## MULTISIM DEMO 2.3: THERMAL SENSING WHEATSTONE BRIDGE

Most modern temperature sensors rely on the RTC (Resistance-Temperature-Coefficient) of certain materials. With RTC, a material's resistance changes by a certain percentage for every degree of temperature change. In platinum, the RTC is can be in the ballpark of 0.45% °C<sup>-1</sup> (although it can be different) which means that the resistance of a given piece of platinum changes by 0.45% for every degree of temperature change.

In order to convert a change in resistance into a change in voltage, which is something which can be rather easily measured and manipulated, a wheatstone bridge can be utilized. We will use a Platinum RTD (Resistive Temperature Device) in a wheatstone bridge in this demo.

Let's create, investigate, and then analyze the Wheatstone Bridge circuit shown in Figure 2.3.1.



Thus far we have used relatively basic and generic components in our circuit designs, but one of Multisim's forte's is its easily accessible libraries of specialty parts. These consist of electrical models of components which companies actually offer in the real world. In this demo, we'll use a real, live RTD (well as "live" as a circuit component can be). If you wanted to, you could go and buy this part.

For starters, we need to find the appropriate Temperature Sensor. For these simulations we'll use the Honeywell Sensing and Control/HEL-700-T Thin Film Platinum RTD with Teflon Insulated Leads. RTD stands for Resistance Temperature Detector.

To manually track down the specific RTD component do the following:

- 1. Bring up the Select a Component window (Control-w).
- 2. Under Group, select: Misc.
- 3. Under Family, select: TRANSDUCERS.
- 4. Under Component, select: HEL-705\_U012.
- 5. Place the component into the schematic.



With the RTD in place, attach a multimeter across its leads. Make sure to add a GROUND connection. The result should look like Fig. 2.3.3.



Now notice it says, "Key = T" below the RTD. Just like in the SPDT switches in the three-way switch problem (Demo 2.1), the value of the T1 can be controlled using its assigned key. However, in the SPDT case one could only flip the switch back and forth...you could only change it's state, and therefore only one command was needed. With the RTD as well as other variable devices such as variable resistors, capacitors, and inductors, you can increase *or* decrease the value of the device depending on which key combination is used. For example, in the schematic above, press the "t" key once. Notice that the value underneath the component changes to 32.0. This means that the temperature of the RTD is now  $32.0^{\circ}$ C. To decrease the temperature, press Shift-t once. This will bring the temperature back to  $27.0^{\circ}$ C. These basic commands of "key" and Shift-"key" apply for all variable value components.

In all variable components in Multisim (resistors, capacitors, inductors, miscellaneous components) pressing the assigned key "as-is" will cause it to increase its value. Pressing Shift-assigned-key will cause it to decrease in value.

A resistive wheatstone bridge gives the best response when all of the resistor values in it are equal to the initial resistance,  $R_0$ . For example if the resistor which varies has a initial or base-line value of 1000  $\Omega$  then the best output would result when the three other resistors all had values of 1000  $\Omega$ .

So for our circuit, we need to pick an initial temperature which corresponds to an initial resistance of the platinum RTD, which we can then use to make a good wheatstone bridge. To do this, we first need to decide on a starting temperature. Let's assume that our device will be working in a room with a normal temperature of about 30°C (yes a little hot, but we can pretend it is in a factory or somewhere similar.)

However, earlier we noticed that when we pressed "t", the temperature automatically jumped to  $32.0^{\circ}$ C. This is because the increment value for each key-press is set by default to  $5.0^{\circ}$ C. We need to change that. To do that:

- 1. Double Click on the RTD.
- 2. Make sure the Value Tab is selected.
- 3. As shown in Figure 2.3.4, change Increment Value to 1°C.
- 4. Click OK.

	HEL-705-U012
	Change Sensor Reading:
	Increment Value: 1 °C
	Replace OK Cancel Info Help
Fig	<b>rre 2.3.4</b> Adjusting the Increment Value of the RTD to 1°C

Now that the resolution of the RTD is five times finer, adjust the temperature to  $30.0^{\circ}$ C. Once it is at the appropriate value, open up the multimeter readout window, and make sure the resistance measurement function (ohmmeter) is selected and begin the interactive transient simulation by pressing  $\triangleright$  or F5. Note the resistance value read out should be about 1.114 k $\Omega$  as shown in Fig. 2.3.5. Consequently, we need to set the other resistors in the wheatstone bridge to a value of 1.114 k $\Omega$ .



Now let's build the actual circuit. First, delete the multimeter, and then reincorporate the RTD into a full circuit, which you need to build, based on that shown in Figure 2.3.1. Don't worry about what resistor values you place since we're going to give them different values anyway in a minute. Additionally, this time, while you're placing the resistors, take advantage of the copy function that Multsim has. To do this:

- 1. Place one resistor (again the value isn't important).
- 2. Double click on the resistor to bring up its Property window as shown in Fig. 2.3.6.
- 3. Make sure the Value tab is in front.
- 4. Manually enter the value of  $1.114 \text{ k}\Omega$  into the "Resistance (R)" field since it is not one of the default values available.
- 5. Click OK
- 6. Click (highlight) the resistor and go to Edit>Copy or just press **Control-c**.
- 7. Click off of the resistor and go to Edit>Paste or just press Control-v.
- 8. Place the new resistor.
- 9. Repeat for the third resistor.

You might think that this won't save too much time, but if it is late at night and you need to place six of the same kind of component, pressing Ctrl-c and then Ctrl-v five times in sequence is a lot quicker than going through all of the windows six times.

Finish the circuit by attaching wires where appropriate. The result should be similar to that shown in Fig. 2.3.7 on the next page.

Resistor	
Label Display Value Fault Pins User Fields	
Resistance (R): 1.114k	
Tolerance: 0 v %	
Component Type:	
Hyperlink:	
Additional SPICE Simulation Parameters	
Temperature Coefficient (TC1): 0 $\Omega/^{\circ}$	
□ Temperature Coefficient (TC2): □ Ω/°C2	
□ Nominal Temperature (TNOM): 27 °C	
Layout Settings	
Footprint: Edit Footprint	
Manufacturer:	
Replace  OK  Cancel  Info  Help	
Figure 2.3.6 Resistor Property window showing 1.114 k $\Omega$ being inserted into the Resistance (R) field.	



Now the wheatstone bridge in Fig. 2.3.7 will generate a output voltage  $V_{23}$  of approximately 0 V when the RTD is measuring 30.0°C. To measure the voltage,  $V_{23}$  we need to use the voltmeter function on the multimeter, so add a multimeter to the circuit, and connect it as shown in Fig. 2.3.8.



To measure the voltage  $V_{23}$ :

- 1. Double click on the Multimeter to bring up the Multimeter screen
- 2. Set the voltmeter option by clicking on the  $\checkmark$  button.
- 3. Begin the simulation by pressing either the  $\triangleright$  or F5.
- 4. Observe the value as depicted in Fig. 2.3.9.



Notice that the voltage at 30.0°C is not actually coming up as 0 V, but instead as 646.388  $\mu$ V. This is because the value which we measured for the RTD earlier had a limited number of significant digits, so this demonstrates the rounding error. Still, for our purposes, 646.388  $\mu$ V is pretty tiny.

Now let's see what happens when the temperature sensed by the RTD increases to 42.0°C. While the simulation is still running, click on the schematic window (to make it the active window), and change the temperature of the RTD using the appropriate key combinations (press

"t" a few times) to set it to 42.0°C as shown in Fig. 2.3.10. Observe the voltage being read out by the Multimeter (in in the voltmeter setting). This output voltage allows us to calculate the sensitivity of this temperature sensing-Wheatstone bridge circuit. To do this divide the change output voltage by the change in temperature.

$$S = \frac{-118.682 \times 10^{-3} - 646.388 \times 10^{-6}}{42.0 - 30.0} = -9.95 \text{ mV/°C}$$

This means that for every degree change in temperature,  $V_{23}$  changes by almost 10 mV. This voltage can easily be read by other electronics and then converted into a numerical temperature value on a digital readout.

As you should notice, the sensitivity S is negative, meaning that the larger the temperature the more negative the output voltage. If you'd like to switch it so that the output voltage increases (becomes more positive) with increasing temperature, all you need to do is switch the leads of the voltmeter.

