

Note to the Teacher

In this investigation, students will learn how a potentiometer can be used in an electronic circuit as a variable resistor or as a voltage divider. Students will construct simple electronic circuits that use a DC voltage source, a fixed value resistor and a rotary potentiometer. This investigation consists of two activities.

Activities

This investigation consists of 2 activities: both of which are lab based. These activities support robotics instruction and participation in competitive events.

- This investigation should take approximately 2 forty minute periods.
 - Students should work in cooperative teams of 2 or 3.
 - Managing a classroom when multiple investigations are being done using multiple Vex systems but only one crystal frequency is not recommended.
 - Refer to Inventors Guide Unit Six (page 21)–Control and Appendix E–Control Configuration (page 11-18).
 - Recommendation is to purchase addition crystal sets from Vex (see Unit 6 page 22 in the Inventors Guide).
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When completing this lesson (including all extension activities), students will be able to:

1. Understand how a potentiometer works as a variable resistor and as a voltage divider.
2. Demonstrate and understand how to use a DMM as an ohmmeter, a voltmeter, and an ammeter.
3. Apply Ohm's Law to predict current (I), resistance (R), and voltage (E).
4. Understand the voltage divider principles.
5. Explain results and the relationship (R vs. I).
6. Predict some values of dependent variables as some circuit controlled variables are subjected to a change
7. Graph data and interpret it.
8. Follow an experimental procedure.
9. Calculate experimental error.
10. Make conclusions. The students are guided to those conclusions by answering related questions.

Note to the Teacher *continued*

Description of the investigation

Students will work in teams of two or three on each of the two exercises. Students will have to first gather the components, parts, and equipment necessary to perform the lesson.

A. In the first exercise, each team will investigate the use of the potentiometer as a variable resistor. Each team will construct a series DC circuit, measure resistance and current, compare measured and calculated values, and answer related questions. Each team will use the data of exercise 1 to plot resistance versus current and answer related questions.

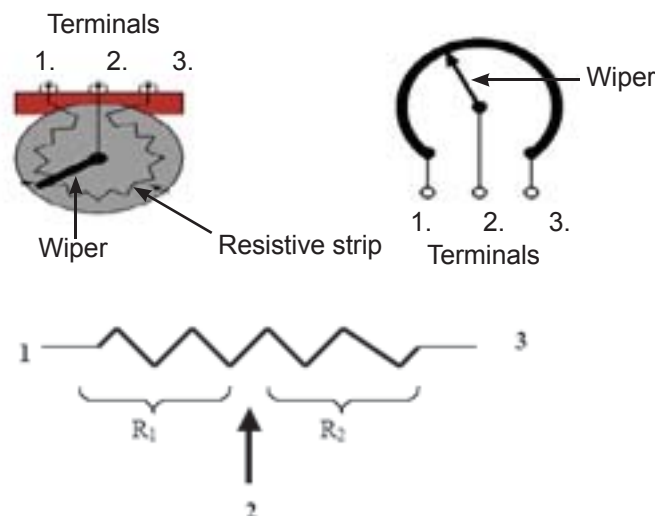
B. In the second exercise, each team will connect the potentiometer as a voltage divider, record voltage and resistance measurements, predict parameter values, and answer related questions.

Materials required for the lessons:

- Digital multimeter (with the ability to measure milliamps)
- 10 kW Potentiometer
- 1 kW Resistor
- 9 Volt Battery
- Battery attachment
- Alligator Clips/Connecting Leads

POTENTIOMETER AS A VARIABLE RESISTOR / Lab Activity 1

If one of the outer terminals and the wiper terminal (say terminal 2 and 3) are connected with a wire (short), then the potentiometer is used as a two terminal device – variable resistor. Alternative configuration is by only using the wiper and one of the outer terminals while leaving the third outer terminal not connected to anything. The value of the resistance between the two resulting terminals is adjusted by manually turning the knob (moving the wiper.) In this case we simply treat the potentiometer as a resistor when we perform calculations.



Note to the Teacher *continued*

Imagine a series circuit with a 9V battery, a fixed 1.0 K Ω resistor and a 10.0 K Ω potentiometer used as a variable resistor.

Note: Make sure the correct steps are taken to measure current, resistance or voltage otherwise some damage to the instrument or incorrect readings may occur.

a) The current in the circuit is calculated as:

Using Ohm's Law $E = I \times R$

$$I = E / R$$

$$R = E / I$$

then

$$I = E / R_T \text{ where } R_T = R_{\text{fixed}} + R_{\text{pot}}$$

b) Predicting the R_{pot} resistance.

Suppose the measured current was 2.2mA, then the variable resistor's value is calculated as follows:

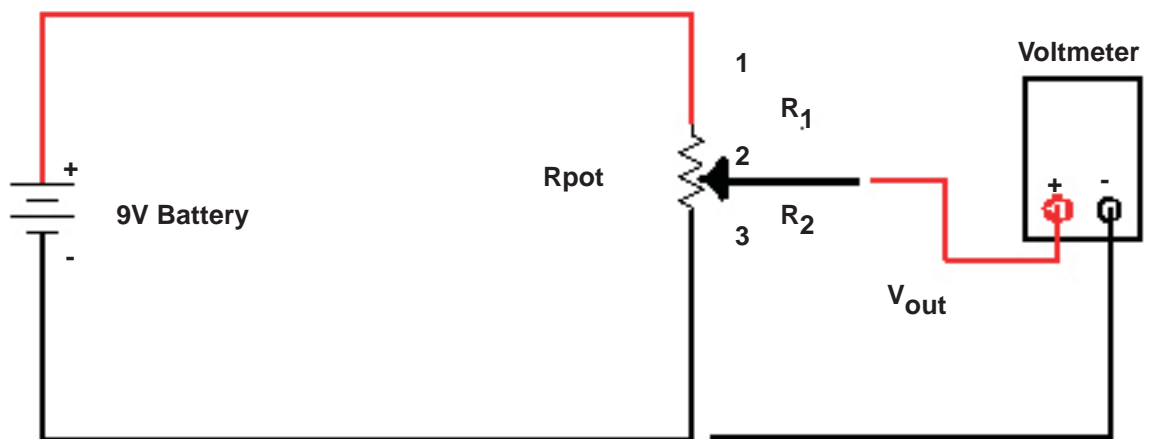
$$R_T = E / I = 9V / 2.2 \text{ mA} = 9V / 0.0022A = 4090.91 \Omega$$

Then

$$R_{\text{pot}} = R_T - R_{\text{fixed}} = 4090.91\Omega - 1K\Omega = 3090.91\Omega = 3.09K\Omega$$

POTENTIOMETER AS A VOLTAGE DIVIDER / Lesson 2

When all three terminals of a potentiometer are used in a circuit, the potentiometer is used as a voltage divider. When a DC voltage is applied to one of the outer terminals (terminal 1) and the other terminal (terminal 3) is connected to ground, the output voltage at the wiper (terminal 2) may be varied between the value of 0V and the applied DC voltage by turning the knob on the shaft of the potentiometer.



Note to the Teacher *continued*

Related Equations:

$$R_{\text{pot(max)}} = R_1 + R_2$$

V_{out} : [output voltage]

E: [Battery - DC voltage]

$$V_{\text{out}} = E \times (R_2 / R_{\text{pot(max)}})$$

If the value of V_{out} is known, we can calculate (predict) the value of R_2 by rearranging the above equation.

$$R_2 = V_{\text{out}} / E \times R_{\text{pot(max)}}$$

The amount of current through the circuit is constant all the time as long as the battery's voltage does not change. The reason for this is that the total resistance seen by the battery is always equal to $R_{\text{pot(max)}}$.

Therefore, one can also calculate V_{out} as follows:

$$I = E / R_{\text{pot(max)}} \text{ and}$$

$$V_{\text{out}} = I \times R_2, R_2 = V_{\text{out}} / I$$

Once we know the value of R_2 , the value of R_1 is calculated.

$$R_1 = R_{\text{pot(max)}} - R_2$$

As the wiper arm is moved, R_1 and E remain unchanged. The only variables in the circuit are R_2 and R_1 . As R_2 value decreases, the output voltage drops. When R_2 is decreased to zero Ohms (wiper is moved to terminal 3), the output voltage is then equal to zero volts. On the other hand, as the value of R_2 is increased by turning the knob so that the wiper arm moves towards terminal 1, V_{out} increases towards the applied DC voltage. Therefore, it is fair to say that the output voltage can be varied between the voltage values applied at terminals 1 and 3.

Experimental error

There are many things that can cause experimentally measured numbers to fall off-target from the predicted values. Here are a few:

- *Systematic error* is something in the experiment that always throws off the data in the exact same way. Some examples of systematic errors are: dead battery, improperly connected components, defective motor.
- *Random error* is caused by small factors that constantly change and affect the experimental results. In this experiment, random error may be caused by varying starting points, sloppy measuring procedures, or battery level.

This investigation includes worksheets where students capture data and write conclusions. Below is some sample data presented in graph format using MS Excel.

Standards Addressed

Science Standards

Content Standard "A" Science as Inquiry

Content Standard "B" Physical Science

Content Standard "E" Science and Technology

Unifying Concepts

- Systems, Order, and Organization

Note to the Teacher *continued*

- Evidence, Models, Explanation
- Constancy, Change, and Measurement
- Evolution and Equilibrium

Math Standards

Numbers and Operations

Algebra

Geometry

Measurement

Problem Solving

Reasoning and Proof

Communications

Connections

Technology Standards

The nature of Technology Standards 1, 2, 3

Design 8, 9, 10

Abilities for a Technological World 12

The Designed World 16, 17

How to use the lesson materials

1. Review the other lesson materials thoroughly.
2. Read “Overview/PowerPoint/Lesson Guide.” It will serve as a general guide for the lesson content. It is also modifiable, but note that it is only modifiable if you use the “Save As” option or browse to it. (If you click on it in the lesson page, you will not be able to modify it.) To get a version you can modify, go to “File/Save As” to save a copy to your computer, or browse to Vex Curriculum/Content/Lessons/ home_brew/potentiometer_1/potentiometer_1.ppt on the Vex curriculum, and copy it to your computer.
3. Read the remainder of this document. It will serve as a general guide for how to teach the lesson content.
4. Have your students review all the materials in “Background.” Under “Helper Link”, “Current” and “Voltage” provide background on these subjects. Under “Resources”, “Multimeter Guide” provides instruction about using a multimeter. Keep in mind that different multimeters require slightly different instruction, however, and that you will have to thoroughly understand the multimeter you use and be able to explain how to use it to your students. “Variable Resistor Worksheet” and “Voltage Divider Worksheet” should be used with the corresponding lessons. Note that you should choose whether to print and hand out these excel documents and ask students to work from them, or whether you want to tell students to save the file to their own computer, and modify the documents by adding data gathered from their own experiments. Lack of computers and potential technical problems may make printing the table and asking students to construct a similar table the easier option.
5. Modify and add to the lesson in the way that will best serve your classroom.
6. Teach the lesson, drawing on lesson materials where appropriate. You may wish to begin the lesson by having your students go through “Introduction for Students” and the PowerPoint Lesson Guide, as these will provide background

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both on the information and the lesson.

7. Assign the “Checking for Understanding” Quiz.

8. Note that this lesson has been envisioned as part 1 of a 2 part lesson on making a home brew sensor. While some teachers may wish to teach it as a stand alone unit, combining it with part 2 should provide more insight for your students into the nature of programming, sensors and dials, in addition to the information about electronics and potentiometers found in this part of the lesson.