Measure resistance with a microcontroller

Create a voltage across an unknown resistance and digitize it.

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Stepper motors contain coil windings that require resistance measurements. Measuring resistance in a production environment often requires some special circuits that minimize errors. Resistance is easy to measure indirectly using a constant-current source to force a voltage across the winding’s unknown resistance, measuring the voltage, and applying Ohm’s Law.

Figure 1 shows the basic concept of a circuit I designed to check the resistance of the wire coil winding of a stepper motor. An op amp configured as a differential amplifier produces a voltage proportional to the unknown resistance. You can use this circuit to measure resistances—just start by identifying the range of resistances to measure. The stepper motor has a coil with a resistance of 50 Ω ±15%, which ranges from 42.5 Ω to 57.5 Ω.

Next, define the scale measurement or digital value within the microcontroller. The nominal value of the DUT (device under test) should be close to half of the scale selected. Thus, you should set the full-range scale from 0 Ω to 100 Ω.

If you use a microcontroller that contains a 10-bit ADC, it will produce a digital span from 0 to 1023 counts. Set the range of the ADC so that 0 Ω produces a count of 0 and 1023 Ω produces a count of 1023. This range simplifies the math and maximizes measurement precision. Half of this scale, 512 counts, represents 51.2 Ω. That’s close to the nominal 50-Ω measurement of the DUT. Table 1 shows the correlation among the input voltage to the ADC, the number of counts, and the coil’s resistance.

The differential configuration of the op amp works as a four-wire measuring circuit similar to those used in many DMMs. Using separate wires for excitation current and voltage measurement eliminates much of the common-mode noise and errors introduced from the DUT wiring and connections.

Table 1. The relationship among the input voltage, digital counts, and coil resistance.

<table>
<thead>
<tr>
<th>ADC input voltage</th>
<th>Digital counts</th>
<th>DUT resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 V</td>
<td>0</td>
<td>0.0 Ω</td>
</tr>
<tr>
<td>2.5 V</td>
<td>512</td>
<td>51.2 Ω</td>
</tr>
<tr>
<td>5.0 V</td>
<td>1023</td>
<td>102.3 Ω</td>
</tr>
</tbody>
</table>

You must define the op amp’s gain and, from that, the resistor values. In this circuit, the op amp provides adequate voltage for the microcontroller. It also provides isolation between the DUT and the microcontroller’s ADC input. To minimize errors, select resistors $R_A$ through $R_D$ so that the op amp operates at unity gain. To verify that you can run the op amp at unity gain, you must calculate the current that passes through the coil. Using the values from Table 1, calculate the current ($I_{IN}$) needed to achieve a half scale of 51.2 Ω:

$$I_{IN} = \frac{2.5 V}{51.2 \, \Omega} = 48.8 \, mA$$

The constant-current source is based on an LM317 regulator, which can easily provide 48.8 mA. Thus, you can run the op amp at unity gain, which simplifies selection of the resistance values of $R_A$, $R_B$, $R_C$, and $R_D$. For unity gain, all resistors should be equal. Their values should be considerably higher than the DUT’s resistance. Keep the resistor values between 10 kΩ and 100 kΩ.

The circuit works best if you use resistors with 1% or better tolerance. If you need to reduce cost, then measure 5% resistors from a batch with a DMM. Select the four resistors that best match each other’s values. You may be able to achieve better than 1% matching this way.

The op amp also provides some isolation that can prevent dangerous voltages from reaching the microcontroller’s ADC input. An op amp such as the LM6132 connected to a 5-V power supply will limit the power supply’s output voltage to 5 V, even under extreme conditions.

To operate an LM317 regulator as a constant-current source, you need to calculate a resistor value:

$$R = 1.25/I_{IN}$$

where $I_{IN} = 48.4 \, mA$, so $R = 25.86 \, \Omega$. You should, therefore, use a fixed 15-Ω resistor and a 20-Ω potentiometer.

You can find an illustration of the complete circuit, including the LM317 constant-current circuit, in the online version of this article at www.tmworld.com/2011_02. The online article also includes a software flow chart for the microcontroller. T&MW