Circuits Sleight of Hand—Gesture Sensing with Flexible Resistors (CBL Module #2 Fall 2019)

Circuits Stuff You'll Learn/Review Today:

- What is resistance? What gives rise to resistance (or conductance) in graphite layers?
- What is voltage? How can we think about KVL (in appropriately technical terms).
- How can we use a circuit to sense something about the environment (light last week; mechanical this week; humidity/salinity in future weeks). That is, why do we need a voltage divider?
- Circuit assembly techniques (conductive paint and glue!)
- More Arduino coding/interfacing + servo motors. Binary numbers (0s and 1s) *
- Applications:
    a. Gesture sensing glove.
        i. Measurement and Display
        ii. Rotate a servo motor attached to an articulated hand; OR rotate an indicator rod
    b. Vibration sensing, time permitting. Mount to beam, let the resistor flex back and forth, watch it on Arduino display

Resistance is NOT Futile: Build a pencil resistor

First we'll build pencil drawn variable resistors; the resistance value changes primarily as a result of mechanical deformation. Such resistors are inexpensive and easy to fabricate. As well, they lend themselves very well to all sorts of fun applications. But first, time to build a pencil resistor!

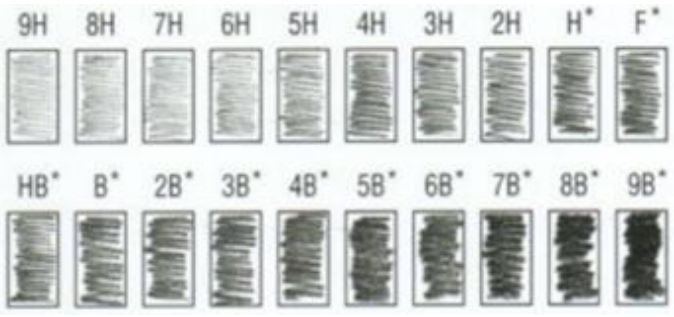


Figure 1. Different grades of pencil lead. Image credit: http://www.efxkits.us/pencil-resistors-working-with-simple-project

One needs nothing more than a pencil and paper. The key element is the graphite, which is electrically conductive. Its microstructure forms small non-conductive gaps when in tension, and generally better conducting platelets when in compression. The resistance of graphite varies depending on the grade of pencil lead, which is graded as illustrated in Figure 1.

1. Using a pencil, draw a thick, straight line of graphite carbon on a piece of paper several inches in length. Measure the resistance between two points of contact as a function of distance between the two points of contact. Do this systematically so that you can chart out length vs. resistance. Is the trend linear? Make a plot of resistance vs length to find out. This will also inform you essentially how a pot works on the inside.
2. Next, attach two wires using conductive paint. Let it dry for a while. When the paint appears dry, test the connectivity with an ohm-meter.
3. While you are waiting for your resistor to dry, think of some applications—where would you want to sense bending, twisting, vibrations, etc. Think of at least 3 different ideas! [Refer to Liao et al 2015 article as necessary]
4. If all went well, move to next step. If not, reapply conductive paint of wire bond glue
5. Apply packaging tape to top and bottom layers of the pencil + paper resistor. This makes the resistor more mechanically durable (otherwise it could easily tear).

Gesture sensing glove application

Build a gesture sensing glove using a voltage divider configuration (Figures 2 and 3). Position correlates to resistance changes. Measure how: Carefully trace out R vs. bend angle curve, for a few positions. Resistance changes voltage. Arduino does analog read of voltage and reacts by turning motor as indicator, actuating articulated hand or dial indicator (See Next Sections)

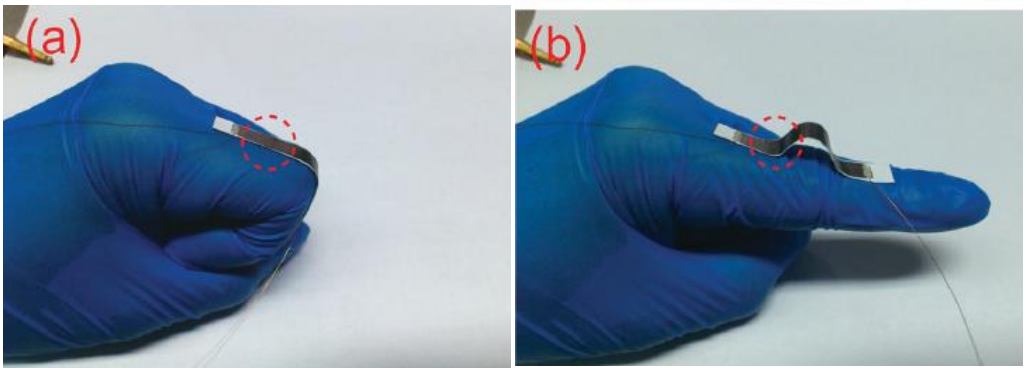


Figure 2. Pencil resistor mounted to glove. Bending the finger changes the resistance, which we can sense as a change in voltage.

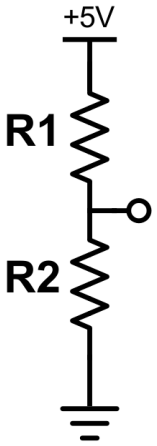
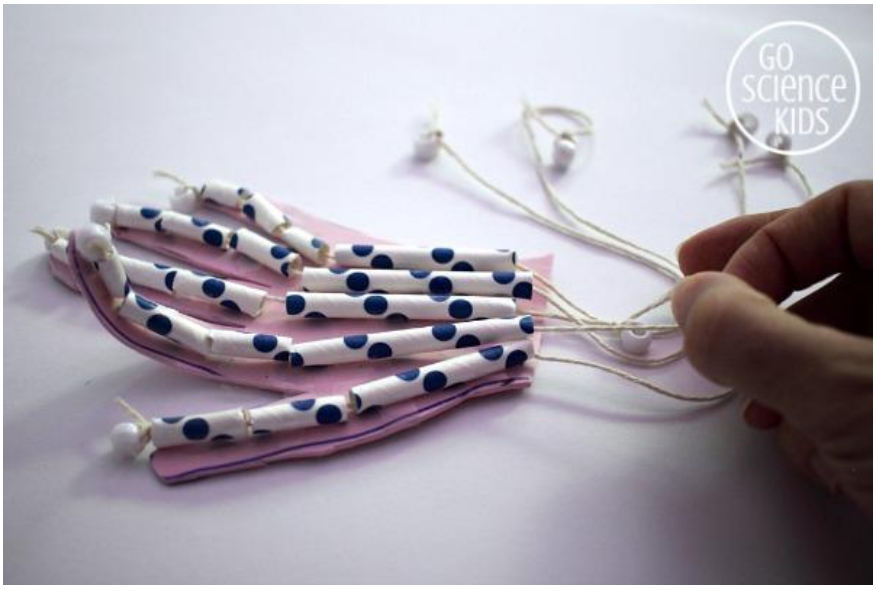


Figure 3. Voltage Divider configuration. One of these resistors represents the flexible resistor. The other is a typical resistor.

Articulated Hand

See directions on how to make an articulated hand at: https://gosciencekids.com/articulated-hand-movable-fingers-joints-tendons/. The servo motor can connect to the string "tendons" to make the hand move. You'll need to get creative on how to make those connections! And with how the angle of the servo correlates to the position of the human finger flexing to turn the motor. Remember: the servo motor has 3 wires: 2 for power (typically red and black); and 1 signal wire to send the control signal to turn to a certain angle (typically yellow) via digital pulses. Here is a GREAT tutorial with more info on servos.



Servo Dial Indicator/Display

Alternatively, you can build a dial that indicates the position of the finger. An example is illustrated in Figure 4. Play a game and see if you can get the dial to a desired position.

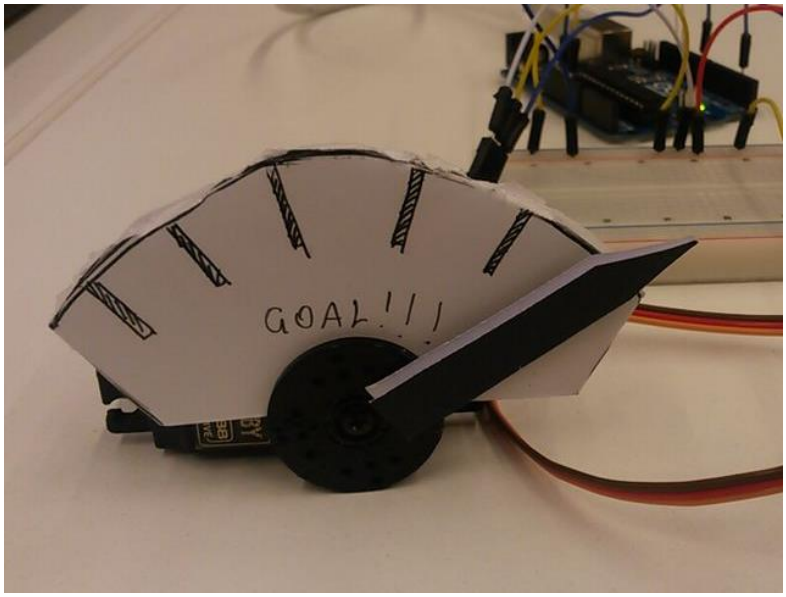


Figure 4. Example Dial Indicator. Note the servo hiding in the background. Image credit: https://www.instructables.com/id/Arduino-Jump-Challenge/

Arduino Code

The example code is modified from the 'knob' tutorial (Arduino IDE > File > Example > Servo > knob.ino). You will likely need to optimize the values in the map() functions. This means you need to know the min and max readings for when your finger sensor is flexed vs. straight.

```
/*
 Arduino gesture sensing glove + servo actuation
 by Jon Erickson, 30 Sep 2019
 based on code by: Scott Fitzgerald
 http://www.arduino.cc/en/Tutorial/Knob
*/

#include <Servo.h>

Servo myservo;  // create servo object to control a servo

int voltageReadingPin = A0;  // analog pin used to measure output of voltage
divider
int servoControlPin = 9; //servo signal pin (sends PWM pulses)
```

```
int val;    // variable to read the value from the analog pin
int angle; // angle to which servo is truned

void setup() {
  Serial.begin(9600); // turn on serial port communication
  myservo.attach(servoControlPin);  // attaches the servo on pin 9 }

void loop() {
  Vout = analogRead(potpin);            // reads the value of the voltage
divider (10 bit number value between 0 and 1023)
  angle = map(Vout, 0, 1023, 0, 180);     // scale it to use it with the
servo (value between 0 and 180)
  myservo.write(angle);                  // sets the servo position according
to the scaled value

  Serial.print("Analog read (0-1023) = ");
  Serial.println(Vout);
  Serial.print("Angle (deg) = ");
  Serial.println(angle);

  delay(15);                           // waits for the servo to get there
}
```