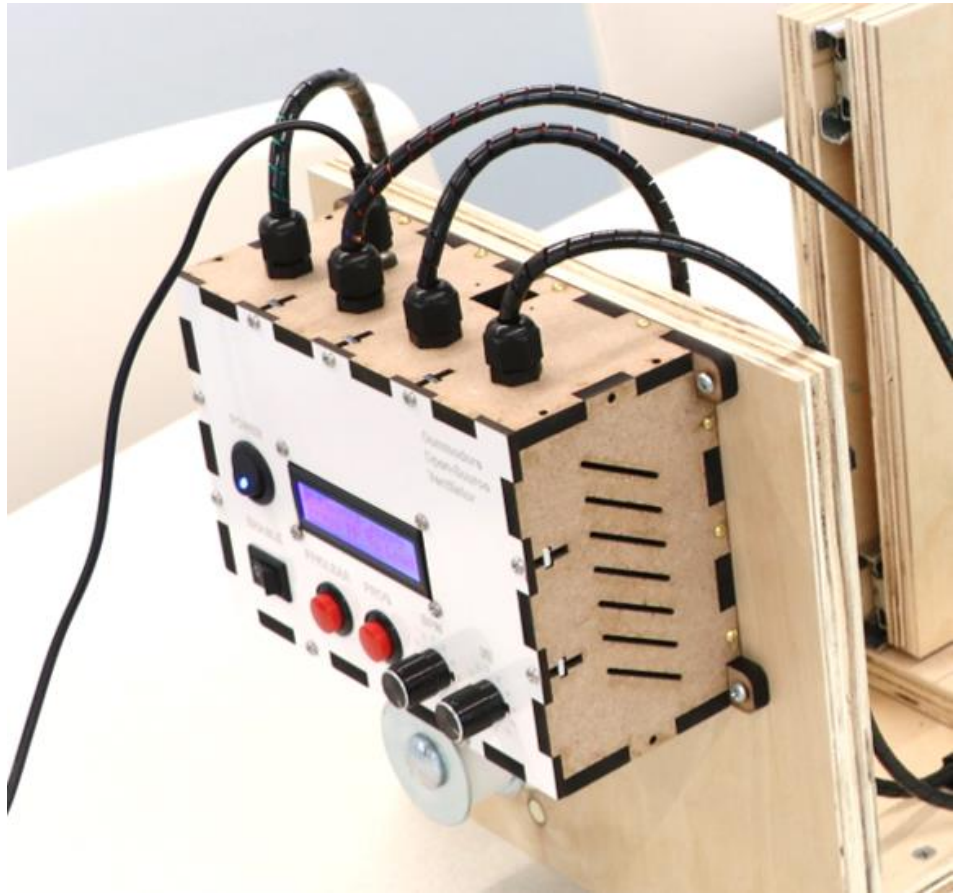
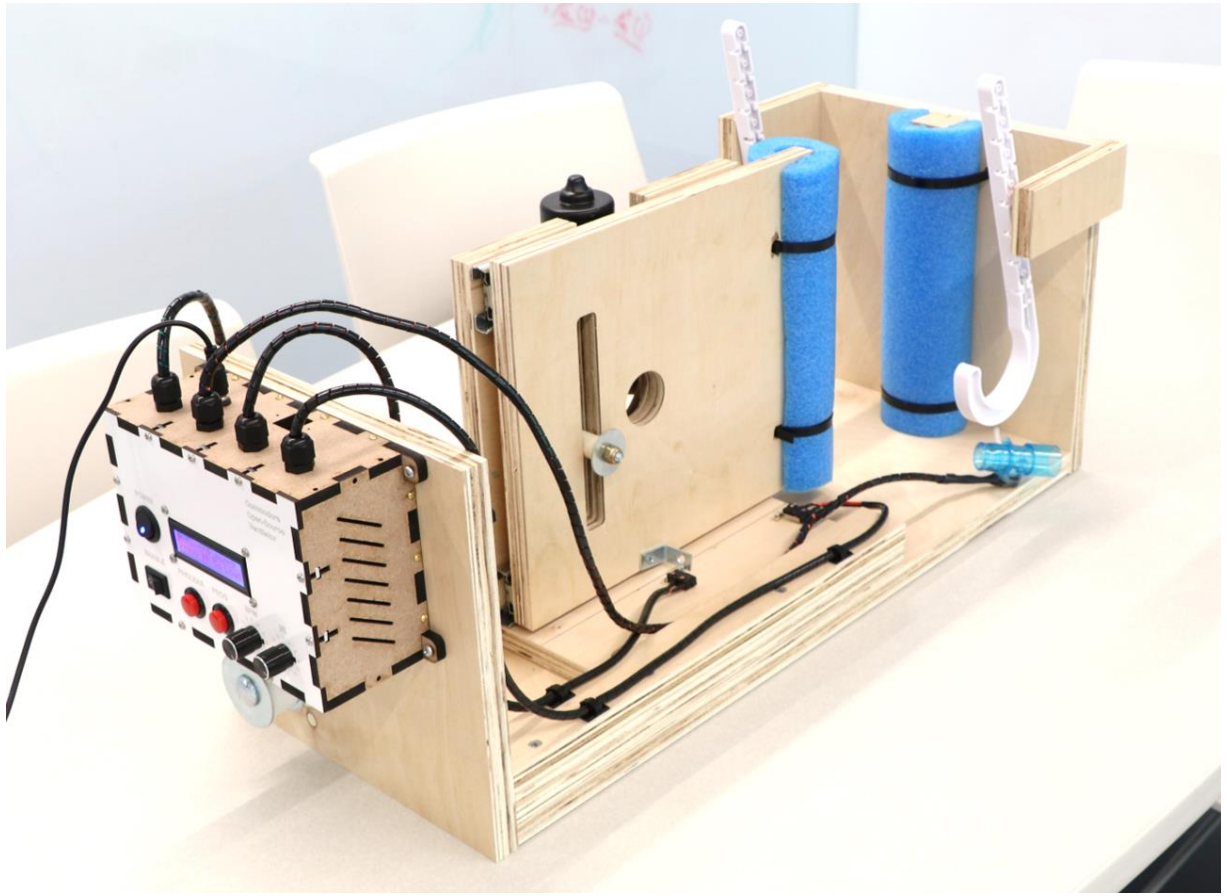
Commodore Open-source Ventilator (COV) version 3.1

Control Electronics Assembly





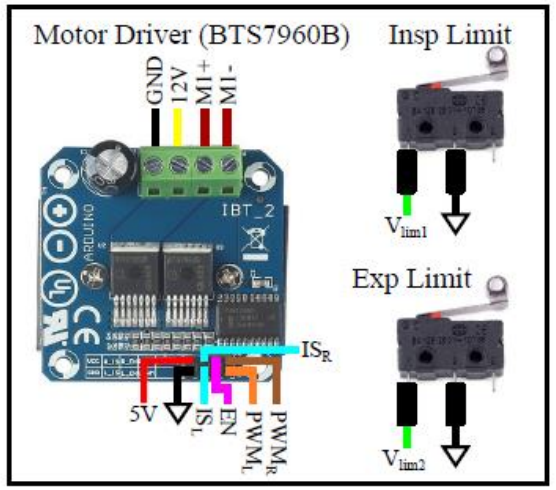
Disclaimer

- This device has not been tested on a live human and does not currently have FDA approval.
- This device is currently only intended for patients who are sedated, intubated, and chemically paralyzed, and should only be operated under the care of an experienced physician.
- No material on this site is intended to provide medical advice. All designs are intended for investigational use only.
- This site does not represent any official policies or procedures of Vanderbilt University.
- The material on this site is provided with no warranties explicit or implied.

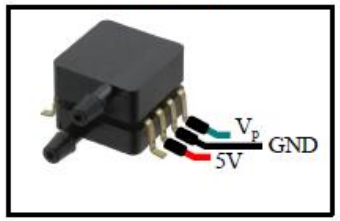
Wiring Guide

- Use best practices for soldering and wiring.
  - Ensure adequate ventilation and consider using a fume extractor
  - Use lead-free solder if available
  - When soldering onto terminals, lugs or header pins, always use insulating heat-shrink to minimize the possibility of electrical shorts.
  - Ensure that whatever wire gage you use is rated for the current capacity that it is expected to carry.
  - NEVER WORK ON LIVE CIRCUITS. Make sure everything is unplugged before working.

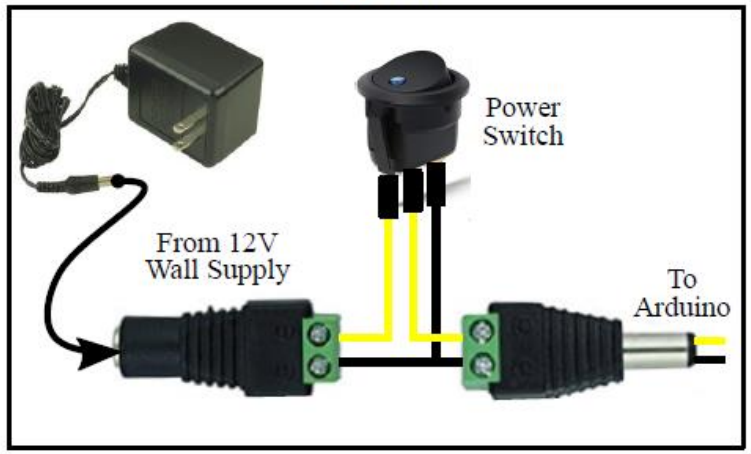
Motion Control



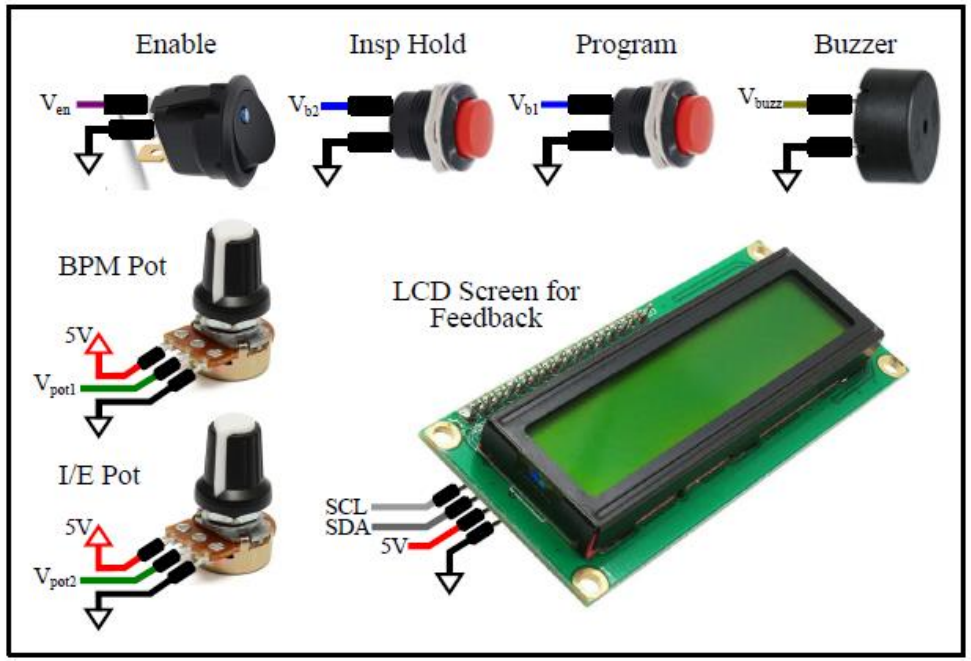
Pressure Sensor



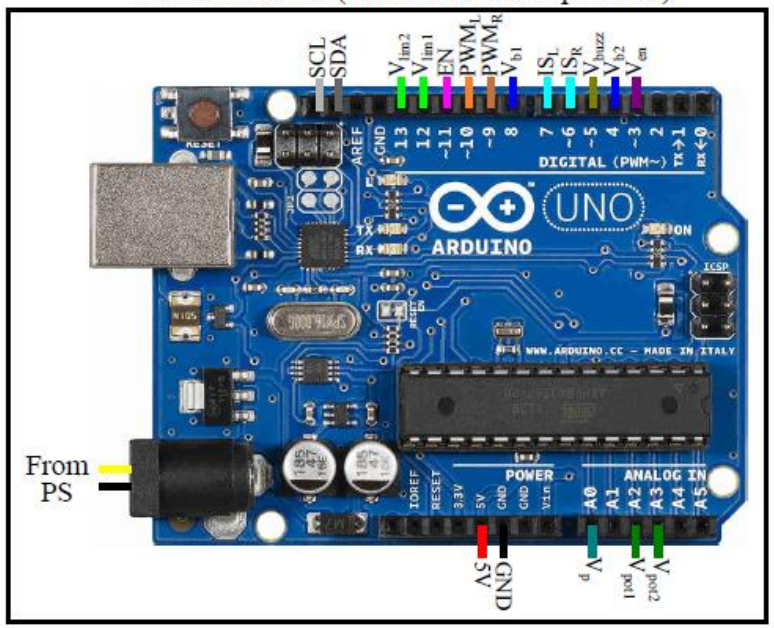
Power In



User Interface



Microcontroller (Arduino Uno or equivalent)



Electronics Hardware	Qty
Arduino Uno or equivalent	1
Motor Driver (BTS7960B)	1
LCD Screen with i2c Backpack	1
Rotary Potentiometers (10k)	2
Momentary Pushbuttons (Off-Mom)	2
Rocker Switches	2
Piezoelectric Buzzer	1
Pressure Sensor (see ‘Pressure Sensing’)	1
DC Barrel Jack with Screw Terminal (M)	1
DC Barrel Jack with Screw Terminal (F)	1
12VDC Transformer with 3A Output	1
24AWG Hook-Up Wires (M-F,M-M)	several
20-22AWG Speaker Wire	1M
Solderless Breadboard	1
(Optional) CoV Shield for Uno	1
Spiral Cable Wrap	2M
Adhesive-Backed Cable Brackets	several

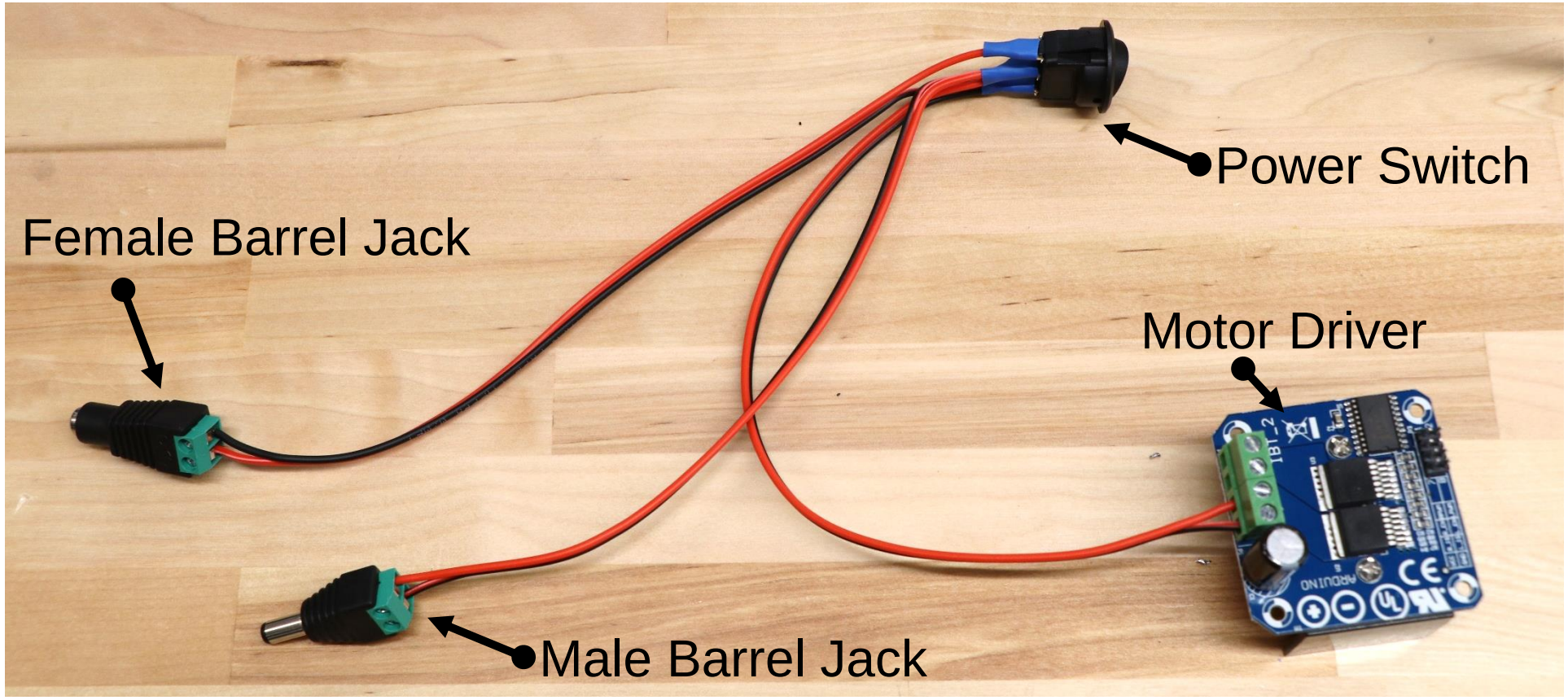
1. A Note on Wire Selection

- Ensure that any wires used for power transmission or motor current are rated to handle the amperage.

AWG	Diameter		Turns of wire, without insulation		Area		Copper wire							
							Resistance/length[7]		Ampacity,[8] at 20 °C insulation material temperature rating, or for single unbundled wires in equipment for 16 AWG and smaller[9]			Fusing current[10][11]		
									60 °C	75 °C	90 °C	Preece[12][13][14][15]	Onderdonk[16][15]	
	(in)	(mm)	(per in)	(per cm)	(kcmil)	(mm^2)	(mΩ/m[a])	(mΩ/ft[b])	(A)			~10 s	1 s	32 ms
0000 (4/0)	0.4600[c]	11.684[c]	2.17	0.856	212	107	0.1608	0.04901	195	230	260	3.2 kA	33 kA	182 kA
000 (3/0)	0.4096	10.405	2.44	0.961	168	85.0	0.2028	0.06180	165	200	225	2.7 kA	26 kA	144 kA
00 (2/0)	0.3648	9.266	2.74	1.08	133	67.4	0.2557	0.07793	145	175	195	2.3 kA	21 kA	115 kA
0 (1/0)	0.3249	8.251	3.08	1.21	106	53.5	0.3224	0.09827	125	150	170	1.9 kA	16 kA	91 kA
1	0.2893	7.348	3.46	1.36	83.7	42.4	0.4066	0.1239	110	130	145	1.6 kA	13 kA	72 kA
2	0.2576	6.544	3.88	1.53	66.4	33.6	0.5127	0.1563	95	115	130	1.3 kA	10.2 kA	57 kA
3	0.2294	5.827	4.36	1.72	52.6	26.7	0.6465	0.1970	85	100	115	1.1 kA	8.1 kA	45 kA
4	0.2043	5.189	4.89	1.93	41.7	21.2	0.8152	0.2485	70	85	95	946 A	6.4 kA	36 kA
5	0.1819	4.621	5.50	2.16	33.1	16.8	1.028	0.3133				795 A	5.1 kA	28 kA
6	0.1620	4.115	6.17	2.43	26.3	13.3	1.296	0.3951	55	65	75	668 A	4.0 kA	23 kA
7	0.1443	3.665	6.93	2.73	20.8	10.5	1.634	0.4982				561 A	3.2 kA	18 kA
8	0.1285	3.264	7.78	3.06	16.5	8.37	2.061	0.6282	40	50	55	472 A	2.5 kA	14 kA
9	0.1144	2.906	8.74	3.44	13.1	6.63	2.599	0.7921				396 A	2.0 kA	11 kA
10	0.1019	2.588	9.81	3.86	10.4	5.26	3.277	0.9989	30	35	40	333 A	1.6 kA	8.9 kA
11	0.0907	2.305	11.0	4.34	8.23	4.17	4.132	1.260				280 A	1.3 kA	7.1 kA
12	0.0808	2.053	12.4	4.87	6.53	3.31	5.211	1.588	20	25	30	235 A	1.0 kA	5.6 kA
13	0.0720	1.828	13.9	5.47	5.18	2.62	6.571	2.003				198 A	798 A	4.5 kA
14	0.0641	1.628	15.6	6.14	4.11	2.08	8.286	2.525	15	20	25	166 A	633 A	3.5 kA
15	0.0571	1.450	17.5	6.90	3.26	1.65	10.45	3.184				140 A	502 A	2.8 kA
16	0.0508	1.291	19.7	7.75	2.58	1.31	13.17	4.016			18	117 A	398 A	2.2 kA
17	0.0453	1.150	22.1	8.70	2.05	1.04	16.61	5.064				99 A	316 A	1.8 kA
18	0.0403	1.024	24.8	9.77	1.62	0.823	20.95	6.385	10	14	16	83 A	250 A	1.4 kA
19	0.0359	0.912	27.9	11.0	1.29	0.653	26.42	8.051	—	—	—	70 A	198 A	1.1 kA
20	0.0320	0.812	31.3	12.3	1.02	0.518	33.31	10.15	5	11	—	58.5 A	158 A	882 A
21	0.0285	0.723	35.1	13.8	0.810	0.410	42.00	12.80	—	—	—	49 A	125 A	700 A
22	0.0253	0.644	39.5	15.5	0.642	0.326	52.96	16.14	3	7	—	41 A	99 A	551 A
23	0.0226	0.573	44.3	17.4	0.509	0.258	66.79	20.36	—	—	—	35 A	79 A	440 A
24	0.0201	0.511	49.7	19.6	0.404	0.205	84.22	25.67	2.1	3.5	—	29 A	62 A	348 A
25	0.0179	0.455	55.9	22.0	0.320	0.162	106.2	32.37	—	—	—	24 A	49 A	276 A
26	0.0159	0.405	62.7	24.7	0.254	0.129	133.9	40.81	1.3	2.2	—	20 A	39 A	218 A

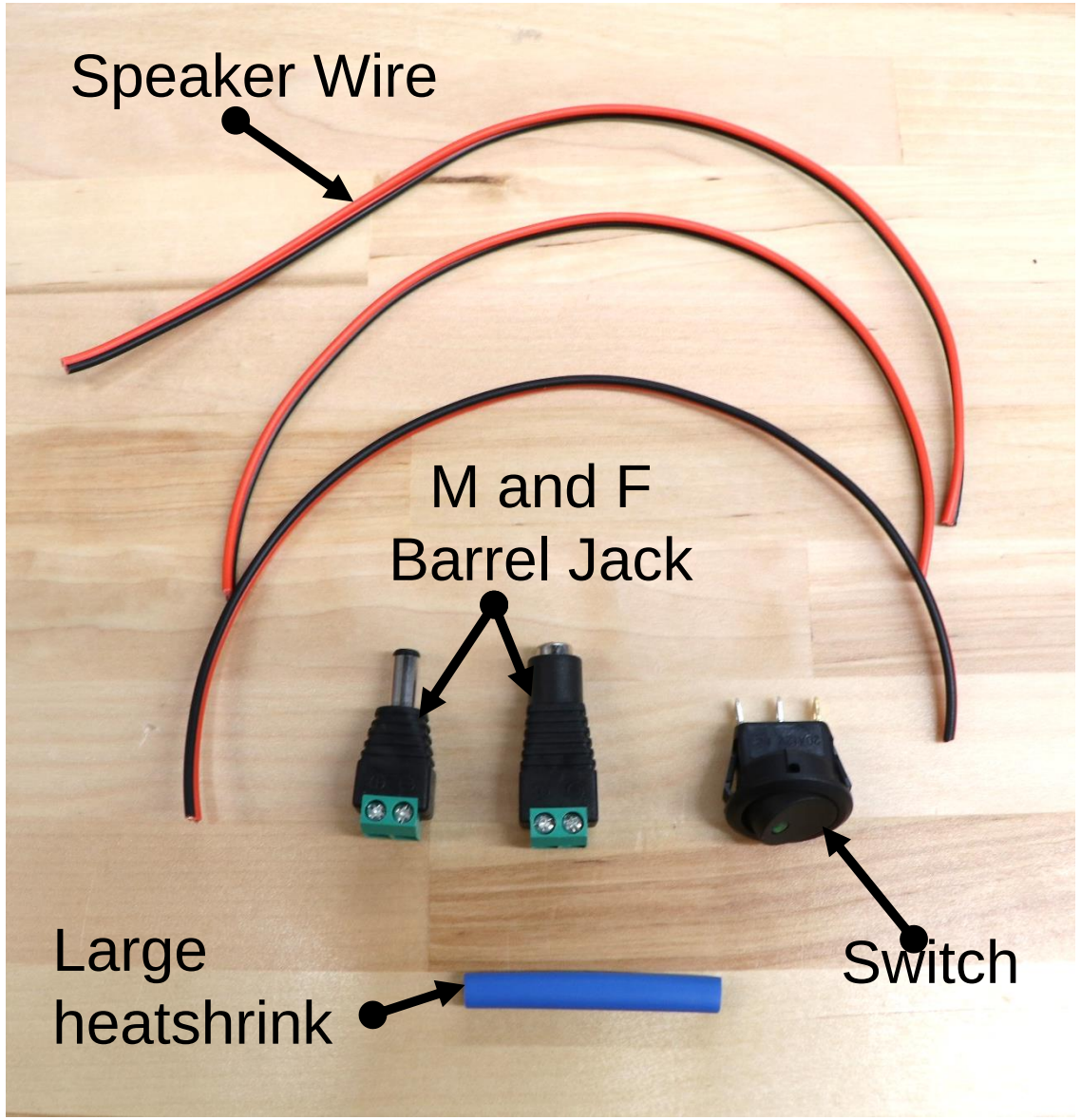
2. Wiring Up the Power Switch

- In this step, we will be wiring the power switch assembly as shown below.
- Completion time: <5 minutes



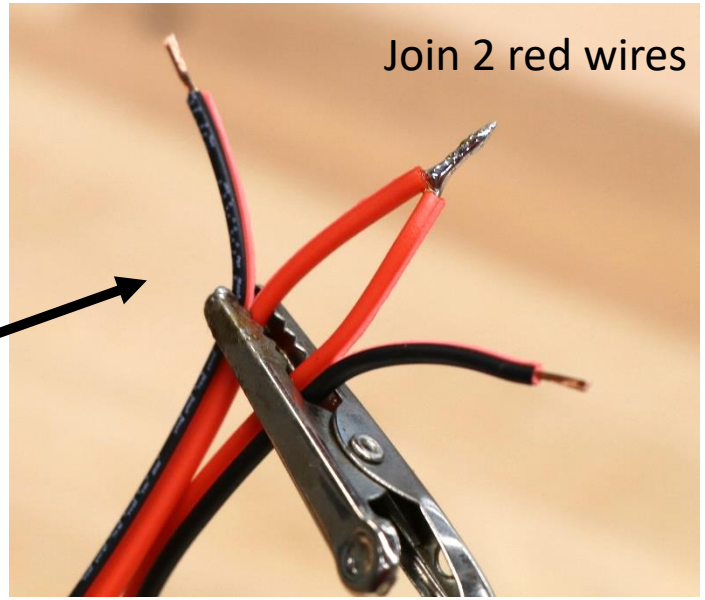
2.1 Collect Components

- Collect the following:
  - 1 power switch (with integrated LED),
  - 1 male barrel jack adapter
  - 1 female barrel jack adapter
  - Large (3/8”) heatshrink
  - 2 pieces of 8” long 22AWG red/black speaker wire
  - 1 piece of 10” long 22AWG red/black speaker wire.

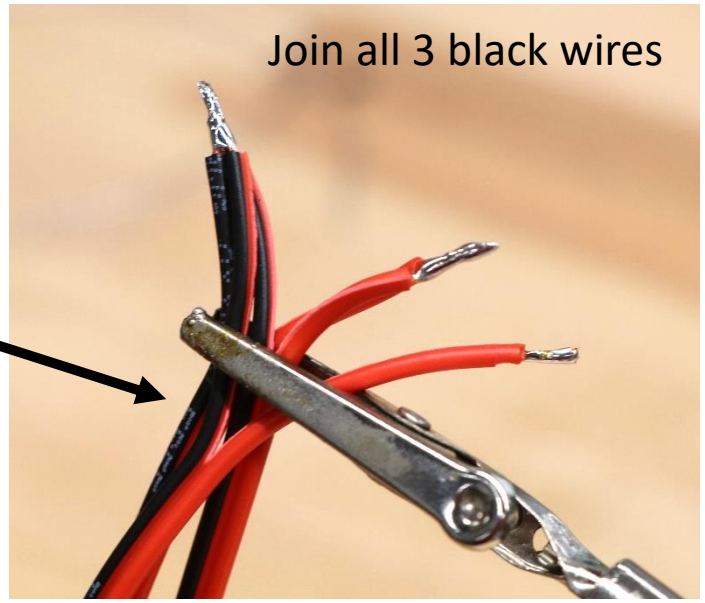


2.2 Twist and Tin the wires

- Grab the 10” and one 8” piece of speaker wire.
- Separate red from black from each end for about 1”, on both ends, and strip both wires. Do not tin them yet.
- On one side, twist the two exposed strands of the red wire together, and apply solder to tin both of them together, effectively joining them. See the image on the right.

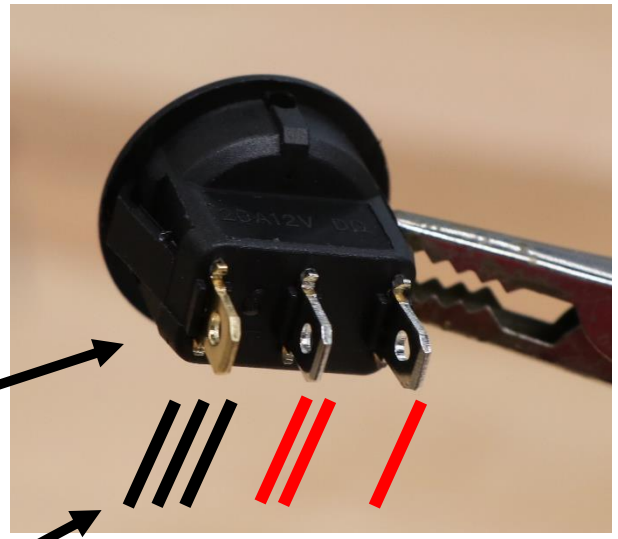


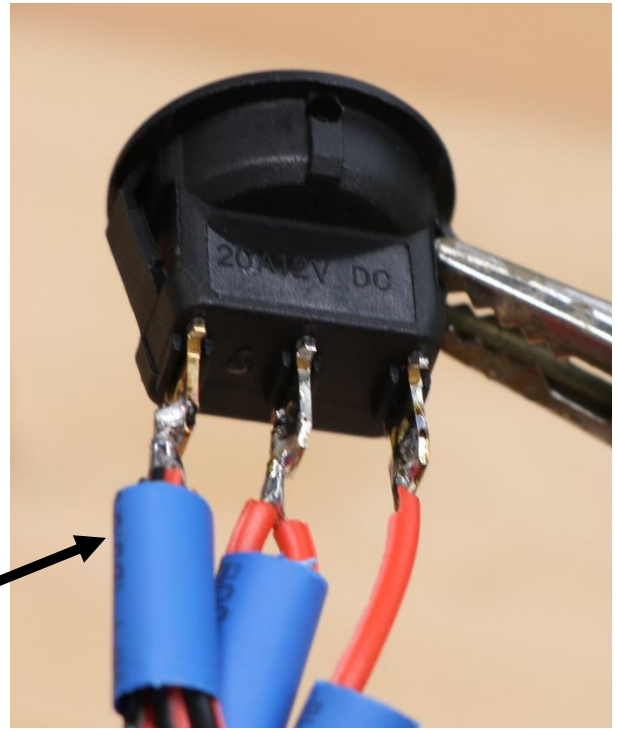
- Grab the other 8” piece of speaker wire, separate red from black for about 1” on both ends, and strip both wires. Do not tin them yet.
- Twist the exposed strands of one side of all three black wires together and solder them on the same side as the red wires you just soldered, effectively joining them. See the image on the right.
- Go ahead and tin all other exposed wire strands



2.3 Solder Power Switch

- Grab the power switch and look at the bottom.
- There are 3 terminals. The two silver terminals are the switch contacts. The gold terminal is the integrated LED return path.
- We will solder the lonely red wire to the outside silver terminal, the two joined red wires to the middle silver terminal, and the three black wires to the gold terminal.
- Tin each of the switch terminals with solder.
- Slide a ½” length of large heatshrink over the single red wire, the two joined wires, and the three joined black wires.
- Solder the wires to the terminals as shown on the right.



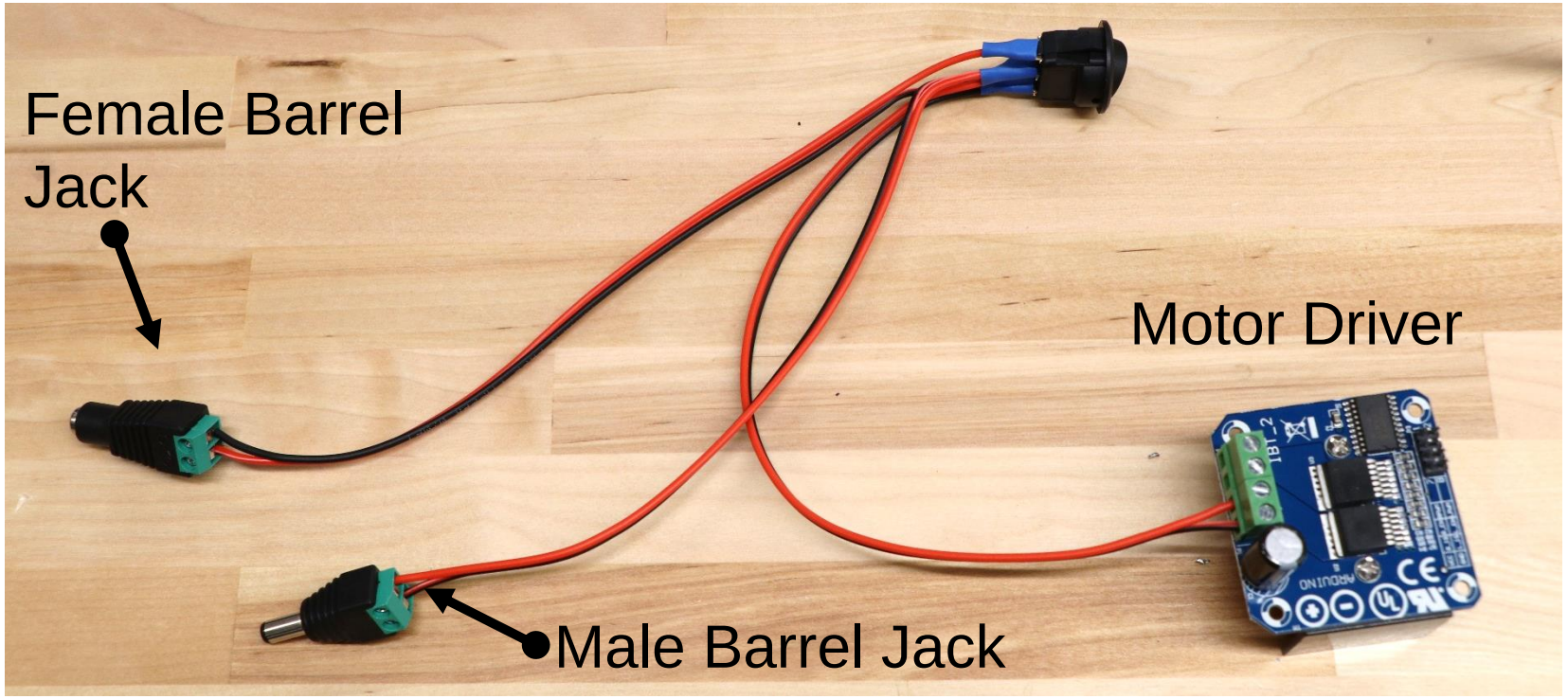


2.3 Solder Power Switch (con’t)

- (continued from previous slide)
- Use a heatgun to shrink the heatshrink around each of the solder joints.
- You’re done! The wired rocker switch should look like the image.

2.4 Putting it all together

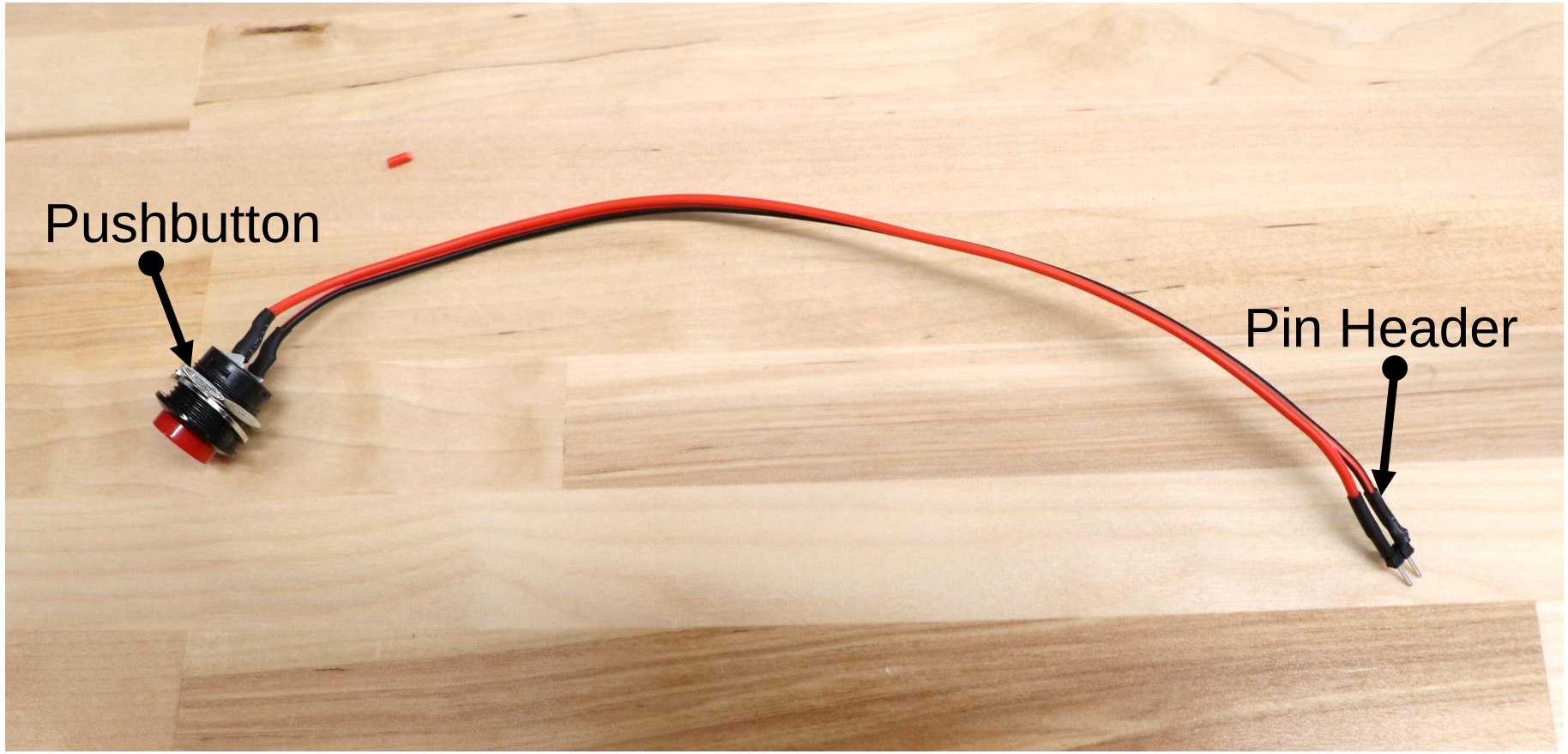
- The lonely red wire on the outside switch terminal and it's associated black wire go to the female barrel jack. **OBSERVE THE (+) AND (-) MARKINGS ON THE JACK SCREW TERMINAL!!** Red goes to the (+), black goes to the (-).
- The 8" middle red wire and it's accompanying black wire goes to the male barrel jack. Same as before, observe the terminal markings.
- You're done for now! The other 10" piece will eventually go to the motor driver as shown.



Observe Polarity Markings!

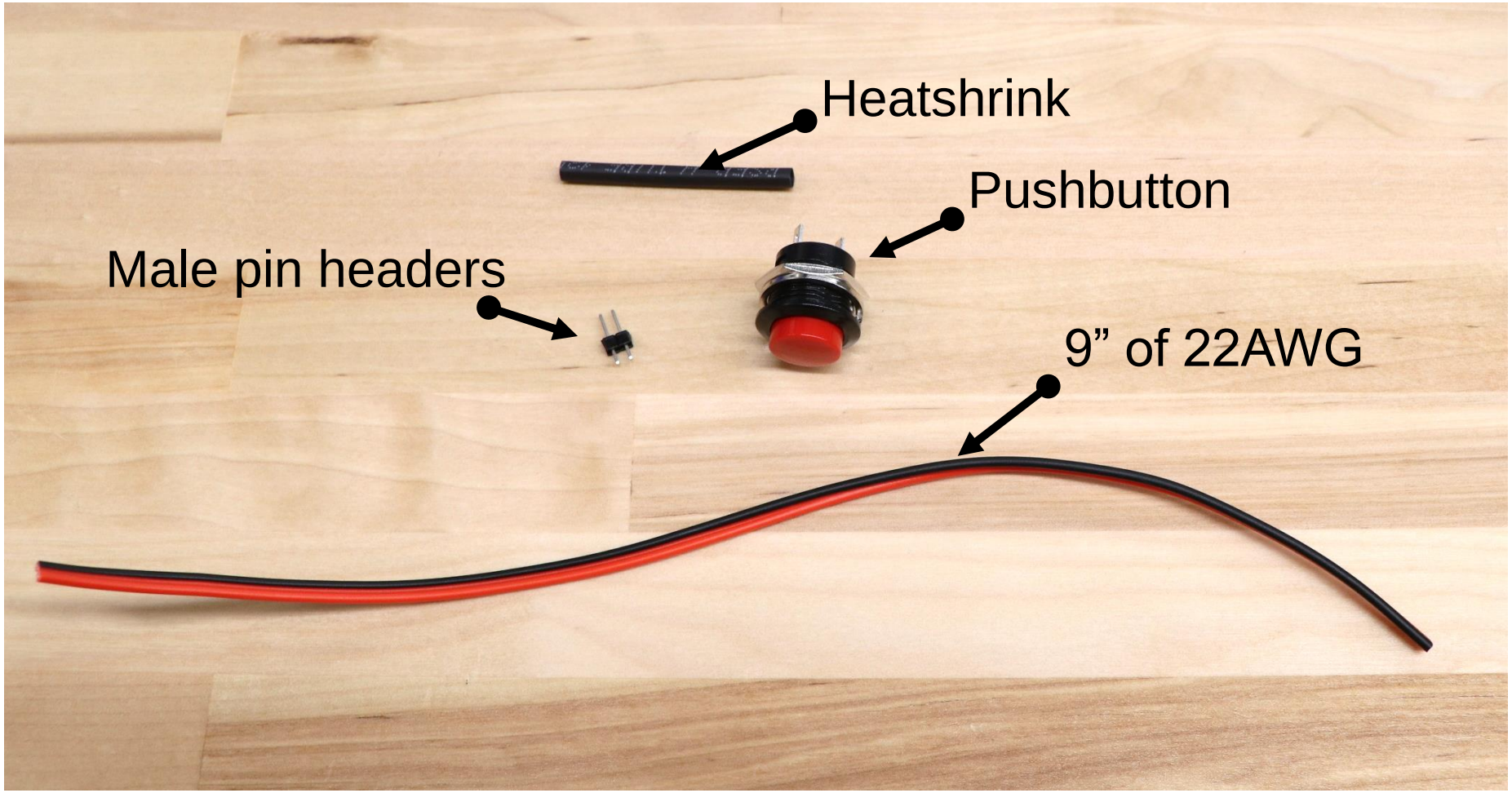
3. Wiring Pushbuttons

- In this step, we will be wiring a pushbutton to a 2-pin male header as in the image below.
- Completion time: <5 minutes



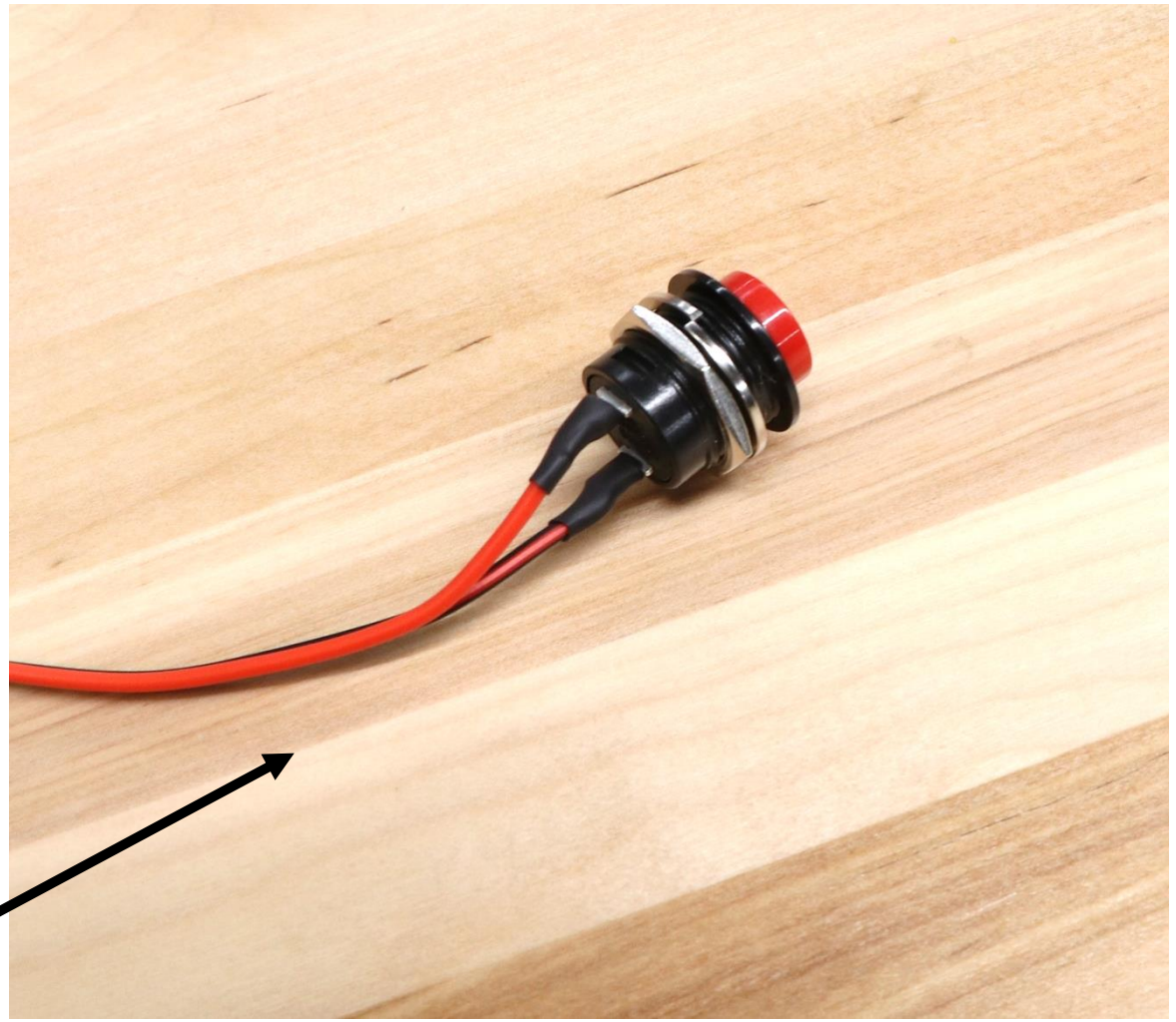
3.1 Collect Components

- Collect pushbutton, two male pin headers, heatshrink, and 9” of 22AWG speaker wire (yours might be the same color for both wires; that’s fine)



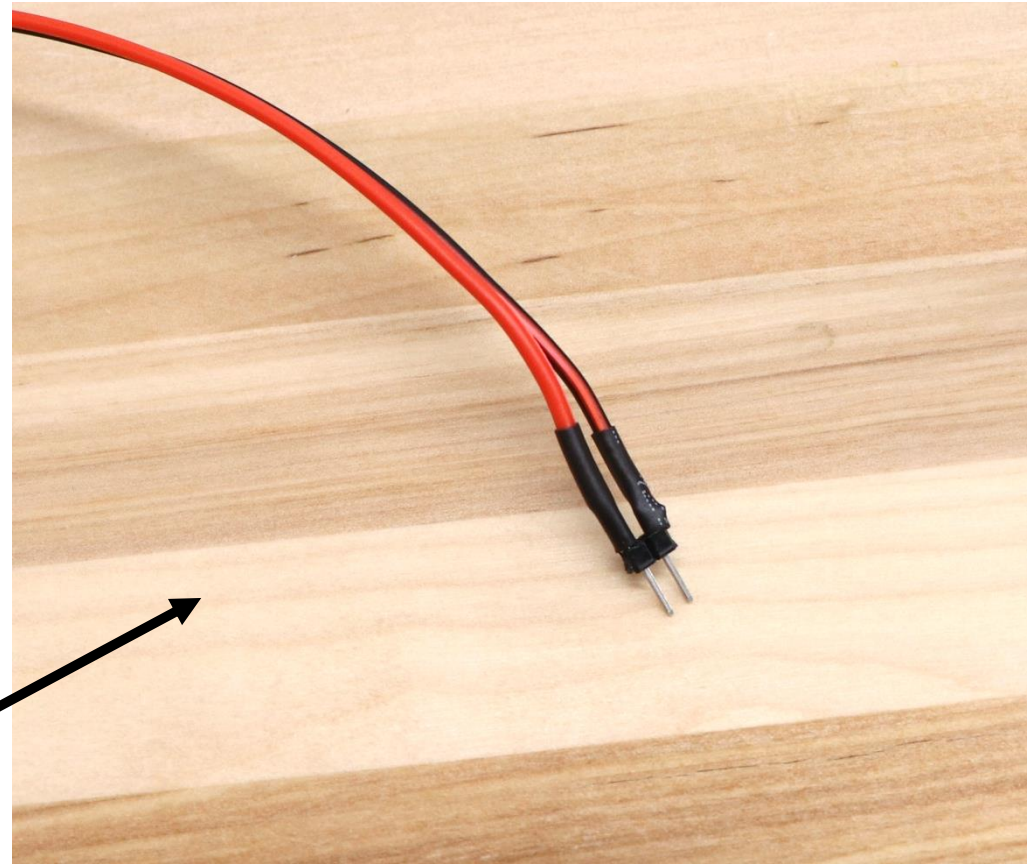
3.2 Wire up the button-side

- Separate the red wire from the black wire for about an inch at both ends, and strip ~1/4” off of all wire ends.
- Tin the exposed wire strands and the terminal lugs on the pushbutton
- Slide a short (~3/8”-1/2”) length of heatshrink around the separated wires at one end.
- Solder this side of the wire pair to the pushbutton lugs (polarity doesn’t matter), and slide the heatshrink over the newly-created solder joint.
- Use a heatgun to shrink the heatshrink around the solder joint
- The button-side should look like the image when you’re done



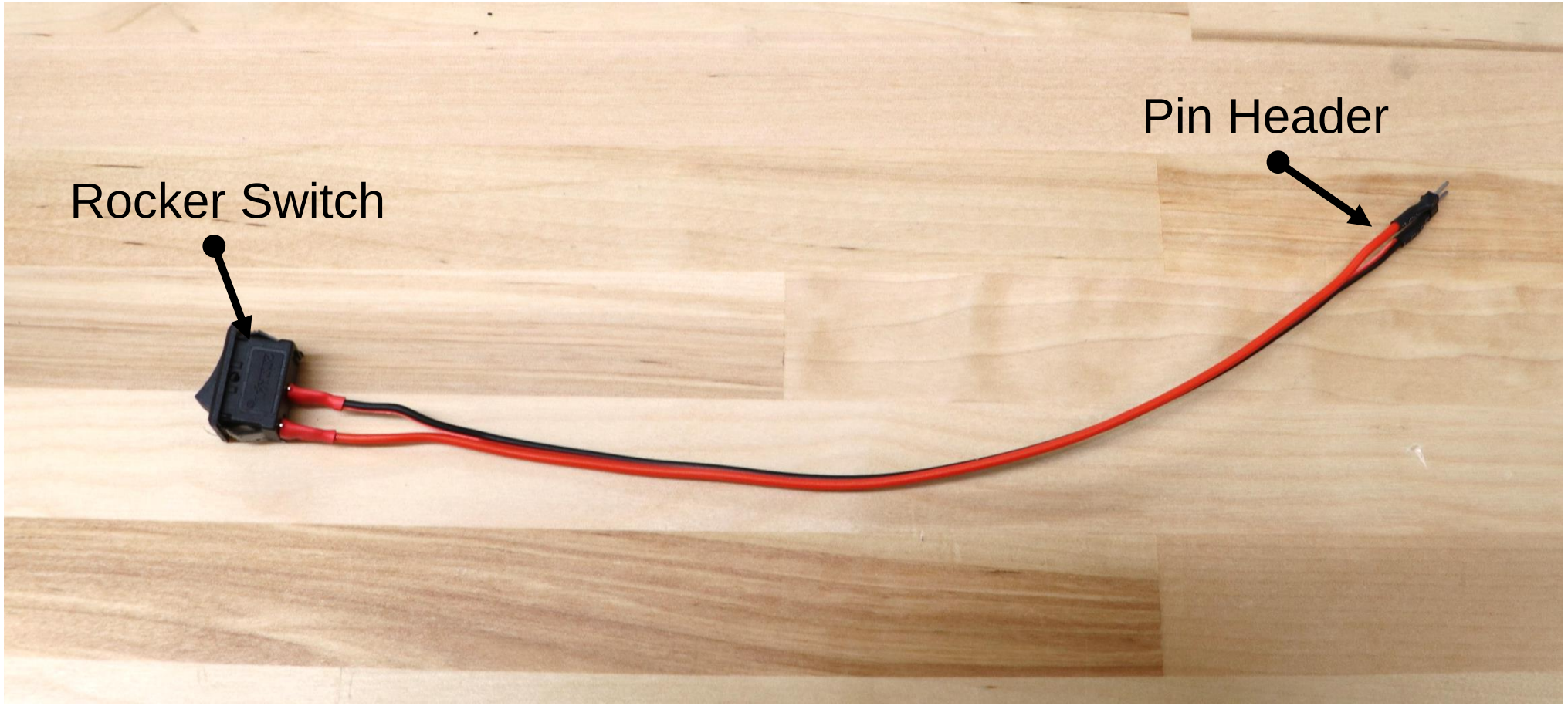
3.3 Wire up the pin side

- Collect your 2-pin male header pin and tin the short pins.
- Slide some heatshrink over the other end of the speaker wire (opposite the button).
- Solder the exposed, tinned wire to the short leads on the male header pin.
- Push heatshrink down to fully cover the solder joint and use a heatgun or a lighter to shrink it around the joint.
- The pin-side should look like the image when you’re done.



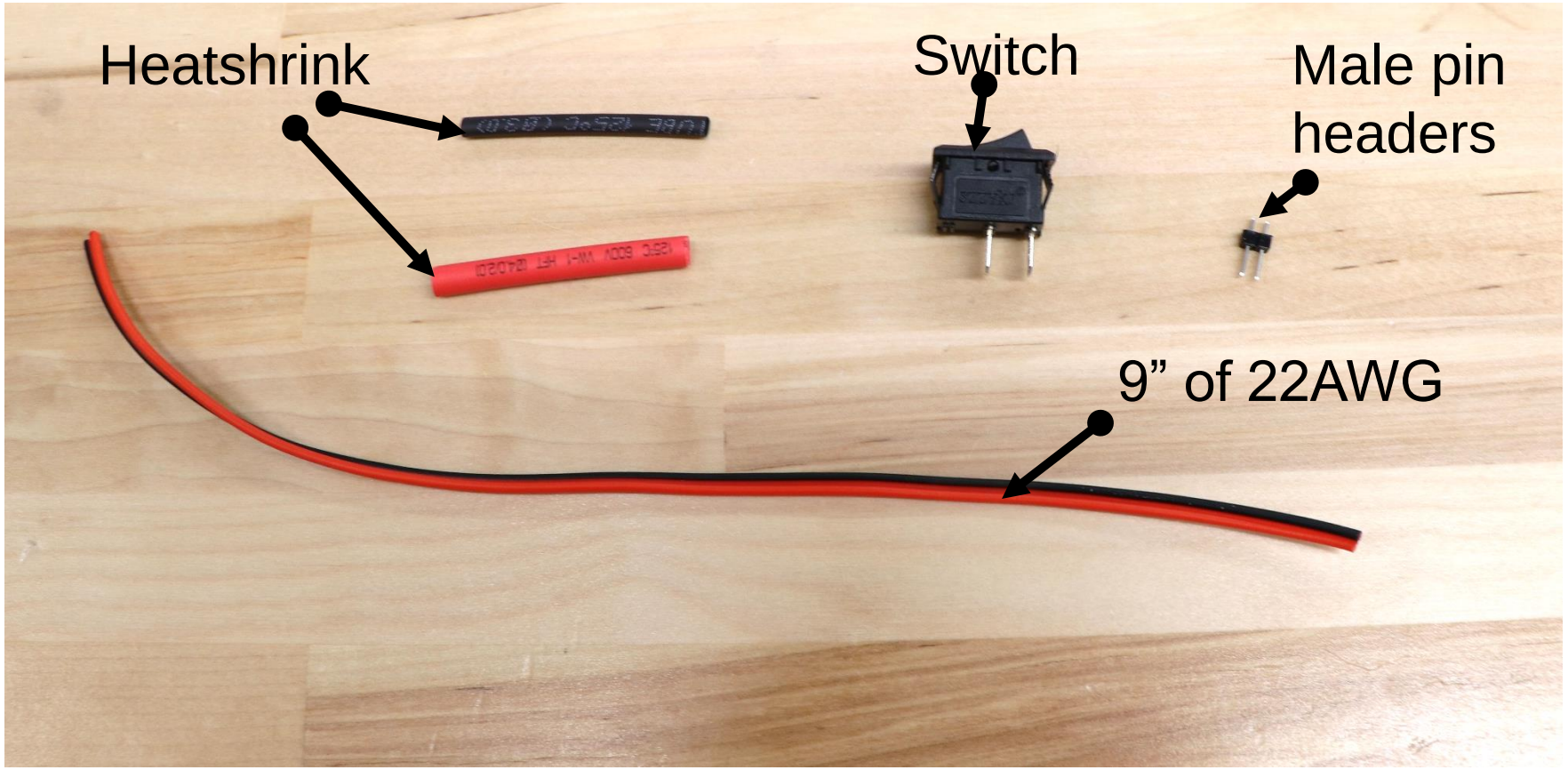
4. Wiring Rocker Switches

- In this step, we will be wiring a rocker switch to a 2-pin male header as in the image below.
- Completion time: 5 minutes



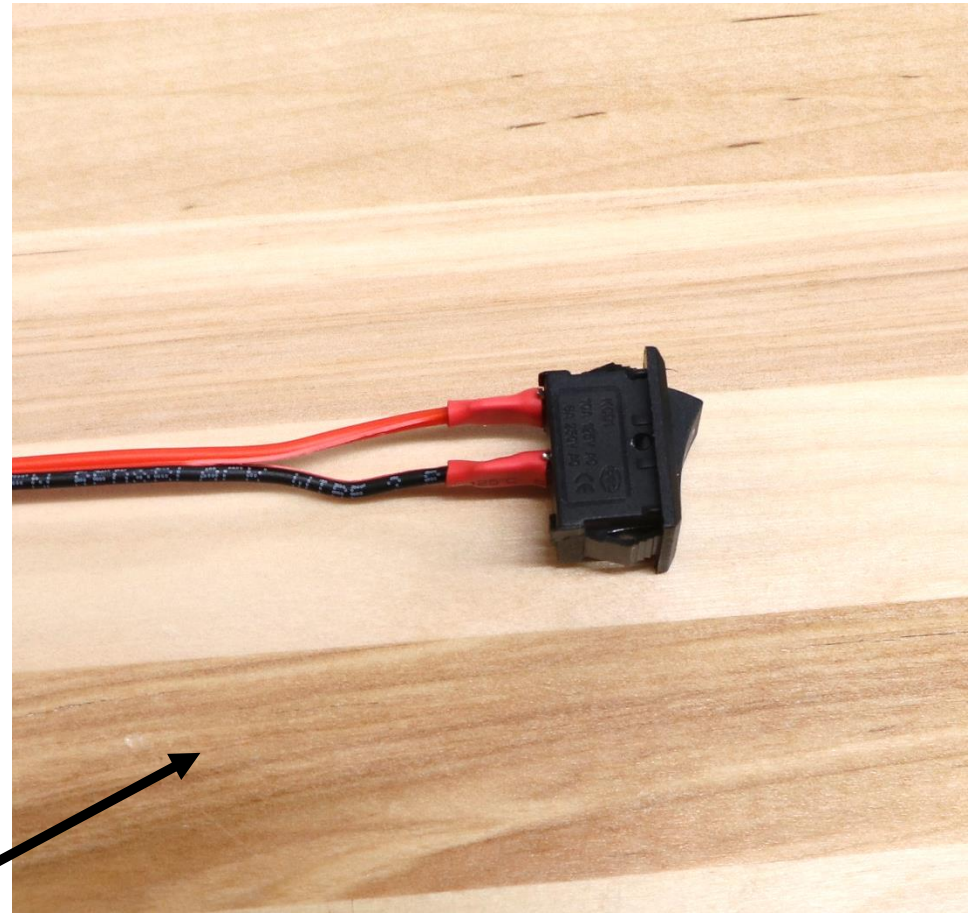
4.1 Collect Components

- Collect rocker switch, two male pin headers, heatshrink (3/16”-1/4” for the switch terminal, and 1/8” for pin header), and 9” of 22AWG speaker wire (yours might be the same color for both wires, that’s fine.)



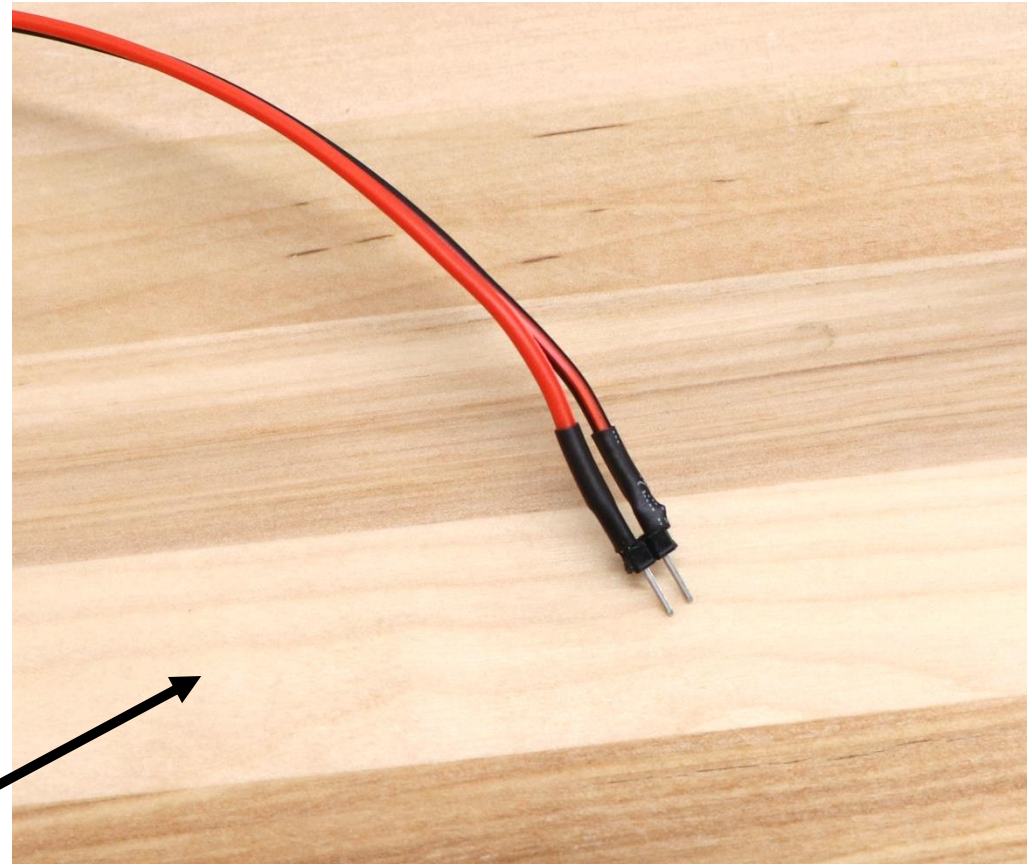
4.2 Wire up the switch-side

- Separate the red wire from the black wire for about an inch at both ends, and strip ~1/4” off of all wire ends.
- Tin the exposed wire strands and the terminal lugs on the switch
- Slide a short (~1/2”) length of the larger heatshrink around the separated wires
- Solder one side of the wire pair to the switch lugs (polarity doesn’t matter)
- Use a heatgun to shrink the heatshrink around the solder joint
- The switch-side should look like the image when you’re done



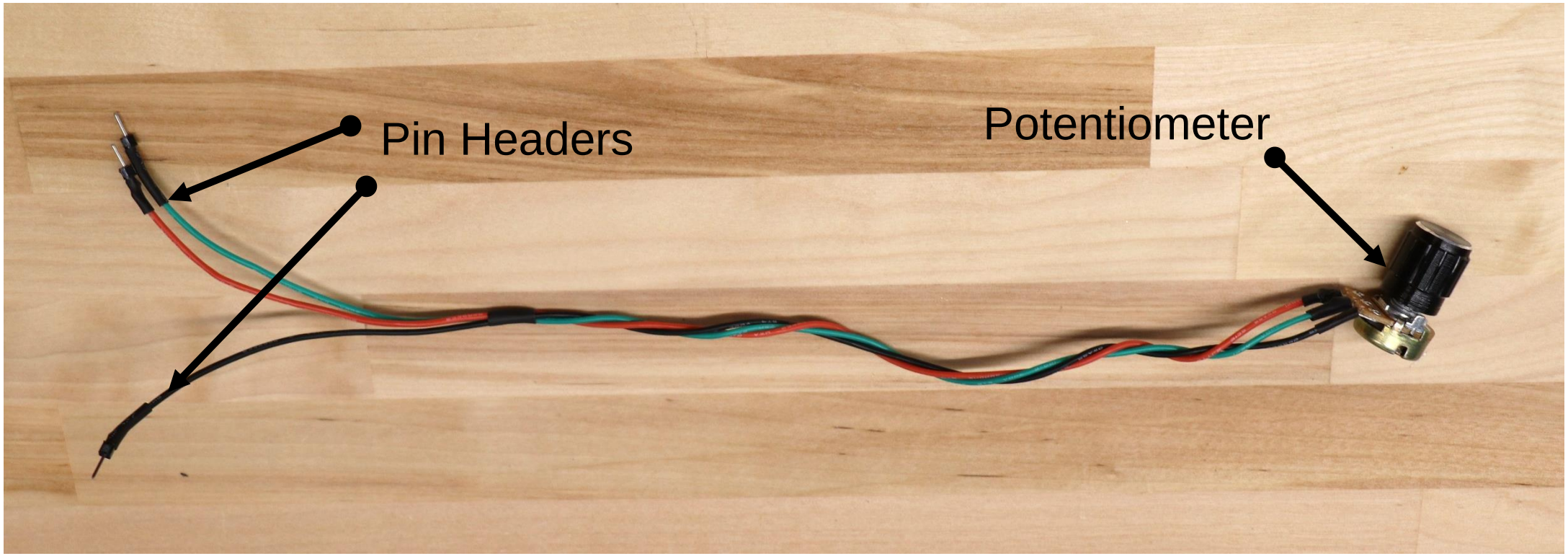
4.3 Wire up the pin side

- Collect your 2-pin male header pin and tin short pins.
- Slide some of the smaller heatshrink over each wire on the other end of the speaker wire (opposite the button).
- Solder the exposed, tinned wire to the short leads on the male header pin.
- Push heatshrink down to fully cover the solder joint and use a heatgun or a lighter to shrink it around the joint.
- The pin-side should look like the image when you’re done.



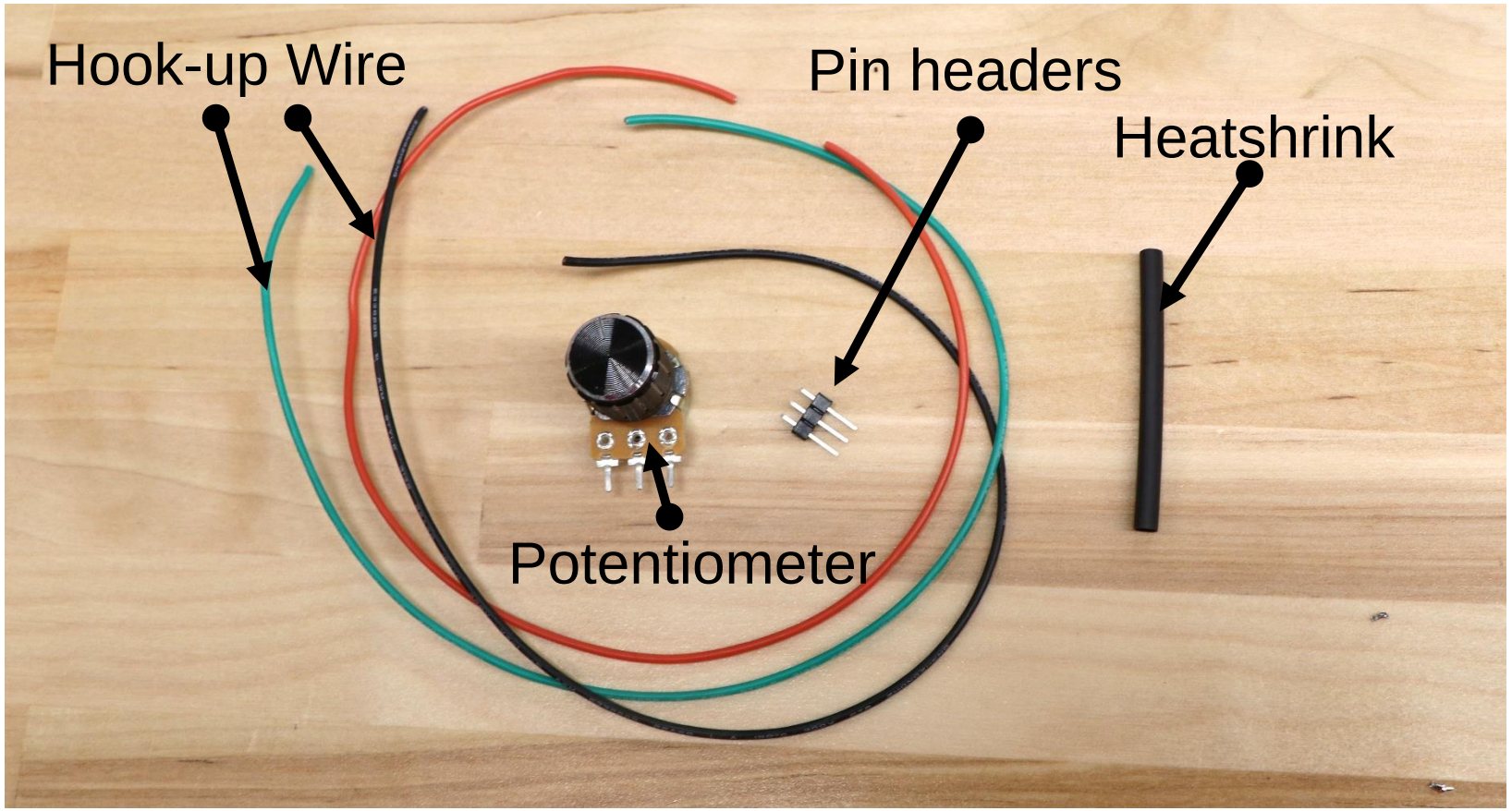
5. Wiring Potentiometers

- In this step, we will be wiring a potentiometer to a 3-pin male header as in the image below.
- Completion time: 5-7 minutes



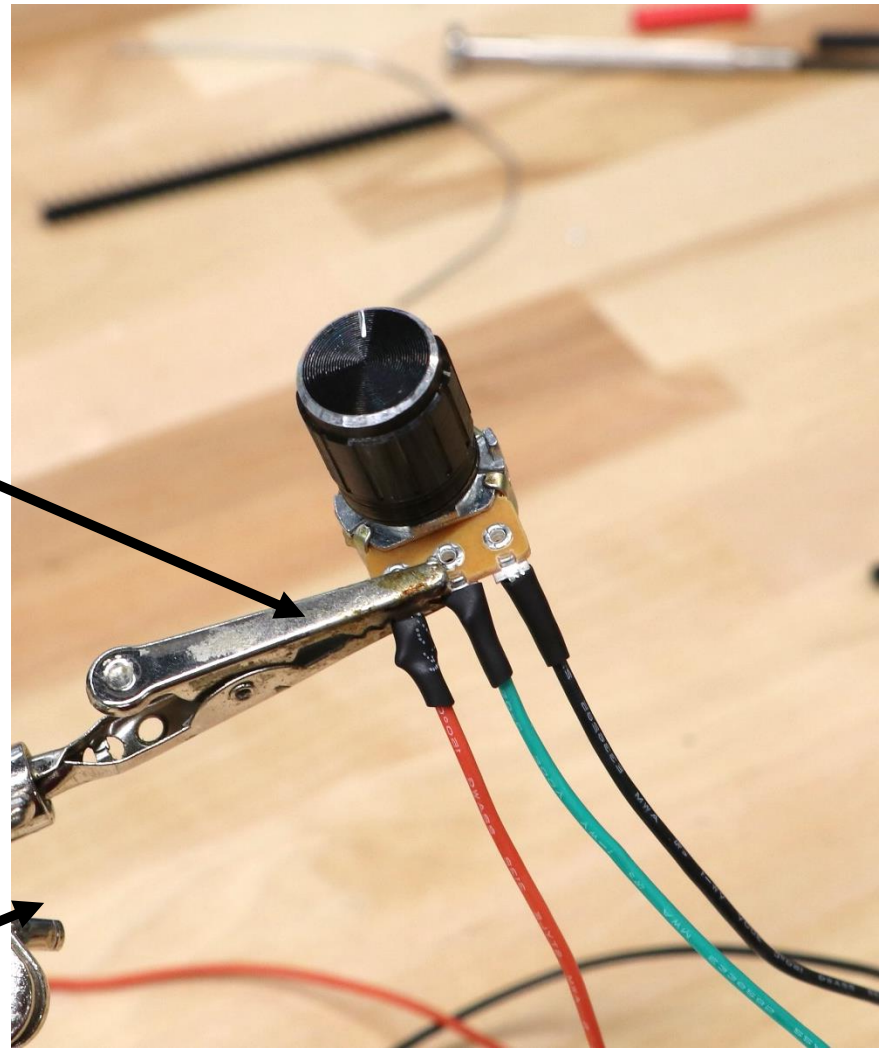
5.1 Collect Components

- Collect potentiometer, 3-pin male header, and 3 different-colored, 10” pieces of 22-24AWG hook-up wire
  - Use **red/yellow** the 5V wire, **blue/black** for the GND wire, and **green/white** for the signal wire



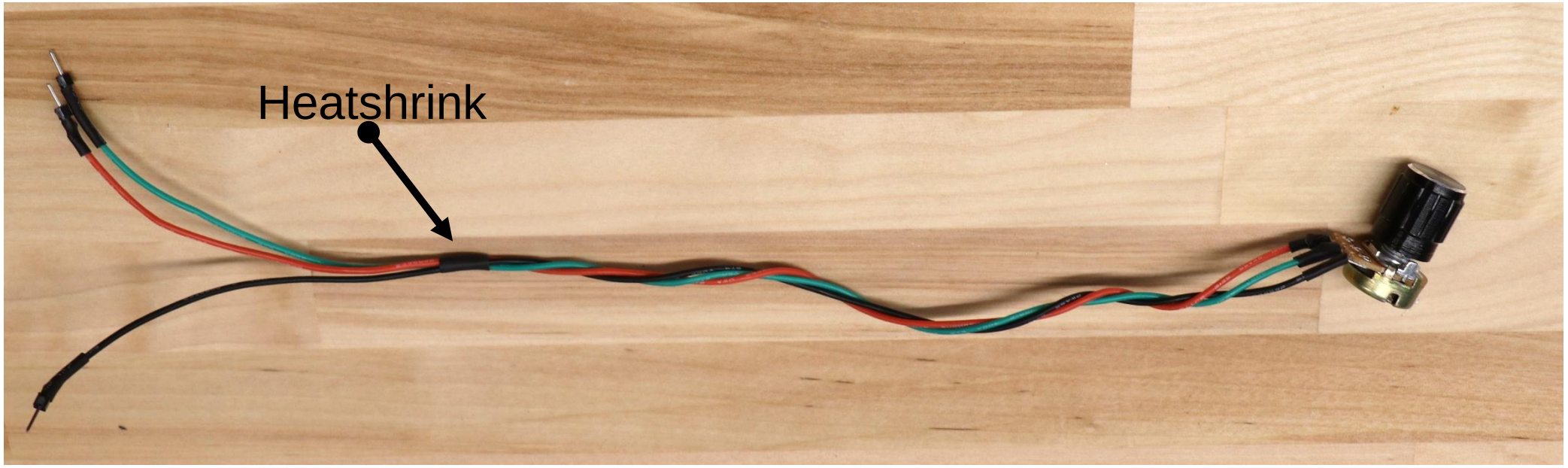
5.2 Wire up the potentiometer-side

- Strip ~1/4” off of each end of each wire and tin the exposed strands.
- Tin the pins on the potentiometer with solder
- Solder the tinned wire to the tinned potentiometer pins, orienting the 5V, SIG, and GND wires as shown in the picture. **Orientation Matters!**
- Slide ½” length of heatshrink over each of the soldered joints and use a heatgun or lighter to shrink. Be careful **NOT** to point the heatgun at the pot! This can thermally warp the wiper contact and ruin the potentiometer!
- The potentiometer should look like the image when you’re done



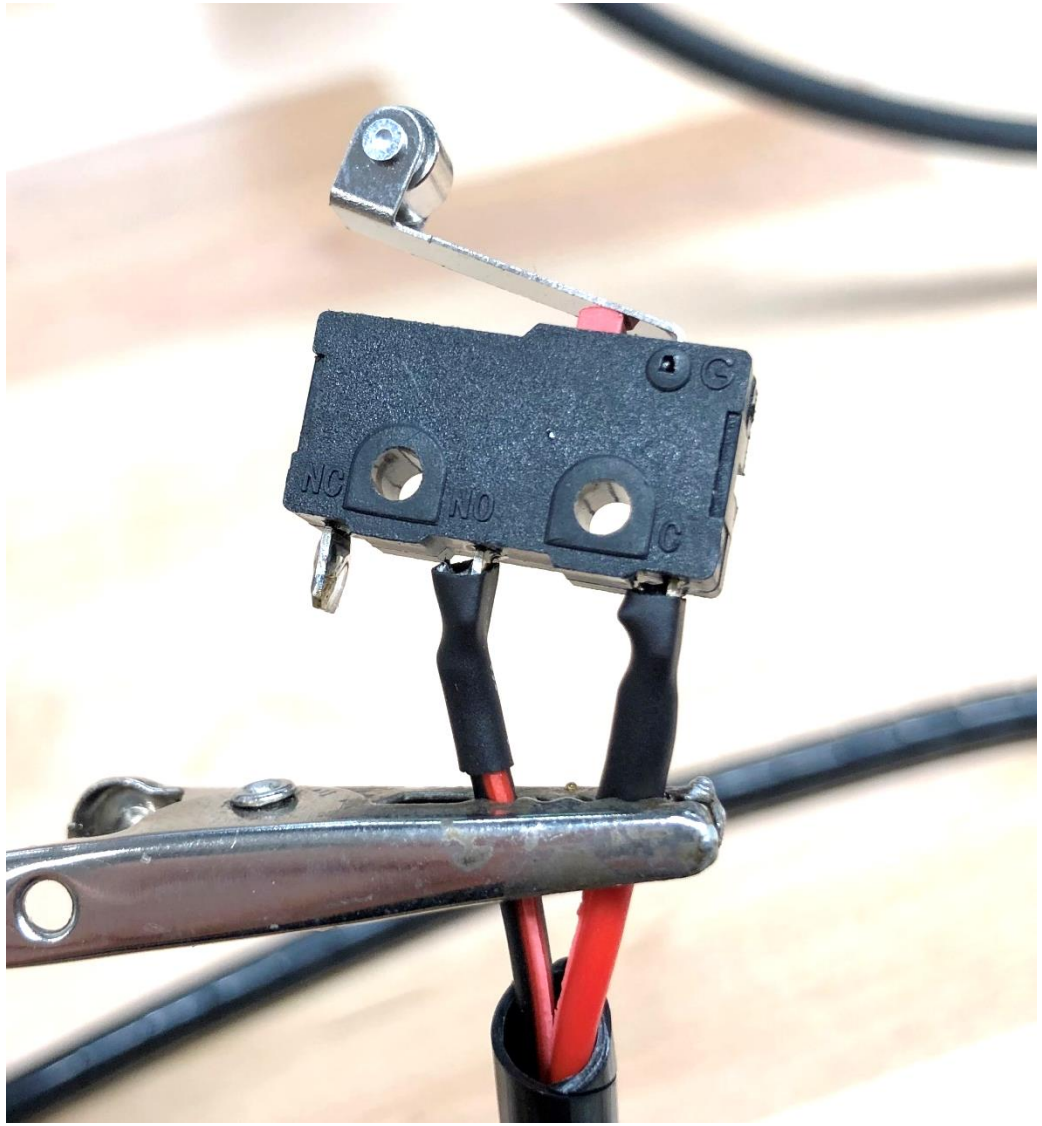
5.3 Wire up the pin side

- Lightly twist the wires and leave about 3” of them untwisted on the pin side. Use a small piece (1/2”) of heatshrink to keep them from coming untwisted.
- Slide ½” length of heatshrink over each of the three wires. They should already be stripped/tinned.
- Tin the short pins of each of the pin headers with solder
- Solder each tinned wire to a separate pin header, and cover the joint with heatshrink. Use a heatgun or lighter to shrink it.
- The assembled potentiometer should look like the image when you’re done.



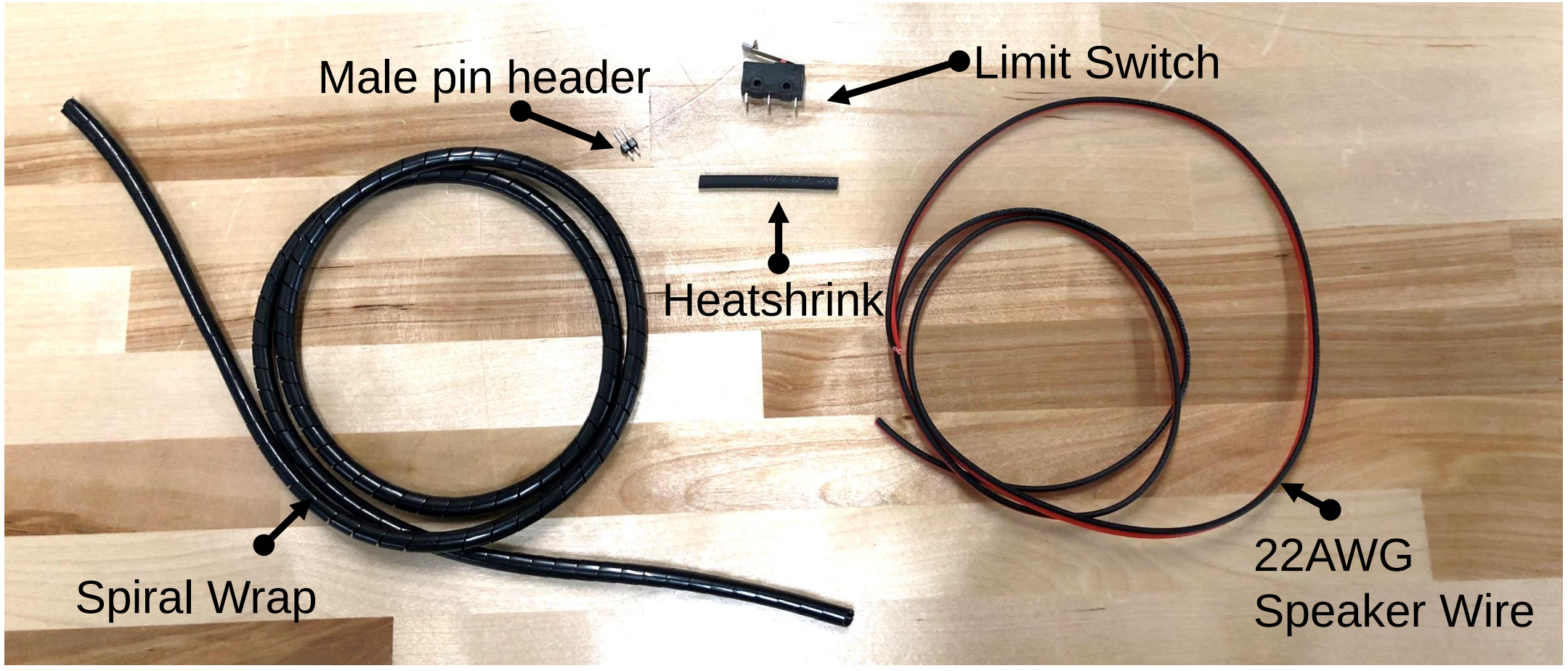
6. Wiring Limit Switches

- In this step, we will be wiring a limit switch to a 2-pin male header, as shown, and encapsulating it in spiral cable wrap
- Completion time: 5-7 minutes



6.1 Collect Components

- Collect limit switch, two male pin headers, heatshrink (3/16”-1/4” for the switch terminal, and 1/8” for pin header), 50” of 22AWG speaker wire (yours might be the same color for both wires), and 38” of spiral cable wrap.



6.2 Cable Wrap

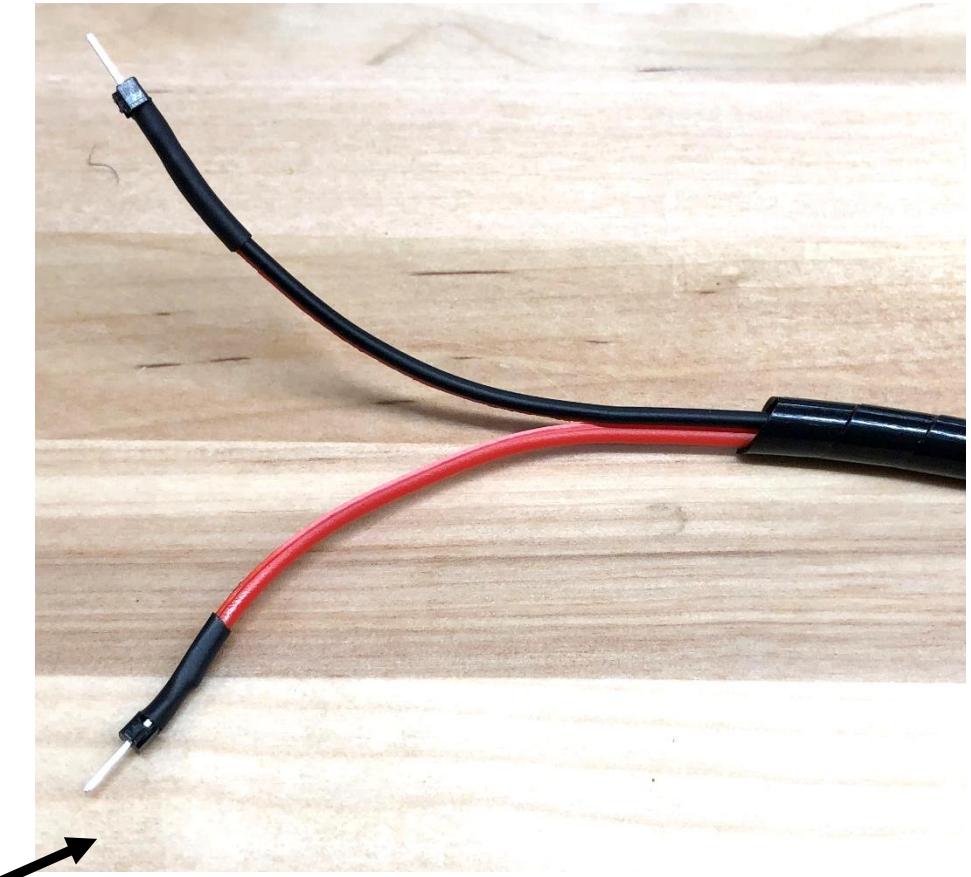
- Before soldering, snake the speaker wire through the cable wrap. It’s easiest to do this now; once you tin/strip/solder the wire it becomes difficult to slide the cable wrap over. Leave ~1” of wire on one end, and the rest sticking out the other end, as shown (you will probably have more sticking out)

6.3 Wire up the limit switch-side

- Separate the red wire from the black wire for about an inch at both ends, and strip ~1/4” off of all wire ends.
- Tin the terminals on the limit switch with solder
- Solder the tinned wire (on the 1” side) wire to the tinned terminal lugs. Polarity doesn’t matter, but the terminals do, since one is disconnected. We want to solder to the ‘C’ and ‘NO’ terminals, as shown in the inset image.
- Slide ½” of heatshrink over each of the soldered joints and use a heatgun or lighter to shrink.
- The limit switch should look like the image when you’re done.

6.4 Wire up the pin side

- Collect your 2-pin male header pin and tin short pins.
- On the other end of the speaker wire (opposite the switch), separate the red from the white wire for about 2-3”, and slide some of the smaller heatshrink over each wire.
- Solder the exposed, tinned wire to the short leads on the male header pin.
- Push heatshrink down to fully cover the solder joint and use a heatgun or a lighter to shrink it around the joint.
- The pin-side should look like the image when you’re done.

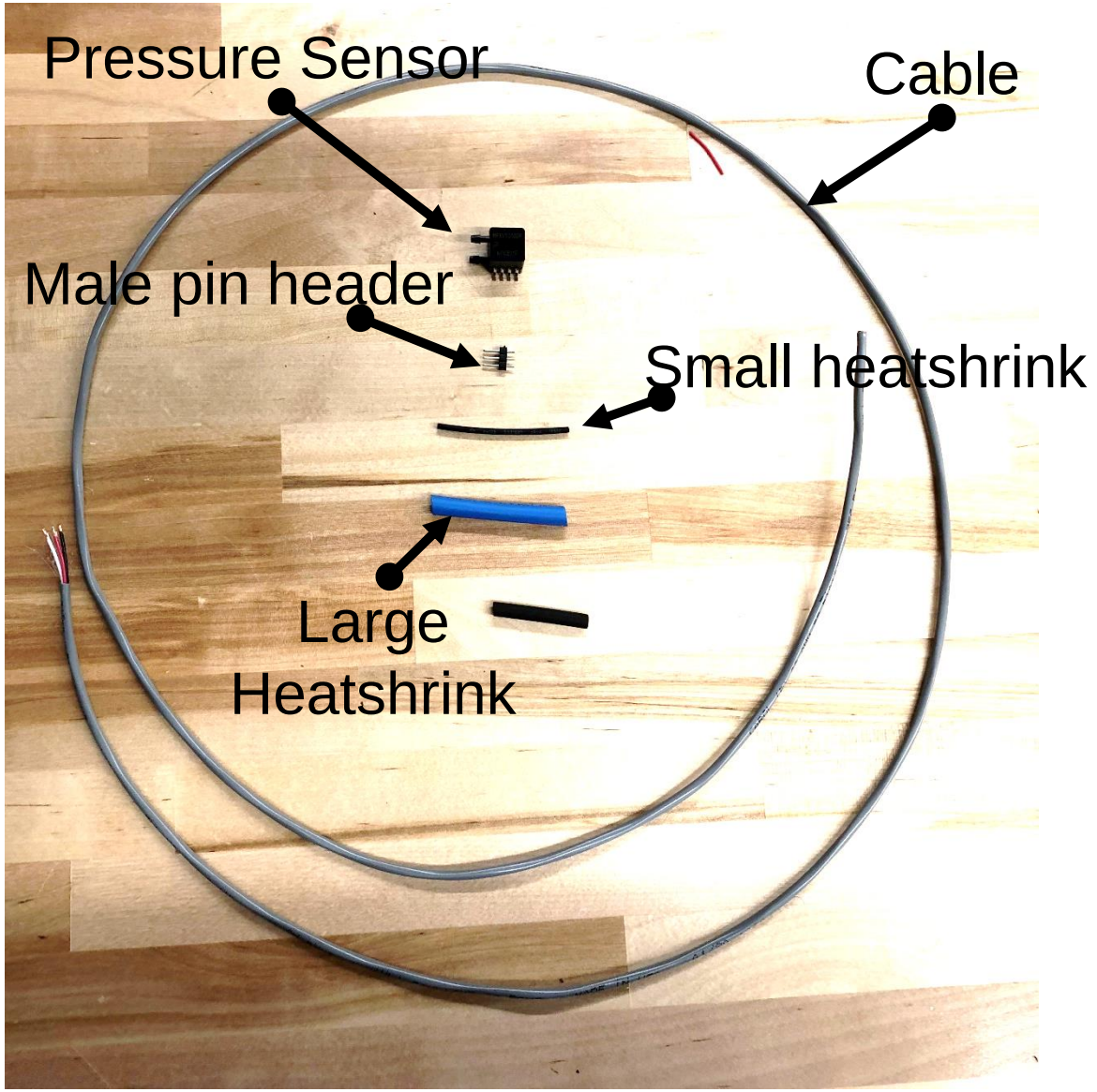


7. Wiring Pressure Sensor

- In this step, we will be wiring a pressure sensor to a 3-pin male header as in the image.
- Completion time: 7-10 minutes

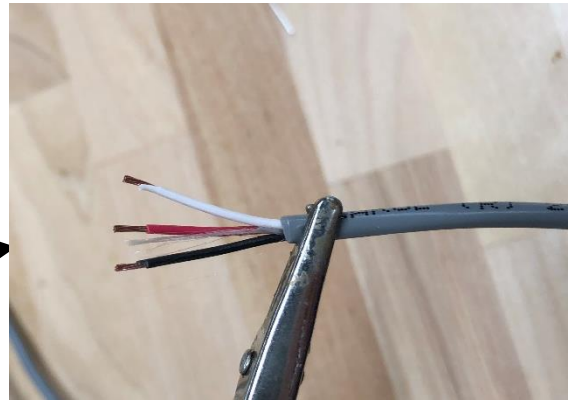
7.1 Collect Components

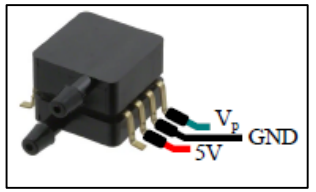
- Collect the following:
  - Pressure Sensor
  - 3 pin male header
  - Small (1/16”-1/8”) heatshrink
  - Larger (1/8”-1/4”) heatshrink
  - 54” of three-conductor cable

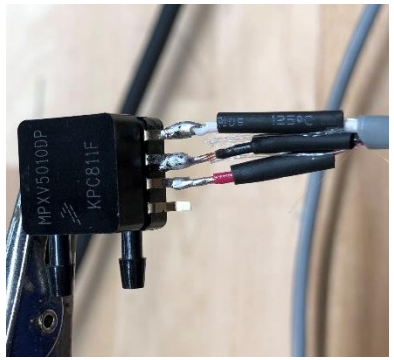


7.2 Solder Pressure Sensor

- Strip ~1” of the grey insulation away from the multi-conductor cable on one side.
- Strip the individual colored wires and tin them.
- Slide ~1/2” of the small heatshrink over each of the three wires.
- With the barbed fittings facing you, tin the back three pins on the right side of pressure sensor as shown here.
- Solder the red wire to the 5V pin, the black wire to the GND pin, and the white wire to the Vp pin.
- Slide the smaller heatshrink over the solder joints and use a heatgun to shrink.
- Slide ~3/4” of the larger heatshrink over all three wires and use a heatgun to shrink



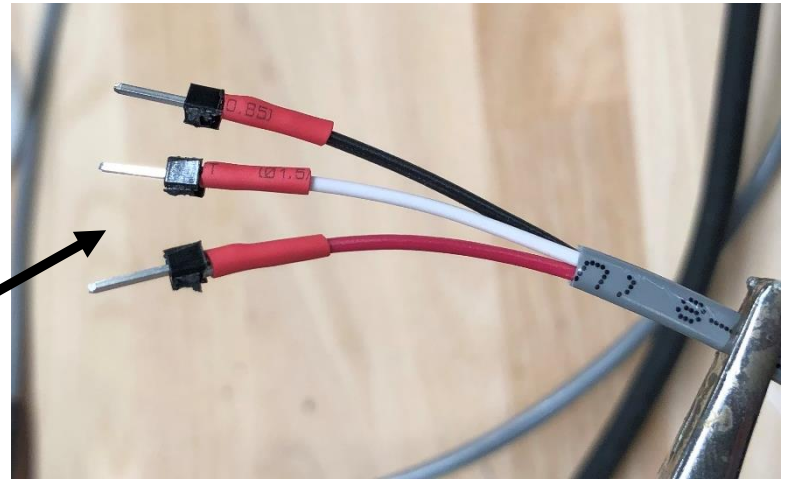




7.3 Strain-Relief and Finish

- Using a hot glue gun, liberally apply hot glue around all of the pins you just soldered, making sure to join them to the wire and heatshrink. Once the hot glue cools, the pressure sensor side is done.

- Flip the cable over to the other side and strip ~1.5” of the grey insulation away to expose the three colored wires.
- Strip and tin each of the wires.
- Slide ~3/8” of the small heatshrink over each wire.
- Solder each wire to its own male pin header.
- Slide the heatshrink over the solder joint, and shrink.
- You’re done!

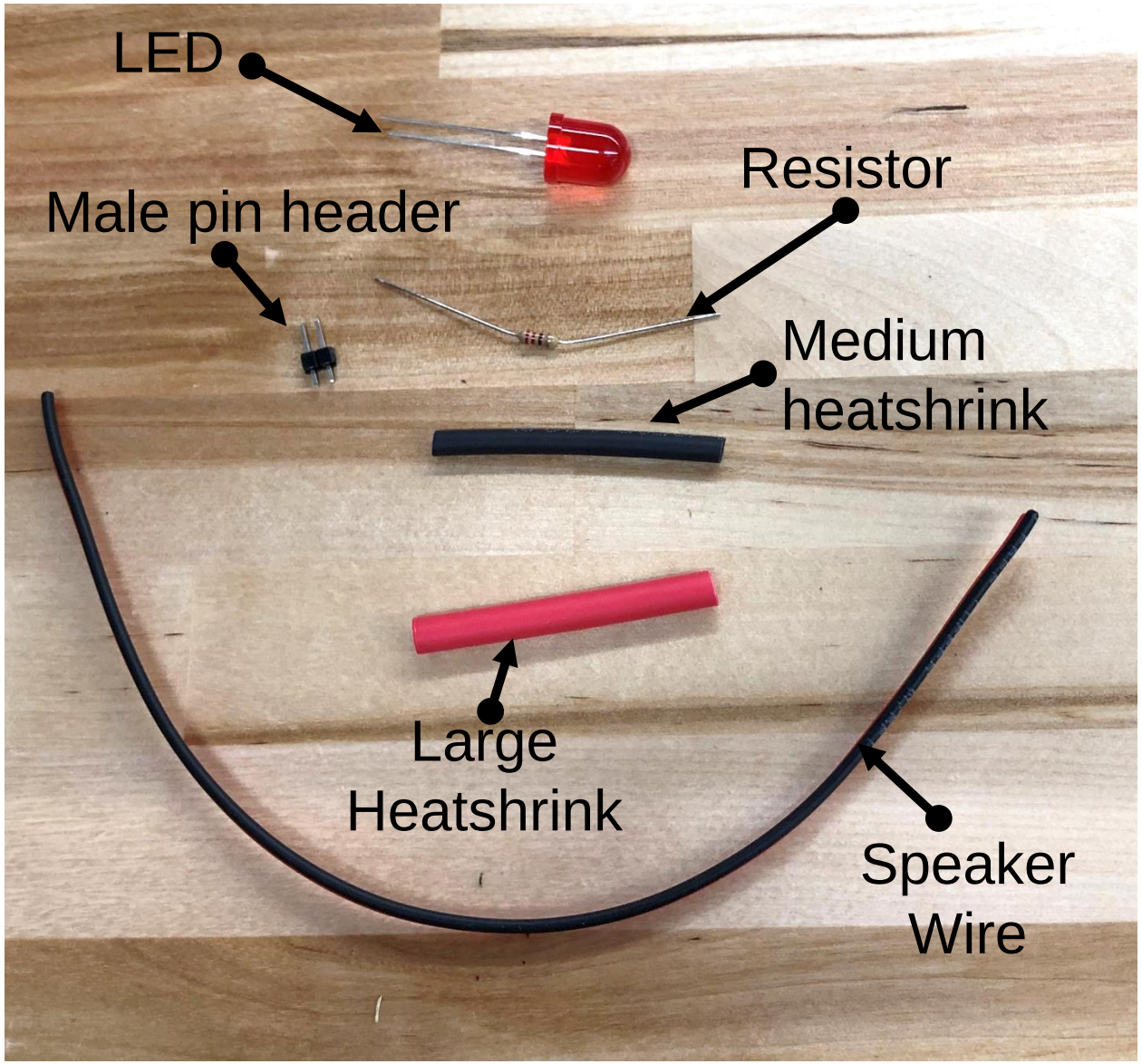


8. Wiring the Alarm LED

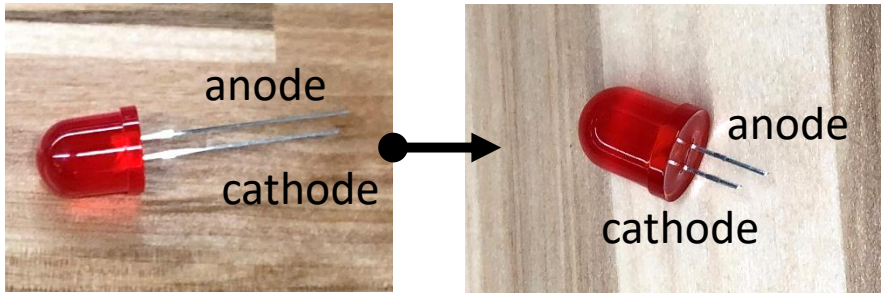
- In this step, we will be wiring a 10mm red LED to a male pin header, as shown in the image.
- Completion time: 5-7 minutes

8.1 Collect Components

- Collect the following:
  - 10mm LED
  - 2 pin male header
  - 1 220 ohm resistor
  - Medium (1/8”) heatshrink
  - Larger (3/16”) heatshrink
  - 10” of 22AWG red/black speaker cable

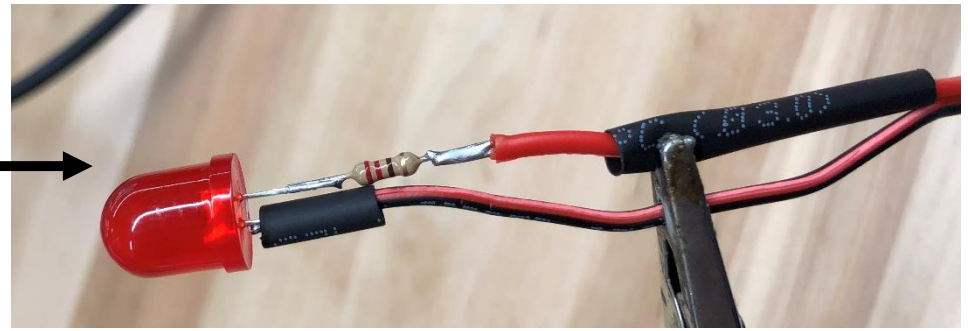


8.2 Solder LED



- Grab the LED and note the longer lead – this is the anode which will go to the red wire.
- Trim the LED leads but ensure that the anode lead remains a bit longer by about 1/8” or so.
- Grab the resistor and trim its leads down to about ~3/8”, and solder one end to the anode of the LED.

- Grab the speaker wire and separate red from black at one end for about 2.5”.
- Trim the red wire by the length of the LED anode and resistor.
- Strip the red and black wire and tin with solder.
- Slide some medium heatshrink over each wire (~3/8” length for the black side, and enough to cover the anode+resistor for the right side).
- Solder the red wire to the free end of the resistor, and the black wire to the cathode lead of the LED.



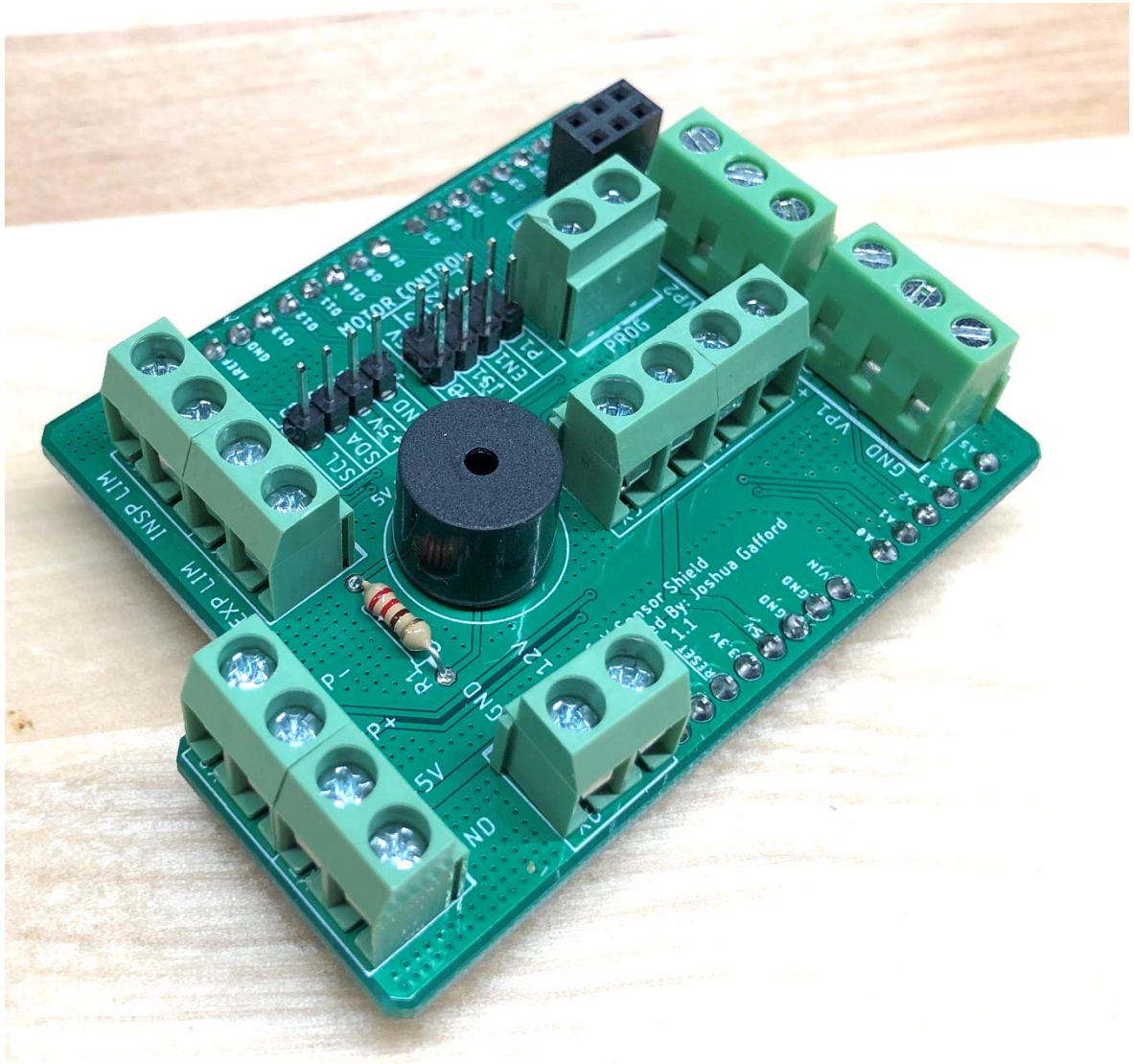
8.3 Solder LED con’t.

- Slide the medium heatshrink over the solder joints and shrink with a heatgun, being sure to fully encapsulate the resistor.
- Slide ~3/4” of the larger heatshrink over both wires all the way up to the LED and use a heatgun to shrink.

- Flip the speaker wire over to the other side separate red from black for about 1”
- Strip and tin each of the wires.
- Slide ~3/8” of the small heatshrink over each wire.
- Solder the wires to a 2-pin male header.
- Slide the heatshrink over the solder joint, and shrink.
- You’re done!

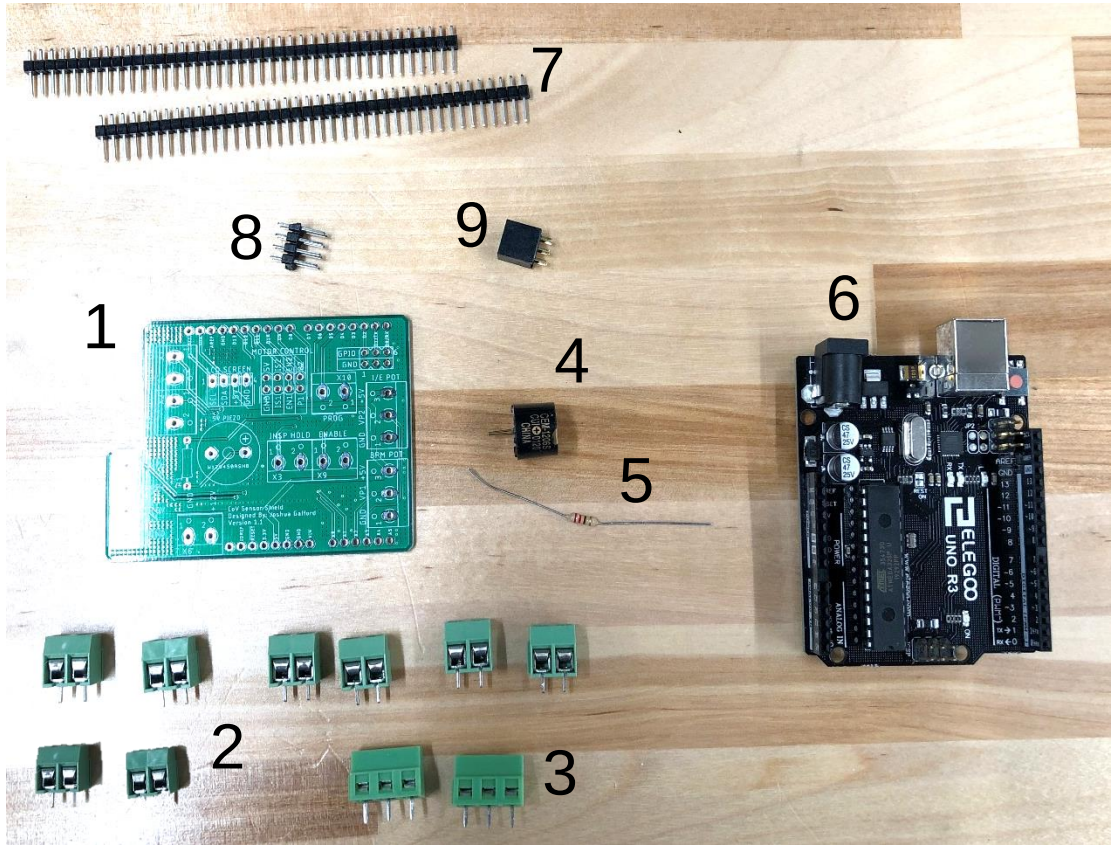
9. Soldering the CoV Shield

- In this step, we will be soldering screw terminals, header pins, a piezo buzzer, and a resistor to the CoV shield for the Arduino Uno.
- Completion Time: 7-10 minutes



9.1 Collect Components

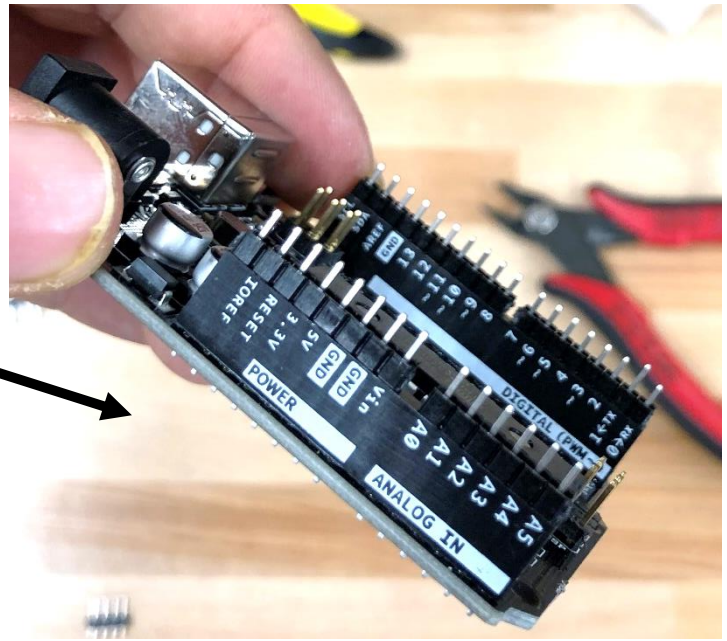
- Collect the following:
  1. CoV shield PCB
  2. 8 2-pos screw terminals
  3. 2 3-pos screw terminals
  4. 1 piezo buzzer
  5. 1 220 ohm resistor
  6. 1 Arduino Uno or equivalent
  7. A bunch of header pins
  8. A 4x2 pos male header pin*
  9. A 3x2 pos female header socket*



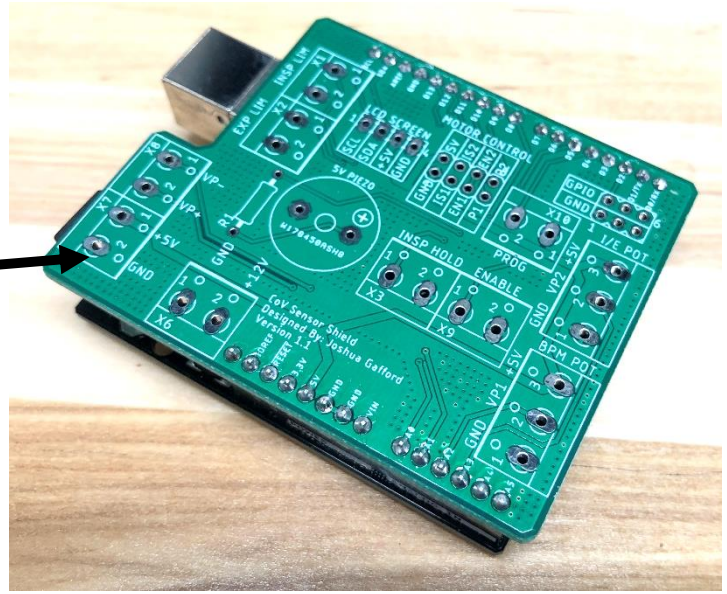
*: If you don't have any more 3x2 female sockets or 4x2 male header pins, just trim down a single- or double-row female socket/header pin to the right size

9.2 Solder Stacking Headers

- Grab the Arduino, and break off enough male header pins to stack in each of the Arduino's female header sockets. You'll need 1 6-pin row, 1 10-pin row, and 2 8-pin rows. Go ahead and press them into the Arduino sockets.

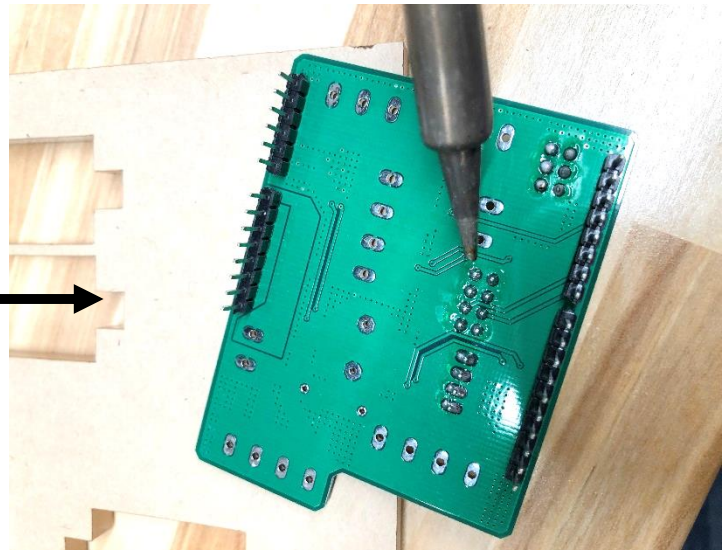


- Lay the CoV PCB over the Arduino such that the short side of the pins extend through the plated holes. Soldering the stacking headers while they're socketed in the Uno ensures that they will line up correctly once soldered.
- Solder the pins to the plated holes. Use a soldering iron to heat the pin and the hole simultaneously, and feed solder in from the opposite side of the pin. Do this for all of the holes.

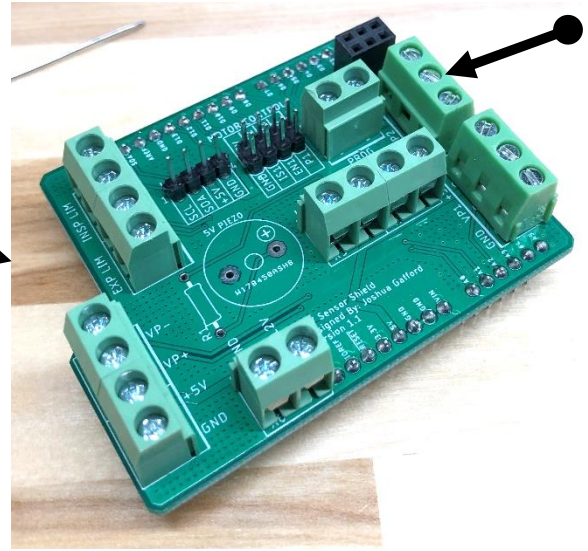


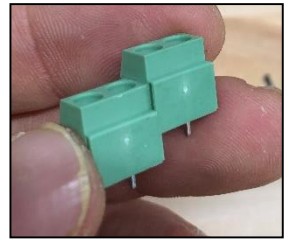
9.3 Pin Headers and Screw Terminals

- Carefully remove the shield from the Uno, taking special care not to bend any pins.
- Solder the 4x1 LCD male header, 4x2 motor control male headers, and 3x2 GPIO/GND female header sockets. Place the headers into their respective holes and flip the board over to solder the pin leads to the plated holes from the bottom. You may need something to prop the board up (I'm using a ¼" piece of acrylic here)



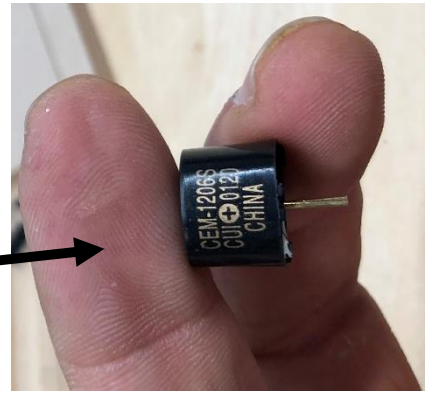
- Solder the screw terminals using the same approach as above. Note that the Insp Lim/Exp Lim, Insp Hold/Enable, and pressure sensor terminals consist of two 2-pos headers ganged together. There are tiny dovetail features that allow them to be snapped together (see inset).
- Ensure that the screw terminal openings are facing OUTWARDS. Pay close attention to the 3-pos terminals, as the back side has what appear to be small terminal openings (but they aren't!).





9.2 Solder Piezo

- Grab the piezo buzzer and the resistor, and place them into their respective sockets. Observe the polarity marking on the piezo (see image), and align this positive (+) terminal with the (+) marking on the PCB silkscreen.



- Flip the board over and solder the piezo and resistor leads to the plated holes on the back of the board.
- Look around at all the edges of the board. If all of the screw terminal openings are facing out, you're done!