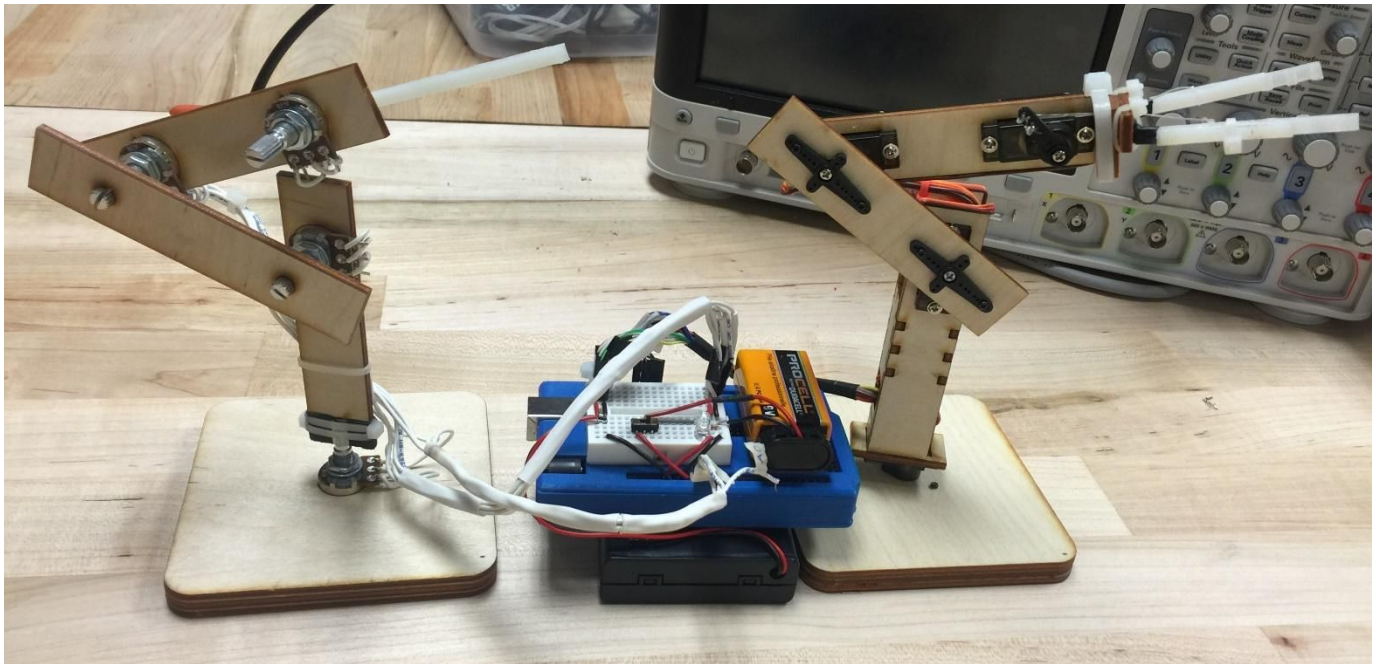
Mini Robotic Arm



"Micro Servo Robot"
Originally developed by **Pinaut**

Modified by Project-in-a Box developers:
by Buu Truong, Jordi Medellin

Dear Student,

The ECE 196 course and Project in a Box team would like to give credit to Pinaut for making his Micro Servo Robot, which inspired us to create a similar project as one of the choice of this class' projects. We hope, through the process of building this robotic arm, you will gain a fundamental understanding of how a robotic arm function.

Sincerely,
P.I.B Team

Description

This is a 3 axis robotic arm with a small gripper. The project has 3 main components: the mechanical arm, controlling arm, and the microcontroller (Arduino Uno). The mechanical arm motion is enabled by 4 micro servo motors, and those motors are controlled by 4 potentiometers on the controlling arm, which are communicated using the microcontroller. As a user motions the controlling arm, the mechanical arm mimics the movement of the controlling arm; therefore, user can perform precision tasks with the robotic arm.

Objective

This project is used to demonstrate how a simple concept of controlling a servo motor with a potentiometer can be used to make a practical device like a robotic arm. The main takeaway for this project is to understand how servo motors are controlled, programmed, and what they can be potentially used for. Such servo motors can be used for controlled movements that require specific directions (directions usually ranging 0-180 degrees or 0-360 degrees). By programming the servo motors, you will also learn to become familiar with the Arduino environment, which uses C, or C++ language. Another objective is to understand how variable resistors like potentiometers can be used.

Overview

Challenge #1: Design the Robotic Arm Frame

Challenge #2: Construct the servo mechanical arm

Challenge #3: Build the potentiometer controlling arm

Challenge #4: Assemble both arms to the Arduino

Challenge #5: Program your robotic arm

You Will Need

1. 4 - 180-degree micro servo motors (recommend MG90s micro metal geared servo)
2. 4 - 22k linear potentiometer
3. 1 - Arduino Uno
4. 1 - 40 pcs 1 pin male to male jumper cable wires
5. 1 - 4x1.5v AA battery case with on/off switch
6. 4 - AA batteries
7. 1 - 9v battery
8. 1 - 9v battery clip connector with lead wires
9. 1 - 5mm LED white light emitting diodes
10. 1 - 330-ohm resistor
11. 1 - SPDT 3 pins vertical slide switch
12. 1 - box of cable zip-tie in various sizes
13. 1 - set of 170 tie-points mini breadboard
14. 1 - bottle of super glue

Optional Supplies:

1. 1 - Arduino ProtoShield prototype shield (replacement of breadboard)
2. 1 - Arduino Uno case (recommend 3D printed case)
3. 1 - set of heat shrink wire wrap cable sleeve tubing (highly recommend)
4. 1 - DPDT vertical slide switch (only use with prototype shield)

Challenge #1: Design the Robotic Arm Frame

The first step of this project is to design 2D frames for your mechanical (servo) arm, and the controlling (potentiometer) arm. I recommend using Inkscape to design your frame; however, you are free to use any software for this purpose. ****NOTE:** If you have any questions regarding Inkscape, you should ask the tutor or refer back to the specific documentation on Inkscape.

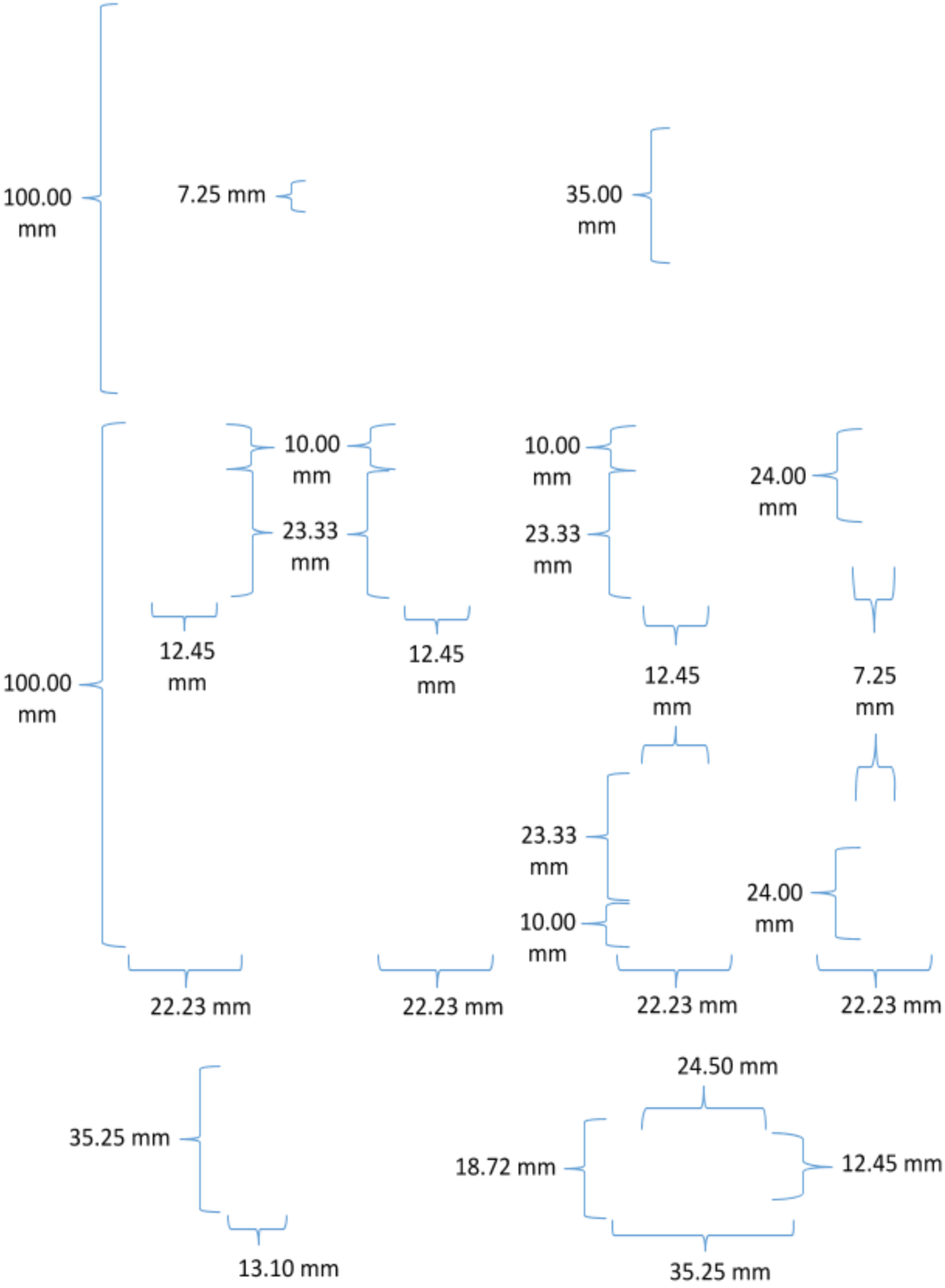
BLUEPRINT OF MECHANICAL ARM

Task: You are going to design the mechanical arm, consisting of 9 separate parts. You should follow the given diagram below for specification of each part; however, you are free to alter and completely design your owner parts. The goal is to produce a PDF file containing all 9 parts at appropriate setting for laser cutting.

General steps:

1. Design all of the 9 parts following the given dimensions in the below diagram
2. Make sure that you have the appropriate laser cutting setting (i.e. set the fill of your parts to “none”, stroke (edge) to red (R:255), and the width of stroke to 0.001 inch
3. Save your design in PDF format for laser cutting, and SVG format for editing

****NOTE:** You do not need to follow step 2 if you are planning to cut your parts out without using the laser cutter.

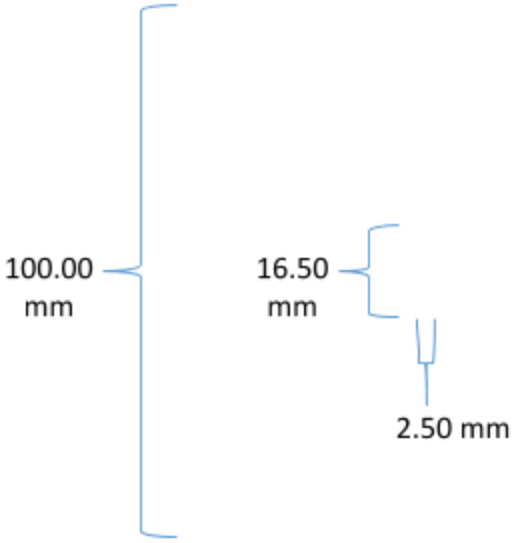


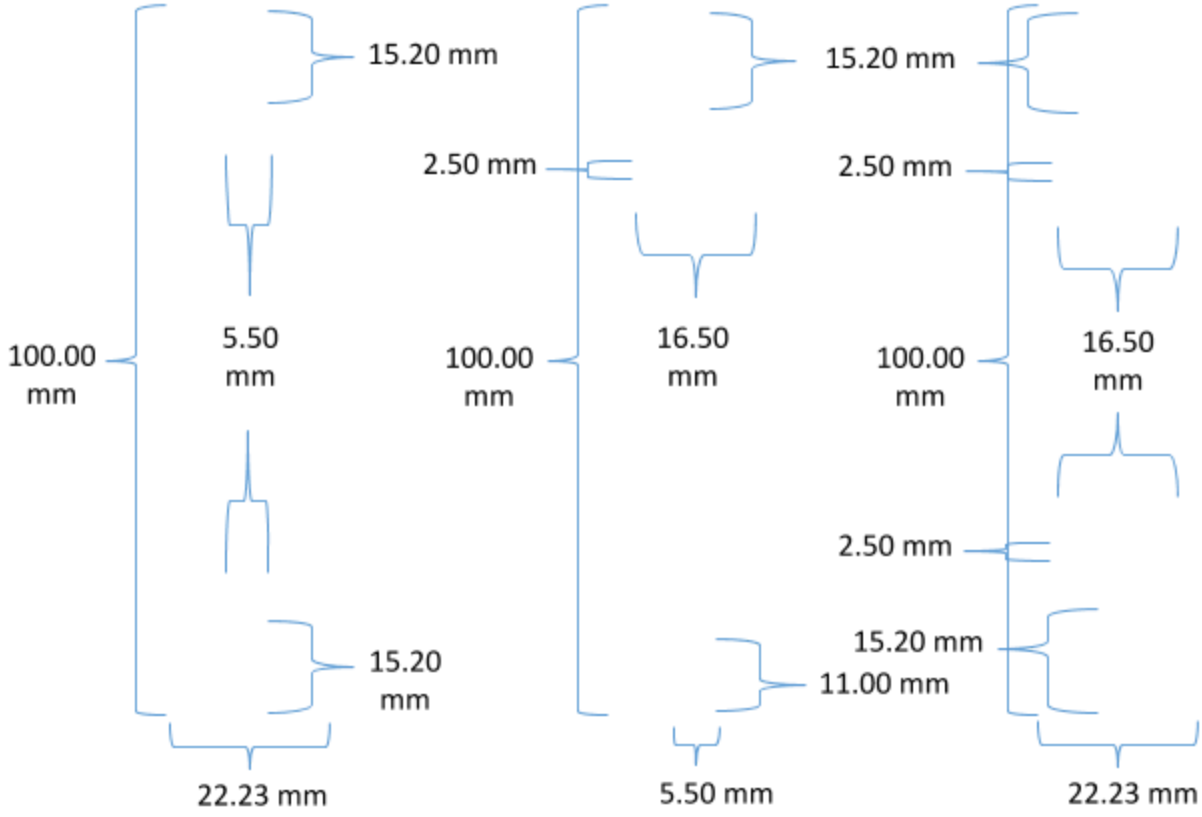
BLUEPRINT OF CONTROLLING ARM

Task: You will be doing the same task as the previous step, designing the frame of the controlling arm; however, you only have 5 separate parts to create. The goal is to output a PDF file of your parts with correct setting for laser cutting.

General steps for manual cut and laser cut:

1. Design all 5 parts following the diagram below.
2. Set appropriate setting for laser cutting if you are using such method
3. Save your design as both PDF and SVG formats.



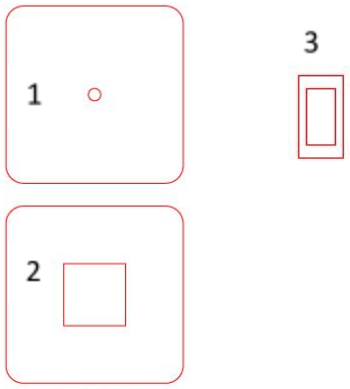
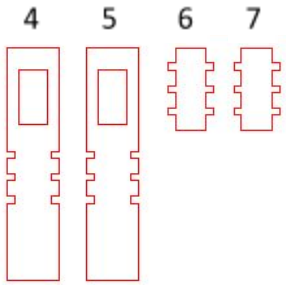
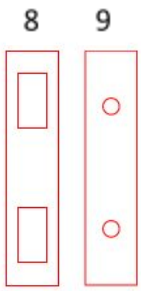


Challenge #2: Construct the Servo Mechanical Arm

Before starting the building process, you should check for faulty servo motors and potentiometers by using the circuit setup in your "Intro to Arduino" documentation (challenge #7). After you have selected 4 fully functional servo motors and potentiometers, you can now start with the process of building the servo arm. The frame of the arm can be built with a variety of materials including but not limited to balsa wood, acrylic plastic, heavy duty cardboard, and foam board. Also, there are 4 servo motors in the arm: base, shoulder, elbow, and gripper. (see the diagram on page 13 for visual illustration)

CUTOUT OF FRAME

Task: The first step is to cut out the arm structure based on the given template. There are two options to cut out the frame: manual cut and laser cut. Manual cut is when you are cutting out the frame using a x-acto knife by tracing the template. Laser cut is referred to the use of a laser cutter for the process. The goal is to cut out the following parts: ****NOTE**: All parts are labeled with number.

Base servo housing	Shoulder servo housing	Elbow & gripper servo housing
		

General steps for manual cut:

1. Print out the PDF file of the template in standard A4 paper
2. Glue the template onto the material of your choice
3. Cut out the parts by using x-acto knife to trace the shapes

General steps for laser cut:

1. Upload the PDF file of the template onto the laser cutter program
   WARNING: the included PDF file is set specifically to cut 1/8-inch-thick balsa wood. For other material or thickness, you must open the SVG file of the template in Inkscape to create a new PDF file with appropriate setting.
2. Put appropriate material into the laser cutter and begin the cutting process

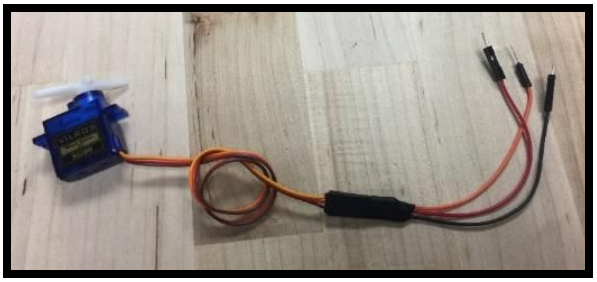
****NOTE: If you have difficulty in using the laser cutter, please ask tutor for assistance or refer back to the specific document on how to operate the laser cutter.**

SERVO WIRE EXTENSION

TASK: Before you start the assembly process of the mechanical arm, you should extend the wires of your 4 servo with the jumper cable. The goal is to add an extra-long wire to each servo.

General steps:

1. Add 3 jumper cable wires (male to male) to each of the 4 servo. You do not need to match the color of servo wires, but you should label the black or dark brown color wire with a piece of tape for ease of identifying the 3 servo wires in later step.
2. Seal off the pin connected area with electrical tape or heat shrink wire wrap tube for all 4 servo motors.



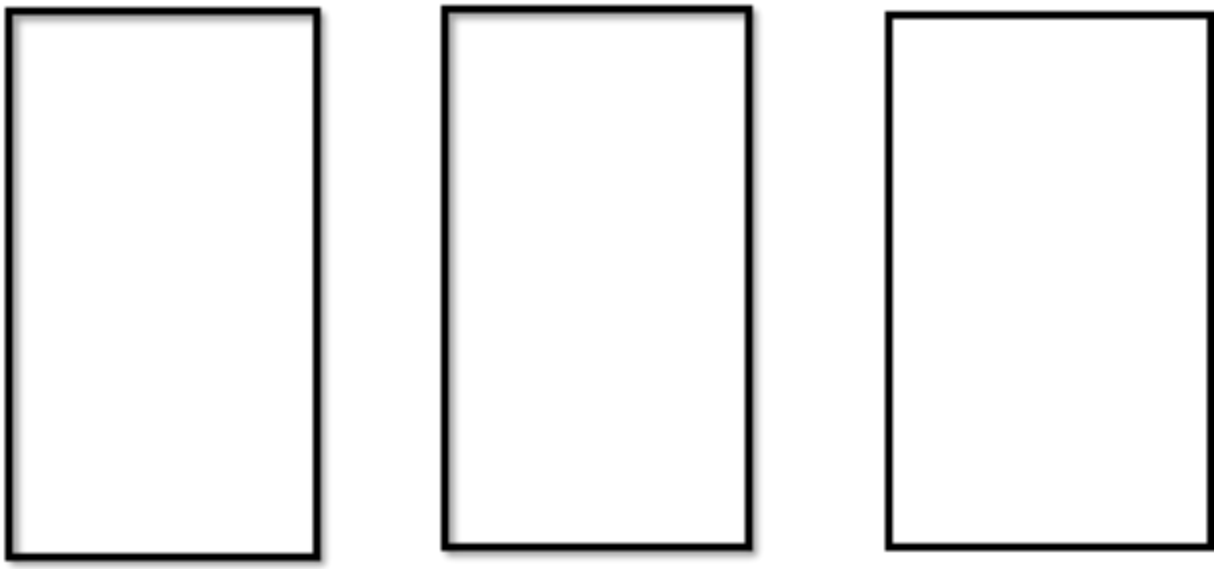
ASSEMBLY OF MECHANICAL ARM

TASK: After you have all your parts neatly cutout, it is time to assemble all the parts together with the servo. The goal is to fully assemble the mechanical arm. ****NOTE:** All of the servo arm parts are labeled with number.

General steps:

1. Start at the base of the arm, glue part 1 and 2 together using super glue.
2. Glue a servo horn onto the bottom of the base (the side with the square cutoff)
3. Install a (base) servo onto the top of the base with the provided screw
4. Screw on part 3 (servo mount) onto the base servo with provided screws
5. Glue part 4, 5, and 6 together to form the housing for the shoulder servo, then glue the whole housing onto the base servo. (add zip-ties for extra support) ****Note**: Do NOT glue part 7 with the other 3 pieces to close up the housing
6. Mount a (shoulder) servo onto the housing with provided screws
7. Glue 2 servo horns onto part 9
8. Attach part 9 to the shoulder servo by screw one of the part 9 horn to the shoulder. ****IMPORTANT**: since the servo can only make a 180-degree rotation, you must make sure to install the horn at an angel where shoulder servo can appropriately move part 9 for the full 180-degree unobstructed (up and down direction).
9. Mount the last 2 servo motors onto part 8 with the provided screws
10. Attach one of part 8 servo onto the remaining part 9 horn. Again, you should calibrate the angle of rotation appropriately.
11. Neatly organize the wires with glue and zip-ties, so all the wires are going out at the same place (at the bottom of the shoulder housing)

12. Glue part 7 onto the shoulder housing, after you have finished with the cable management process.
13. Add a horn on the gripper servo, which is the last servo

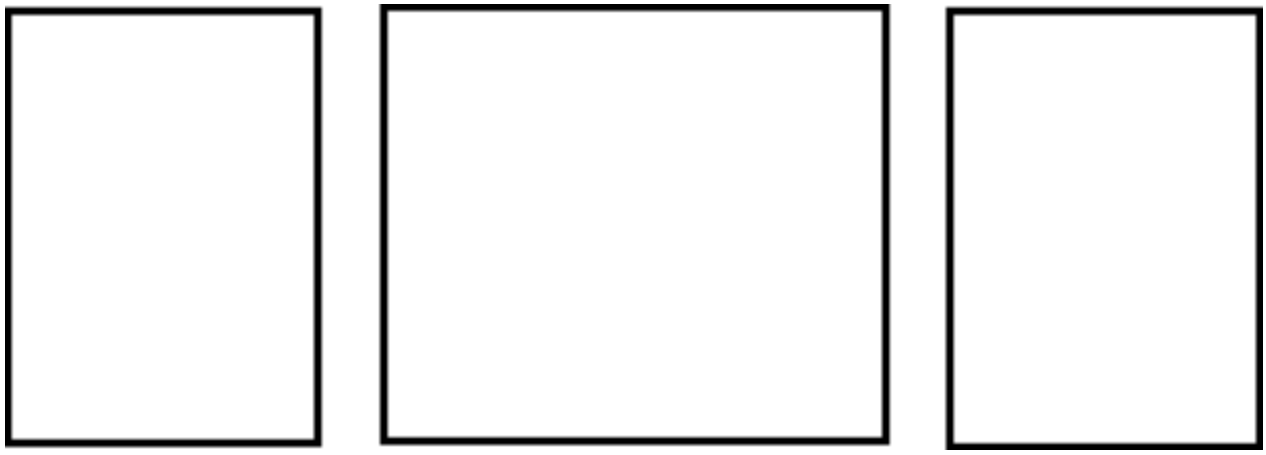


BUILD THE GRIPPER

TASK: The last part of your mechanical arm is the gripper, which is constructed with zip-ties. The goal is to build a simple and functional gripper.

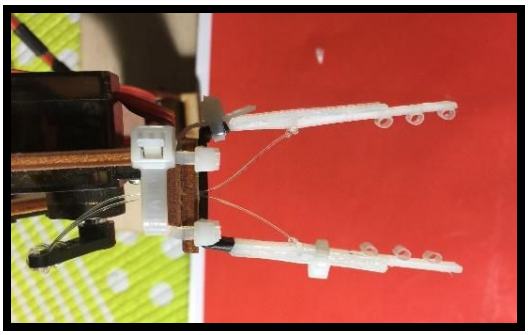
General steps:

1. Glue the 2 leftover rectangular pieces of part 8 together, and glue another leftover rectangular piece of part 4 to it to form a T-shaped part.
2. Drill a hole through the T-shaped part at the top-center position. The hole should be large enough to allow 2 pieces of string to pass through unobstructed.

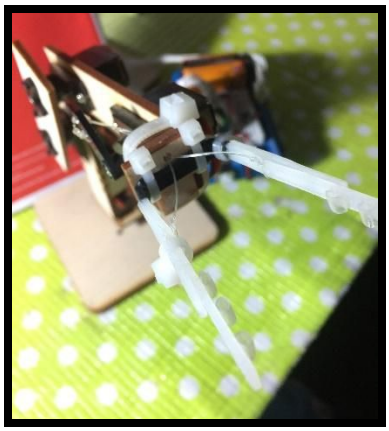


3. Bend one of your largest zip-tie into a U-shaped. You should make a small cut at the 2 edges of the U-shaped to help form the shape more easily. (add tape for extra support after making the cut)

4. Drill a hole on each side of the U-shaped zip-tie as shown in the picture, and tie a string to each side through the hole. ****NOTE:** If you don't have string, you can use jumper wire as substitute.



5. Zip-tie the U-shaped gripper to the T-shaped part at top-center position, and close to the hole.
6. Secure the T-shaped part onto the arm structure, where the gripper servo is located, using glue and zip-tie.
7. Run the 2 strings on the U-shaped gripper through the hole on T-shaped part, and tie both strings to the (gripper) servo horn.



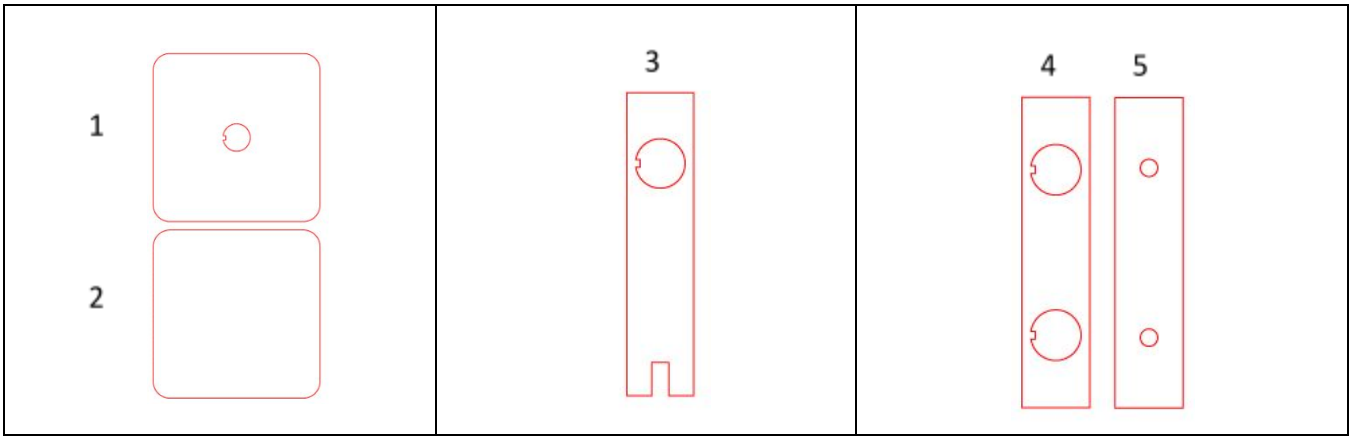
Challenge #3: Build the Potentiometer Controlling Arm

After you have successfully constructed the mechanical arm, your next step is to build the control arm. Similarly, you can construct this arm from the same material that you have chosen for the construction of the mechanical arm, and there are 4 potentiometers (pots) in the arm: base, shoulder, elbow, and gripper. (see the diagram on page 13 for visual illustration)

CUTOUT OF FRAME

Task: The steps for cutting out the frame of the control arm is exactly the same as the cutout steps of the mechanical arm. You will also need to follow a template to cut the frame via manual or laser cut. The goal is to cut out the following parts:

Base pot housing	Shoulder pot housing	Elbow & gripper pot housing



General steps for manual cut and laser cut:

4. Follow the same general steps in mechanical arm.

SOLDER WIRES TO POTENTIOMETERS

Task: As you already aware, a potentiometer had 3 terminal resistors, each of which needs 3 wires solder to it. The goal is to have all 4 pots soldered with fairly long wires. You should use the provided jumper cables (male to male). Also, you should extend those wires longer by adding the male to female jumper cables to the male to male cables, and seal the connected pin area with heat shrink tubes.

General steps:

1. Cut off one end of a jumper cable and strip the cable
2. Solder the cables to the potentiometers. ****NOTE:** If you are having difficulty with this process, please ask tutor for help or refer back to the specific document on soldering

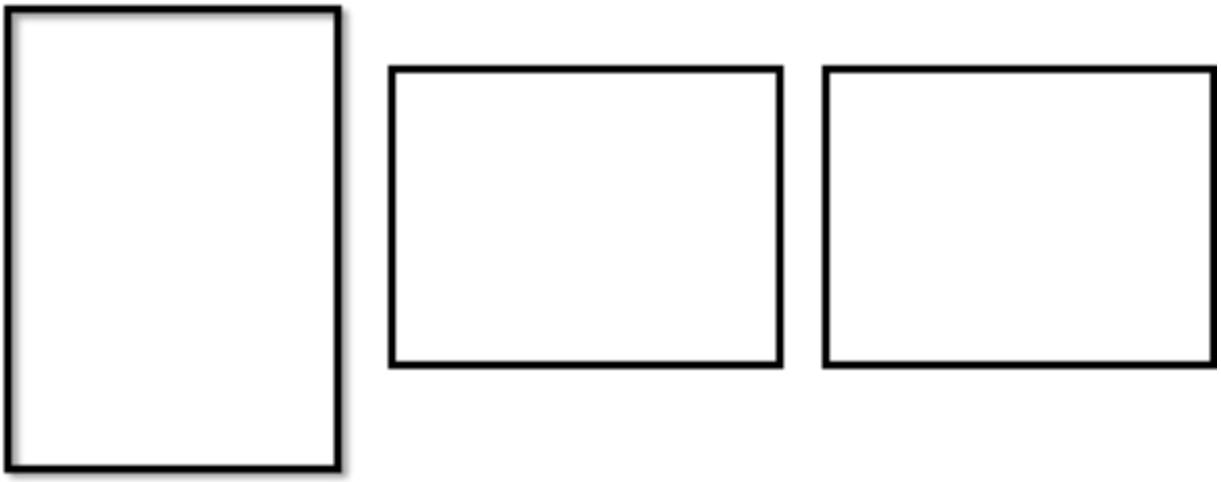
ASSEMBLE OF CONTROL ARM

Task: You are going to construct your potentiometer control arm. This process will require some calibration to ensure the controlling arm and the mechanical arm move in sync.

General Steps:

1. Glue part 1 and 2 together to form the base, and add a potentiometer on it
2. Mount part 3 onto the base potentiometer using tape, zip-tie, and glue. Also, you can install another (shoulder) pot into part 3 as well

3. Before attaching part 5 to the shoulder potentiometer, you should use the circuit setup from “Intro to Arduino” to calibrate the appropriate turning angle in relation to the shoulder servo. Attach part 5 to it, after you have the correct turning radius
4. Attach the (elbow) pot onto part 5 after proper calibration is completed
5. Mount part 4 to the elbow potentiometer and add the last (gripper) pot into part 4
6. Glue a 6 cm long zip tie near the gripper potentiometer

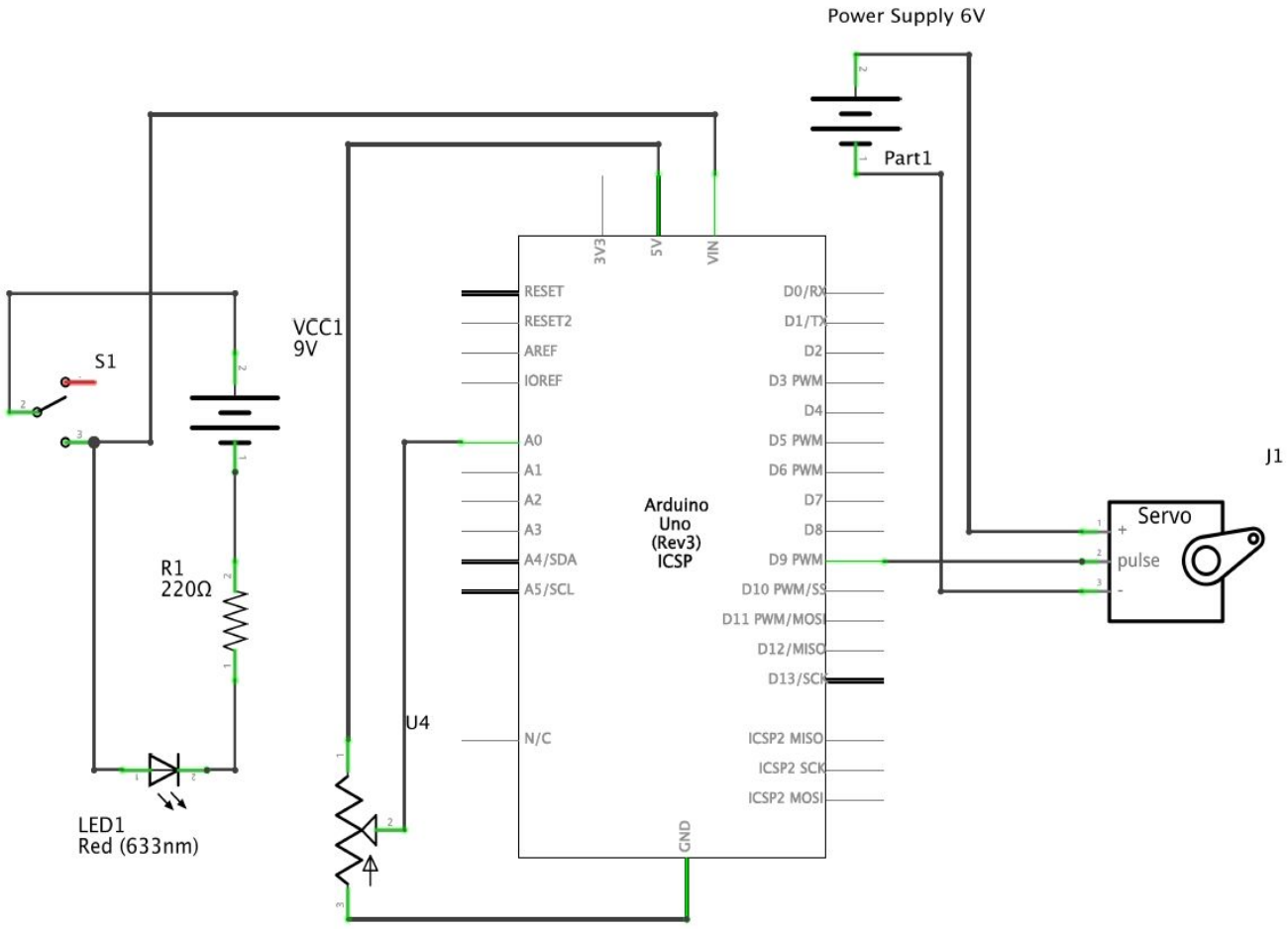


Challenge #4: Assemble both arms to the Arduino

Task: You will connect and assemble all of the components together. The schematic below represents the first connection of the robotic arm with one servo and one pot connected to your circuit board. Starting at the bottom, the base servo motor (signal wire) is connected to pin 9 on the Arduino UNO, and the base potentiometer (signal wire) is connected to pin A0. The goal is to connect the other 3 servo motors and pots to the circuit board following the schematic below.

General Steps:

1. Read the diagram below, showing the robotic arm circuit with only one potentiometer and one servo motor connected. ****NOTE:** Use the provided mini breadboard to build your circuit on OR use the prototype shield, which will require some soldering



2. Start connecting the base servo motor's signal wire (orange) to Pin 9, which is mapped in conjunction to the first potentiometer (signal wire), and it is connected to Analog pin A0. The analog pin on the potentiometer is the center pin, and the two outer pins are the positive and negative terminals that can be connected on either side.
3. After connecting the base motor and base potentiometer, you will need to connect the second (shoulder) servo motor to pin 10, and its corresponding, second (shoulder) potentiometer to pin A1.
4. Now, as you can see a trend building up to the final servo and pot, you will connect the elbow, and lastly the gripper.
5. Connect all 4 servo motors' negative (dark brown), and the positive (red) terminals to the 6V battery (4 AA battery case).
6. Connect all 4 potentiometers and the Arduino to the 9V battery. The potentiometer terminals (positive and negative) can be found on either side of the potentiometer pins.
7. Finally, connect the LED, switch, and resistor following the schematic below.

****NOTE:** If you are using the prototype shield instead of the breadboard, you can use a DPDT switch to regulate both the 9V and the 6V power supplies.

Challenge #5: Program Your Robotic Arm

Task: You will now program the code that allows the 4 pots to control the 4 servo motors at the same time. Recall the challenge #7 that you have completed in the "Intro to Arduino" section, you have learned how to control one servo with one pot, and now all you need to do is to control 3 more servo motor with 3 more pots.

General Steps:

1. To program the arm, start by referring back to the project called "Intro to Arduino" on challenge #7. You should upload that code into the newly constructed circuit from the previous challenge, and don't forget to alter the pins number of the code to the appropriate pins according to the circuit. ****NOTE:** Your servo motor can only make 180-degree rotation, and your potentiometer can make around 340-dregree rotation; therefore, you should map your pot to only make 180-degree rotation like your servo motor. The goal is to have your pot and servo turn with the same degree of rotation.
2. If one of the servo and pot is working properly, then you should add similar code for the rest of servo motors and potentiometers.

Resources

This project was inspired from: http://letsmakerobots.com/robot/project/micro-servo-robot

Arduino Environment: https://www.arduino.cc/en/Main/ArduinoBoardUno

Servo motor: https://learn.adafruit.com/analog-feedback-servos/about-servos-and-feedback