force, pressure or flow rates. A common industrial application for resistive bridges is precision weigh scales. In this application, weight is translated into a voltage using a resistive bridge embedded in a load cell similar to Figure 1.

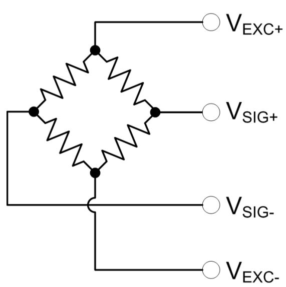

Figure 1. Resistive Bridge in a Load Cell

Such a 4-wire load cell requires an excitation voltage, $V_{EXC\pm}$, and outputs a differential signal voltage, $V_{SIG\pm}$, proportional to the applied weight. Typically, $V_{SIG\pm}$ (max) is on the order of tens of millivolts, requiring a low-noise, precision delta-sigma ADC with integrated gain to provide repeatable measurements for such low-level signals.

ADC accuracy parameters such as offset error, offset drift, gain error and gain drift are also important to ensure the weigh scale output correlates to the correct weight. Furthermore, accuracy can be improved at a system-level using techniques such as AC bridge excitation.

To meet the demanding performance needs of precision resistive bridge measurements, Texas Instruments released the ADS1261, a 24-bit, 40 kSPS, 10-channel, delta-sigma ADC with integrated AC excitation output drive circuitry.

Using the ADS1261 for Precision Bridge Measurements

The ADS1261 incorporates several features necessary for precision bridge measurements, including:

1. **Integrated PGA** – programmable gains from 1 to 128 V/V with input-referred noise as low as 6 nV_{RMS}
2. **Differential voltage reference inputs** – enables ratiometric measurements to provide lowest-noise signal acquisition
3. **AC excitation** – controls external switches to reverse bridge excitation polarity in order to reduce offset and offset drift

This document focuses on AC excitation to demonstrate why it is important and how it works using the ADS1261.

What is AC Excitation?

While some ADCs – including the ADS1261 – integrate chopping techniques to reduce *device* offset, these methods only reduce those errors that occur after the chopping circuitry. Therefore, any offset prior to the device's input can still degrade measurement accuracy.

Conversely, AC excitation, or bridge chopping, is a method to reduce *system-level* offset errors from a resistive bridge. Reducing the system offset has the added benefit of reducing offset drift, an error term that is not easily removed by calibration.

AC excitation operates by using external switches to alternate the bridge polarity between measurements, and should not be confused with excitation using a true AC-signal. Figure 2 depicts a simplified connection diagram for a typical AC excitation circuit using the ADS1261.

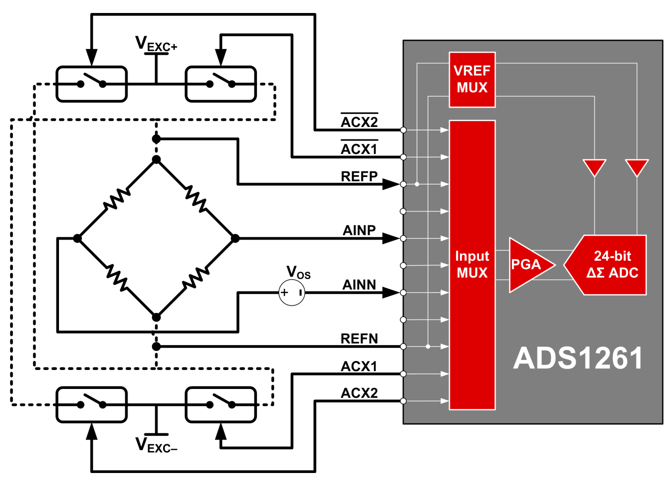

Figure 2. AC Excitation Circuit Using ADS1261

Using the ADS1261 to Implement AC Excitation

AC excitation subtracts two consecutive measurements – V_{PHASE1} and V_{PHASE2} – to remove offset error. The resulting input voltage, V_{IN}, is calculated using Equation 1.

$$V_{IN} = (V_{PHASE1} - V_{PHASE2}) / 2 \qquad (1)$$

In Phase 1 of the ADS1261's AC excitation mode, the ACX1 and $\overline{\text{ACX1}}$ outputs are enabled such that V_{EXC+} connects to the top of the bridge and V_{EXC-} connects to the bottom of the bridge. Figure 3 shows this "forward" polarity configuration.

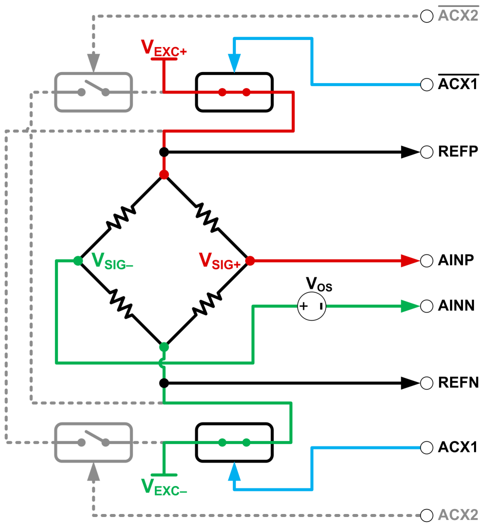

Figure 3. Phase 1 Connection Diagram

Equation 2 shows V_{PHASE1} in terms of $V_{SIG\pm}$ as well as the offset term, V_{OS}, that represents all offsets in the measurement system.

$$V_{PHASE1} = V_{SIG+} - (V_{SIG-} + V_{OS}) \tag{2}$$

In Phase 2, the ACX outputs are reversed such that only the switches connected to ACX2 and $\overline{\text{ACX2}}$ are enabled. This configuration routes V_{EXC+} to the bottom of the bridge and V_{EXC-} to the top, reversing the polarity of the signal seen at the ADC's inputs (AINN and AINP). Figure 4 shows this "reverse" polarity configuration.

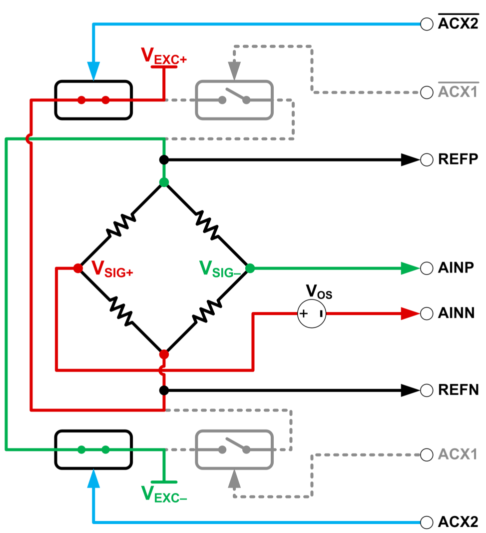

Figure 4. Phase 2 Connection Diagram

In this configuration, V_{PHASE2} is represented by Equation 3. Note that while the measurement polarity was reversed, the bridge offset has not changed.

$$V_{PHASE2} = V_{SIG-} - (V_{SIG+} + V_{OS}) \tag{3}$$

Replacing V_{PHASE1} and $V_{PHASE\ 2}$ from Equation 1 with Equation 2 and Equation 3, respectively, yields V_{IN} in terms of $V_{SIG\pm}$ and V_{OS} as shown in Equation 4.

$$V_{IN} = ([V_{SIG+} - (V_{SIG-} + V_{OS})] - [V_{SIG-} - (V_{SIG+} + V_{OS})]) / 2 \tag{4}$$

Reducing Equation 4 and combining similar terms results in a final input voltage (Equation 5) that is independent of the system offset voltage, V_{OS}.

$$V_{IN} = 2 \cdot (V_{SIG+} - V_{SIG-}) / 2 = V_{SIG+} - V_{SIG-} \tag{5}$$

Simplifying AC Excitation with the ADS1261

While the ADS1261's integrated AC excitation circuitry can drive external switching components to reverse the polarity of the bridge, this ADC offers additional features to ensure reliable operation.

For example, Phase 2 (Figure 4) reverses the excitation voltages such that V_{EXC+} and V_{EXC-} are connected to REFN and REFP, respectively, resulting in a negative differential reference voltage, V_{REF}. Since this is outside the ADC's operating conditions, the ADS1261 automatically reverses the reference inputs during Phase 2 such that a positive V_{REF} is always applied to the ADC. Using a different ADC without this functionality would require manual V_{REF} reversal.

The ADS1261 also ensures that the output drive signals are non-overlapping so the bridge excitation signals ($V_{EXC\pm}$) cannot be applied to both sides of the bridge simultaneously. Moreover, the AC excitation chop rate is synchronized to the conversion data rate to avoid unnecessarily fast switching.

Alternative Device Recommendations

Texas Instruments offers additional ADCs for high performance resistive bridge measurements. Table 1 summarizes these devices and includes a discussion of their performance tradeoffs compared to ADS1261.

Table 1. Alternative Device Recommendations

Device	Optimized Parameters	Performance Trade-Off
ADS1262	32-bit resolution	No AC excitation
ADS1232	Lower cost	

Conclusion

Measuring resistive bridges requires both precise and accurate systems. The 24-bit ADS1261 from Texas Instruments is a low noise, high accuracy delta-sigma ADC that integrates AC excitation output drive circuitry to help reduce system-level offset and offset drift.

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ('TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

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