Ballistic Chronograph MK2 Assembly Manual

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Description

This is a complete assembly manual for td0g's Ballistic Chronograph MK2. The MK2 is based heavily on the original MK1 but altered to improve manufacturability by individual enthusiasts..

For a complete overview, please visit https://td0g.ca.

Tools Required

- 3D printer with 200mm x 200mm bed
- Soldering Iron & Solder
- Small Side Cutters
- Allen Wrenches
- Dupont Crimper Kit (Optional but Recommended)

Chronograph Configuration

Before proceeding, you must decide on some basic configuration options.

- The **gate sensor – gate sensor distance**: I suggest approximately 500 mm, although my prototype is 385 mm and seems to function well.
- The **gate sensor height**: A single-sensor height is cheaper and smaller, but the sensor area is only 40 mm. A double-height sensor yields an 85 mm sensor height
- The **gate sensor slit width**: I used a 3 mm slit, but for slightly improved accuracy you can also use a 2 mm slit.
- The **gate sensor width**: I used a 125 mm width and it seems to work well in most conditions, but a 100 mm width gate will increase sensitivity and allow use in brighter ambient light.

3D Printing & Extrusion

1. Download the latest .STL files from https://github.com/td0g/BallisticChronograph.
2. 3D print the **Arduino Mount** and **Crossmember**. Once these parts are printed, you can begin assembling the Arduino mount assembly (Step 6)
3. 3D print two **Gates**. Note that there are a few different options, be sure to print the correct **Gate**. Once these parts are printed, you can begin assembling the gate assemblies (Step 12)
4. Once the Gates have been printed, continue two copies of the **Sensor Cover** and **Emitter Cover**. I chose to print one pair of covers in black and the other pair in white to diffrentiate the gates easily.
5. Cut two 2020 extrusion rails. The Gates are 65mm wide, so the length of the rails must be the desired gate sensor – gate sensor distance plus 65mm (eg. to have the sensors 500mm apart, the rails must be 565mm long).

Arduino Mount Assembly

6. Take 2x 10mm M4 screws and T-nuts. Install them in the large holes in the **Arduino Mount**. NOTE – I didn't have T-nuts so I used hex nuts and hot glue as a bodge in the photo.

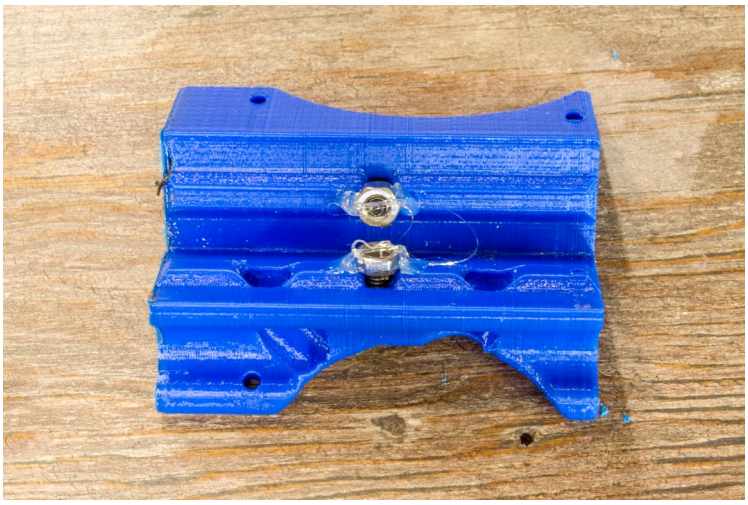

Figure 1: M4 screws and nuts loosely installed in Arduino Mount

7. Slide the **Arduino Mount** onto a 2020 extrusion rail and install it at the midpoint.

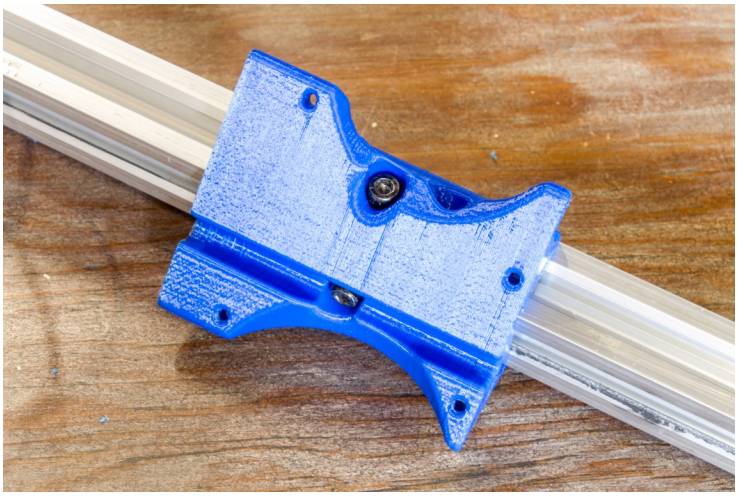

Figure 2: Positioned at midpoint and screws tightened

8. Install the Arduino Uno on the **Arduino Mount** using 8mm M3 screws.

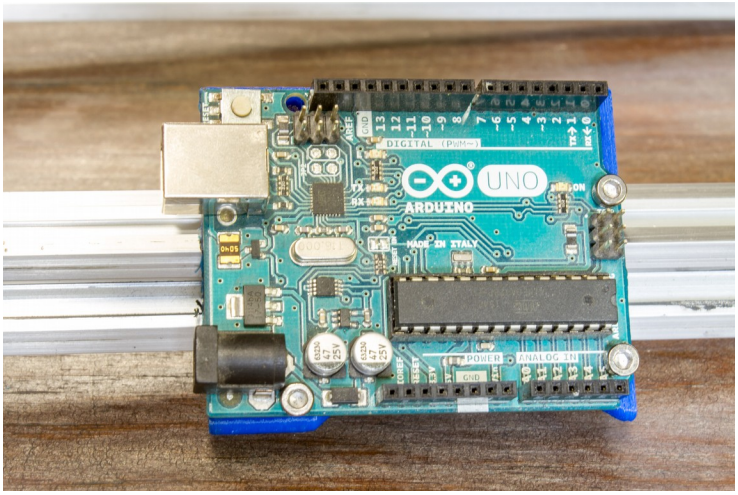

Figure 3: Arduino Uno installed on mount

9. Install the LCD Keypad shield on the Arduino.

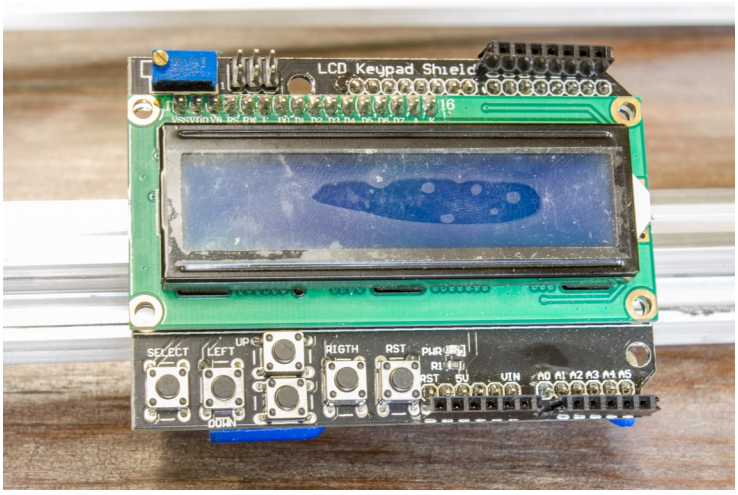

Figure 4: LCD Keypad Shield installed on Arduino

10. Upload the firmware to the Arduino. You may use one of the firmware versions available at https://github.com/td0g/BallisticChronograph.
11. Install the **Crossmember** onto the 2020 extrusion rails using 2x 8mm x M4 screws and T-nuts. See the figure below for the orientation.

Figure 5: Crossmember installed on rails

Light Gate Assembly

12. Take 4x 12mm M4 screws and T-nuts. Install them in the holes at the base of the **Gate**. Do not tighten until the 2020 extrusion rails are installed.

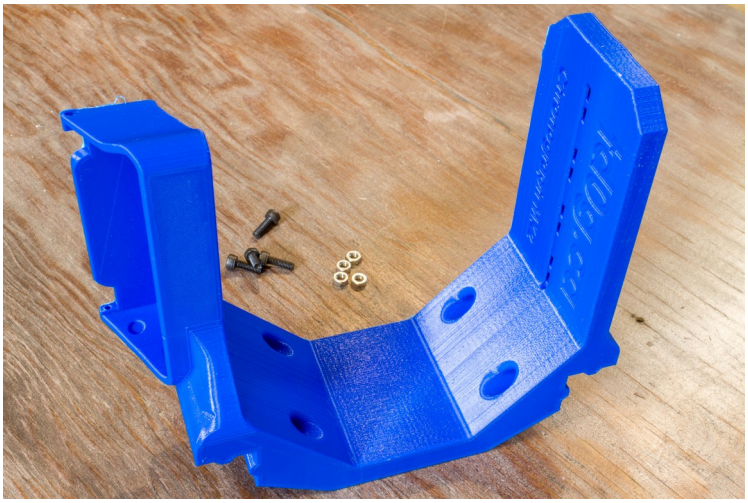

Figure 6: Gate and fasteners

13. Run a pair of 22-gauge wires through the hole in the **Gate** at the base of the emitter housing. The emitter side is wider and has a text inscription.

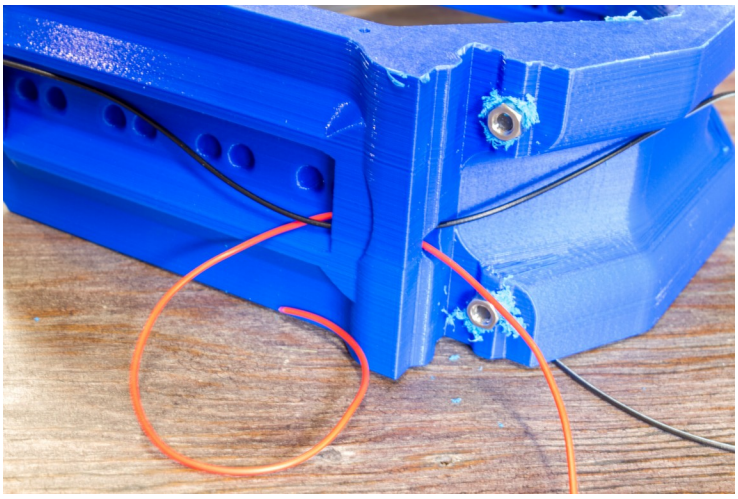

Figure 7: 22-gauge wires in emitter housing

14. Run three 22-gauge wires through the hole at the base of the sensor housing.

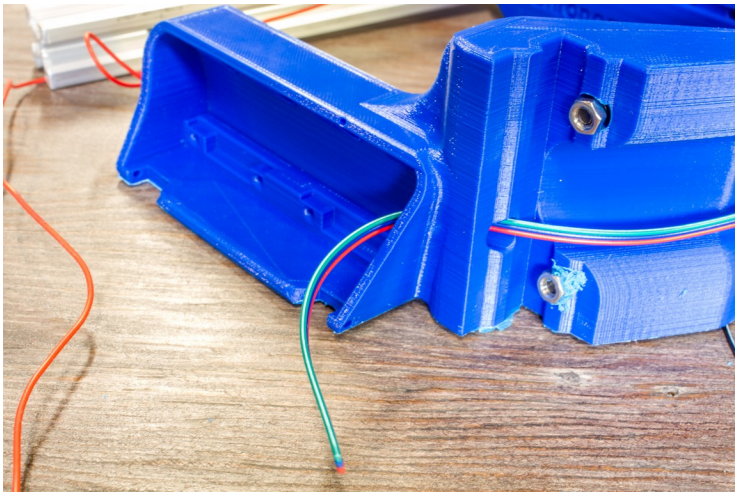

Figure 8: 22-gauge wires in sensor housing

15. Install the 2020 extrusion rails on the **Gate**. Make sure the Arduino mount is the right way up and installed on the same side as the sensors on the Gate (narrower side without text inscription). Also, make sure wires are situated in the top slot of the extrusion. Tighten the M4 screws on the gate.

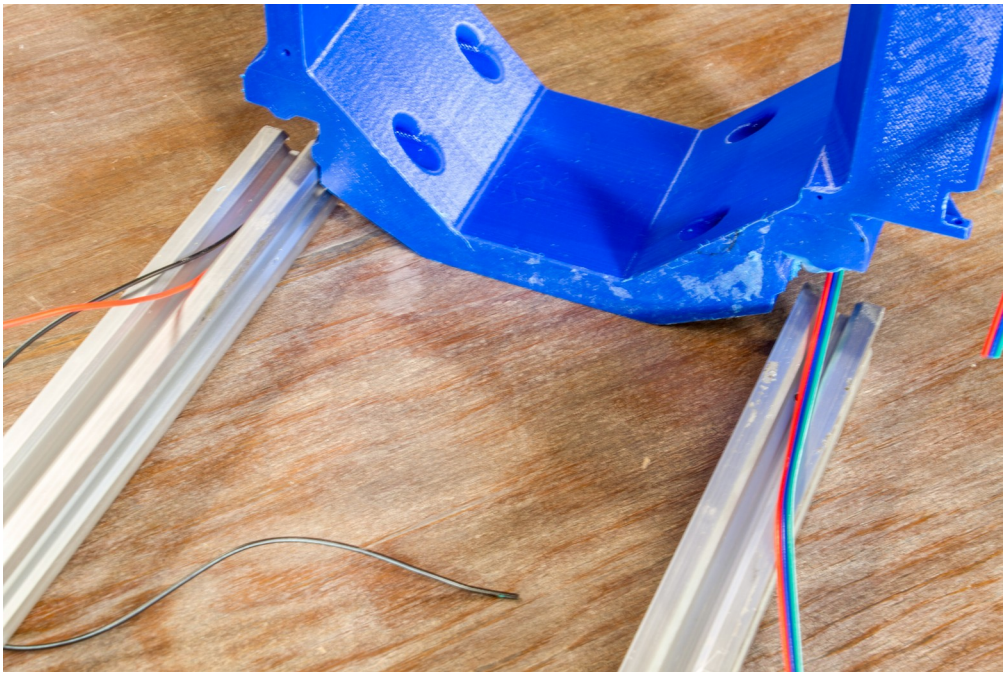

Figure 9: Preparing to install the 2020 extrusion rails (emitter on the left, sensor on the right)

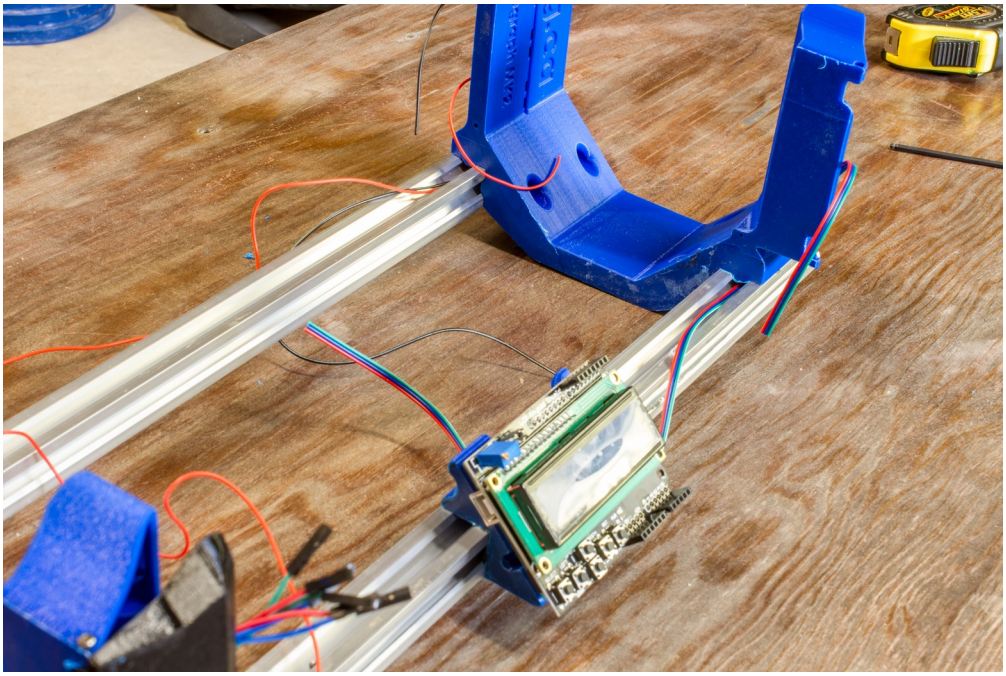

Figure 10: Extrusion installed. Note how the wires are routed.

16. Screw 3x 6mm x M2 screws into the side of the **Gate**.

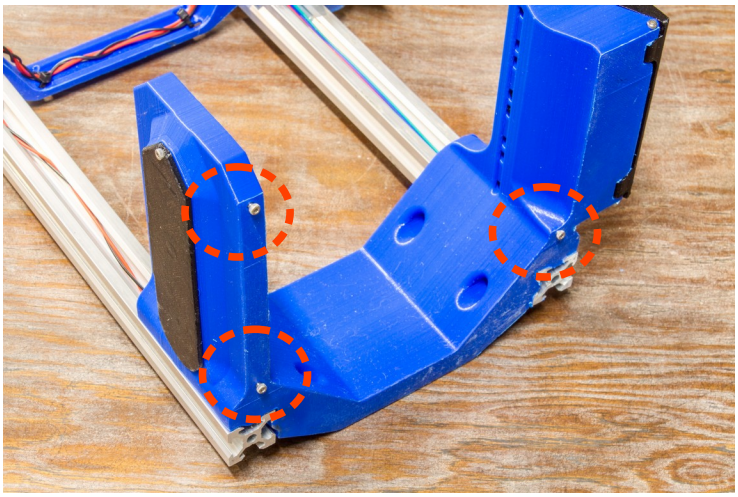

Figure 11: 22-gauge wires in sensor housing

17. Repeat for the other gate.

Emitters

18. Install four (single-height) or eight (double-height) LED's in the **Gate's** emitter housing. Orient the LED's with the anode (longer lead) on the right.

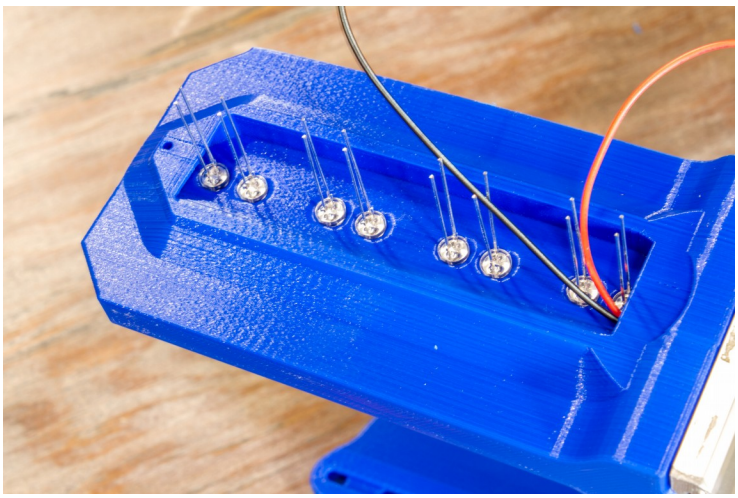

Figure 12: Emitter diodes installed. Note the longer leads on the right.

19. Solder the LED's in series (anode to cathode). Solder the wires to the anode of the top LED. Solder the other wire to the cathode of the bottom LED. Inspect the leads to make sure none are touching!

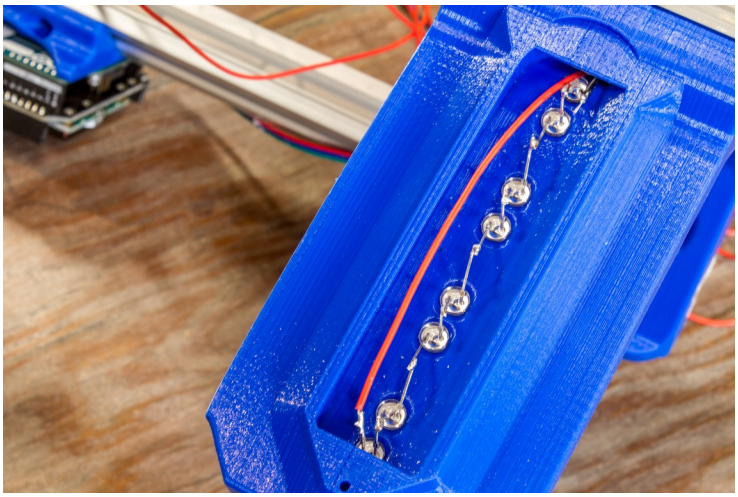

Figure 13: Removing insulation from 22AWG wire

20. A series resistor or current regulator **MUST** be installed on the LED circuit. Please see Appendix A for a guideline on selecting an appropriate resistor or regulator.
21. Install the E**mitter Cover** onto the emitter housing using a 6mm M2 screw.

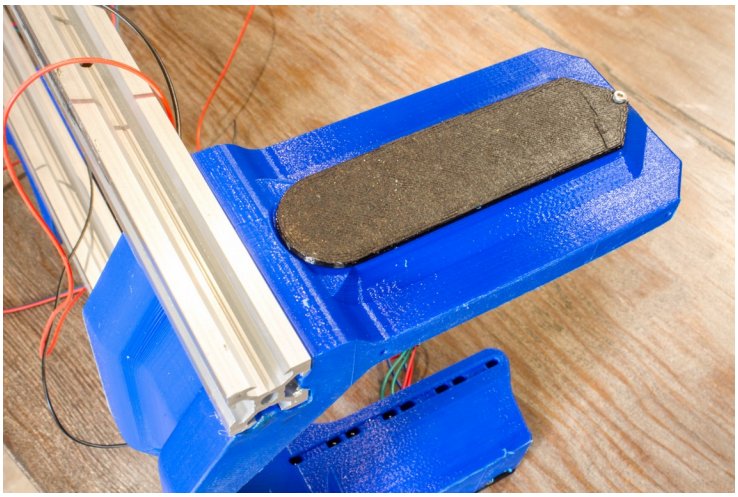

Figure 14: Emitter Cover installed

22. Repeat for the other **Gate**.

Sensors

23. Take three female-female jumper wires that are the same colour as the three wires in the emitter housing.

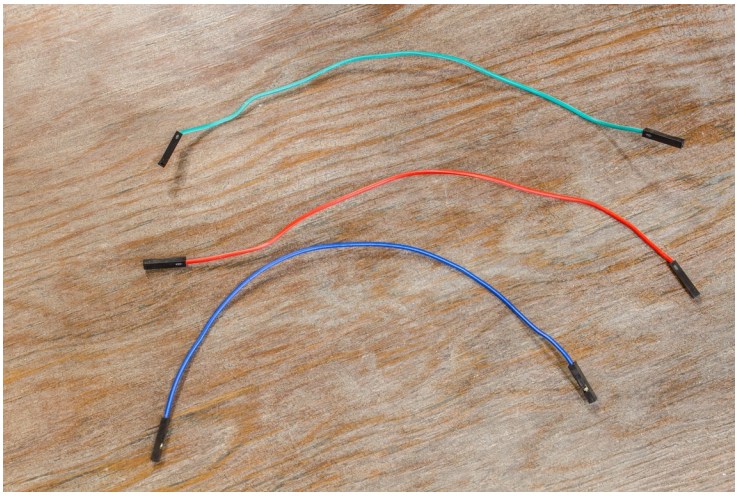

Figure 15: Three female-female jumper wires

24. Cut the jumpers in half.
    - If you are building a double-height sensor, then prepare them to be soldered together on the wires in the emitter housing.
    - If you are building a single-height sensor, prepare on half of the jumper to be soldered.

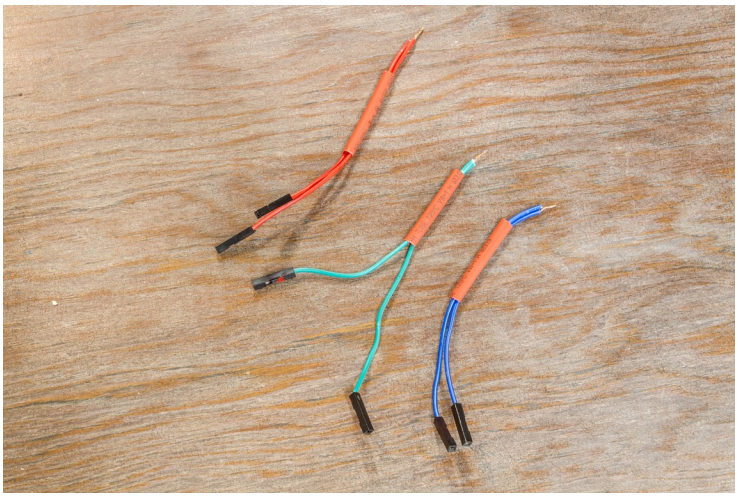

Figure 16: Jumper wires prepped for soldering (double-height sensor configuration)

25. Solder the jumpers onto the wires inside the emitter housing.

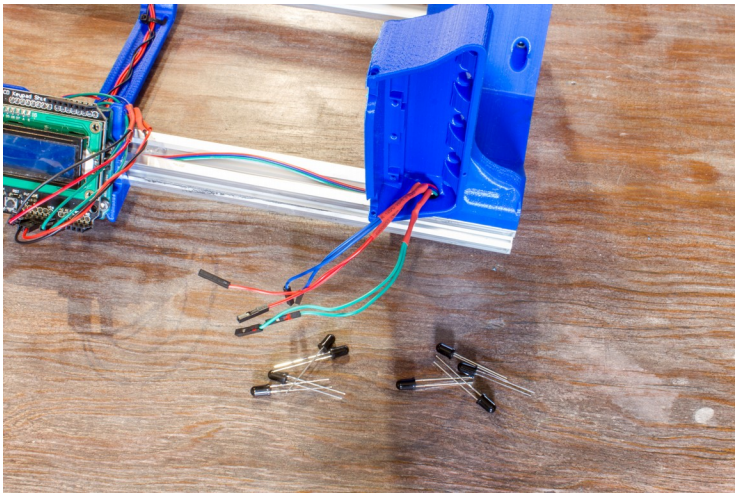

Figure 17: All three wires have two female Dupont connectors wired in parellel for a double-height sensor

- ***NOTE**: Steps 24 – 28 must be performed for each Light Gate board installed. The photos show two Light Gate boards installed.*

26. If the photodiodes aren't already installed on the Light Gate boards, place four (single-height sensor) or eight (double-height sensor) of them into the holes. Orient them with the anode (longer lead) toward the edge of the case.

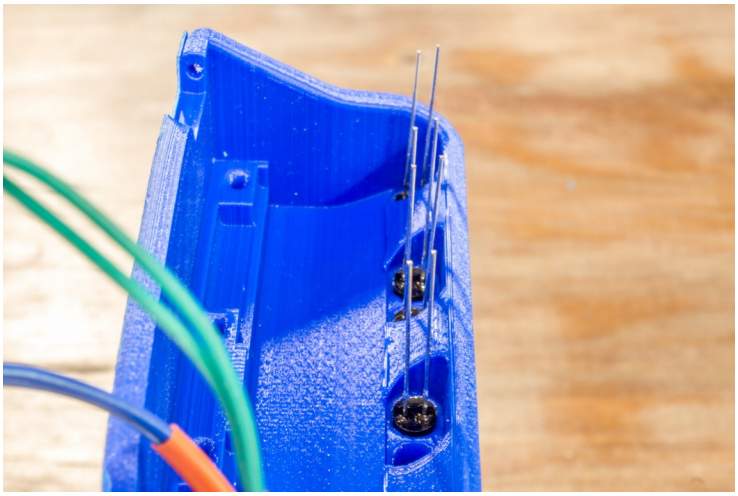

Figure 18: Photodiodes positioned

27. Loosely position the Light Gate board onto the photodiode leads.

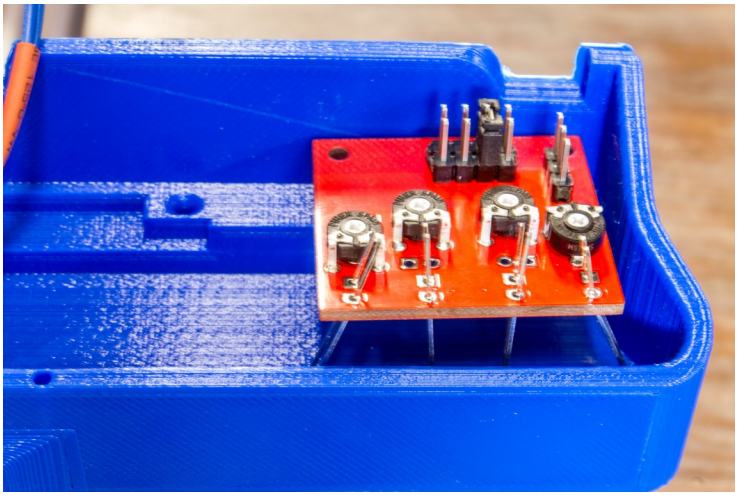

Figure 19: Light Gate board loosely installed

28. Bend the outer photodiode leads inward using a tool. The Light Gate board can then be positioned flat inside the housing.

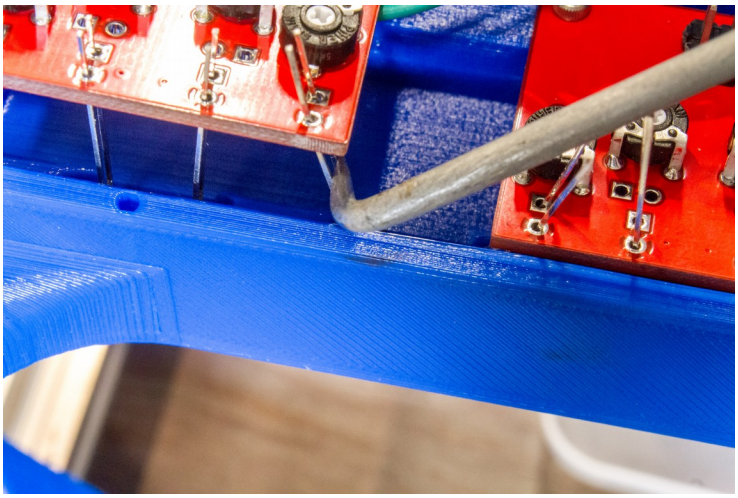

Figure 20: Outer photodiode leads are crooked

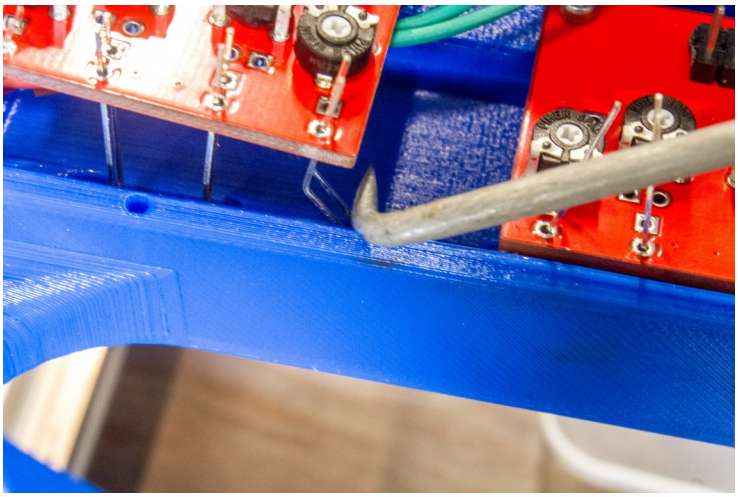

Figure 21: Photodiode leads are bent and the board can be positioned correctly

29. Secure the Light Gate boards with 2x 8mm x M2 screws per board.

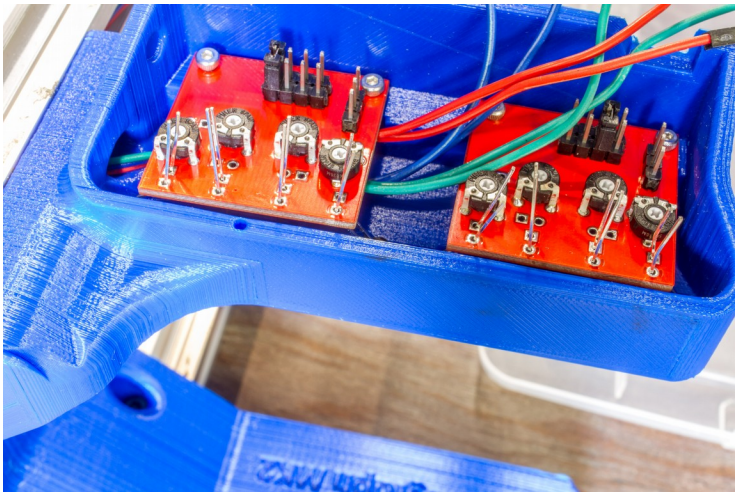

Figure 22: Light Gate boards secured with M2 screws

30. Check that the photodiodes are correctly positioned in their holes.

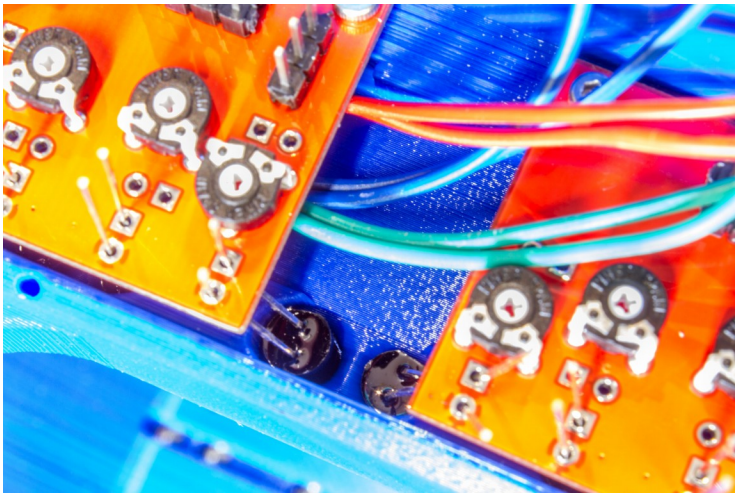

Figure 23: Photodiode is crooked

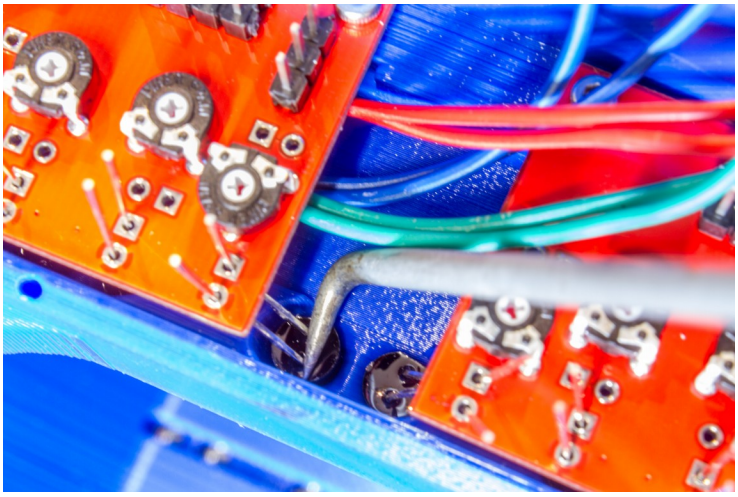

Figure 24: Photodiode is pushed in straight

31. Solder the photodiodes on the Light Gate boards and trim the leads.

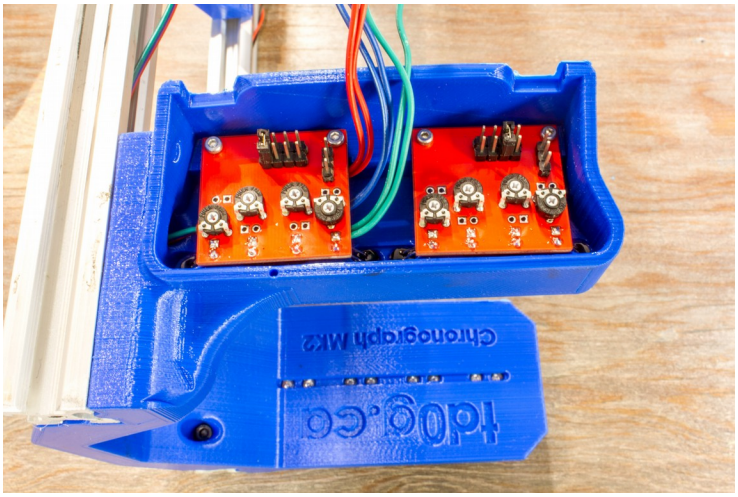

Figure 25: Photodiodes soldered and excess leads trimmed

32. Install the jumpers to the Light Gate boards in parallel.

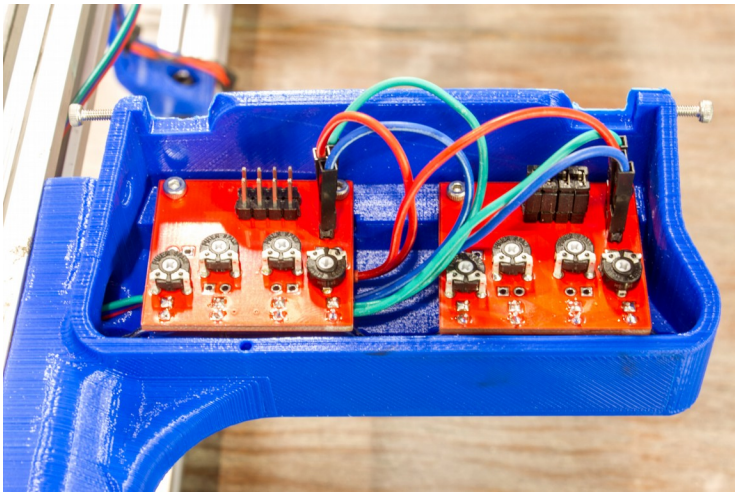

Figure 26: Removing insulation from 22AWG wire

33. Install the Emitter Cover onto the emitter housing using 2x 12mm x M2 screws. Begin screwing a 10mm x M2 screw into the front of the cover, but do not tighten. This screw is used for locking the cover closed.

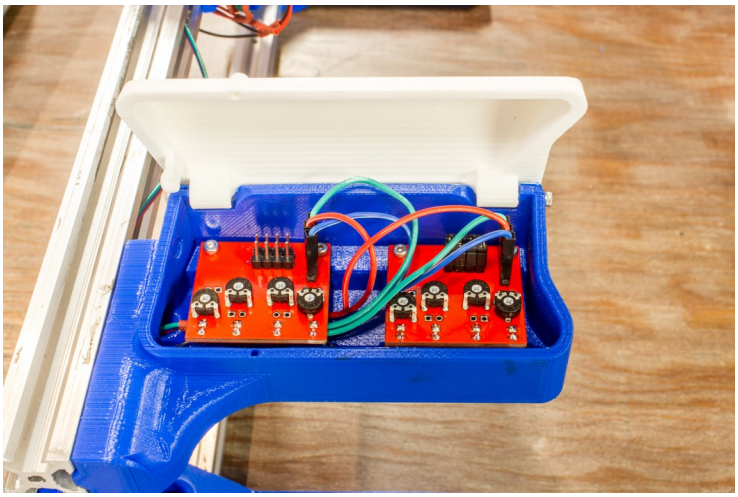

Figure 27: Boards wired up and jumpers installed on board on right – board on left still needs jumpers installed

34. Repeat for the other sensor.

Wiring It Up

35. Route the sensor wires through the holes on the top of the **Arduino Mount**.

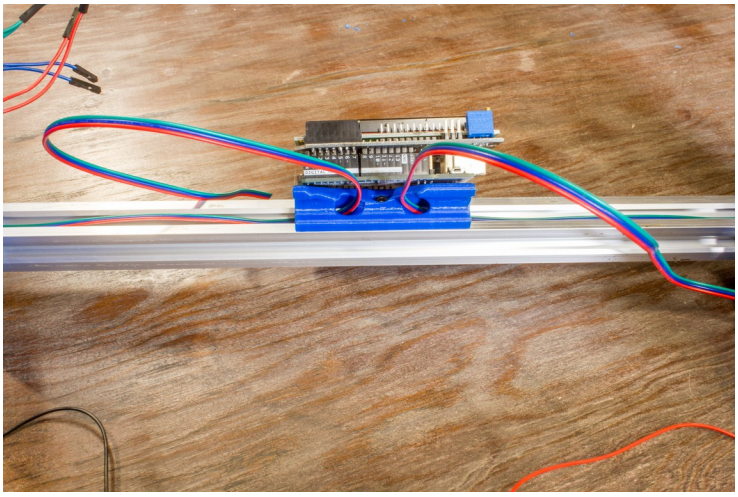

Figure 28: Emitter wires routed through Arduino Mount

36. Add male Dupont pins to the sensor output wires (so that they can be connected to the Arduino). Cut the V+ and GND wires and solder them together. See the following figure as a guide.

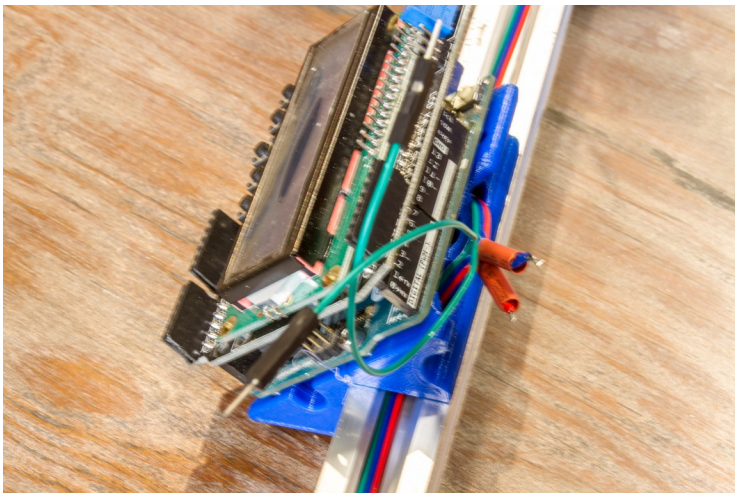

Figure 29: Male Dupont connectors on Signal wires. V+ and GND wires are connected and prepped for the jumper wire to be soldered.

37. Cut two male-male jumper wires in half (one red and one black). Solder them onto the ends of the V+ and GND wires so that they can be plugged into the Arduino's 5V and GND pins. Connect the Signal wires to pins A1 and A2. NOTE: Do NOT connect the V+ wire to the Vin pin – this may damage the Light Gate board!

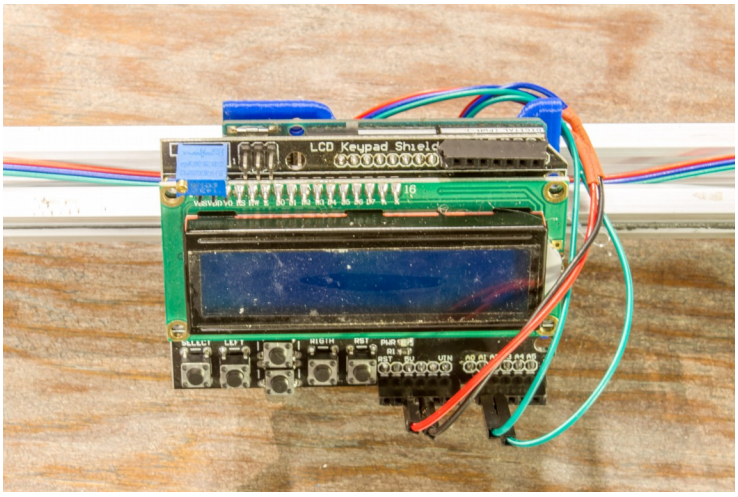

Figure 30: Sensors all wired up

38. Loosely install two zip-ties in the crossmember. Take the wires from the emitter housings and braid them so that they meet at the crossmember and are routed through the zip-ties.

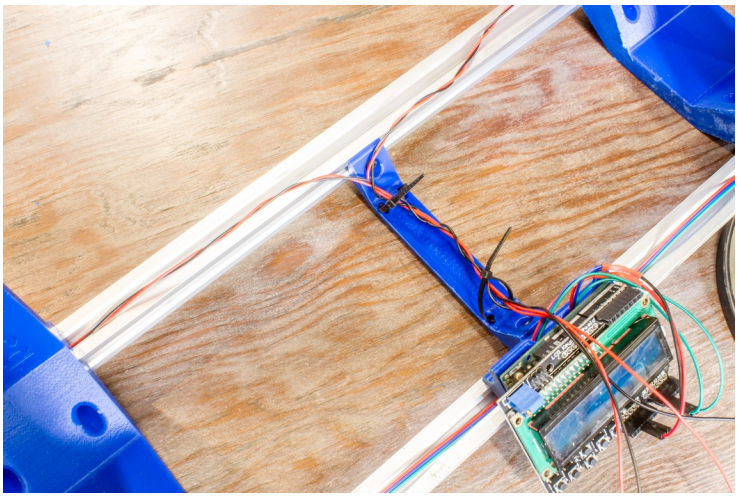

Figure 31: Emitter wiring loosely positioned

39. Use one more zip-tie to fix the wires where they meet. Tighten the zip-ties on the **Crossmember.**

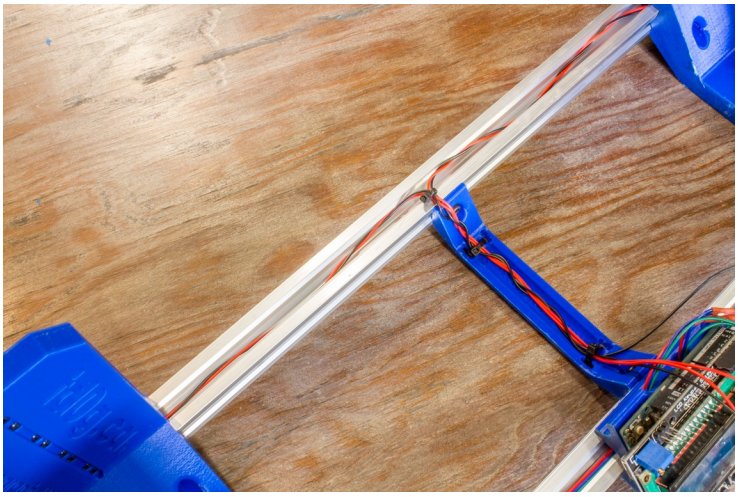

Figure 32: Emitter wiring secured with zip-ties

40. Connect the Positive and Negative wires in parellel and solder them to the other ends of the male-male jumper that was cut in half earlier. Connect to the Arduino's Vin and GND pins.

Calibrating

41. Make sure the BallisticChronographLCD firmware is installed.
42. Make sure all the jumpers are installed on the sensor boards.
43. Turn all of the potentiometers fully clockwise.
44. Power up the ballistic chronograph.
45. Start turning the first potentiometer counter-clockwise until the LCD display indicates less than 100. Then turn the potentiometer clockwise very slowly until the number returns to 100.
46. Repeat step 46 for all potentiometers.
47. Using a metronome app on your phone, set the metronome to 60 BPM.
48. Push the Right button on the LCD keypad.
49. Sync the metronome to the flashing LCD by changing the metronome's BPM for several seconds. Be sure to return the BPM to 60 when finished.
50. Observe the timing for at least 50 beats.
    - If the LCD flashes faster than the metronome, increase the calibration factor by pushing the Up button.

- If the lCD flashes slower than the metronome, decrease the calibration factor by pushing the Down button.
- If the LCD is synced with the metronome for 50 beats, press the Select button to save the calibration factor.

NOTE: This method of clock calibration works because a clock error of 0.1% causes 1 millisecond of lag per beat,. 50 millisconds of lag can be detected.

APPENDIX A – EMITTER CURRENT REGULATING

Two simple methods exist for powering the Chronograph:

- Battery (12V – 18V)
- Power Supply (12V – 18V, 1A)

Following are a few potential power supplies, possible current regulating circuits, and some notes.

Power Supply	Current Regulating Circuit	Notes
18V Power Tool Battery	4x 8.2-ohm resistors in series with LED’s	18V will cause the Arduino to reset if the LCD’s backlight is left on. It is fine if the backlight is turned off.

DONE!