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

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.

Such a 4-wire load cell requires an excitation voltage, \( V_{\text{EXC}} \), and outputs a differential signal voltage, \( V_{\text{SIG}} \), proportional to the applied weight. Typically, \( V_{\text{SIG}} \) (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\(_{\text{RMS}}\)
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.

Using the ADS1261 to Implement AC Excitation

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

\[
V_{\text{IN}} = \frac{(V_{\text{PHASE1}} - V_{\text{PHASE2}})}{2}
\] (1)
In Phase 1 of the ADS1261’s AC excitation mode, the ACX1 and ACX2 outputs are enabled such that V\(_\text{EXC+}\) connects to the top of the bridge and V\(_\text{EXC-}\) connects to the bottom of the bridge. Figure 3 shows this “forward” polarity configuration.

\[ V_{\text{PHASE1}} = V_{\text{SIG+}} - (V_{\text{SIG-}} + V_{\text{OS}}) \] (2)

In this configuration, V\(_\text{PHASE1}\) is represented by Equation 3. Note that while the measurement polarity was reversed, the bridge offset has not changed.

\[ V_{\text{PHASE2}} = V_{\text{SIG-}} - (V_{\text{SIG+}} + V_{\text{OS}}) \] (3)

Replacing V\(_\text{PHASE1}\) and V\(_\text{PHASE2}\) from Equation 1 with Equation 2 and Equation 3, respectively, yields \( V_{\text{IN}} \) in terms of \( V_{\text{SIG+}} \) and \( V_{\text{OS}} \) as shown in Equation 4.

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

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

\[ V_{\text{IN}} = 2 \cdot (V_{\text{SIG+}} - V_{\text{SIG-}}) / 2 = V_{\text{SIG+}} - V_{\text{SIG-}} \] (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\(_\text{EXC+}\) and V\(_\text{EXC-}\) are connected to REFN and REFP, respectively, resulting in a negative differential reference voltage, V\(_\text{REF}\). Since this is outside the ADC’s operating conditions, the ADS1261 automatically reverses the reference inputs during Phase 2 such that a positive V\(_\text{REF}\) is always applied to the ADC. Using a different ADC without this functionality would require manual V\(_\text{REF}\) reversal.

The ADS1261 also ensures that the output drive signals are non-overlapping so the bridge excitation signals (V\(_\text{EXC}\)) 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>
<thead>
<tr>
<th>Device</th>
<th>Optimized Parameters</th>
<th>Performance Trade-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADS1262</td>
<td>32-bit resolution</td>
<td>No AC excitation</td>
</tr>
<tr>
<td>ADS1232</td>
<td>Lower cost</td>
<td></td>
</tr>
</tbody>
</table>

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.
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