

DIY Photometer Building Instructions

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Parts List

Final parts list:	Quantity	Price	Total price
TRIMMER 1K OHM 0.2W PC PIN TOP (Potentiometer)	4	\$ 0.40	\$ 1.60
15 Position Header Connector Through Hole	2	\$ 0.98	\$ 1.96
RES 1K OHM 1/4W 5% AXIAL	2	\$ 0.03	\$ 0.06
SWITCH TACTILE SPST-NO 0.05A 12V	2	\$ 0.23	\$ 0.46
16 Position Header Connector Through Hole	1	\$ 1.02	\$ 1.02
LCD MODULE 16X2 CHARACTER	1	\$ 9.65	\$ 9.65
LED BLUE CLEAR T-1 T/H	1	\$ 1.21	\$ 1.21
LED EMITTER VISIBLE 765NM 50MA RAD	1	\$ 2.98	\$ 2.98
LED GREEN CLEAR T-1 T/H	1	\$ 0.37	\$ 0.37
SENSOR OPT 470NM AMB SIDELOOKER	1	\$ 2.66	\$ 2.66
m-Cresol Purple sodium salt, 0.04% w/v aq. soln.	1	\$ 12.70	\$ 12.70
1-Gang 18 cu. in. Shallow New Work Electrical Box	1	\$ 3.37	\$ 3.37
Decora 1-Gang Wall Plate, White	1	\$ 0.65	\$ 0.65
Arduino Nano	1	\$ 8.99	\$ 8.99
Clear Liquid Sampling Sample Glass Bottles Vials Screwcap Capacity 10ml (0.3 Oz) Pack of 10	1	\$ 8.29	\$ 8.29
Custom PCB from OSH Park	0.33	\$ 19.50	\$ 6.44

See included Excel file for Digi-Key part numbers. Some pin header connectors and additional soldering may be necessary depending on where you source the LCD and Arduino Nano. You will also need a few feet of 20 gauge wire (it doesn't have to be exact) and electrical tape. Heat shrink wrap may be used in some areas for a cleaner aesthetic.

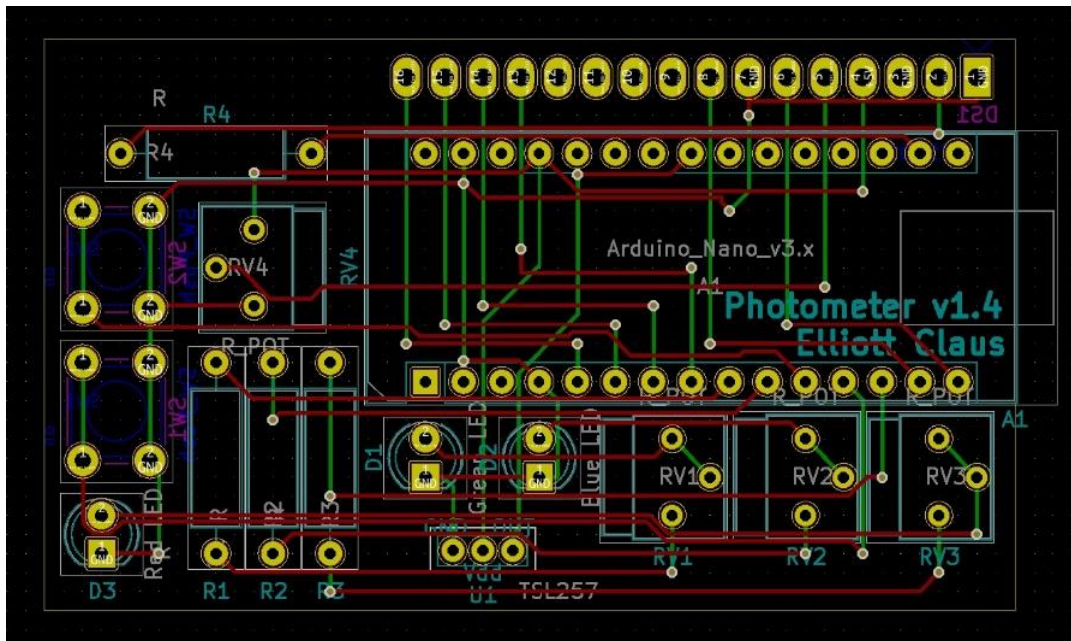
Ordering PCB

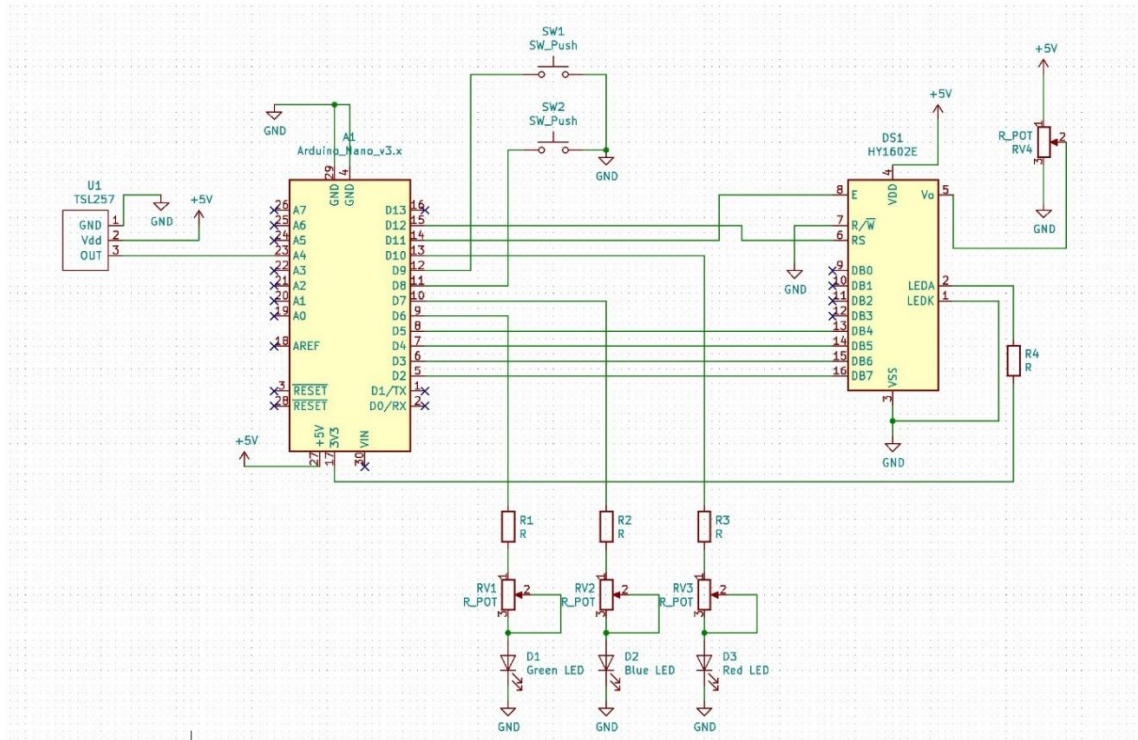
OSH Park makes ordering PCB's seamless with a KiCAD file. <https://oshpark.com/> Go to the website and upload the included KiCAD file. It should be a .kicad_pcb filetype. Ensure that the part was uploaded correctly, and then follow their steps to order it. OSH Park parts take between 2-3 weeks to arrive.

Soldering PCB

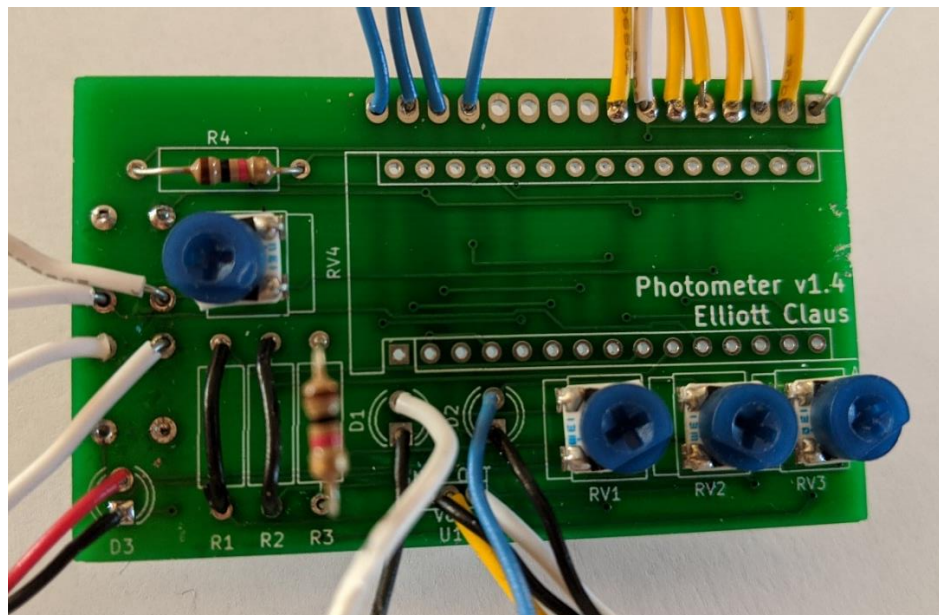
If you don't know how to solder, read the included soldering guide. If you are still unsure, search "how to solder" on YouTube. Soldering will be easier with a "helping hand" stand and a pair of needle nose pliers to help insert parts into the board.

The wiring diagram for the circuit and the PCB layout diagram are included below and as separate files.

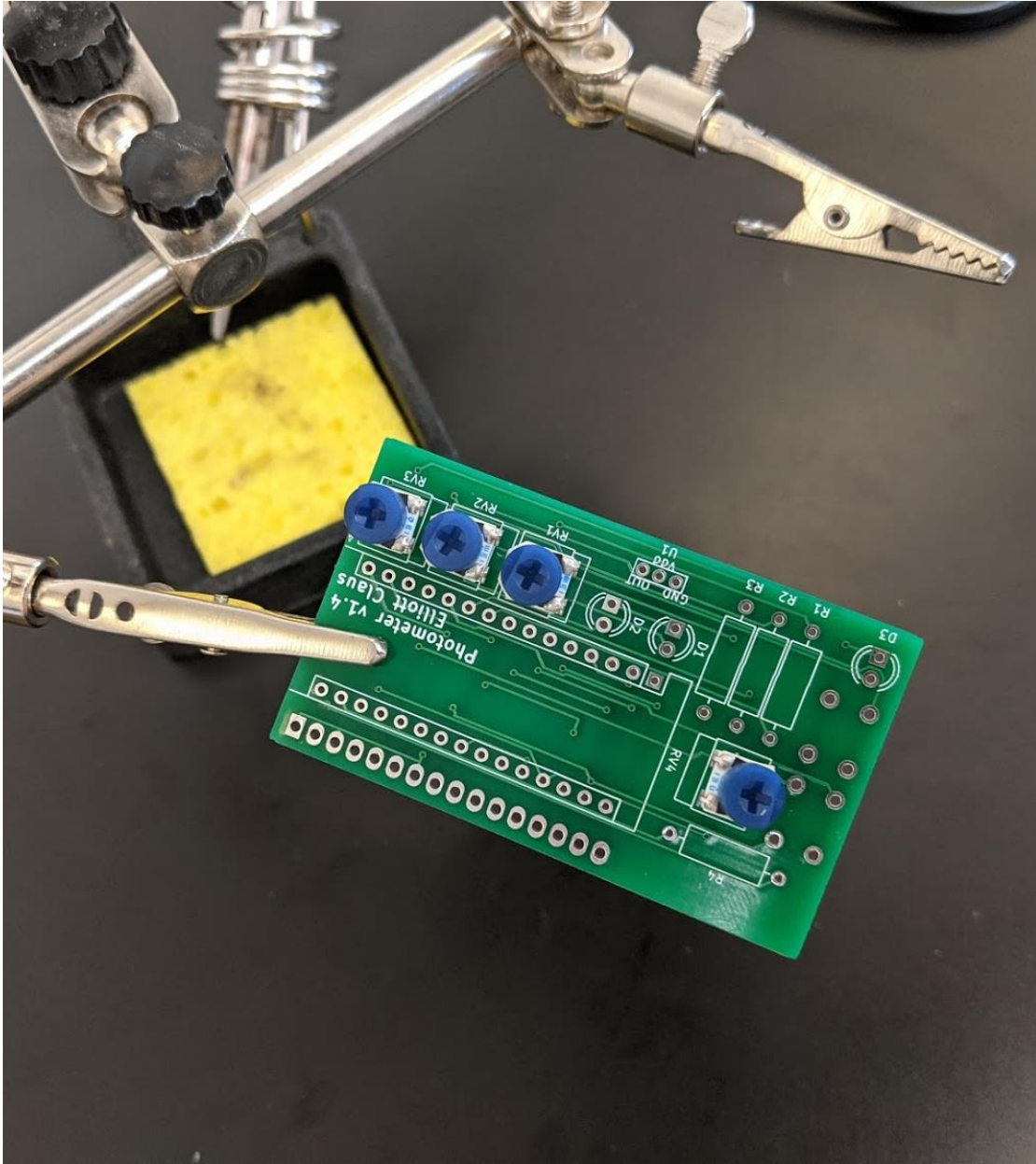




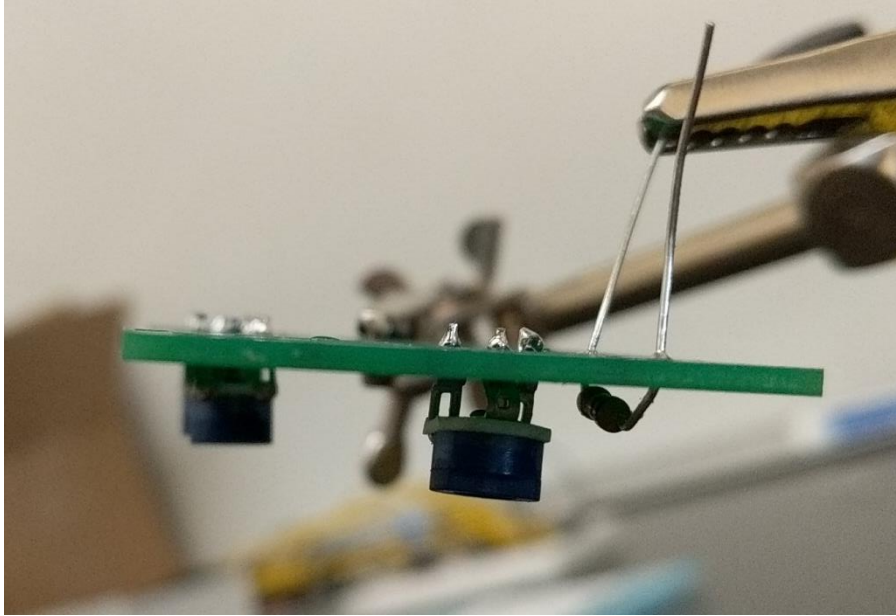
For reference, below is a photo of the completed board, minus the 15 position header connectors for the Arduino Nano. (Note: The solder connections for the wires are on the underside of the board in the photo below. You should solder on the top of the board for a better connection.)



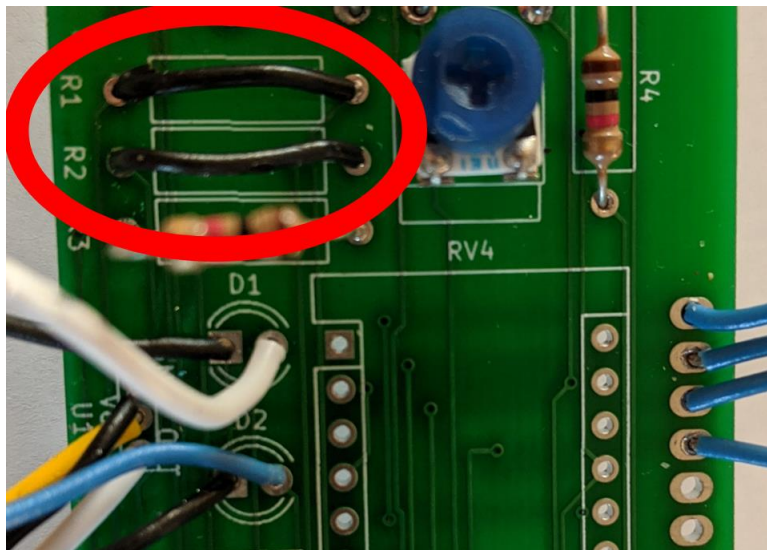
1) Start by installing the potentiometers in RV1 through RV4. Needle nose pliers will help with the installation. Solder them on the back side of the PCB. See photo below for correct placement:



2) Install the two 1K Ohm resistors, one in “R3” and one in “R4.” These can be installed oriented in either direction. See example photo below:

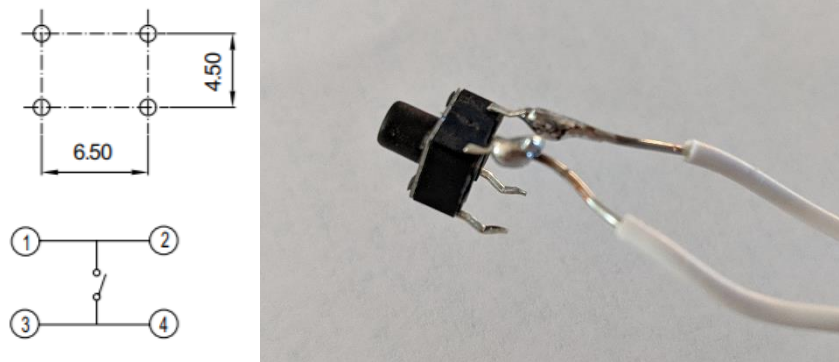


3) Make two jumper cables to connect “R1” and “R2” together.



4) Snip off the excess wire on the backside of the board.

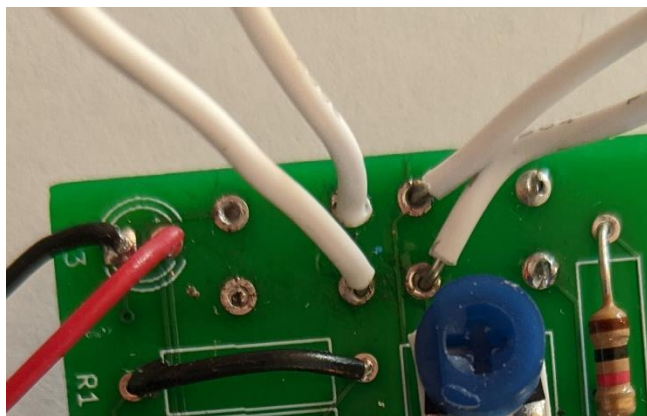
5) Solder the buttons to at least 2-5 in. of wire. Each button has four options, and there are two pairs which are electrically identical. See included diagram. This means you don't need to connect all four pins to the board, but you need to connect the correct two.



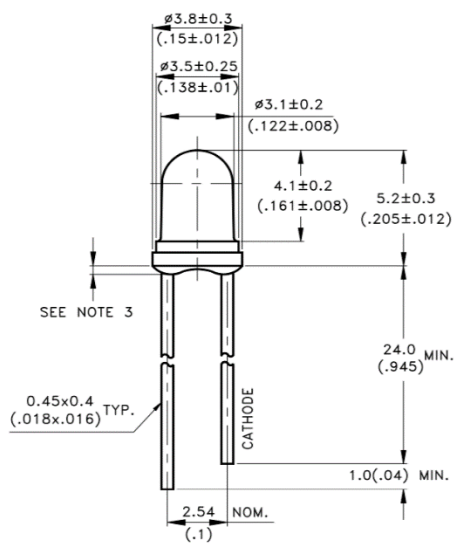
Physical diagram (in mm), wiring diagram underneath it. One wire needs to connect to (1) or (2) and the other to (3) or (4).

6) After soldering them, cover the exposed wires with electrical tape or heat shrink wrap.

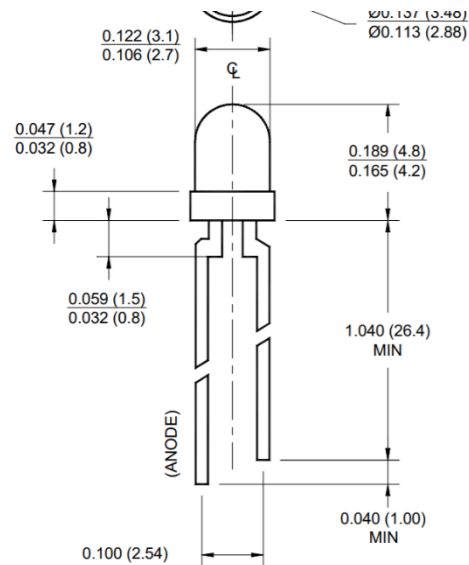
7) Once that is done, solder the other end of the wires to the PCB. Check the PCB diagram to ensure you put each one in its correct place. There are other ways to correctly wire the switches to the board, but this is an example of one way to do it. Snip off excess wires from the other side of the board.



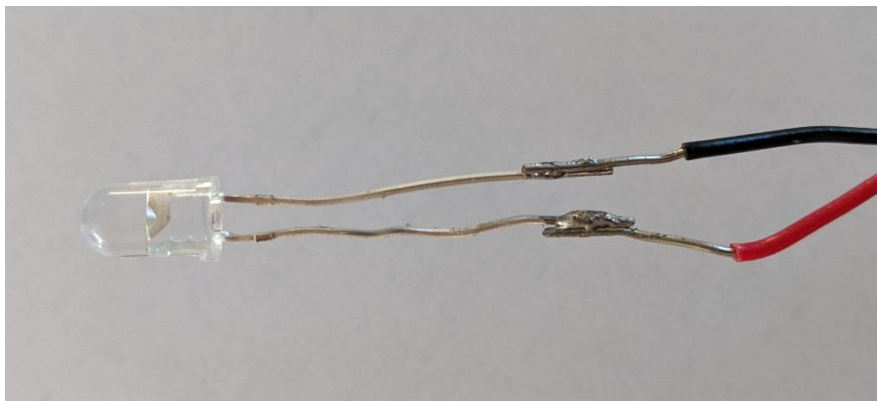
8) Solder the LEDs to wires at least 3 in. long. You need to keep track of the positive and negative sides of the LEDs. Solder the shorter wire to ground. In the diagrams below, you will note that the shorter side is negative (goes to ground) and the longer side is positive. One suggestion is to use a specific color of wire for ground on all the LEDs, as well as different colors for the positive wires to keep track of which color of LED is which. The red LED is the largest. The green and blue LEDs have different shapes. View the diagrams below to ensure you get them correct. (Anode is positive, cathode is ground for the diagrams.)



Green LED



Blue LED

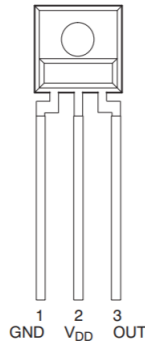


Red is anode, black is cathode in this image. (Not the prettiest soldering joints, but they work)

Cover exposed wire with electrical tape or heat shrink wrap.

9) Once you have the LEDs soldered to wires, solder them to the PCB. Attach green to D1, blue to D2, and red to D3. The square hole in D1-D3 is ground. Snip off the excess wire on the back side.

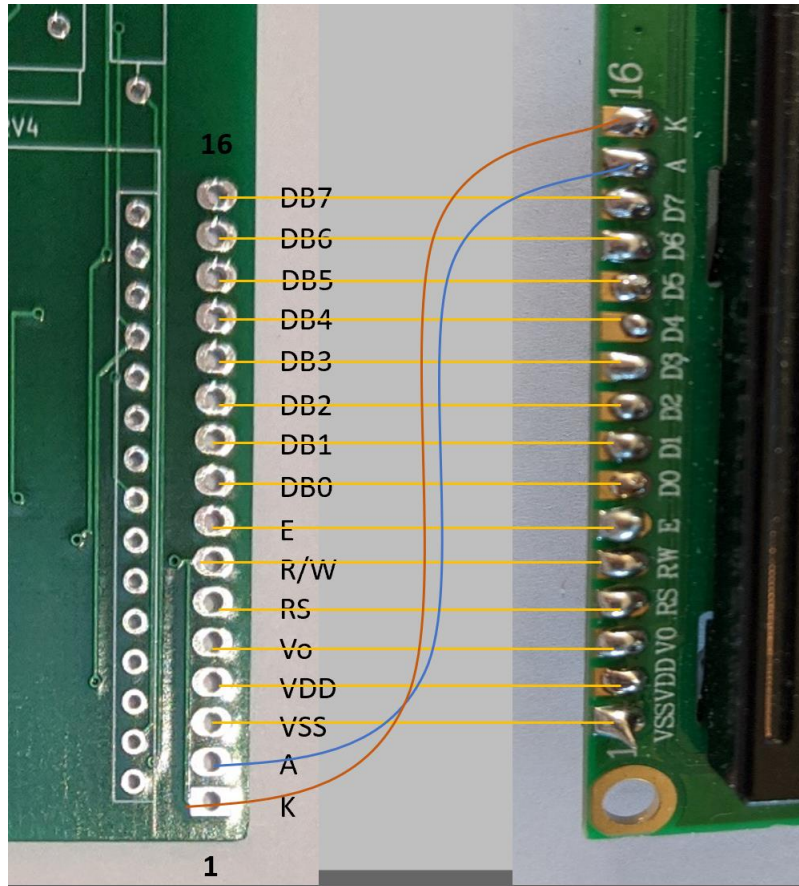
10) Solder 3-5 in. of the 20 gauge wire onto the Light-to-Voltage Converter. Cover wires individually with electrical tape or shrink wrap. Then solder wires to PCB at U1. Snip off excess wire.



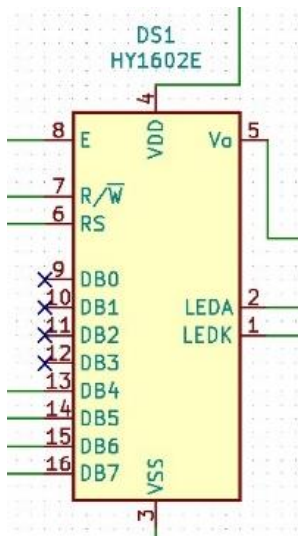
Front view of Light-to-Voltage Converter

11) Solder the two 15 Position Header Connectors for the Arduino Nano to the board. Plug it in to make sure it fits. Unplug it before soldering anything else.

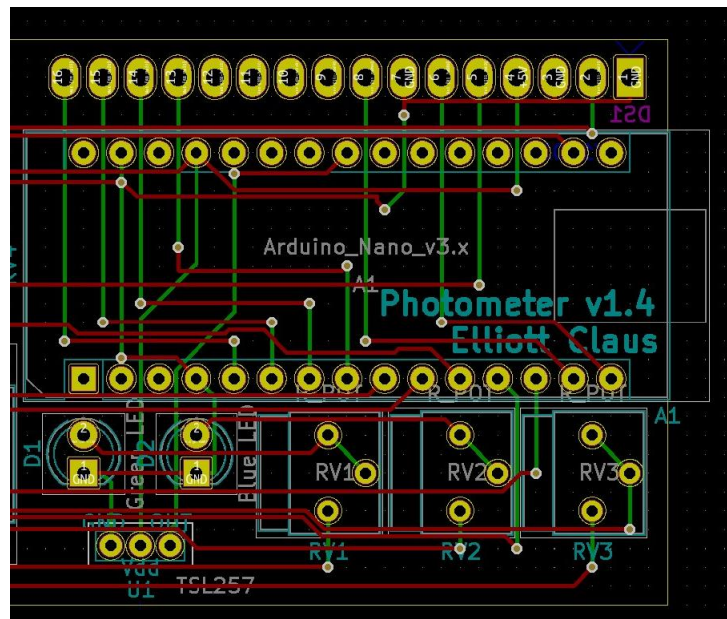
12) Install the pins for the 16x2 LCD. This step is crucial as the LCD screen's pins are in a different order than on the PCB. On the LCD panel A and K are pins 15 and 16, whereas in the PCB has them as pins 1 and 2. See photos below for more detail and information.



Above is an image of how the pins should eventually be connected. Left is PCB, right is LCD.

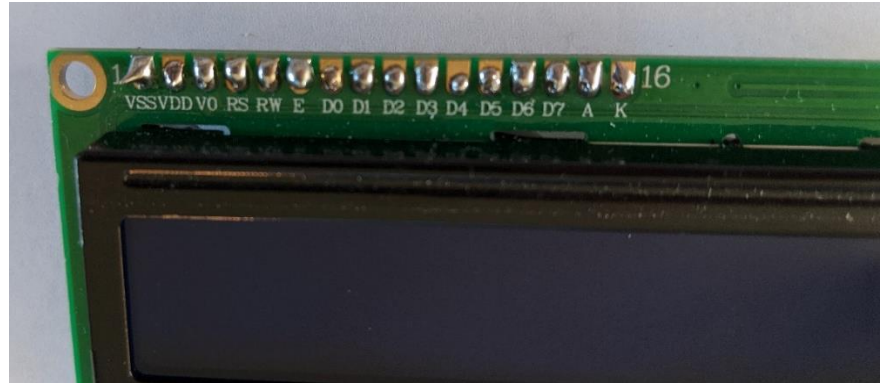


Pin order for the PCB.



Pin order on the PCB. Top row of pins goes from 16 to 1.

PIN NO.	SYMBOL
1	V _{SS}
2	V _{DD}
3	V ₀
4	RS
5	R/W
6	E
7~14	DB0~DB7
15	NC
16	NC



Pin order on specified LCD.

Pin order on example LCD.

Start by soldering sixteen 2-3 in. wires to the 16 Position Header Connector. On one end, two wires should be 1-2 inches longer than the other fourteen (so that they can cross and plug in on the other side of the pins). Once you have the 16 Position Header Connector, then solder the other end of the wires to the board. Make sure the pin labels on the LCD match the labels on the pin diagram for the PCB.

Code to Arduino

Download and install Arduino from their website.

<https://www.arduino.cc/en/main/software>

Open the included .ino file. See photo below if you are confused where the buttons and menus are.

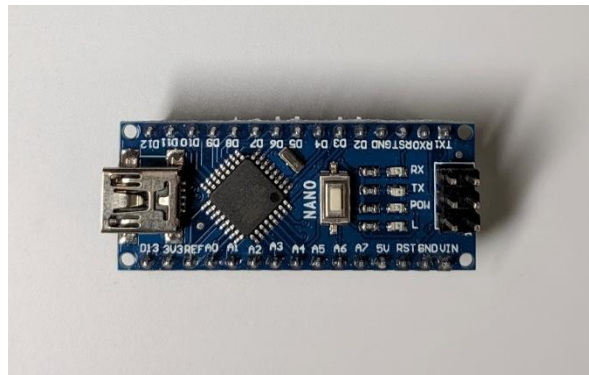
Go to the Tools drop down menu.

Change “Board:” to Arduino Nano.

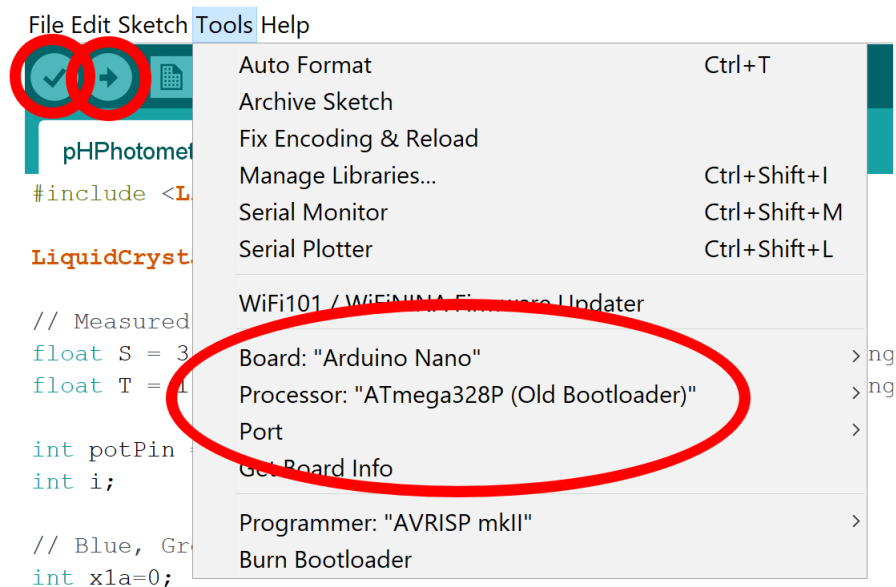
Change “Processor:” to ATmega328P (or whichever model of Arduino Nano you bought).

Change “Port” to the USB port that your Nano is plugged in to. (Note: If you don’t know which port it is plugged into, choose one, and then go on to the next step. If it is the wrong one, try a different one.)

In the top left, click the check mark button. It will say “Verify” when you mouse over it. There should be no errors. Then click the (→) button that says “Upload”. This will upload the code to the Arduino Nano.



Above is a picture of the Arduino Nano. Below is the Arduino Tools menu with the buttons mentioned highlighted.



Testing Before Assembly

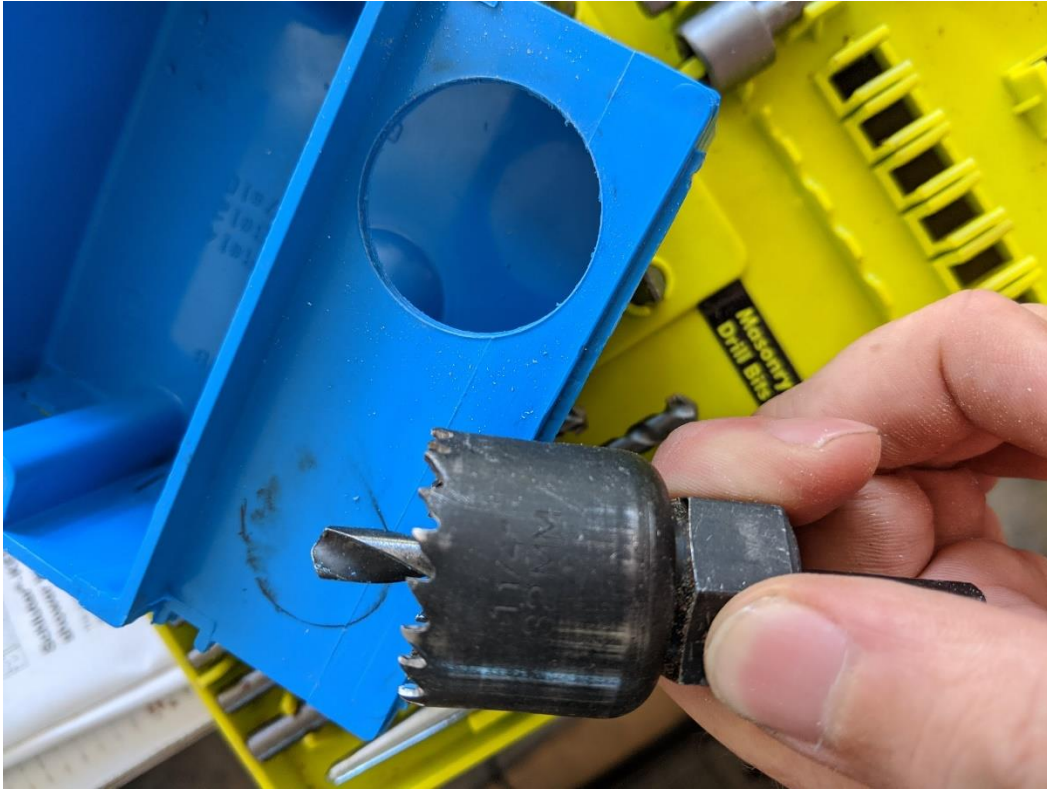
Plug the screen into its connector and the Arduino Nano into the PCB. Use a screwdriver to turn the potentiometer, RV4, until text is visible on the screen.

Turn all three LED potentiometers, RV1 to RV3, to be around the middle, not at either extreme.

Press each button to make sure it works. Each LED should turn on for two seconds independently, in the order of blue, green, and then red. Then the screen should show the readings. Do not worry if the Light-to-Voltage Converter does not register the LEDs, you will fix this by finishing the assembly.

Electrical Box Modification

Drill a 1 ¼ in. hole into the top of the box.

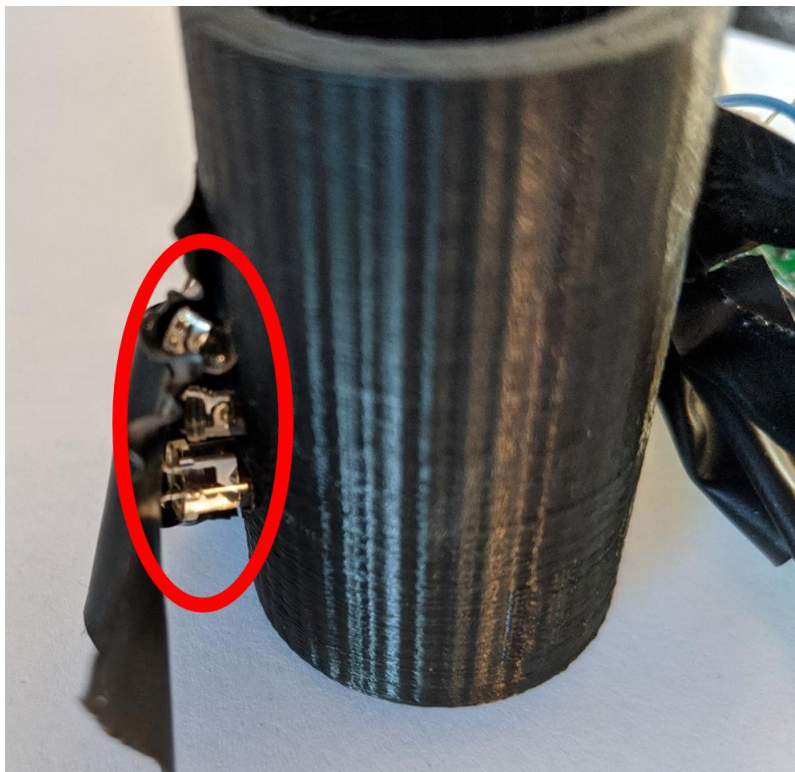


Use pliers to open the top right port on the bottom edge to insert the USB cable. See photo below. (Extra holes were made to test different configurations.)



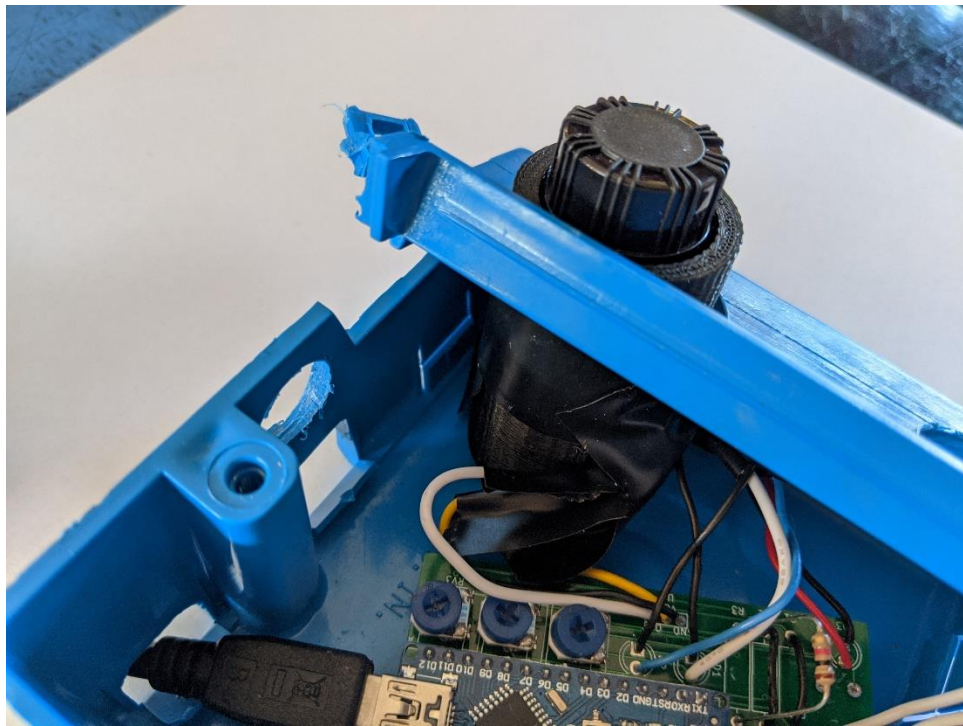
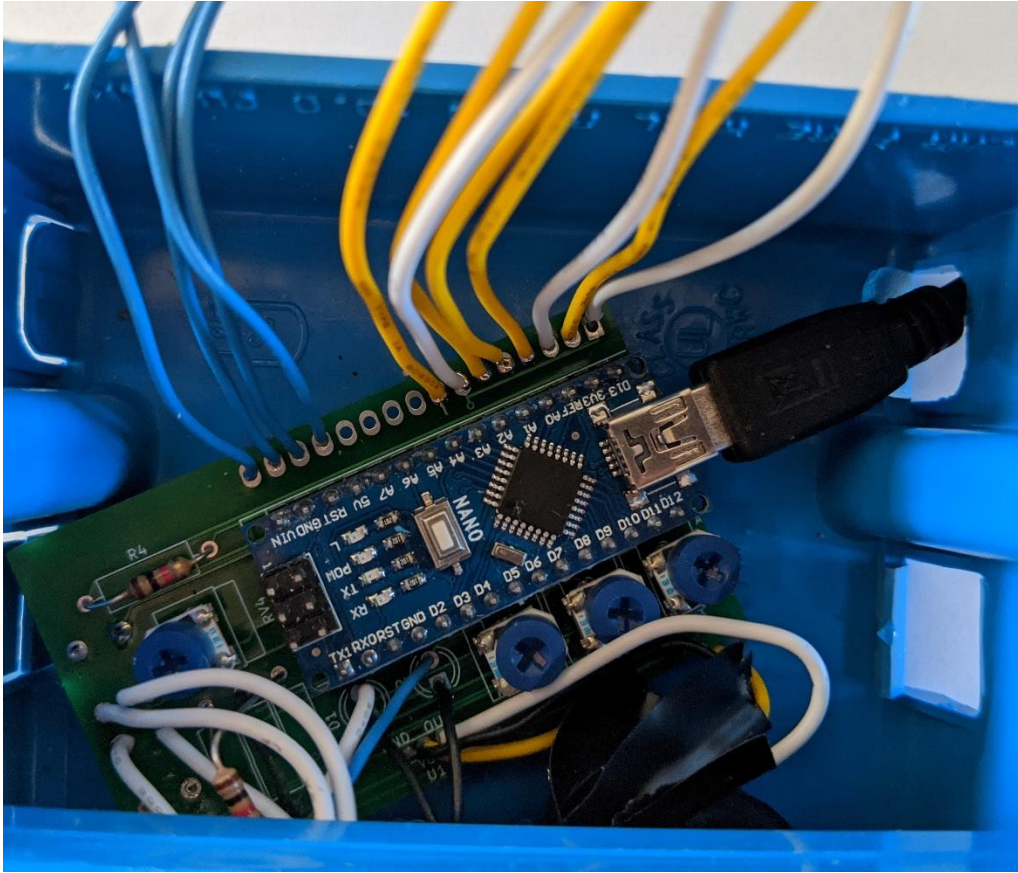
Assembly

Use electrical tape to secure the LEDs into the holes in the vial holder. Place a vial in the vial holder so the LEDs can't be pushed too far inside. Next, tape the Light-to-Voltage Converter in place on the opposite side from the LEDs, on the outside. It does not need to be pretty, but there should be no exposed wires touching, none of the components should come out when pulled gently, and there should be no place for light to leak in from the outside (other than the top if there is no vial in place).

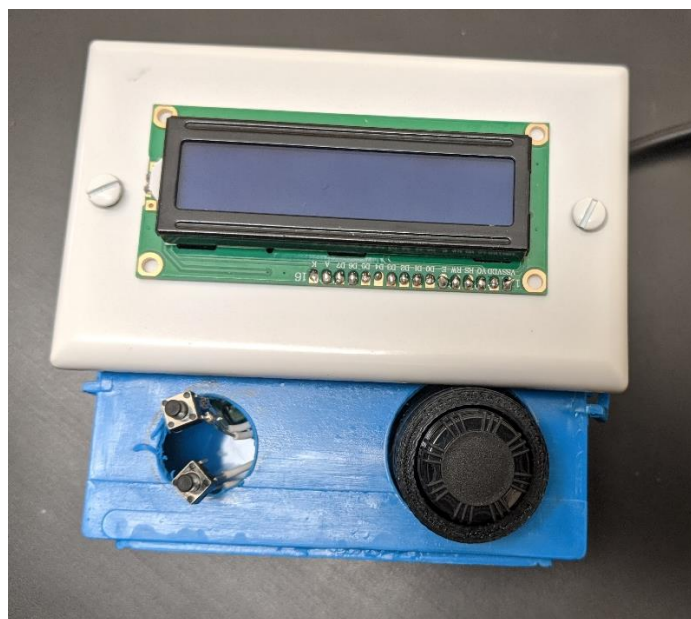


This image shows the LEDs right before they are taped in place.

Next, click together the Arduino Nano onto the PCB. Unplug the LCD from its connector and place the remaining assembly into the electrical box. Then plug the USB cable into the Arduino Nano through the side of the box.



Then you can close and latch the lid to keep the vial holder in place. Next screw (at least one side, if both screws don't line up) the electrical outlet cover in place. Make sure the buttons and 16 Position Header Connector are sticking out, and then plug the LCD in. Final assembly should look something like the image below. You can add an additional hole for the buttons if you want.



Use a white paint pen or a knife to mark a line on the vial holder and on each lid for the 10 ml vials. This will ensure that you always insert the vials into the photometer in the same orientation/direction to minimize variable distortion from the glass.

Final Calibration

Test to make sure all the buttons, LEDs, and LCD are correctly functioning. Put in a sample vial with water in it (no dye). Ensure that none of the blank measurements read 1020 or within 10 of that number. If any of them are, adjust the potentiometers so the corresponding numbers are lower. Use a screwdriver to turn RV1, 2, or 3 to adjust the blank absorbance

number. All three absorbances should be between 200 and 950. (Maybe shoot to have the blank measurements around 700, though it may not make any significant difference, as long as they are between 200 and 950.)



All three LEDs will not turn on at the same time, but this is an example image of them inside the vial holder.

Congratulations! Your photometer is complete. Now you are ready to follow the DIY Photometer Sampling Procedure.