LABORATORY 2
Using Analog Sensors with Arduino

OBJECTIVES

1. Learn how to use a potentiometer as a sensor.
2. Explore circuits used for reading sensors.
3. Build and test Voltage reading, angle reading and temperature reading sensors with Arduino.
4. Learn the basics of the Arduino programming

INFORMATION

A sensor (also called detector) is a converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument or electronics circuit. The same physical parameter could be measured using different principals and level of technology and with different accuracy. A sensor is a device which receives and responds to a signal when actuated. A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes. For instance, if the mercury in a thermometer moves 1 cm when the temperature changes by 1 °C, the sensitivity is 1 cm/°C. Sensors that measure very small changes must have very high sensitivities.

1. Potentiometer.

The potentiometer (or pot, as it is more commonly known) is a simple electro-mechanical transducer. It converts rotary or linear motion from the operator into a change of resistance, and this change is (or can be) used to control anything from the volume of a hi-fi system to the direction of a huge container ship. The pot as we know it was originally known as a rheostat (or rheostat in some texts) and is essentially a variable wire-wound resistor.

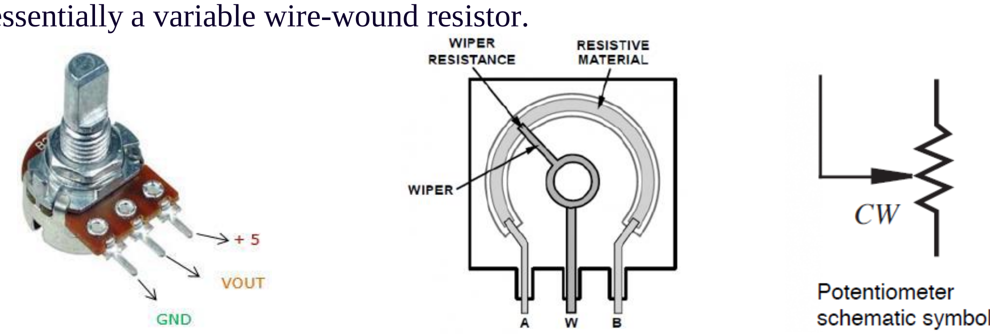
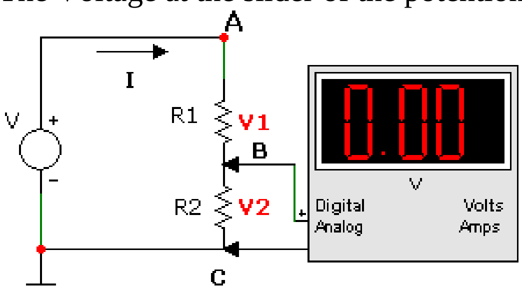


Figure 2.1. Potentiometer

In our application, a potentiometer is an electrical device used to produce variable output voltage when it is connected to a DC voltage source. The user can therefore adjust the output voltage of the potentiometer simply by turning a shaft that is attached to the center of the potentiometer. As the resistance R1 and R2 of the potentiometer changes, so does the voltage, which thus causes the potentiometer to act as a variable voltage divider – Figure 2.2. This varying voltage can be measured by the Arduino Controller and is directly proportional to the angular position of the shaft connected to the center of the potentiometer. This allows you to obtain an analog measurement of the variable voltage and convert it to an angular position. With the Potentiometer in Figure 2.1 one can determine both position and direction of rotation. Use this sensor to get an analog measurement of angular position. For instance, such measurement can help to understand the position of robot arms or other mechanisms.

By turning the shaft of the potentiometer in Figure 2.2., you change the amount of resistance on either side of the wiper which is connected to the center pin of the potentiometer. This changes the voltage at the center pin. When the resistance R1 between the center and the side connected to 5V is close to zero (and the resistance R2 on the other side is close to 10 kΩ), the voltage at the center pin nears 5V. When the resistances are reversed, the voltage at the center pin nears 0V, or ground. This voltage is the analog voltage that you're reading as an input.

The Voltage at the slider of the potentiometer is calculated by the Equation (2.1).



$$V2 = \frac{R2}{R1 + R2} V$$

Equation (2.1)

Figure 2.2.

The microcontroller of the board has a circuit inside called an ***analog-to-digital converter* or *ADC*** that reads this changing voltage and converts it to a number between 0 and 1023. When the shaft is turned all the way in one direction, there are 0 volts going to the pin, and the input value is 0. When the shaft is turned all the way in the opposite direction, there are 5 volts going to the pin and the input value is 1023. In between, the function ***analogRead()*** returns a number between 0 and 1023 that is proportional to the amount of voltage being applied to the pin.

2. Temperature sensor LM35

The temperature sensor LM35 in Figure 2.3 provides output voltage of 10 mV/degree Celsius and has highly linear output characteristics. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature.

The LM35 does not require any external calibration or trimming to provide typical accuracies of ±0.5 ^{O}C at room temperature. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. The LM35 is rated to operate over a −55^{O}C to +150^{O}C temperature range.

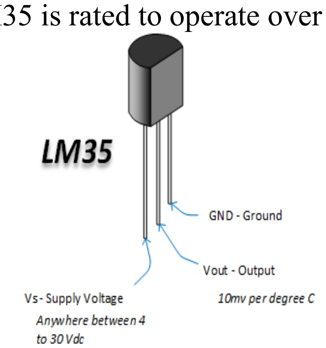


Figure 2.3. LM 35 package

Equipment

- Proto-Board PB503
- Oscilloscope Tektronix TDS210
- Digital multimeter (DMM)
- Dual Voltage Power Supply
- Potentiometer 10kΩ
- LM35
- LED
- Resistors: 220Ω, 10kΩ

PRE-LABORATORY PREPARATION

The lab preparation must be completed before coming to the lab. Show it to your TA at the beginning of the lab and get his/her signature in the Signature section of the Lab Measurements Sheet.

1. The nominal specification for the linear potentiometer is 10 kΩ at a 250° turning angle. Compute the potentiometer output voltage for the circuit in Figure 2.2 with Vin=5V. Complete the nominal voltages at the angles given in Table 2.1.
2. Study the example Arduino sketch for Potentiometer https://www.arduino.cc/en/Tutorial/ReadAnalogVoltage
3. Modify the sketch to display the potentiometer turning angle on the Serial Monitor and store it under a different name.
4. Study the example Arduino tutorials and sketch for the temperature display http://www.instructables.com/id/Arduino-and-LM35-Based-Temperature-Monitor-for-Beg/

PROCEDURE

1. Potentiometer

1.1. Use a 10 kΩ potentiometer built in a Proto-Board, connect it to Arduino and construct the circuit shown in Figure 2.4. The Potentiometer and its diagram are shown in Figure 2.6.

1.2. Upload the Voltage Reading sketch and record the results from the Serial Monitor in Table 2.1 of the LMS.

1.3. Turn the potentiometer knob to the left until it stops, connect the Voltmeter between the slider and the Ground, and measure the voltage V. Record your measurements in row 0° in Table 2.1 of the LMS.

1.4. Turn the knob clockwise in increments shown in Table 2.1 and record the Voltmeter and Arduino Voltage readings until the knob stops at its maximum right position.

1.5. Upload the Arduino Angle Reading sketch. Repeat the measurements from step 1.4 and record the angle results from the Serial Monitor in Table 2.1 of the LMS.

1.6. Compare the results of the experiment with the pre-lab calculations and explain what you learned about the potentiometer.

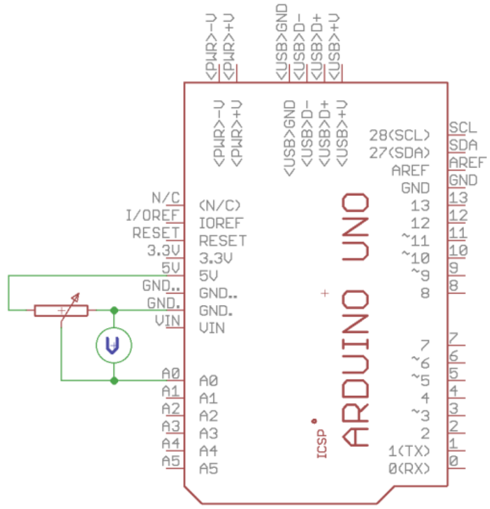
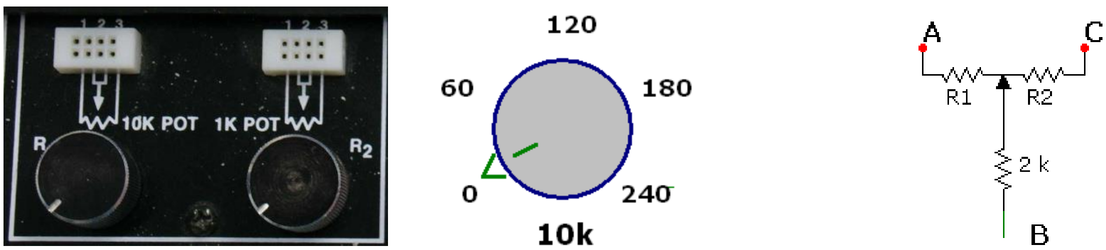


Figure 2.4. Potentiometer Circuit



a) Protoboard potentiometers b) Knob position c) Potentiometer Measurements

Figure 2.5 Potentiometers

2. Temperature sensor LM35

2.1. Connect LM 35 Temperature sensor to the Arduino board and construct the circuit shown in Figure 2.6. The LM 35 pin layout is shown in Figure 2.3.

2.2. Upload the Temperature Reading sketch and record the results from the Serial Monitor in Table 2.2 of the LMS.

2.3. Measure the output voltage of LM35 with Digital Voltmeter and record the values in Table 2.2.

2.4. Calculate the temperature based on 10mV/C^o and compare it with the Arduino readings.

2.5. Hold the LM 35 with your fingers for couple of minutes to measure and record your body temperature. Wait until you see a constant temperature readings.

2.6. Measure the output voltage of LM35 with Digital Voltmeter and record the values in Table 2.2.

2.7. Calculate the temperature based on the 10mV/C^o and compare it with the Arduino readings.

2.8. Let the sensor cool down and repeat the measurements.

2.9. Calculate the % Error between the two methods using Equation 2.2.

$$\%Error = \frac{\text{Calculated } - \text{Measured value}}{\text{Calculated value}} \times 100 \qquad \text{Equation 2.2.}$$

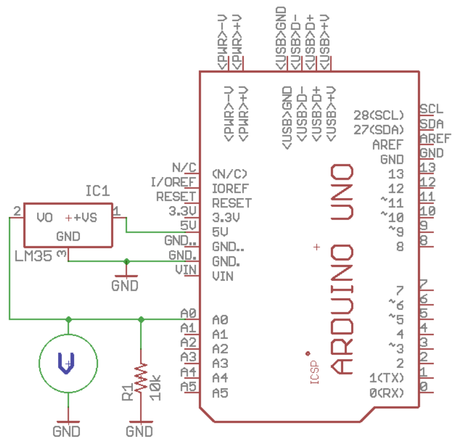


Figure 2.6. Temperature Sensor Circuit

LAB MEASUREMENTS SHEET – LAB 2

Name ______________________

Student No____________________

Workbench No_____

NOTE: Questions are related to observations, and must be answered as a part of the procedure of this experiment.

Sections marked * are pre-lab preparation and must be completed BEFORE coming to the lab.

1. Potentiometer measurements.

Angle (º)	**Nominal Voltage (V)***	**Measured Voltage (V) By Voltmeter**	**Displayed Voltage (V) On Arduino**	**Displayed Angle (º) On Arduino**	**% Error For Voltage Measurements**
0					
30					
60					
90					
120					
150					
180					
210					
240					

Table 2.1 Potentiometer measurements

2. Compare the results of Manual Angle, Voltmeter and Arduino measurements.

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3. Temperature Sensor

	Measured Voltage By Voltmeter (V)	Calculated Temperature (Cº)	Displayed temperature on Serial Monitor	% Error
Room temp.				
Heating the sensor				
Cooling the sensor				

Table 2.2. Temperature sensor measurements

4. Compare the results of Voltmeter and Arduino measurements

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SIGNATURES **TA name:**________________________

To be completed by TA during the lab session.

Check boxes			**Task**	**Max. Marks**	**Granted Marks**	**TA Signature**
			Pre-lab completed.	30		
			Potentiometer connected and Voltage Reading completed	20		
			Potentiometer connected and Angle Reading completed	20		
			Temperature Sensor connected and data collected	20		
			Data collected and observations made	10		
			TOTAL MARKS	**100**		

Final marking to be completed by the TA after the lab session.