OPENWATER – A CITIZEN SCIENCE MONITORING PLATFORM
Turbidity Meter Assembly Instructions

1 INTRODUCTION

These instructions describe how to build the third-generation version of a research quality, relatively low-cost, open-source instrument for measurement of water turbidity in environmental samples. Refer to the R&D Report for a complete description of the design and validation of the instrument. Operating instructions are provided in the SOP. The completed device is shown in Figure 1.

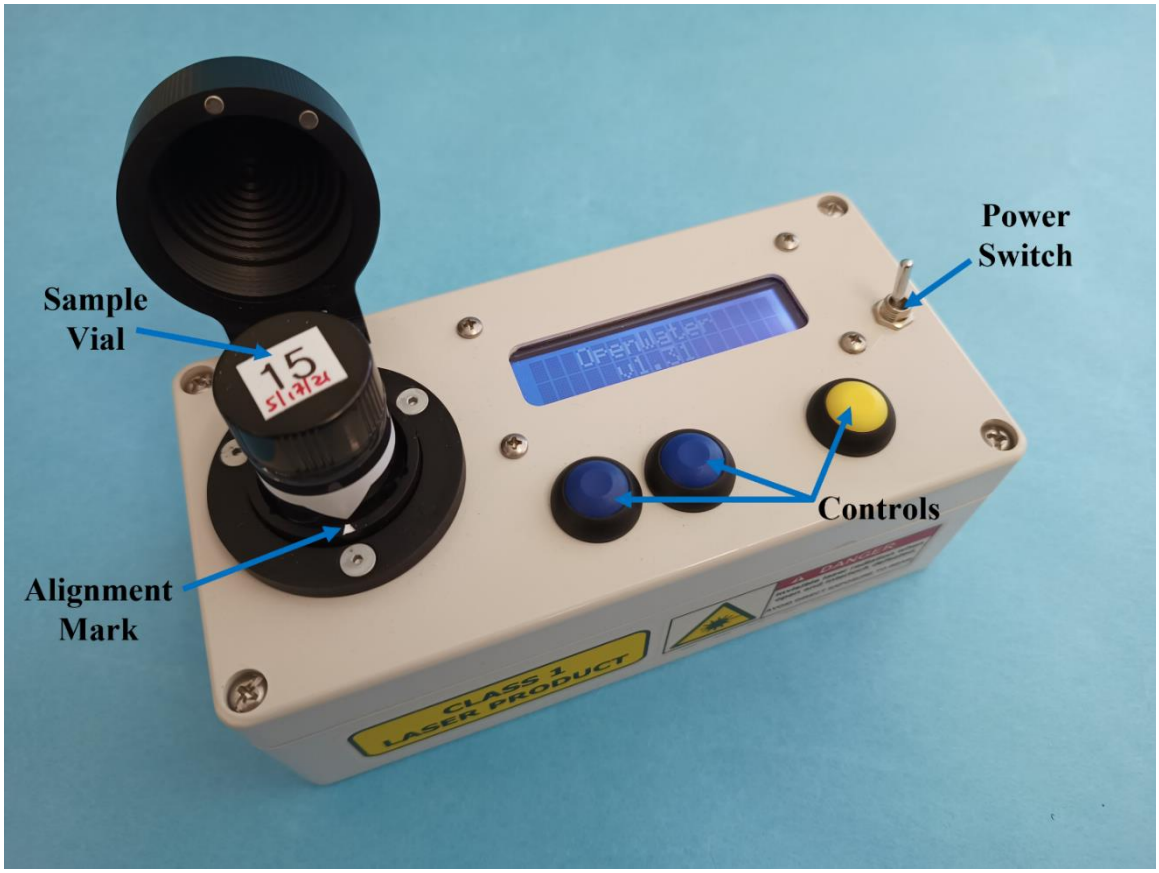

Figure 1. OpenWater Open-Source Turbidity Meter (3rd-Generation Design)

2 STEP 1: GATHER MATERIALS

The Bill of Materials lists everything that needs to be purchased to build the turbidity meter. To best reproduce the performance reported here, have the 3 components of the sample measurement well made by stereolithography (SLA), which is a high-fidelity method of 3D printing. For future development, other fabrication methods may be explored.

3 STEP 2: FABRICATION

3.1 ENCLOSURE

1. Machine the lid of the plastic case (Rose Enclosures, 090816060), following the drawing provided in the Mechanical folder and in Figure 2.

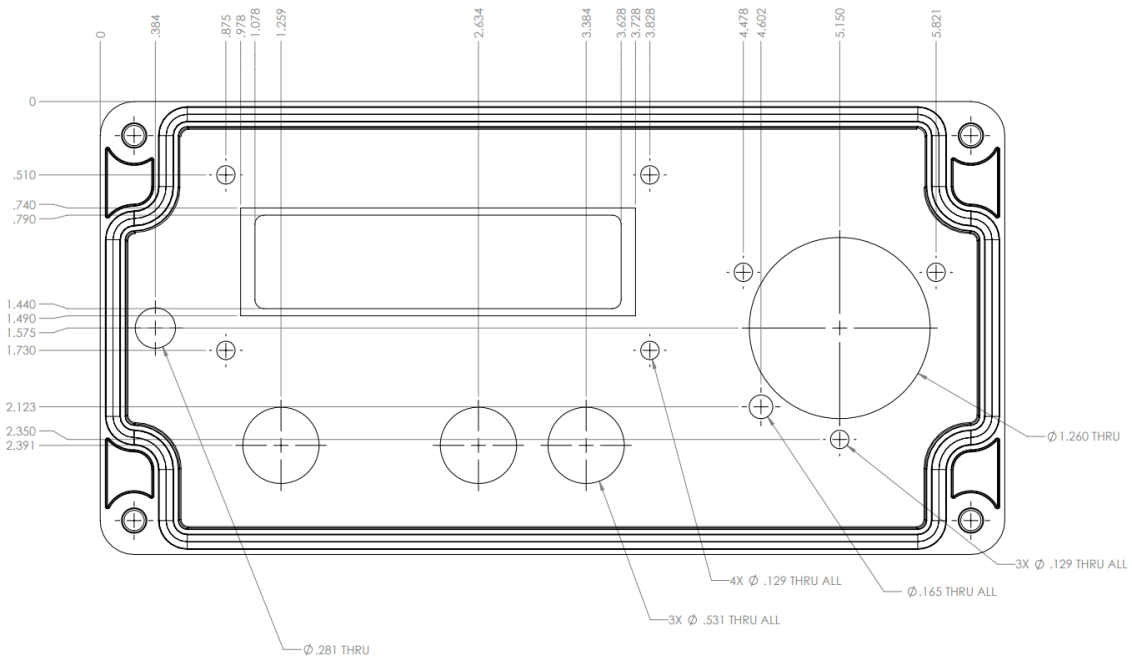

Figure 2. Modifications to the Commercial Enclosure

2. Cut a rectangular piece of 1/16-in. (1.6 mm) thick acrylic or polycarbonate sheet to 2.719 x 0.719 in. (69.1 x 18.3 mm). Round off the corners and glue the window to the case from the inside. The completed lid is shown in Figure 3.

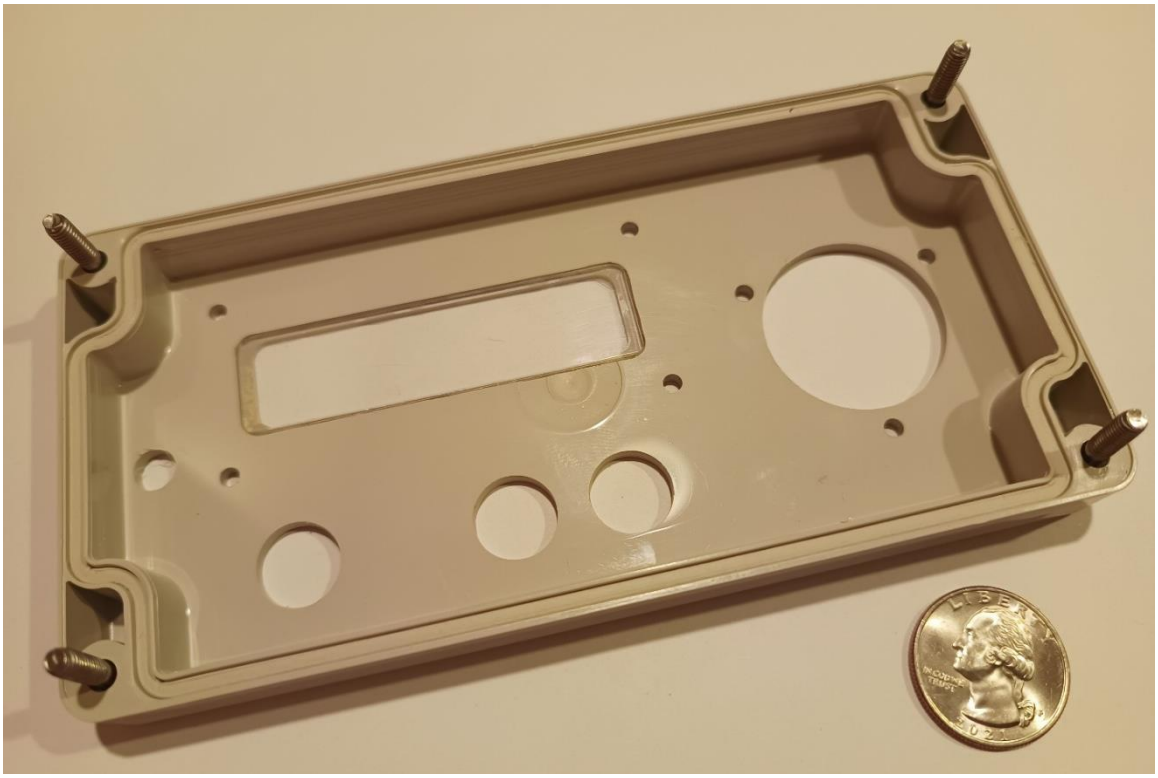

Figure 3. Machined Case Lid Assembled with Acrylic Window

3.2 ELECTRONICS

WARNING! Invisible laser radiation can cause eye damage. Avoid exposure to the beam.

The vertical cavity surface-emitting laser (VCSEL) produces **invisible** radiation at 850 nm. If the laser is operated with a current in excess of the recommended maximum (i.e., in an overcurrent failure mode at 30 mA) it will produce class 3B laser radiation. Class 3B devices have beams that are normally hazardous when a direct exposure occurs within Nominal Ocular Hazard Distance (NOHD). The IEC 60825-1 laser safety standard specifies an NOHD of several meters for class 3B devices.

WARNING! Do not energize the laser outside of an enclosure.

Do not operate the laser with more than 12 mA of current. Refer to the manufacturer data sheet and Application Note 221 in the Electronics folder for more information.

1. The laser control subsystem (Figure 4) is composed of the laser (OPV332, TT Electronics), current source (LM317 voltage regulator and 118-ohm ½-watt resistor), reed switch safety interlock (MS-210-3-1-0300, PIC GmbH), and transistor interface to the microcontroller (2N7000).

IMPORTANT! The reed switch interlock is critical to the safe operation of the instrument.

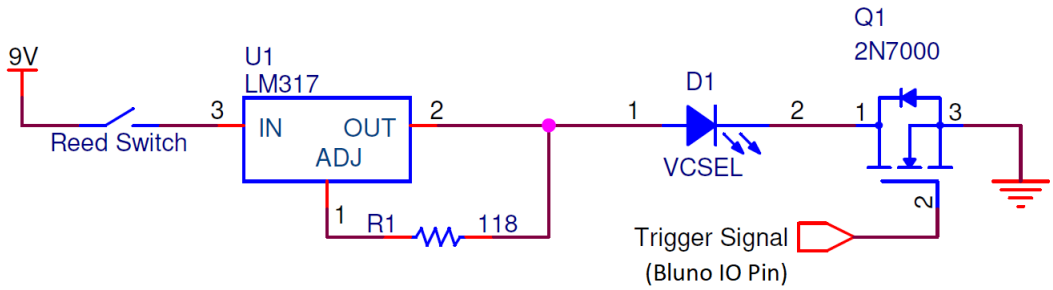

Figure 4. Laser Control Circuit Including Safety Interlock Reed Switch

Assemble the components using 26 AWG electrical wire, as shown in Figure 5. The distance between the pin connectors and the reed switch should be approximately 6.5 in. (165 mm). Terminate the microcontroller connection wires with square pin connectors. Insulate solder connections with heat-shrink tubing and cover the MOSFET and current source with an additional heat-shrink tubing jacket.

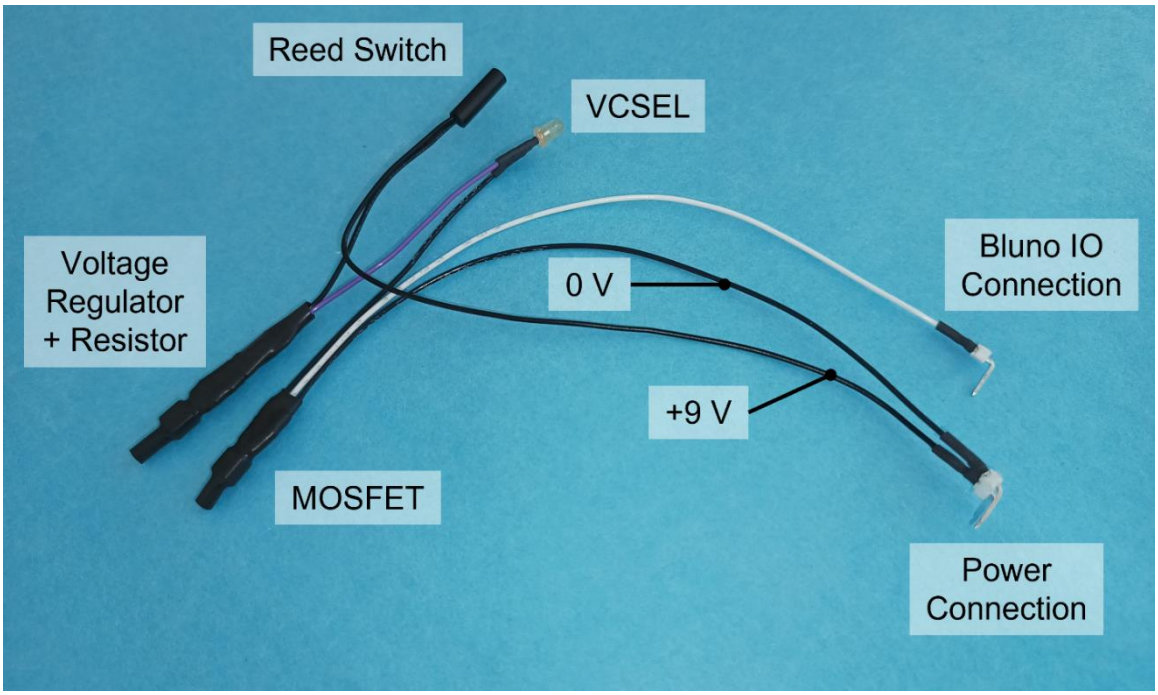

Figure 5. Assembled Laser Control Circuit

2. The light-to-frequency converter (TSL237, AMS) only requires one 0.1 µF decoupling capacitor connected across the power supply (refer to the data sheet in the Electronics folder). Solder a surface mount capacitor (e.g., TPSD107K010T0150V, Kyocera AVX) between pins 1 (GND) and 2 (V_{DD}) of the converter, close to the body of the package (Figure 6). Space the capacitor far enough away from the plastic device package that

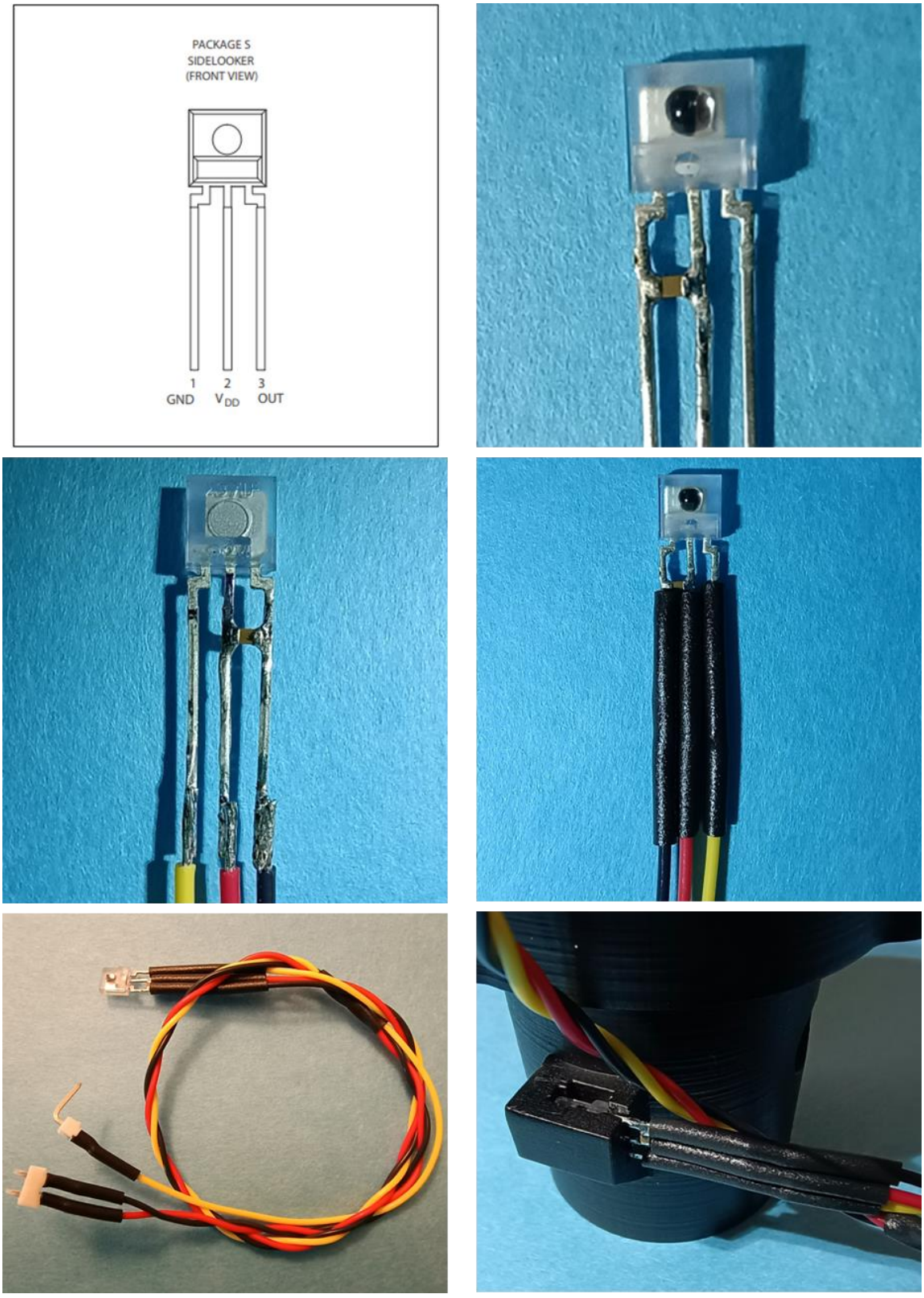

Figure 6. Light Sensor Circuit

it will not interfere with installation of the sensor into the housing in the Sample Well. Connect 6 in. (150 mm) of 26 AWG electrical wire to each pin and terminate the wires with square pin connectors. Insulate solder connections with heat-shrink tubing and cover the LTF pins and capacitor with an additional heat-shrink tubing jacket.

3. The LCD shield (772, Adafruit) is supplied as a kit, including on-board pushbuttons for LCD control (Figure 7). The assembly instructions are in the Electronics folder or online at adafruit-16x2-character-lcd-plus-keypad-for-raspberry-pi.pdf. Since the OpenWater meter has front panel buttons, the supplied pushbuttons do not need to be used. Instead, connect 26 AWG jumpers as shown in Figure 8, for connection to the case buttons in Step 4.4.3.

Figure 7. LCD Shield Completed Following Adafruit Instructions, with On-board Buttons

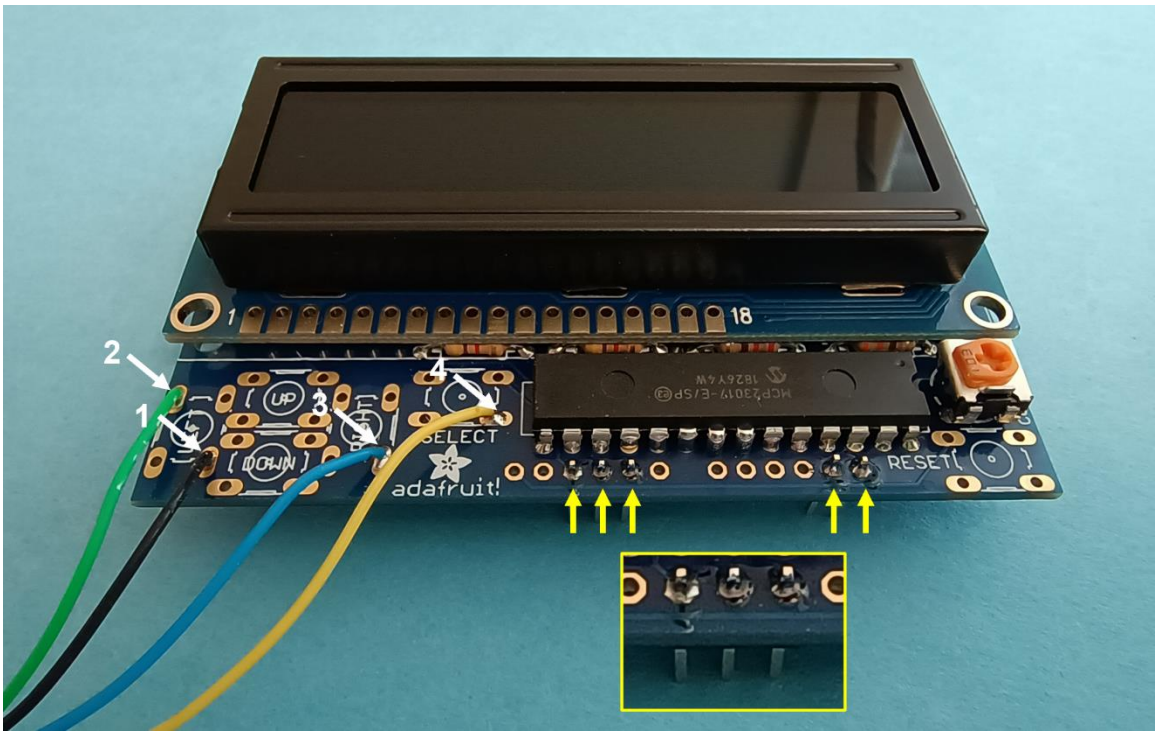

Figure 8. LCD Shield Assembly Modified for OpenWater, with Jumper Wires Installed.

4. The battery holder (FIT0141, DFRobot) is supplied with a power jack that will fit the power connector of the Bluno microcontroller. Insert the toggle switch (M2011SD3W01, NKK Switches) into the positive wire of the power cable. Optionally, inline 2-pin connectors can be installed to simplify battery disconnection (Figure 9).

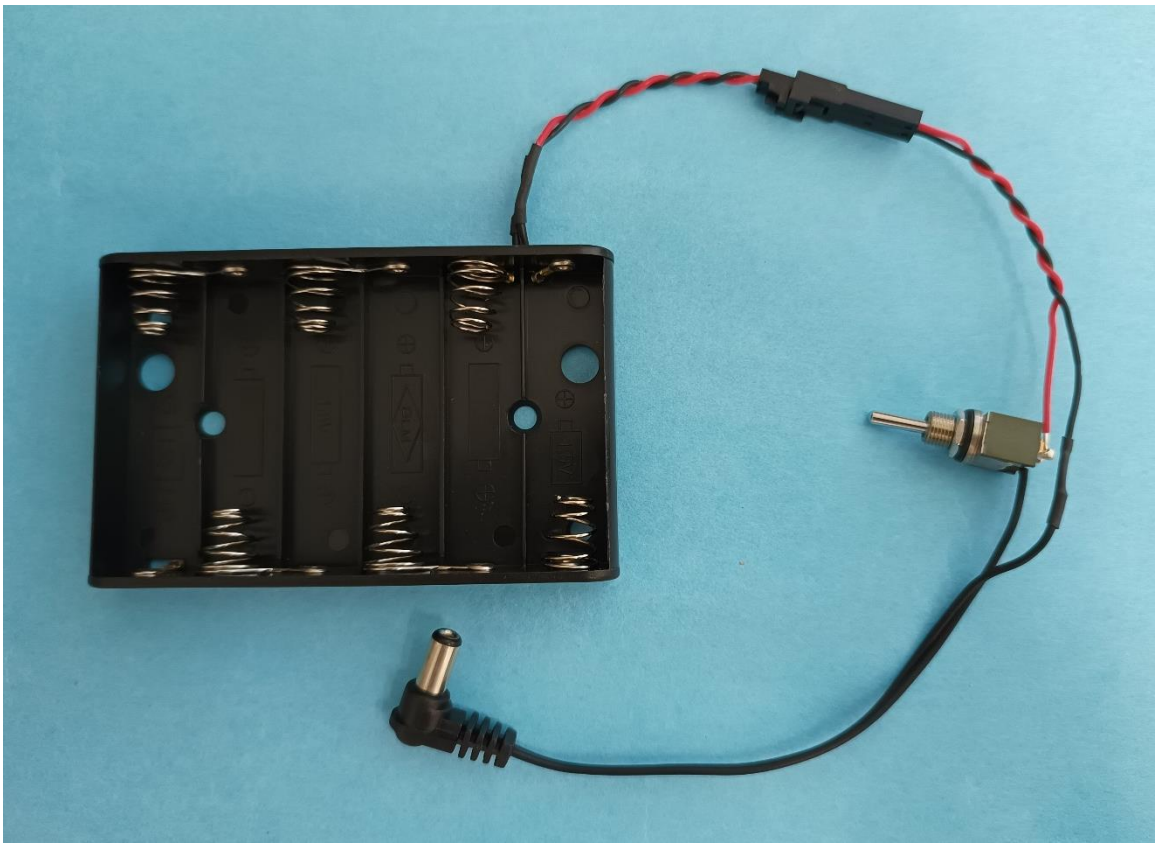

Figure 9. Battery Holder Assembly

4 STEP 3: PROGRAMMING & ASSEMBLY

4.1 BLUNO PROGRAMMING

1. If necessary, install the Arduino IDE on your computer.
2. Install the LCD Shield Library and Time Library (found in the Firmware folder) in the IDE.
3. Open the OpenWater-LCD-Firmware-v1.31.ino sketch in the IDE.
4. Using a USB cable, plug the Bluno into the computer.
5. In the IDE, select the correct port and device model.
6. Upload the sketch to the Bluno.
7. Follow the instructions in the DFRobot Bluetooth User Guide (in the Firmware folder) to rename the Bluetooth device using the "AT + NAME=" command. This will make it easier to identify your device when connecting via Bluetooth.

4.2 SAMPLE MEASUREMENT WELL

1. Press-fit three brass 4-40 threaded inserts into the mounting bosses of the Sample Well. Press-fit a brass 6-32 threaded insert into the spring-plunger boss in the sidewall of the Sample Well.

2. Thread the spring plunger into the boss in the sidewall of the Sample Well. Apply a dab of whiteout to the outer end of the plunger on one side (near the socket head) to make spring adjustments easier.

3. Press-fit two 1/8-in. diameter x 3/16-in. long magnets into the two holes in the rim of the Sample Well Lid. If they are loose, apply a drop of adhesive into the holes before pushing the magnets in, and allow to cure fully.

4. Place the Sample Well Hinge on the outside of the Case lid, and the Sample Well on the inside of the lid, each centered on the large round opening. Use three 4-40 x 1/2-in. flat-head screws to secure the three parts together, with the hinge closest to the top edge of the lid.

5. Assemble the Sample Well Hinge and Sample Well Lid, using the 1/8-in. x 1-in. dowel pin. If the pin is loose, apply a drop of adhesive to the bore of one side of the Sample Well Lid before assembly (push the dowel rod in from the opposite side, to avoid spreading adhesive into the bore of the Sample Well Hinge).

6. Slot the light-to-frequency sensor into the housing of the Sample Well, with the lens of the sensor facing inwards towards the center of the Well. Note that the capacitor will need to be attached correctly for the package to fit in the slot. Wrap the sensor and housing with black electrical tape to ensure a light-tight seal.

7. Push the VCSEL into the round counterbored hole in the sidewall, making sure it is completely seated in the housing. Apply a drop of adhesive over the joint between the VCSEL package and the housing to prevent it from shaking loose.

8. Cut two 2-in. long pieces of PTFE cord stock and insert them in the vertical grooves on the inner wall of the Sample Well.

9. Slide a sample vial into the Sample Well. The vial should slide down the two PTFE inserts, with the spring plunger gently pressing the vial against them. Adjust the spring pressure by screwing the body of the plunger in or out of the boss, until the vial is just barely retained when turned upside down (be careful not to drop the glass vial).

4.3 CASE BASE

1. Cut a 2-in. long piece of the loop side of 1-1/2-in. adhesive-backed Velcro strip. Install the material on the sidewall of the case on the upper left side.

2. Install the battery holder into the case base, in the upper right corner, using double-sided tape or adhesive.

4.4 CASE LID

1. Install the toggle switch into the hole on the far right-hand side of the case lid, with the "On" position oriented upwards (Figure 10).

2. Install the two blue push-button switches into the holes in the bottom-center of the case lid. Install the yellow push-button switch into the remaining hole (Figure 10).

Figure 10. Front Panel Controls of the OpenWater Turbidity Meter

3. Connect one terminal of each push-button switch together in series using 26 AWG wire. Connect one end of the series to the LCD shield using the black wire (1) in Figure 8. Connect the remaining terminal of the 'Up" button to the green wire (2), the "Down" button to the blue wire (3), and the "Select" button to the yellow wire (4) on the shield.

4. Using four 4-40 x 1/4-in. Phillips-head screws, install the four 3/8-in. long hex standoffs to the inside of the case lid around the perimeter of the window. Install the LCD shield onto the standoffs with the screen facing the clear window in the case lid, using four Nylon 4-40 x 3/8-in. Phillips-head screws.

5. Plug the pins of the VCSEL control circuit and the light sensor into the Bluno board at the locations shown in Figure 11. Plug the Bluno board into the LCD shield and secure them together using a zip tie. Plug the power connector from the battery pack into the power jack of the Bluno.

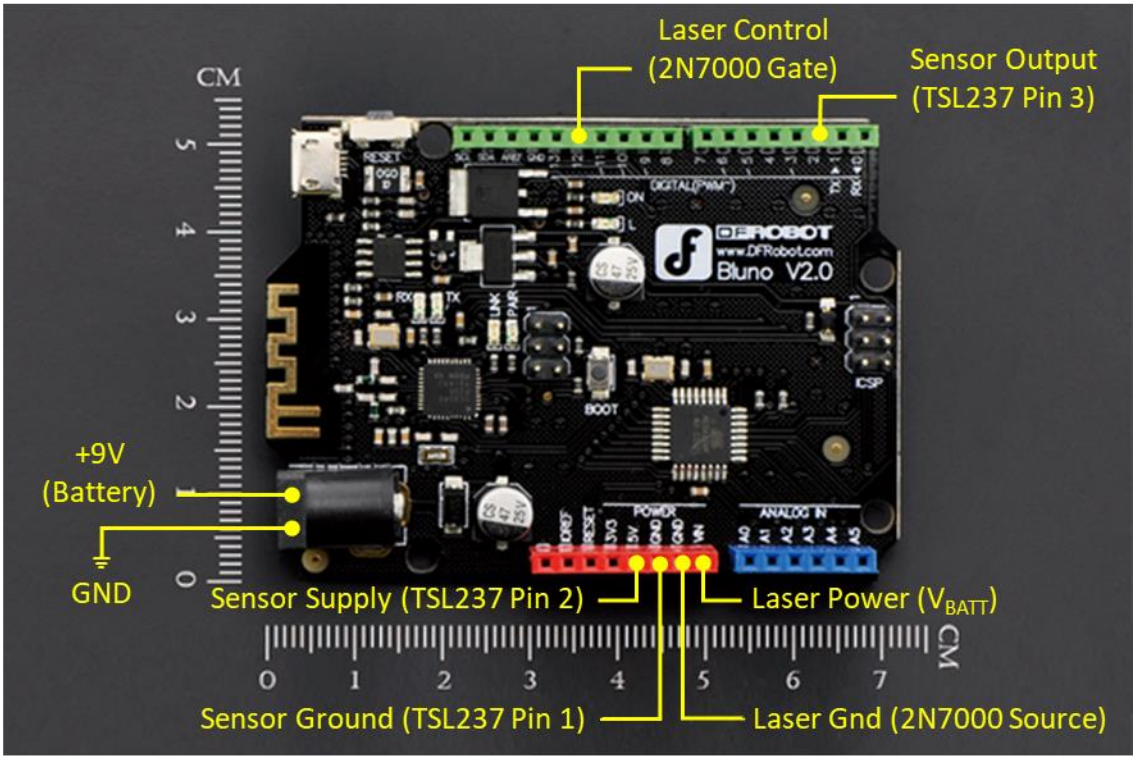

Figure 11. Bluno Microcontroller Connections to Light Source and Sensor

4.5 BATTERY INSTALLATION

WARNING! Do not energize the laser with the case open.

1. Make sure the VCSEL is securely installed in the Sample Well.
2. Make sure the power switch is off.
3. Install the batteries (6 x AA) into the holder.
4. Close the case and fasten with the four screws provided.

4.6 INSTRUMENT LABELING

1. Print the labels provided in the Documentation folder, on 1-in. x 2-5/8-in. polyester labels.
2. Place the Class 1 Laser label (Figure 12, left) on the outside of the case. Locate it on the left side of the front sidewall of the case (Figure 1).
3. Place the Danger label (Figure 12, center) on the outside of the case. Locate it on the right side of the front sidewall of the case (Figure 1).
4. Place the Warning label (Figure 12, right) on the outside of the case. Locate it over the seam (between case base and lid) on the rear sidewall of the case.

Figure 12. Safety Labels for Turbidity Meter Case