RIT Arm V2 – Supinating/Pronating Wrist

Derek Gagnon
RIT BioPrint & Limb Forge
Rochester Institute of Technology
Rochester, New York 14623

June 26, 2018

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I. Purpose

The purpose of this document is to provide an overview of the RIT Arm V2 supinating/pronating wrist assembly. The design integrates into the existing design while adding the additional functionality of: 180 degrees of wrist rotation and a modular accessory attachment terminal. The design accomplishes these improvements with easily 3D printable components and no additional hardware. Governable rotation of the wrist and hand gives users an additional degree of control, allowing for a higher level of functionality. The current design adds no additional bulk and is controlled via fishing line and elastic cord, the same as the other actions of the RIT Arm. An automated testing fixture was designed to determine the number of actuations the design can endure before failure. From this data, an expected lifespan can be extrapolated to improve the design and create maintenance plans. The goal is to create an assistive device capable of a lifespan greater than 10,000 uses.

II. Design Brief

Design Statement:

To design a device that allows for the supination and pronation of the RIT Arm V2 wrist 180 degrees

Deliverables:

Printed arm with additional functionality
3D model

Constraints/Goals:

Cost - $15-$20

Function - Rotation stops at 180 degrees (pronated is default position)

Automatic return to original relaxed position with no sticking

Low profile and doesn't contribute much to the weight of the design

Load - Static and dynamic max "everyday" load: 10N

Lifespan - Cyclic testing of rotation: ~10,000 rotations

Durability - Capable of withstanding 6-foot drop 10 times

Capable of maintaining wrist function after falling with a force equivalent to an average person (analyzed through test with hammer or compression test)

Can still work if completely submerged in water for a temporary time (60 seconds) and 12 hours after being submerged

Modularity - Connect to existing forearm through "standard" connection

Scalability - Easily scalable for different sized people: 100%-150%

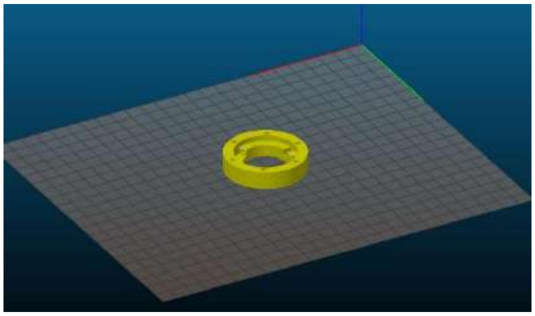
Actuation - Strap/fishing line for rotation will be attached to opposite shoulder from amputation

Actuation of wrist through flexion of pectoralis major (bringing arm forward away from body) about ~1.5 in. of motion. Dependent on size of rotating part

Comfort - Comfortable to wear for entire day with no abrasion on skin with fishing line through use strap or line routing

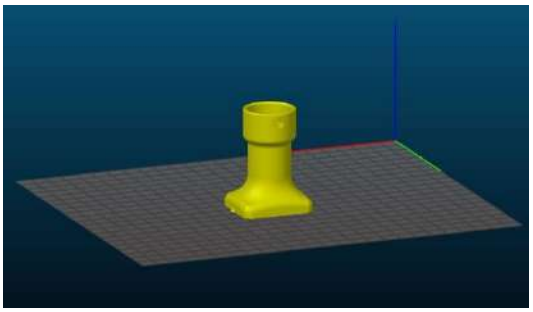
III. Print Settings

Encasement:



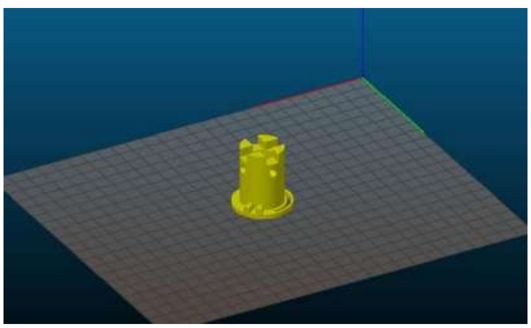
- Material: PLA
- Layer Height: 0.15 mm (highly recommended)
- Top Layers: 7
- Bottom Layers: 5
- Perimeter Shells: 2
- Brim: None
- Infill: 35%
- No supports required

Hand Receptor (forearm to palm connector):



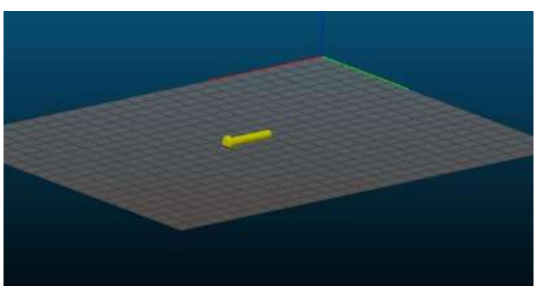
- Material: PLA
- Layer Height: 0.15 mm <u>to</u> 0.25 mm
- Top Layers: 7
- Bottom Layers: 5
- Perimeter Shells: 2
- Brim: None
- Infill: 35%
- No supports required

Modular Connector:



- Material: PLA
- Layer Height: 0.15 mm <u>to</u> 0.25 mm
- Top Layers: 7
- Bottom Layers: 5
- Perimeter Shells: 2
- Brim: None
- Infill: 35%
- No supports required

Wrist Pin:

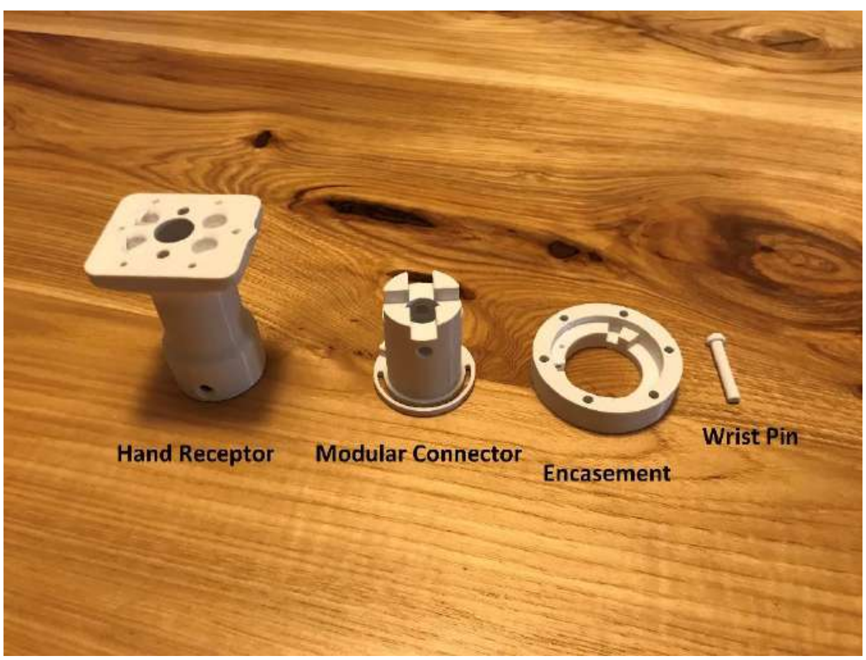


- Material: PLA
- Layer Height: 0.15 mm <u>to</u> 0.25 mm
- Top Layers: 7
- Bottom Layers: 5
- Perimeter Shells: 2
- Brim: None
- Infill: 50%
- No supports required

IV. Assembly Instructions

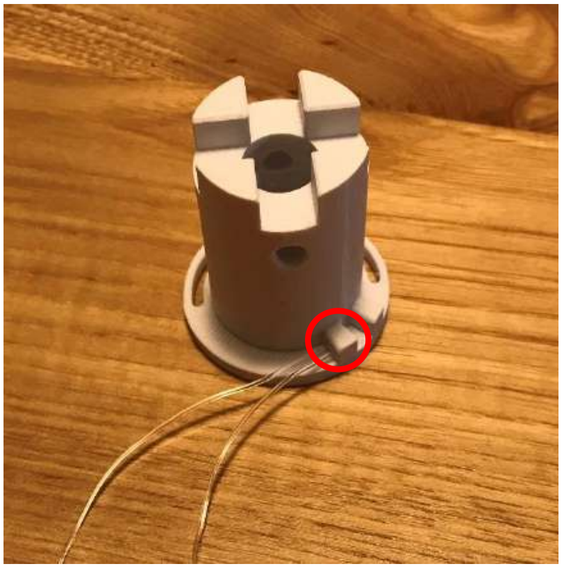
Step 1:

In addition to the printed parts elastic cord (0.8mm for 100% scaled, 1.5mm for 150% scale) 30 lb – 50 lb fishing line is needed for assembly too, the same as that used in the assembly of the rest of the RIT Arm V2. A pair of wire cutters and thin needle nose pliers (not pictured) are recommended tools. About 6 inches of elastic cord and 48 inches of fishing line will be used.



The parts picture above are the 3D printed components of the design, each is labeled with the part name. They will be referred to by these names in the assembly process.

Step 2:

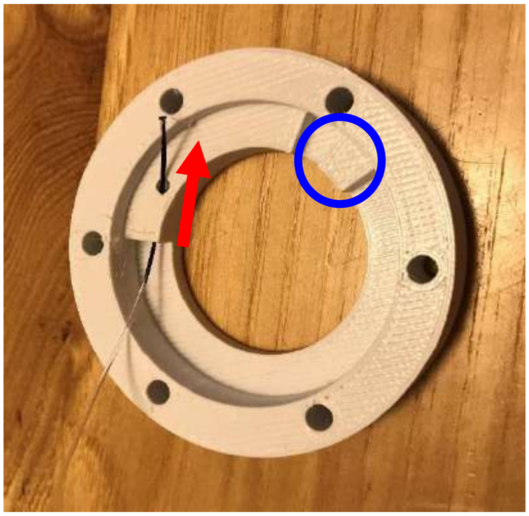


There are two rotation stop nubs on the hidden face of the modular connector. One of these rotation stops has two holes present. Insert the 6 inch length of elastic cord into the hole closest to the internal cylinder and route the cord through the second hole in the same rotation stop. The ends of the cord should come out of the nub as shown above. Make sure the free ends of the cord exit the side of the nub facing away from the second rotation stop.

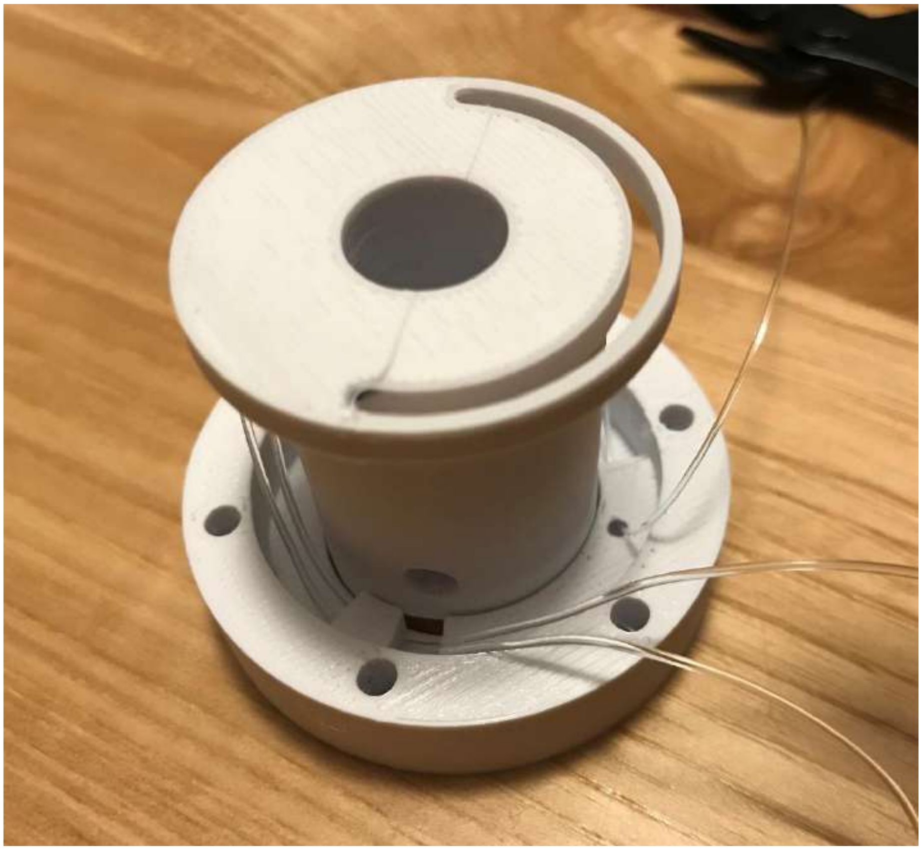
Step 3:

Run the length of fishing line through the remaining rotation stop nub and knot it tightly as show. The knot should be able to sit in the space between the nubs. Snip the extra length of the knot, being sure to snip enough where it will fit into the space but not too much where the knot will become undone.

Step 4:



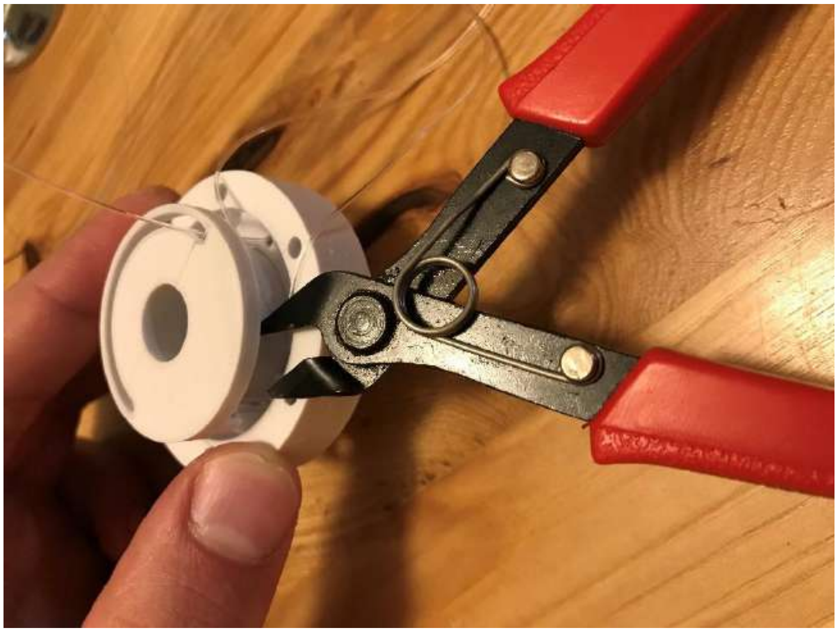
Route the free end of the fishing line through the routing hole in the encasement. A pin can be helpful in guiding the line out of the hole, in the direction of the red arrow. Route the free ends of the elastic cord through the holes in the post circled above in blue.



Match up the holes on the modular connector with the holes on the encasement to ensure they don't entangle. This is easiest if you place the parts together as shown above.

Step 5:

Route the fishing line through the semi-circular slot in the modular connector. Keep the ends of the elastic cord accessible. Knot the two ends of the elastic cord together, making sure to pull the knot tight to seat it in the encasement. A square knot works well here.



Cut the ends of the elastic cord quite close to the knot, while keeping some space to keep the cord secure.

Step 6:

Assembly the hand receptor and modular connector by aligning the holes and pressing the two parts together. Insert the wrist pin into the hole in the hand receptor to lock the two parts together. The assembly is now complete. The fishing line will still have a free end after this assembly, the line gets routed through the forearm cup printed part.

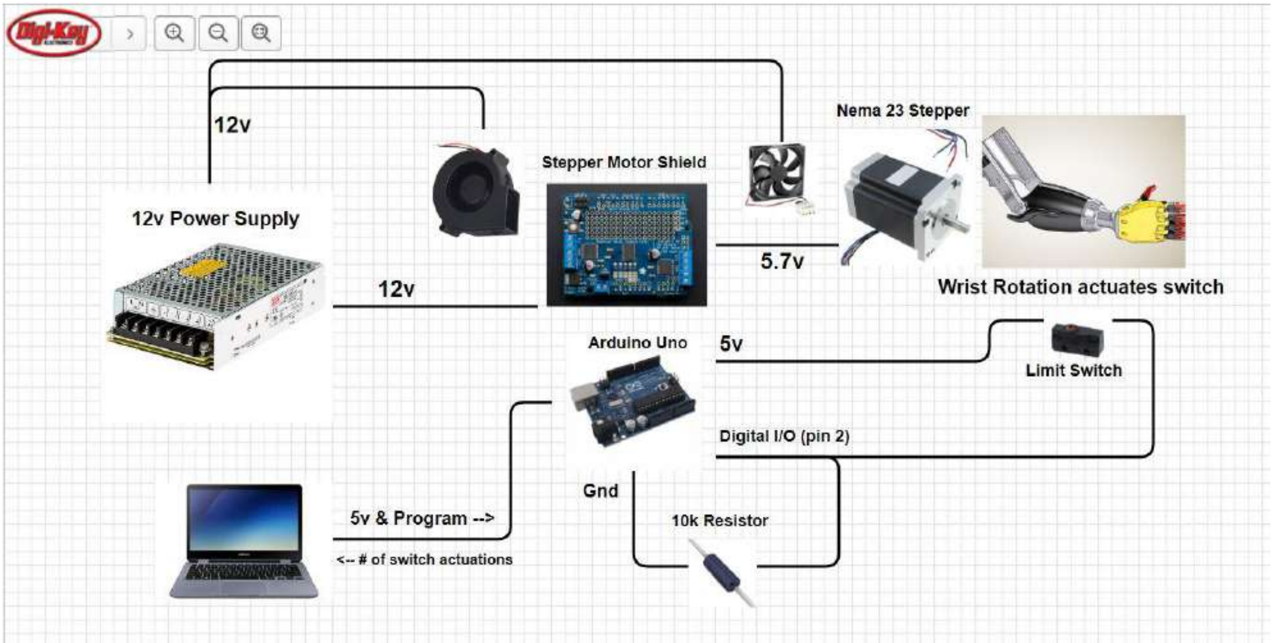
V. Lifespan Testing

To test the lifespan of the supinating wrist design, an Arduino controlled testing fixture was designed to track the rotations a wrist could perform before failure. This data is useful for determining and addressing weak points in the design as well as to assign an expected life to the assembly. The wrist is tested at 100% print scale with 0.8mm elastic cord and 50lb fishing line.

1. Bill of Materials

ID #	Part	Vendor	Price/Unit	Quantity	Total Price	Make/Buy
1	Arduino Uno	Mouser	$24.95	1	$24.95	Buy
2	Nema 23 Stepper Motor	MPJA	$23.95	1	$23.95	Buy
3	Stepper Driver Shield	Adafruit	$19.95	1	$19.95	Buy
4	12v 30a Power Supply	eBay	$18.96	1	$18.96	Buy
5	C14 Plug Module	eBay	$3.00	1	$3.00	Buy
6	12v Blower Fan	eBay	$5.00	1	$5.00	Buy
7	12v 40mm Fan	eBay	$5.00	1	$5.00	Buy
8	10kΩ Resistor	DigiKey	$0.10	1	$0.10	Buy
9	Endstop Micro Switch	DigiKey	$0.50	1	$0.50	Buy
10	Stepper Pulley	-	-	1	-	Printed
11	Heatsink	eBay	$0.65	2	$1.30	Buy
12	Aluminum Extrusions	-	-	6	-	(Donated)
13	Power Supply Cover	-	-	1	-	Printed
14	Fan Mounts	-	-	2	-	Printed
15	Thermal Adhesive	eBay	$7.99	1	$7.99	Buy
	TOTAL	-	-	-	**$110.70**	

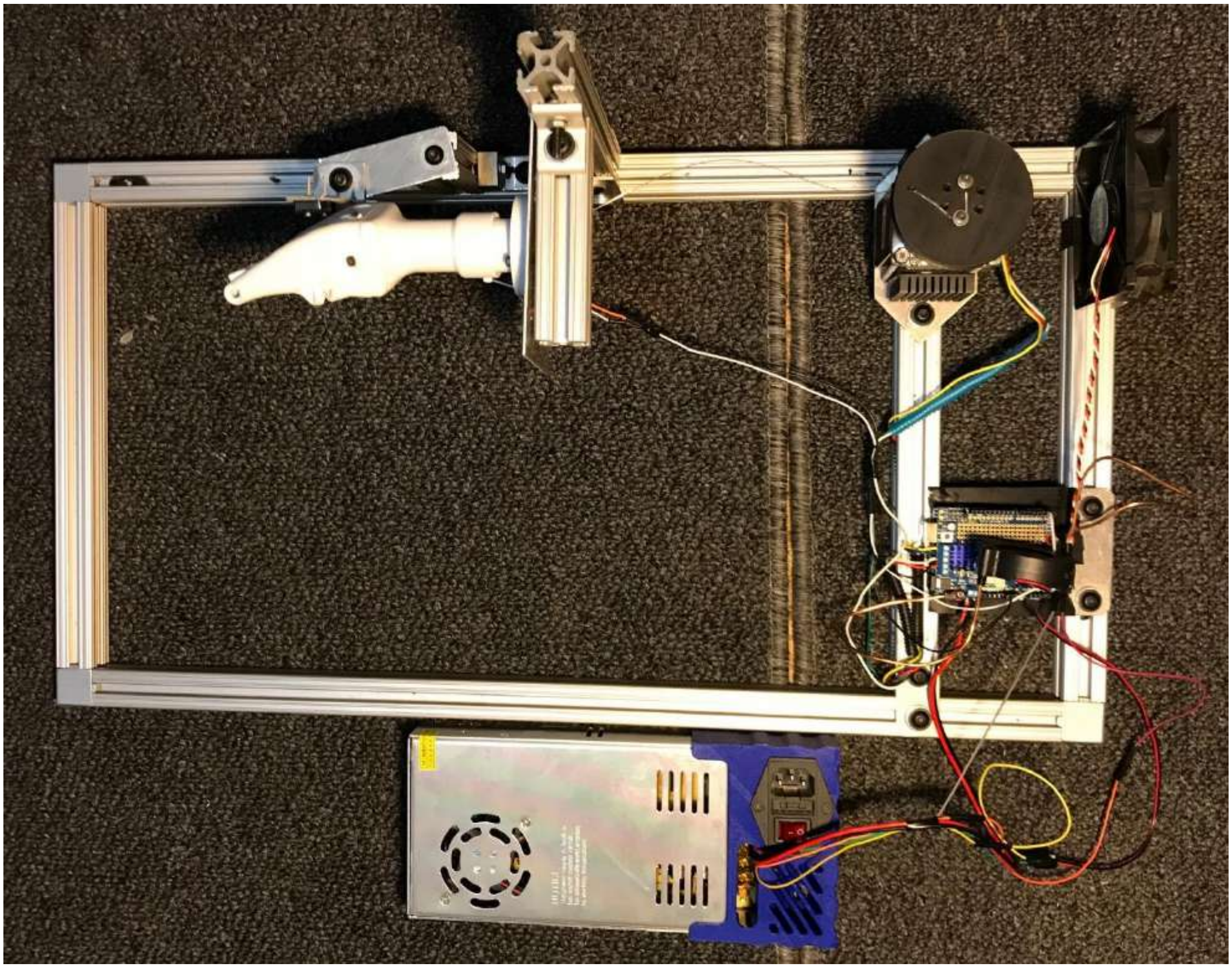
2. Schematic

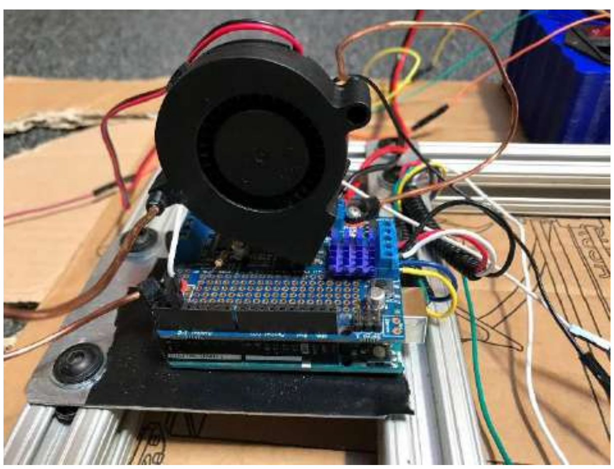


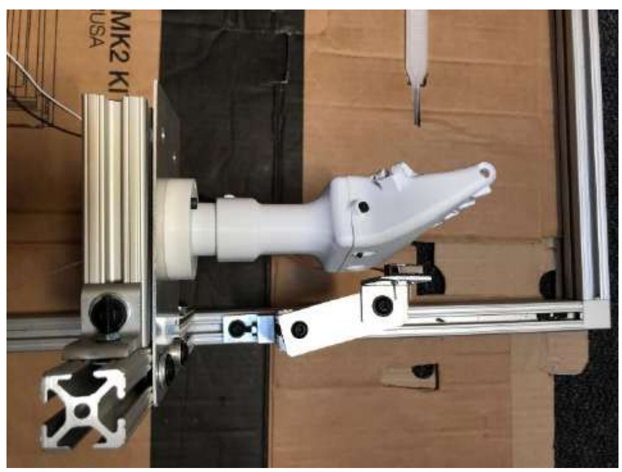
The schematic above demonstrations the full electrical system of the testing apparatus. Power is supplied to the Arduino Uno via the USB (5v). The stepper motor and both cooling fans are power via a 12v power supply. A 12v blower fan was used in conjunction with a heatsink applied with thermal adhesive to cool the TB6612FNG motor driver. This was necessary because the Nema 23 pulled 2.3A when holding and the TB6612FNG driver can provide 1.2A per channel with a peak of 3.0A for ~20ms. Without cooling the chip quickly overheated and shutdown to protect the chipset. With cooling the chip had no problem running the Nema 23 for two days continuously. The 5.7v rated stepper motor was supplied with 12v because it's torque was insufficient to rotate the wrist in the setup, but also to simplify the design. To remedy this, a 12v fan was used to cool the stepper motor also mounted with heatsinks.

The rotation of the wrist was detected and recorded via a snap action limit switch and pull-down resistor. The limit switch was connected to the 5v output and Pin 2 in the Arduinos header. Most of these limit switches have both "Normally Open" (NO) and "Normally Closed" (NO) pins. It is important that the NO pin is used so the Arduino receives a 5v signal when the switch is activated by the rotating wrist. A pull-down resistor is needed to hold the Pin 2 voltage at zero until the switch is closed. The pull-down resistor is connected between the ground and Pin 2 on the Arduino, and its resistance value is negligible.

3. Completed Testing Fixture







4. Arduino Program

WristTestingFinalProgram | Arduino 1.8.5

File Edit Sketch Tools Help

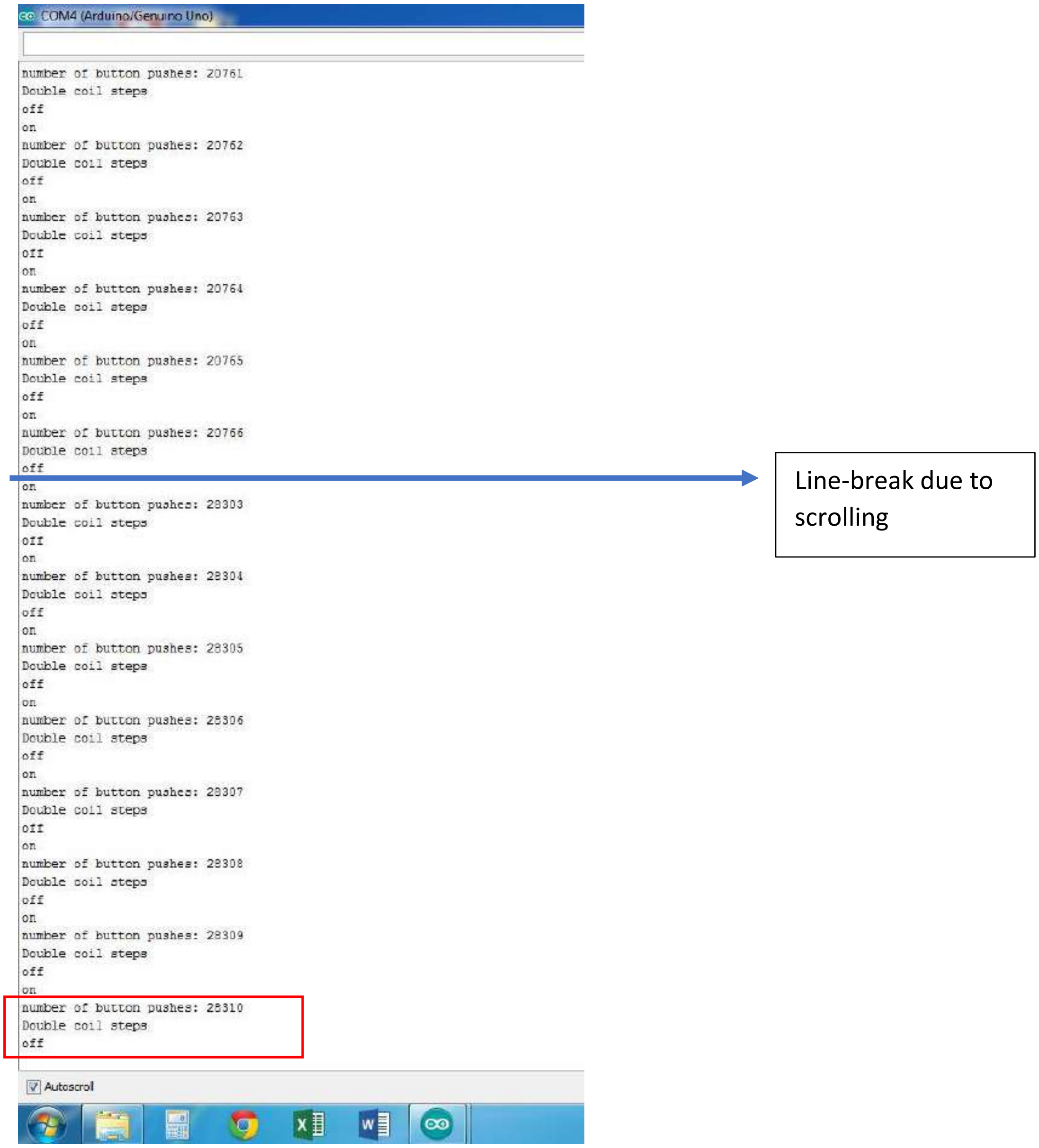
WristTestingFinalProgram

```
// Constant for button
const int  buttonPin = 2;    // the pin that the pushbutton is attached to

// Button Variables:
int buttonPushCounter = 0;   // counter for the number of button presses
int buttonState = 0;         // current state of the button
int lastButtonState = 0;     // previous state of the button

//Stepper Shield
#include <Wire.h>
#include <Adafruit_MotorShield.h>

// Create the motor shield object with the default I2C address
Adafruit_MotorShield AFMS = Adafruit_MotorShield();

// Initailize a stepper with 200 steps per revolution (1.8 degree)
//Motor connnected to port #1 (M1 and M2)
Adafruit_StepperMotor *myMotor = AFMS.getStepper(200, 1);

void setup() {

  pinMode(buttonPin, INPUT); // initialize the button pin as a input:

  Serial.begin(9600); //initialize serial communication at 9600 bps


  Serial.println("Wrist Testing"); //Print title to serial monitor

  AFMS.begin();  // create with the default frequency 1.6KHz

  myMotor->setSpeed(50);  // Set speed of stepper
}


void loop() {
  // read the pushbutton input pin:
  buttonState = digitalRead(buttonPin);

  // compare the buttonState to its previous state
  if (buttonState != lastButtonState) {
    // if the state has changed, the counter increments
    if (buttonState == HIGH) {
      // if the current state is HIGH then the button went from off to on:
      buttonPushCounter++;
      Serial.println("on");
      Serial.print("number of button pushes: ");
      Serial.println(buttonPushCounter);
```

```
//when button is pressed release hand to relaxed position
Serial.println("Double coil steps");
myMotor->step(112, FORWARD, DOUBLE);

delay(1000);


  } else {
    // if the current state is LOW then the button went from on to off:
    Serial.println("off");
    //when button is not pressed suppinate hand
   myMotor->step(112 , BACKWARD, DOUBLE);

  }

}
// save the current state as the last state, for next time through the loop
lastButtonState = buttonState;

}
```

The Arduino programming was quite simple for the longevity testing of the wrist. The Adafruit Stepper Shield had custom libraries that made controlling the stepper motor very straightforward. The programming for the switch and recording the number of switch presses was relatively simple as well. Look to the comments in the code above for more detailed information.

5. Results:



When the wrist was tested, the design was able to withstand more than 28,310 rotations of the wrist. After only 10,000 rotations the elastic cord had deformed and expanded to 150% of its original length, meaning the wrist couldn't return to a neutral position. Note that the weakest aspect of the design is the elastic cord used to return the wrist to a neutral position. At 100% scale, the wrist design uses 0.8mm elastic cord, but at 150% (about adult small size) 1.5mm cord can be used. The 1.5mm cord is significantly more durable and less prone to deformation, therefore should sustain even more rotations. The 3D printed parts survive the test unscathed and could be refitted with elastic cord for more use.

VI. Design Revisions

The only revision that was shown to be necessary was the ability to use larger diameter elastic cord. The design only needs very minor revisions, and even with the current design printed at an adult sized scale, larger elastic cord can be used. The use of 1.2mm or 1.5mm elastic cord should greatly increase the life cycle of the design. The main take away from the testing is that the 3D printed parts performed flawlessly and weren't the failing aspect of the design.

VII. Conclusion

The conclusions derived from the testing done on the RIT Arm V2 wrist supination/pronation assembly are:

- The 3D printed parts require no supports and are easy to print.
- The 3D printed parts of the assembly are more than capable of withstanding the 10,000 cycle (rotations) goal set. More than 28,000 cycles were completed continuously without any noticeable wear on the 3D printed parts.
- The elastic cord is the weak point in the design, luckily many different diameters and options are available, therefore for larger scale RIT Arm prints more durable cord can be used.
- The Wrist assembly process is on the same level of difficulty as the rest of the RIT Arm, requires few specialty tools, and uses the same hardware as the rest of the design.