PHYS245 Lab: Special resistors as Sensors: thermistor and photo-resistor

Purpose

- To demonstrate that some special resistors can be used as sensors
- Use a thermistor (a thermal resistor) to sense the temperature variations.
- Use a photoresistor to detect light intensity.
- More examples for applications of thermistors and photoresistors.

Equipments: ELVIS II, PTC thermistor, NTC thermistor, photoresistor, jump wires, cables with banana plugs, banana-to-minigrabber cables

Sensor is a device that convert a physical quantity into an electrical signal. In this Lab, you will gain experiences with two types of sensors; thermistor and photo-resistor. A thermisor is also known as a thermal resistor. The resistance value of a thermistor changes as function of temperature. Therefore it can be used as a temperature sensor. You will also see other applications of a thermistor such as protection from over-current in a circuit. A photo-resistor is a device whose resistance varies when the light intensity on the device varies. A simple motion detector can be constructed using the photoresistor.

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Pre-Lab exercises

Thoroughly read through the brochure. For experiment II, practice the wirings and placement of components on the picture (next page) of the prototyping board.

Review the procedures for measuring a $I - V$ curve of a light bulb in one of the previous Labs. You will measure the I – V curve for a thermistor in this Lab.

You have measured $I - V$ curve of a light bulb. In this Lab, you will measure the $I - V$ curve of a PTC thermistor. From what you have read in the brochure. Compare the similarities and differences between a light bulb and a PTC thermistor.

ABCDE FGHIJ ABCDE FGHIJ ABCDE FGHIJ

Analog Input Signals
AI 0
AI 1
AI 2
AI 3
AI 4
AI 5
AI 6
AI 7
AISENSE
AIGND

Programmable Function I/O
PFI 0
PFI 1
PFI 2
PFI 5
PFI 6
PFI 7
PFI 10
PFI 11

P2

DMM/Impedance Analyzer
BASE
DUT+
DUT-

Analog Outputs
AO 0
AO 1

Function Generator
FGEN
SYNC
AM
FM

User Configurable I/O
BANANA A
BANANA B
BANANA C
BANANA D
BNC 1
BNC 2
SCREW TERMINAL 1
SCREW TERMINAL 2

Variable Power Supplies
SUPPLY +
GROUND
SUPPLY -

DC Power Supplies
+15V
-15V
GROUND
+5V

Terminal Strips
POWER SUPPLIES

DIO 0
DIO 1
DIO 2
DIO 3
DIO 4
DIO 5
DIO 6
DIO 7
DIO 8
DIO 9
DIO 10
DIO 11
DIO 12
DIO 13
DIO 14
DIO 15
DIO 16
DIO 17
DIO 18
DIO 19
DIO 20
DIO 21
DIO 22
DIO 23

Digital I/O

P3

PFI 8 / CTRL
PFI 9 / CTRL
PFI 12 / CTRL
PFI 3 / CTRL
PFI 13 / CTRL
PFI 14 / PRE

LED 0
LED 1
LED 2
LED 3
LED 4
LED 5
LED 6
LED 7

User Configurable I/O

DSUB SHIELD
DSUB PIN 1
DSUB PIN 2
DSUB PIN 3
DSUB PIN 4
DSUB PIN 5
DSUB PIN 6
DSUB PIN 7
DSUB PIN 8
DSUB PIN 9
GROUND

Terminal Strips

⚠ 60 VDC or 20 Vrms MAX

Variable Supply Max Output: 12 VDC, 500 mA

Experiment I: Introduction to Thermistors

Thermistor is a type of resistor whose resistance varies as a function of temperature. It is widely used as temperature sensors. The temperature measurement is reduced to the resistance measurement of a calibrated thermistor.

To the first order approximation, the change of resistance and the change of temperature is described as:

$$\Delta R = k \Delta T$$

ΔR: change of resistance of the thermistor; *ΔT*: change of temperature; *k*: first order temperature coefficeint

If *k* > 0, the thermistor is called a Positive Temperature Coefficient (PTC) thermistor
If *k* < 0, the thermistor is called a Negative Temperature Coefficient (NTC) thermistor.

For a PTC thermistor, the resistance increases when the temperature increases, for a NTC thermistor, the resistance decreases when the temperature increases. You are given a PTC and a NTC thermistor in this Lab.

PTC thermistor   NTC thermistor

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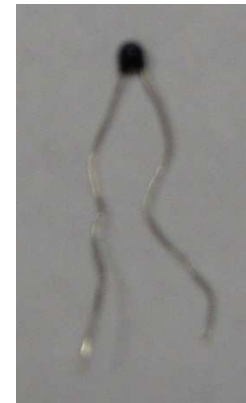
Connect the PTC thermistor to the DMM using the banana-to-minigrabber cables. Activate the DMM and display the resistance of the thermistor. Do not touch the thermistor (because the temperature may change) and allow the resistance to stabilize. Record the resistance value. Ask the TA what is the room temperature in degree Celsius today. If the TA does not know, just assume 20 degree Celsius in the room. This resistance is associated with the temperature value.

Use two fingers to firmly pinch the thermistor. Observe how the resistance value changes on the DMM display. Why does the resistance rises? Because the temperature of the thermistor increases from room temperature toward your body temperature. Wait until the resistance value stops increasing. Record the resistance value. Your body temperature is ~ 36 degree Celsius. Calculate the temperature coefficient *k*.

Switch the NTC thermistor. Repeat the above measurements. Calculate the temperature coefficient *k* for the NTC thermistor.

Experiment II: Use PTC thermistor for over-current protection

PTC thermistor can be used as a over-current protector.

50 Ω at 25 degree Celsius

PTC

Load
R = 50 Ω

1 V power supply
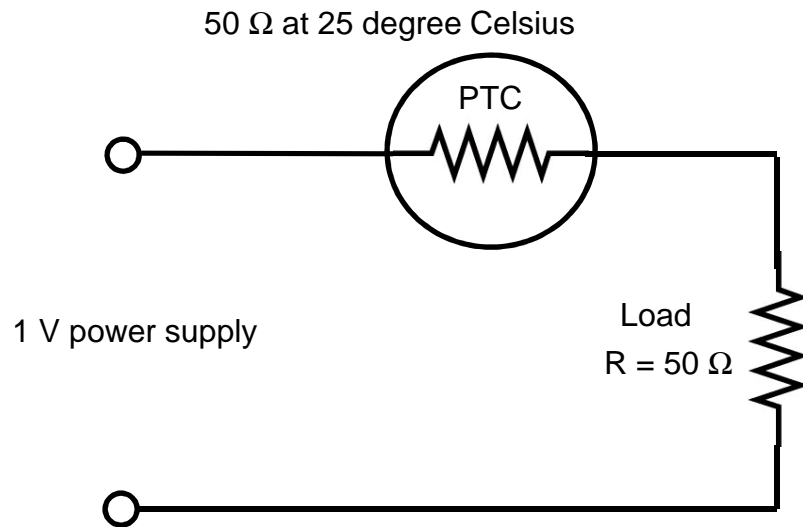
The circuit diagram on the left shows you how a PTC thermistor can be used for over-current protection.

In this example circuit diagram, a PTC is put in series with a Load resistor, and d.c. power (*e.g.* 1 V) is applied. The rated current for the load is 50 mA. This means that serious damage will occur if it is exposed to a current > 50 mA for more than a few seconds. Under normal operation condition, a 10 mA current is flowing through the Load and the PTC.

If a voltage surge (*e.g.* 10 V) is coming from the power supply. Instantaneously the current in the circuit increases to 100 mA. This current will produces 100 times more heat in the thermistor, because the Joule heating power is I^2R. The temperature of the PTC rises rapidly and so does its resistance. Assume the resistance increases to 500 Ω. Therefore the current will be reduced to < 20 mA.

In this manner, the Load is only exposed to the large current (100 mA) for only a short period of time (< few seconds), and thus it is protected from serious damages.

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The verify the over-current protection capability of a PTC thermistor, you can measure the $I - V$ curve of a PTC thermistor. Use the +12 V VPS (Variable Power Supply). Change the voltage from 0 V to 12 V with the increment of 1 V each and measure the currents. After setting the voltage value, wait for at least 60 seconds for the temperature and the resistance value of the thermistor to stabilize.

An example $I - V$ curve of a particular type of PTC thermistor (not necessarily the same type as the one you have) is shown on the right. The most striking feature of the $I - V$ curve is that it is not monotonic. This is a result of the drastic increase of resistance as a function of temperature. This non-monotonic $I - V$ curve also set an upper limit for the current. In this particular case, the upper limit is ~ 0.025 A. Therefore if you put this thermistor in series with load resistor. The current in the load will never go above 0.025 A. So it is protected from a over-current, even if there is a surge of the voltage from the power supply.
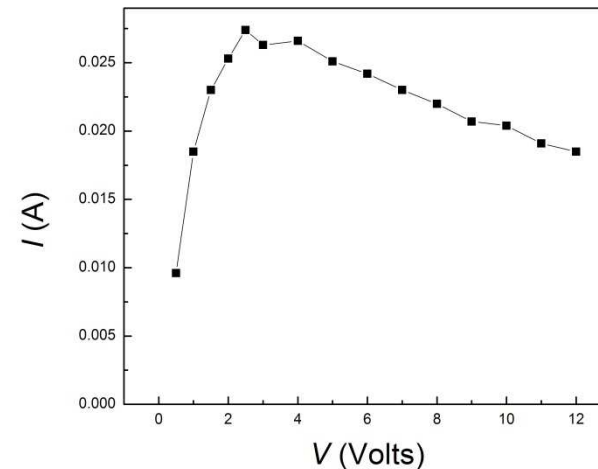
Compare the $I - V$ curve you have measured with the example curve. You should also see the decrease of current at higher voltages.

Calculate resistance (R) and plot the $R - V$ curve for the thermistor. This gives you a clearer picture of how fast the resistance increases as the voltage is increased.

Include the $I - V$ and $R - V$ curves in your Lab report.

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Experiment III: Photoresistors

A photoresistor is a resistive device whose resistance decreases with increasing light intensity. The photoresistor in this Lab is made of semiconducting Cadmium Sulfide (CdCs).

Visually inspect the photoresistor. The active region of the photoresitor is the top side of the device with a zigzag pattern. This region is sensitive to the light intensity.

A picture of active region of photoresistor. Not necessarily the same as the one you use in this Lab.

Use the banana-to-minigrabber cables to connect the photoresistor to the DMM. Activate the DMM to display the resistance to the photoresistor.

First, use Auto range for resistance measurement. The Meter will automatically selects proper range. Let the active region of the photoresistor facing up to receive maximum exposure of the ambient light. After the resistance value stabilizes, record the resistance value. Then use your hand to cover the active region of the photoresistor, and observe the increase of the resistance value. Try your best to shield the ambient light from the active region of the photoresistor, and record the highest resistance value.

You can make a simple motion detector using the photoresistor. Keep the photoresistor connected with the DMM. But Switch the mode to "Specify Range" and select "10 kOhm" range. Place the photoresistor on the bench with the active region facing up. Move your hand slowly across the photoresistor and observe the sudden surge of resistance value on the DMM display. It is a primitive motion detector!

Try to focus on the bar indicator underneath the digital display on the DMM (on the computer screen) instead of the digital display itself. This gives you a more straightforward indication for the resistance changes. Adjust the speed and the height of your hand to achieve the best results.

Now switch to other ranges, and try the same experiment. Identify which range gives the best visual indications of resistance change.