Using Arduino Uno to Measure Changes in Potential Across a Potentiometer Wire with an Ultrasonic Sensor

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Abstract

This experiment measures the fall of potential across a potentiometer wire, using an ultrasonic sensor and Arduino Uno. Arduino is an open-source electronics platform based on easy-to-use hardware and software. This experiment demonstrates the use of reflection of sound from a barrier to measure length of a potentiometer wire and of Arduino to measure potential at different positions of wire. This is a low-cost, effective method to evaluate students' performance on the basis of task-based assignments. It also enhances their skills in determining various parameters through non-conventional techniques by the applying basic concepts of physics. This paper emphasizes the importance of using technology in conducting physics practicals through e-learning.

Key Words: Ultrasonic sensor, Arduino Uno, potentiometer wire.

1 Introduction

Due to lack of funds and facilities in some of the remote areas, it is difficult to conduct practicals in labs with students at both school and college level. Therefore, there is an urgent need for devising some low-cost, effective methods to enhance students' skills in practicals or task-based assignments and evaluate their performances in this field. Arduino Uno has come to the rescue of the above cited problem. It is an open-source electronics platform for engineers and non-engineers based on easy-to-use hardware and software. We just need a specific sensor, Arduino, and code. Arduino hardware can read inputs, such as light on a sensor, button status, detect motion and turn it into an output (voltage), rotate a motor or set of motors, activate or deactivate a motor for any desired time, or turn an LED on/off, etc [1–4]. On the software part, Arduino IDE is an integrated development environment that helps in creating, verifying, and uploading the program to the microcontroller to run programs, which perform specific tasks using various sensors in devices. Before demonstrating the Arduino experiments, we have to download and install Arduino IDE from www.Arduino.cc. There are a variety of sensors available at a very low cost, which, when integrated with the Arduino board, help in determining various physical parameters like resistance, temperature, pressure, e.m.f, etc. Some of these sensors are ultrasonic sensors, LDRs, temperature and humidity sensors, blue tooth sensors, IR sensors, etc. The working of these sensors is based on various basic principles of physics. Therefore, the integrated use of sensors with Arduino board helps in doing various physics experiments at home, thus eliminating the requirement of the lab during pandemic like situations. In this paper, we demonstrate an innovative way of measuring the change in potential across potentiometer wire using an ultrasonic sensor and Arduino Uno Board.

2 Significance of the experiment

1. Basic principles of physics are integrated with low-cost, effective technology.
2. Sensor-based real-time measurement is done.
3. Project and analysis-based learning is enhanced by these experiments.
4. Creating an innovation by designing other experiments based on ultrasonic sensors and obstacle detection, such as crack detection in metals.
5. Task-based assessment skills can be done.
6. Enhances practical and applied components in the curriculum which includes computer-based learning and electronic learning blended with low-cost physics experiments, which have an edge over virtual lab experiments. Here, in this experiment, the student prepares the setup himself, thereby developing skills to make their own apparatus.

3 The working principle of a Potentiometer

The basic principle of the potentiometer is that the potential drop across any section of the wire is directly proportional to the length of the wire, provided the wire has a uniform cross-sectional area and a uniform current flowing through it.

3.1 Conventional Method Used in the Lab

The potentiometer is a long piece of uniform wire across which a standard cell is connected. The current flowing through the wire can be varied using a variable resistance (rheostat) connected in the circuit. The resistance can be manually changed to measure the potential difference. A potentiometer is an instrument used to measure the unknown voltage by comparing it with the known voltage. The readings obtained from a potentiometer are more accurate. It has the advantage of drawing no current from the voltage source being measured and as such, it is unaffected by the internal resistance of the source.

A standard cell is connected across the potentiometer, allowing a constant current to flow through it. The current flowing through the wire can be varied using a variable resistance (rheostat). One end of a connecting wire is connected to the zero end of the potentiometer wire, and the other end is connected through a voltmeter to a jockey that slides over the potentiometer wire, reading the potential difference. To enable accurate measurement, the jockey must be moved until the voltmeter pointer aligns with one of the marks. The length of the potentiometer wire is then noted from the scale. For a given fixed current, a set of voltage (V) and length (L) values are taken. In our method, only the L-shaped block is moved to any position, automatically giving the length of the wire via an ultrasonic sensor and the potential at that position via Arduino code.

3.2 Non-Conventional Method of Measuring the Voltage

Voltage measurement at any point on a wire of uniform cross-section is done using Arduino Uno hardware instead of standard cells or batteries. The required apparatus consists of a potentiometer wire, Arduino Uno hardware, an ultrasonic sensor, a laptop/PC, an L-shaped wooden board, and aluminum foil.

4 Experimental Procedure

Make connections as follows:

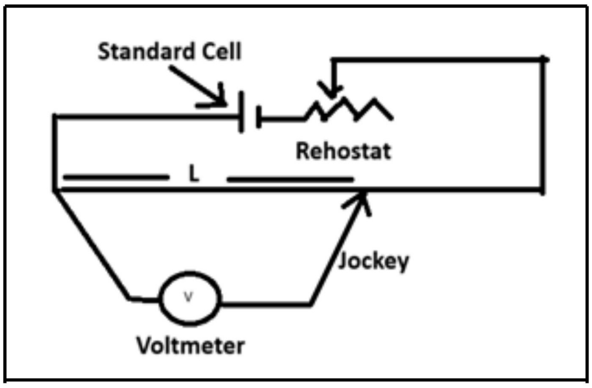

Figure 1: Circuit Diagram of Conventional Potentiometer

1. Take a 100cm long wire of uniform cross-section and fix it on the wooden platform.
2. Mark one end as A and the other end as B.
3. Connect A to the 5V pin of Arduino and the other end to the GND pin.
4. Paste aluminum foil at the bottom of the sliding L-shaped wooden block.
5. Connect the wire with one end wrapped in aluminum foil pasted onto the bottom of the L-shaped wooden board and the second end to A0. The arrangement is shown explicitly in Figures 2 and 3.
6. Connect the ultrasonic sensor to the four pins (GND, Vcc, Trigger, and Echo) on the Arduino board using a breadboard, as shown in Figures 2 and 3.
7. The trigger pin of the ultrasonic sensor is connected to digital pin 7 in Arduino, while the echo pin is connected to pin 10.

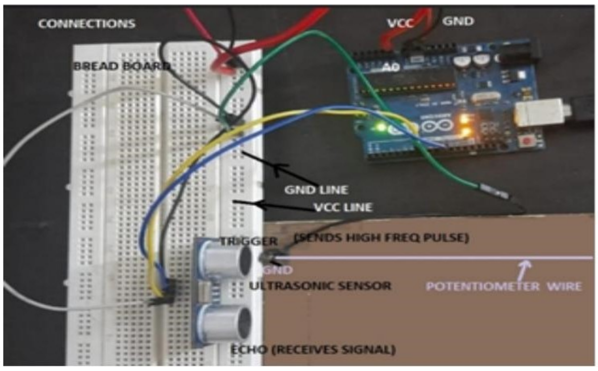

Figure 2: Circuit connections showing Arduino, Breadboard, Ultrasonic sensor, and potentiometer wire

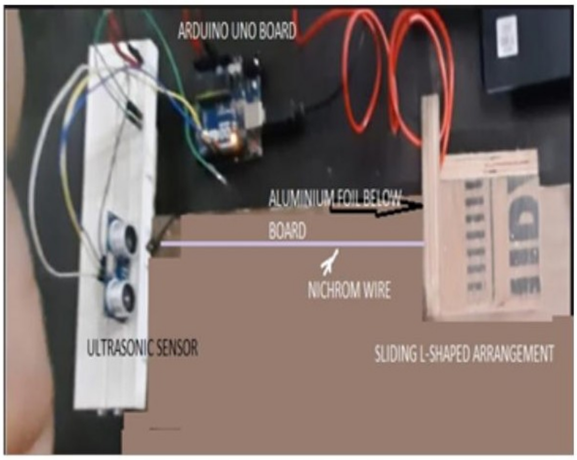

Figure 3: Sliding L-shaped arrangement

8. Write a program in an Arduino file on a PC, verify the program, and upload it to the Arduino board through a cable.

9. The ultrasonic sensor triggers a high-frequency pulse of short duration, and an echo is received by the Echo Sensor.

10. The time interval of the to-and-fro path, measured by the Ultrasonic device, gives the length (L).

11. The potential at different points is read at Analog pin A0, and readings of potential vs. length are tabulated in the PC.

5 Results and Discussion

When an electrical pulse of high voltage (5V) is applied to the ultrasonic transducer, it vibrates and generates ultrasonic waves. These waves strike an obstacle, and the ultrasound waves are reflected in the form of an echo, generating an electric pulse. The sensor calculates the time taken between sending sound waves and receiving the echo using the formula:
Distance $= \frac{Duration}{1000000} * \frac{35000}{2}$
velocity of sound is taken to be 350 m/s = 35000 cm/s.

Ultrasonic detection introduces high-frequency sound waves into a test object without damaging it. Sound waves having a frequency range from 100KHz to 50 MHz are employed in ultrasonic detection. The distance of the obstacle is related to the velocity of sound waves in the medium through which waves are passed and the time taken for echo reception. Hence, the distance between ultrasonic waves and obstacles can be detected using an ultrasonic sensor.
Arduino Uno helps to read the voltage at

EXPT: FALL OF POTENTIAL ACROSS POTENTIOMETER WIRE IS DIRECTLY PROPORTIONAL TO LENGTH OF WIRE					
TIMESTAMP	Potential AT A POINT	DISTANCE FROM ULTRASONIC (Cm)	UNIT	LENGTH L(Cm)	POTENTIAL DIFFERENCE V (VOLTS)
[2020-10-02 13:36:37.367]	3.93	9.75	Cm	0.00	0.00
[2020-10-02 13:32:57.427]	3.90	10.85	Cm	1.10	0.03
[2020-10-02 13:36:07.375]	3.70	16.22	Cm	6.47	0.23
[2020-10-02 13:35:57.388]	3.38	23.19	Cm	13.44	0.55
[2020-10-02 13:33:07.427]	3.26	23.59	Cm	13.84	0.67
[2020-10-02 13:35:47.392]	3.00	28.91	Cm	19.16	0.93
[2020-10-02 13:33:17.418]	2.93	29.00	Cm	19.25	1.00
[2020-10-02 13:33:27.426]	2.63	34.77	Cm	25.02	1.30
[2020-10-02 13:35:37.396]	2.68	35.30	Cm	25.55	1.25
[2020-10-02 13:33:37.415]	2.49	38.43	Cm	28.68	1.44
[2020-10-02 13:35:27.398]	2.33	41.84	Cm	32.09	1.60
[2020-10-02 13:33:47.412]	2.26	43.00	Cm	33.25	1.67
[2020-10-02 13:35:17.400]	2.00	48.81	Cm	39.06	1.93
[2020-10-02 13:34:07.415]	1.65	55.54	Cm	45.79	2.28
[2020-10-02 13:35:07.398]	1.60	56.58	Cm	46.83	2.33
[2020-10-02 13:34:17.412]	1.42	59.99	Cm	50.24	2.51
[2020-10-02 13:34:57.408]	1.29	63.44	Cm	53.69	2.64
[2020-10-02 13:34:27.410]	1.14	65.78	Cm	56.03	2.79
[2020-10-02 13:34:37.405]	0.88	73.08	Cm	63.33	3.05
[2020-10-02 13:34:47.412]	0.91	74.32	Cm	64.57	3.02

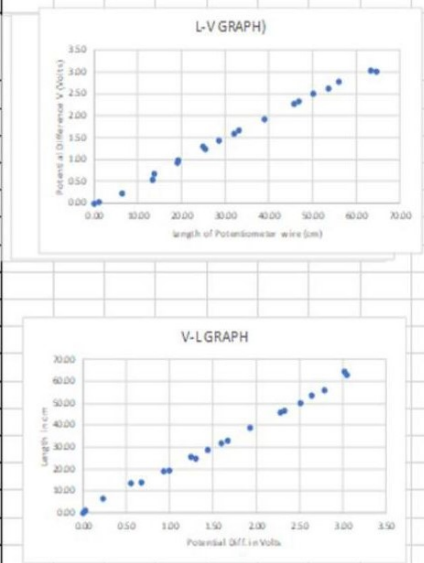

Figure 4: (a) Table showing fall in potential across potentiometer wire is directly proportional to the length of wire. (b) Graph of potential difference vs length of potentiometer wire.

the point where the obstacle is placed on the potentiometer wire. It can be seen from the results that the potential falls as the length or distance increases. Here, we measure potential at a point and not the potential difference. We then calculate the potential difference with the starting point as the reference potential (0).

It is worth mentioning here that Analog pins processing is 10-bit, which divides 5 volts into $2^{10} = 1024$ parts and gives a value between 0 and 1023, depending on the voltage at the analog pin. Digital pins processing, on the other hand, is 8-bit, giving $2^8 = 256$. The values obtained are therefore between 0 and 255.

It can be seen from the results (Figure 4) that as the distance between the ultrasonic sensor and the obstacle increases, there is a fall in potential. Also, the difference in length measured in the potentiometer wire is directly proportional to the potential difference. The time interval is measured in microseconds. Also, the potential is measured to an accuracy of 0.01V. The experiment was repeated thrice and same set of readings were obtained.

6 Conclusion

This experiment enables students to learn the basic concept of fall-in potential across potentiometer wire. Additionally, they can be tasked with devising another experiment using an ultrasonic sensor and Arduino board. For example, ultrasonic waves can detect cracks in the metals. The key takeaways from the experiment are:

1. Nature of propagation of ultrasonic waves in different mediums and use of these concepts in detecting various parameters like potential, finding cracks, etc.

2. Use of technology to take readings using software and hardware to experiment.

Learning through a PC takes into consideration more extensive access and in this paper a blended format of e-learning with technology and doing physical experiments is discussed which has more impact as compared to the virtual labs. This article will orient students and teachers to design their low-cost apparatus at home.

References

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7 Appendix

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/*ULTRA SONIC HAS BEEN DIRECTLY
INSERTED INTO ARDUINO BOARD GROUND
GOES TO GROUND ECHO PIN GOES TO
PIN 13.  TRIGGER PIN GOES TO PIN
12.  PIN 11 is named as vcc Pin
and IS MADE VCC BY USING STATEMENT
digitalWrite(vccPin,HIGH) This
statement makes Pin 11 5V. */ int
sensorPin=A0;// Sliding
const int echoPin = 13;
const int trigPin = 12;
int vccPin = 11;
float involtage;
float outvoltage;
float v;
long duration;
float distance;
int del = 10000;
void setup() {
Serial.begin (9600);
Serial.print(&quot;,&quot;);
Serial.println(&quot;Voltage-Length
Relation in Potentometer&quot;);
pinMode(sensorPin,INPUT);
pinMode(trigPin, OUTPUT); // Sets the
trigPin as an Output
pinMode(echoPin, INPUT); // Sets the
echoPin as an Input
pinMode(vccPin,OUTPUT);
digitalWrite(vccPin,HIGH);
}
void loop() {
// Clears the trigPin
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
```

```
// Sets the trigPin on HIGH
state for 10 micro seconds
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW); // Reads
the echoPin, returns the sound wave
travel time in microseconds
duration = pulseIn(echoPin, HIGH);//
Gives time interval in micro second
since pulse was triggered
// Calculating the distance
distance = duration/1000000.*35000./2.;//
velocity of sound is taken to be 350
m/s = 35000 cm/s
// Prints the distance
on the Serial Monitor
involtage=analogRead(sensorPin);
Serial.print(&quot;,&quot;);
//Serial.print(&quot;V-in at
point&quot;);
Serial.print(involtage*5/1023);
Serial.print(&quot;,&quot;);
//Serial.print(&quot;Distance:
&quot;);
Serial.print(distance);
Serial.print(&quot;,&quot;);
Serial.println(&quot; Cm &quot;);
//analogWrite(outPin,outvoltage);
delay(del);
}
```