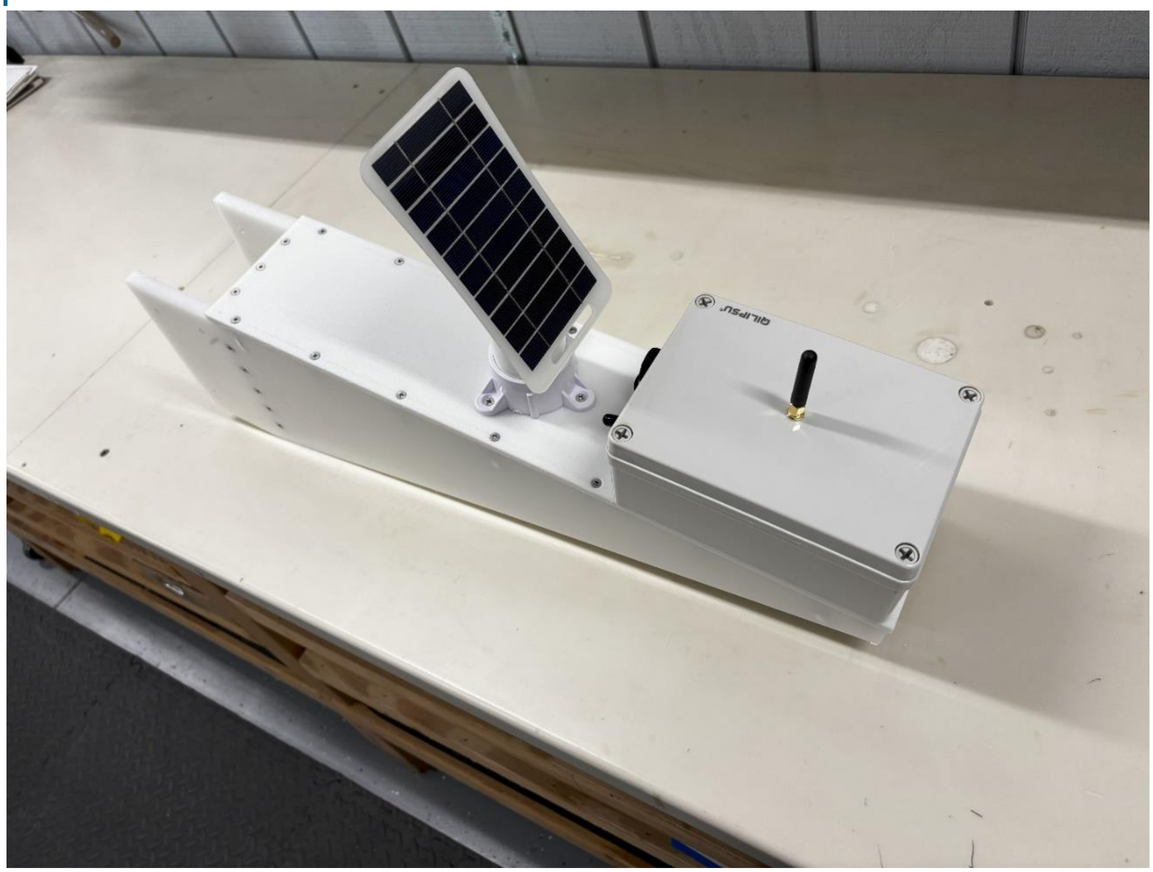
Tide Gauge Project

Construction & Deployment



Ken Howell

1-18-2025

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Introduction

The tide gauge is constructed using low-cost components to provide a system to measure and track the tide level at coastal locations. Water-level detection is performed by an ultrasonic measurement sensor mounted on a small platform, along with a solar panel and LoRa transmitter module. The unit is independent of shore power and will operate under normal conditions through all seasons of the year. The platform is intended to be mounted at a dockside location, extending outward about 15”, in a manner that will ensure a clear vertical path from the sensor to the water level under all tidal conditions. The platform is constructed using HDPE material and stainless-steel fasteners to withstand the rigors of the coastal environment. The electronic components are housed within a weatherproof plastic enclosure. The receiving part of the tide gauge should be located within line-of-sight of the transmitting sensor, at distances up to ¼ mile. The receiving location should have access to the internet to provide the necessary online services required by the system. The receiving part of the tide gauge consists of a LoRa receiver and a Raspberry Pi processor to receive and process the measured tide levels, which are then stored in an InfluxDB database to provide current and historical data access online.

This document describes the fabrication of the tide gauge sensor and transmitting component, and provides instructions for the installation and configuration of all electronic components required to operate the tide gauge.

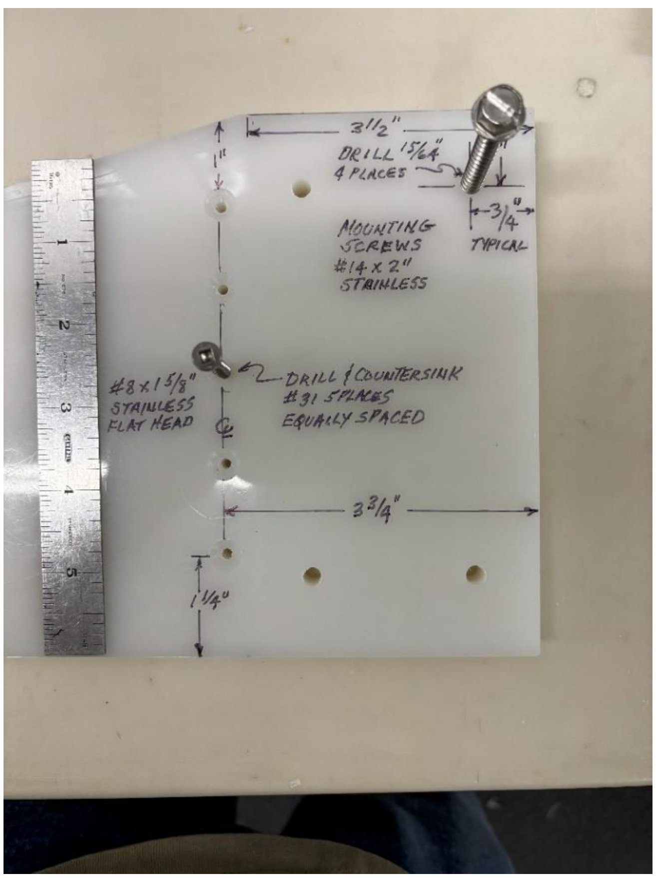
Constructing the Platform

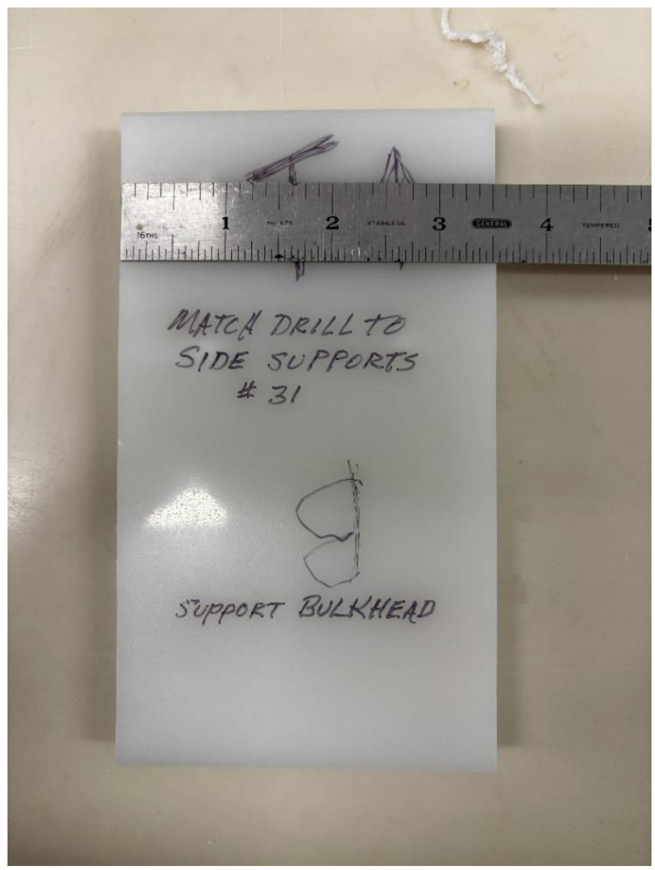
Cutting HDPE to form platform components

The Platform HDPE side supports are cut from ½” material. The overall length of the platform is 24”. The supports are angled from 8” on the wide end to 1” on the narrow end. The wide end can be squared off to a distance of 3 ½” from the end. A plywood jig can be used to maintain a straight cut with the table saw. The bulkhead is cut from ½” material to the dimensions of 3 ½” x 6 ½”. The saw blade should be fine tooth for cutting the HDPE material. The top surface of the platform is cut from ¼” stock to the dimensions of 4 ½” x 20 ½”. The width of the top surface is sized to accommodate the size of the dock mounting post.

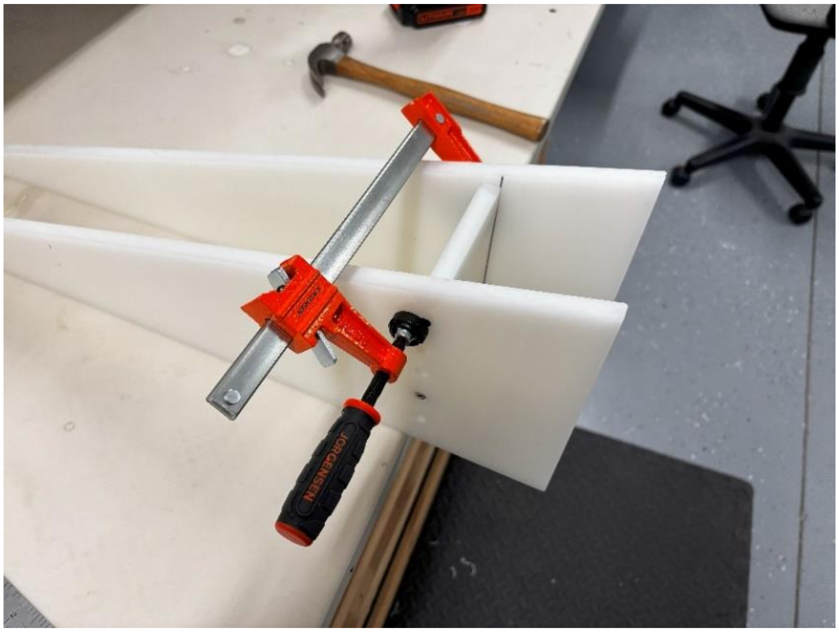
Lay Out Hole Patterns

Using a sharpie and straightedge, layout the hole pattern on the side supports. Maintain the top and bottom edge distance as shown. The holes that attach the supports to the bulkhead are at approximately 1” intervals. The bulkhead is attached 3 ½” from the end of the support, which allows mounting on a compatible dockside railing post. To ensure exact orientation, drilling and countersinking should be performed using a drill press. Drill the bulkhead attachment holes using a #31 drill. The larger post/platform mounting holes are drilled using a 15/64” drill to accommodate the #14 post mounting screws. When countersinking, set the microstop countersink on the light side to start with and progressively add depth until the head of an installed #8 deck screw rests just below the surface of the material.





Note: Sharpie scribe marks and notation can be easily removed with denatured alcohol.

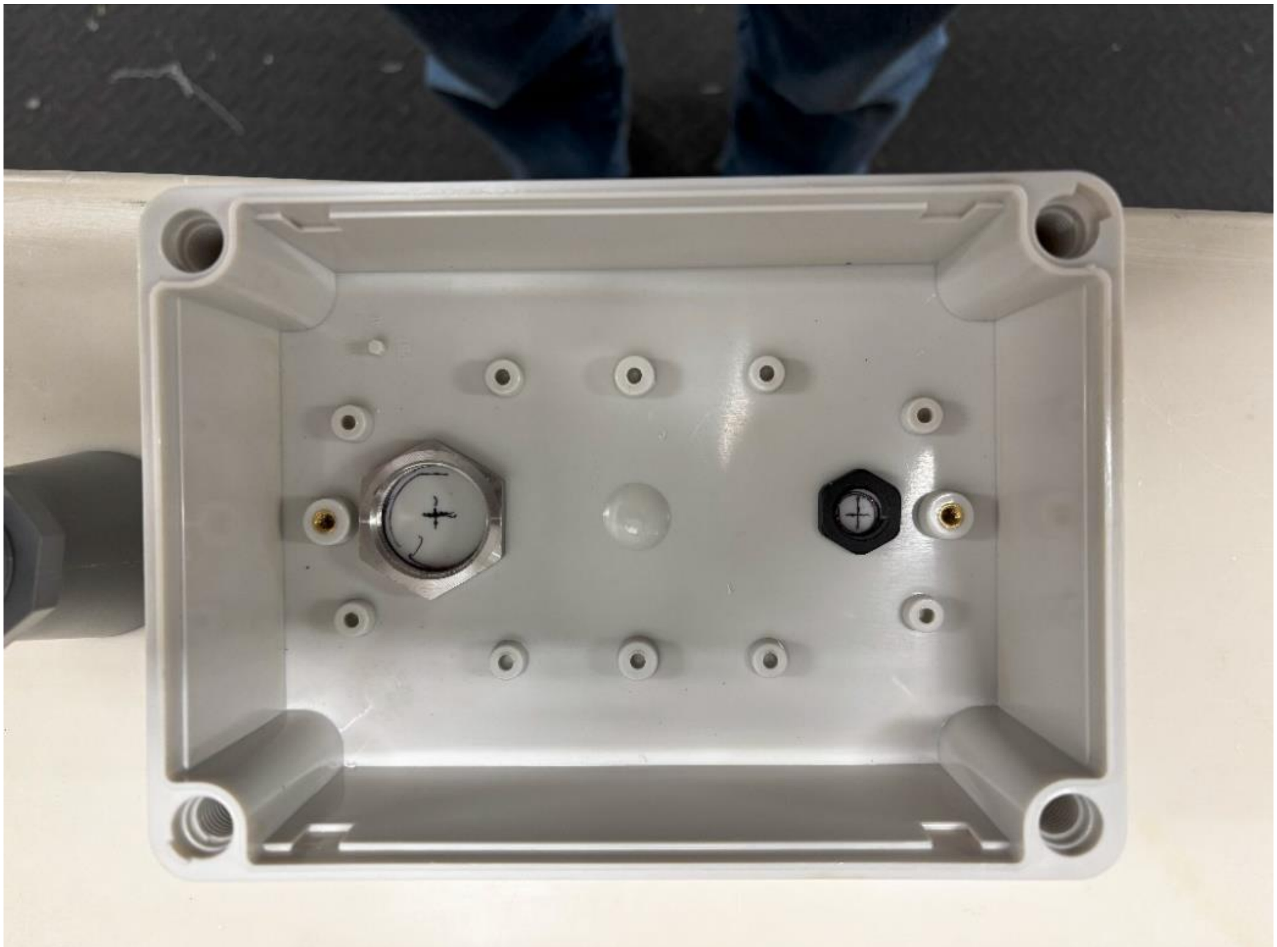


Assemble Support Structure

With a sharpie, draw vertical lines on the side edges of the bulkhead in the exact center of the material. Clamp the supports and bulkhead assembly together on a flat surface, squaring the bulkhead and ensuring that the predrilled holes in the supports are centered over the bulkhead lines. Using a hand-operated electric drill, carefully match drill the bulkhead to a depth of 1 ½” with a #31 drill. Assemble the platform supports and bulkhead using #8 x 1 5/8 flathead deck screws.

Prepare Platform Surface

Layout the hole pattern on the platform top surface ¼” HDPE panel. The holes are spaced about every 3” and should align exactly with the center of the underlying supports. This distance can be exactly determined by measuring across the supports at the bulkhead, from the leading edge of one support to the leading edge of the other. This is the dimension that should be maintained on the top support surface between the scribed lines, with the lines being parallel and equidistant from the edges. The electronics enclosure will be mounted centered at the front of the platform with the forward edge of the enclosure about ¼ - ½” back from the forward edge of the platform. Locate and mark the mounting holes for the equipment enclosure. Note: the holes for the enclosure need to be located precisely as there is minimal edge clearance on the platform surface. Drill and countersink all holes except for the enclosure mounting holes. Although not shown in the photo, there should also be three holes joining the top surface to the bulkhead.



Prepare Electronics Enclosure

Layout the holes for the sensor and solar panel wiring on the bottom of the electronics enclosure. Drill 1/8” pilot holes through the bottom of the enclosure. Then install the subpanel and back drill the subpanel through the pilot holes. Finally, while the enclosure is clamped or screwed in place on the platform, drill completely through the subpanel, enclosure and platform mounting surface. Disassemble and enlarge the holes as appropriate.

Note: the enclosure comes with a perforated subpanel, however the hole spacing does not align properly with the mounting holes in either the CubeCell module or PC board. To remedy this, the holes in the existing subpanel can be filled with an epoxy filler, or a new subpanel can be fabricated from 1/8” plastic sheet, using the existing subpanel as a template. For this installation, an epoxy filler was used, consisting of a mixture of West System epoxy and hardener with the addition of microspheres to thicken the mixture to the proper consistency.

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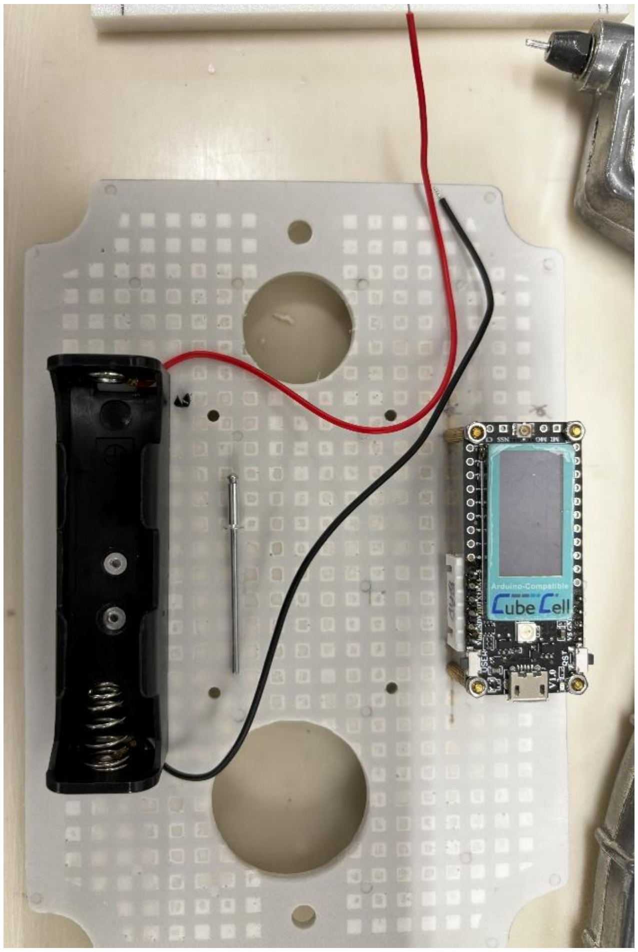


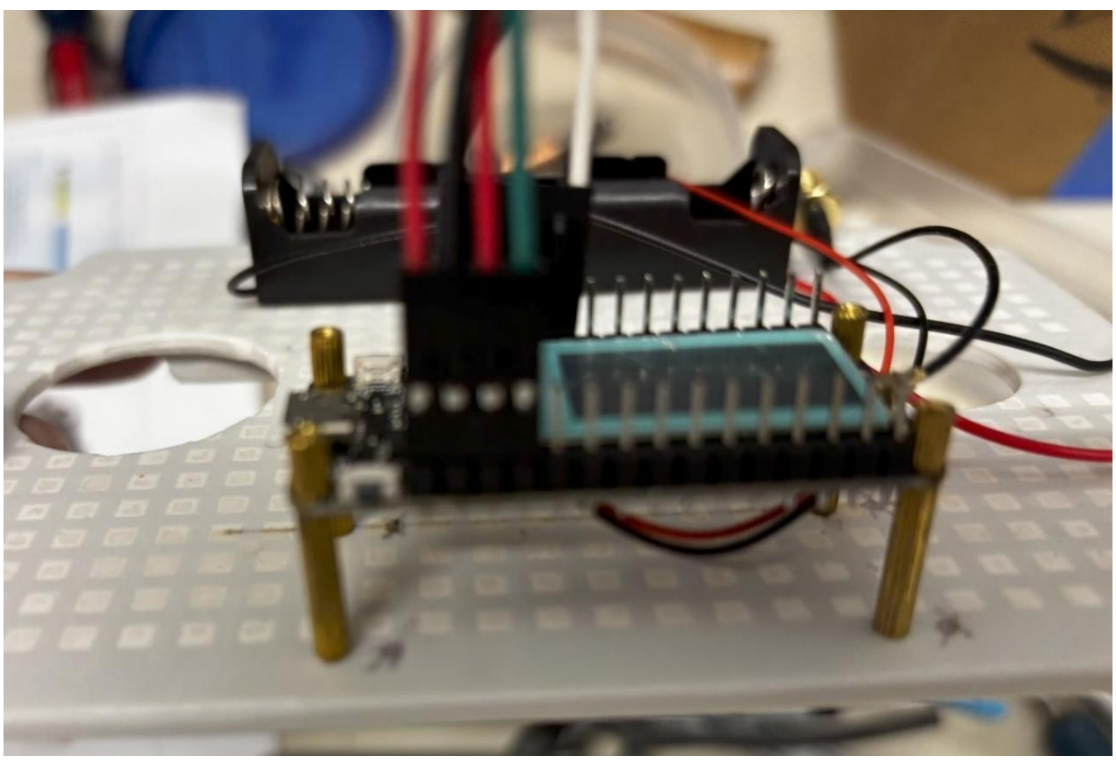
Subpanel Component Installation

On the subpanel, layout the locations for the CubeCell, battery holder, and PC board. This can be facilitated by creating templates to transfer the exact hole locations to the subpanel.

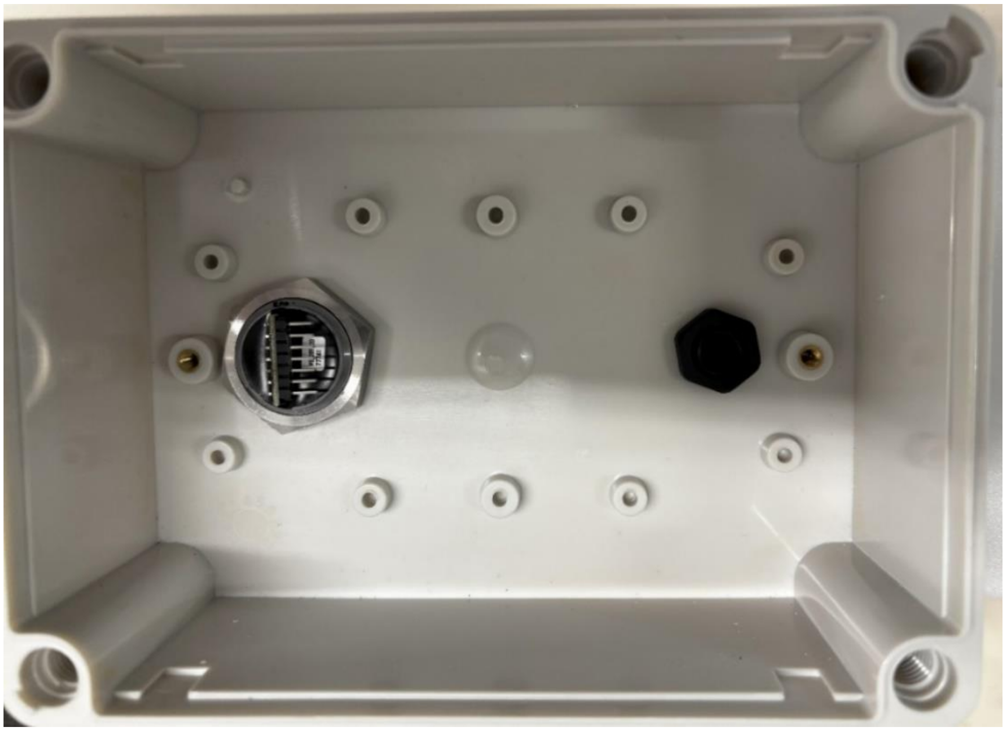
Attach the battery holder with flush style pop rivets or other means. If using rivets, the holes in the battery holder should be countersunk. This can be easily accomplished with a small hand countersink tool. The CubeCell and PC board are mounted using 2mm brass standoffs and hardware.

Solder on the CubeCell headers and connect the pre-fabricated CubeCell battery input lead before mounting it on the subpanel. Note: the CubeCell in the top photo was used for layout purposes and does not have the headers installed.

The mounting holes on the CubeCell have minimal radial clearance. For this reason, brass standoff connectors were used to secure the CubeCell.

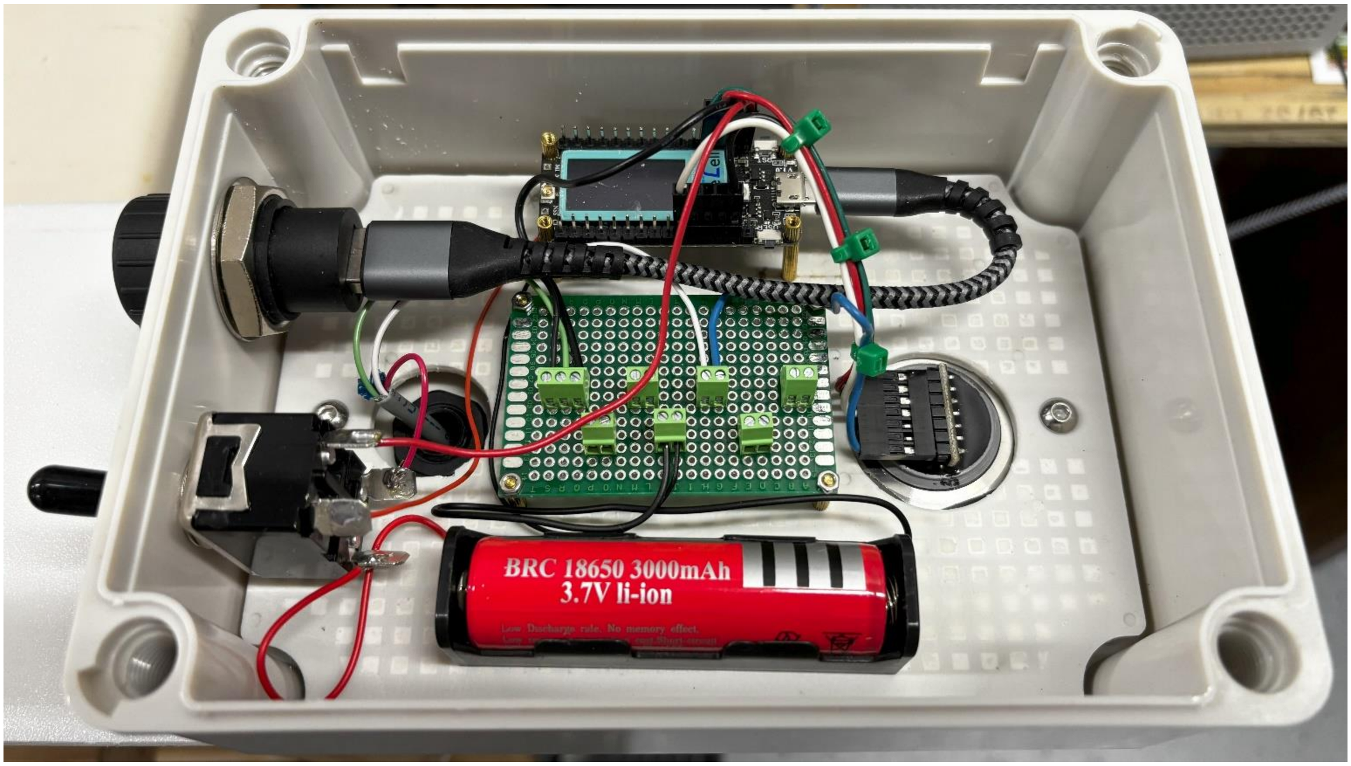


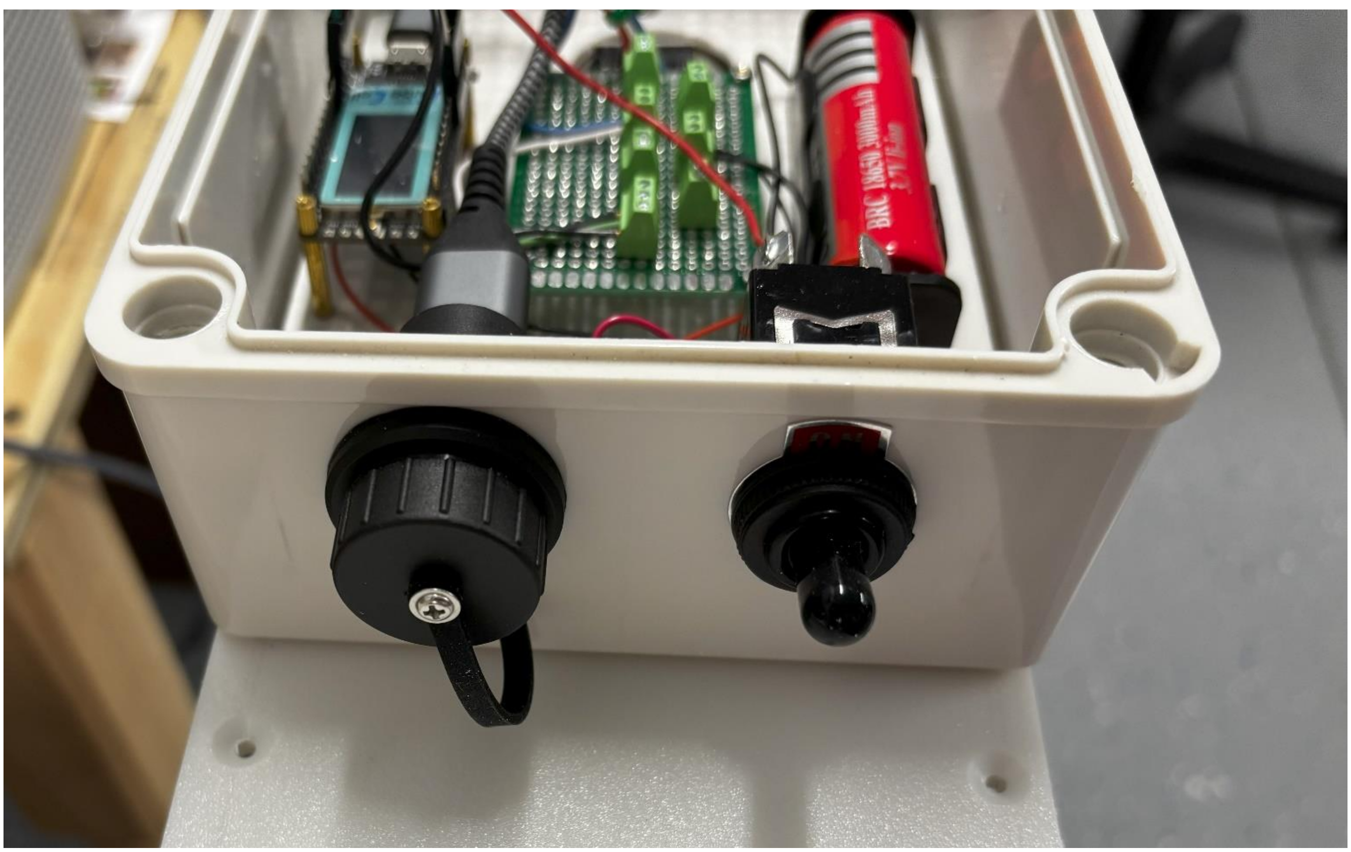
Drill holes in the front side of the enclosure (the side furthest from the sensor) as shown on the next page, to provide for the installation of the USB pass-through coupler and the on-off switch.



When locating the holes, be sure to allow adequate clearance for the component mounting flanges on the exterior surface of the enclosure. Start with pilot holes and then enlarge them using the appropriate size hole-saws.

Install the ultrasonic sensor and cable gland in the bottom of the enclosure, using rubber gaskets to provide a waterproof seal. Do not over tighten. Note: the ultrasonic sensor may require soldering on the 7-pin header prior to installation in the enclosure, depending on which option was ordered with the sensor. In the installation shown, a straight header was used, however, a right-angle header would allow easier access for the mating connector to be installed later (see next page).

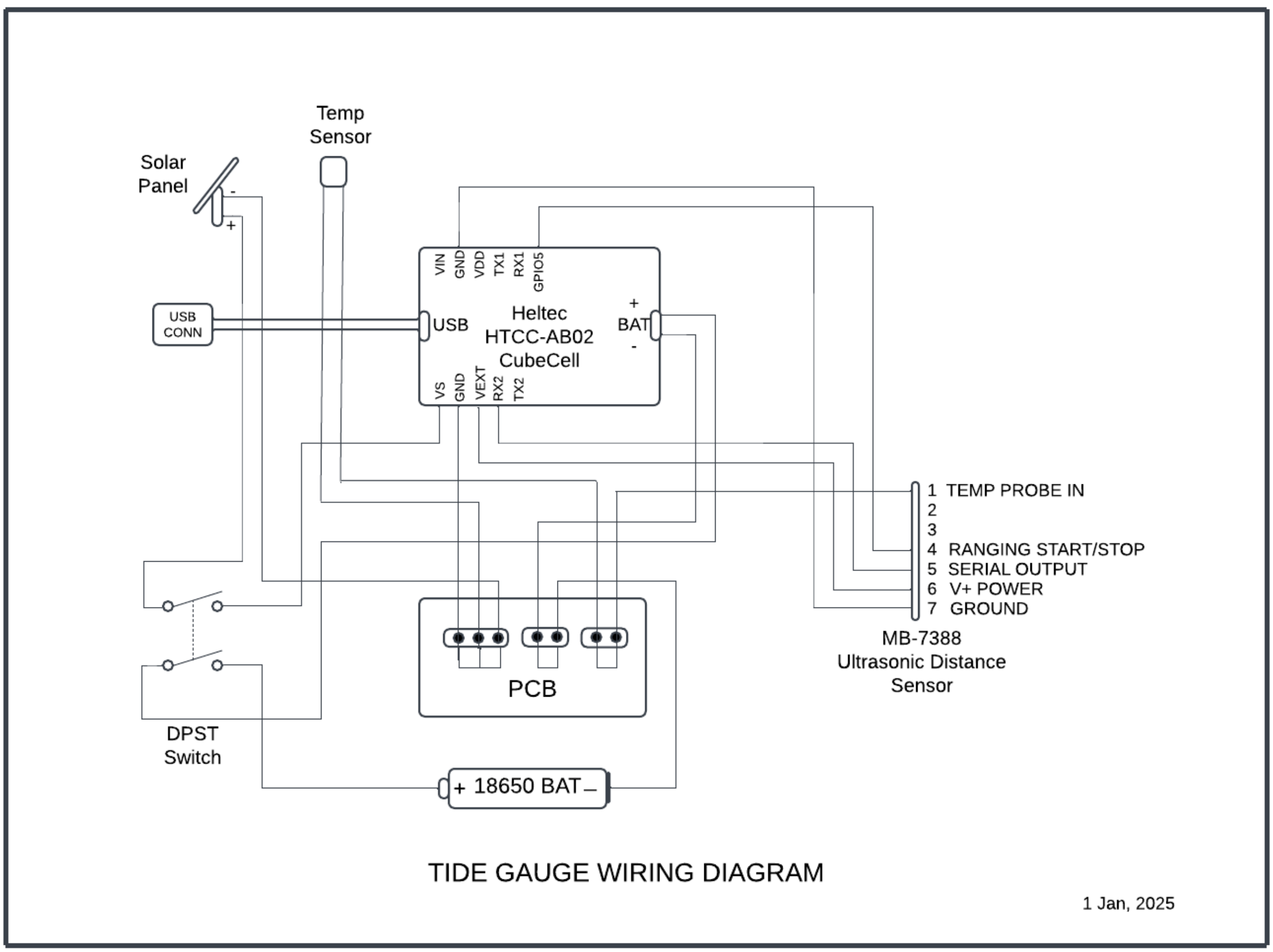

BRC 18650 3000mAh
3.7V li-ion
Low Discharge rate. No memory effect.

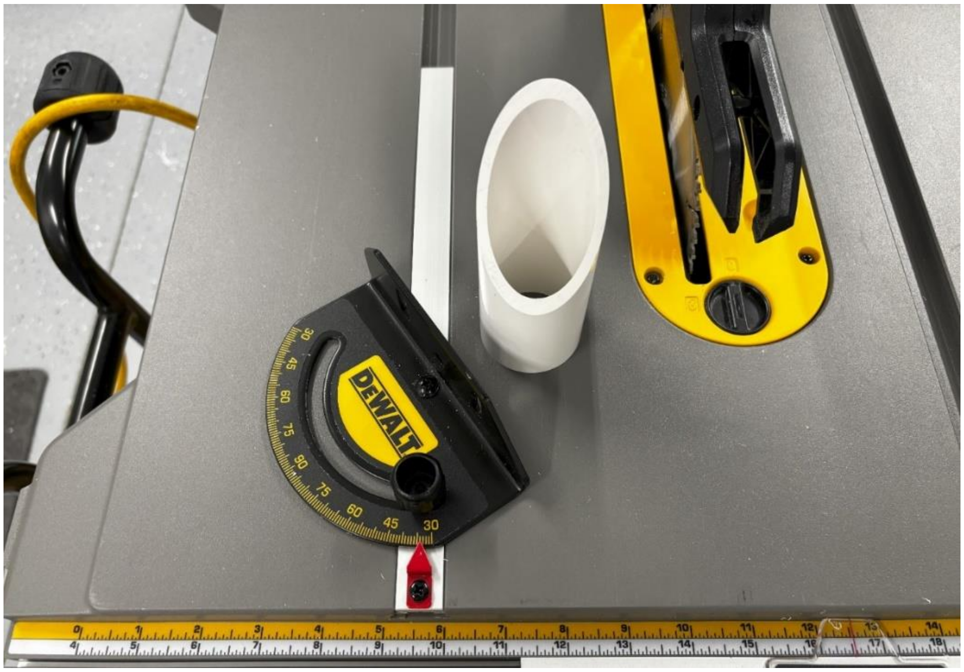


Component Wiring

The PCB and screw terminals are used to facilitate component replacement, if required. Screw terminal leads have soldered jumpers installed on the opposite side of the board. Note that spare terminals were installed but not used. These can be omitted and a smaller PCB used, if desired.

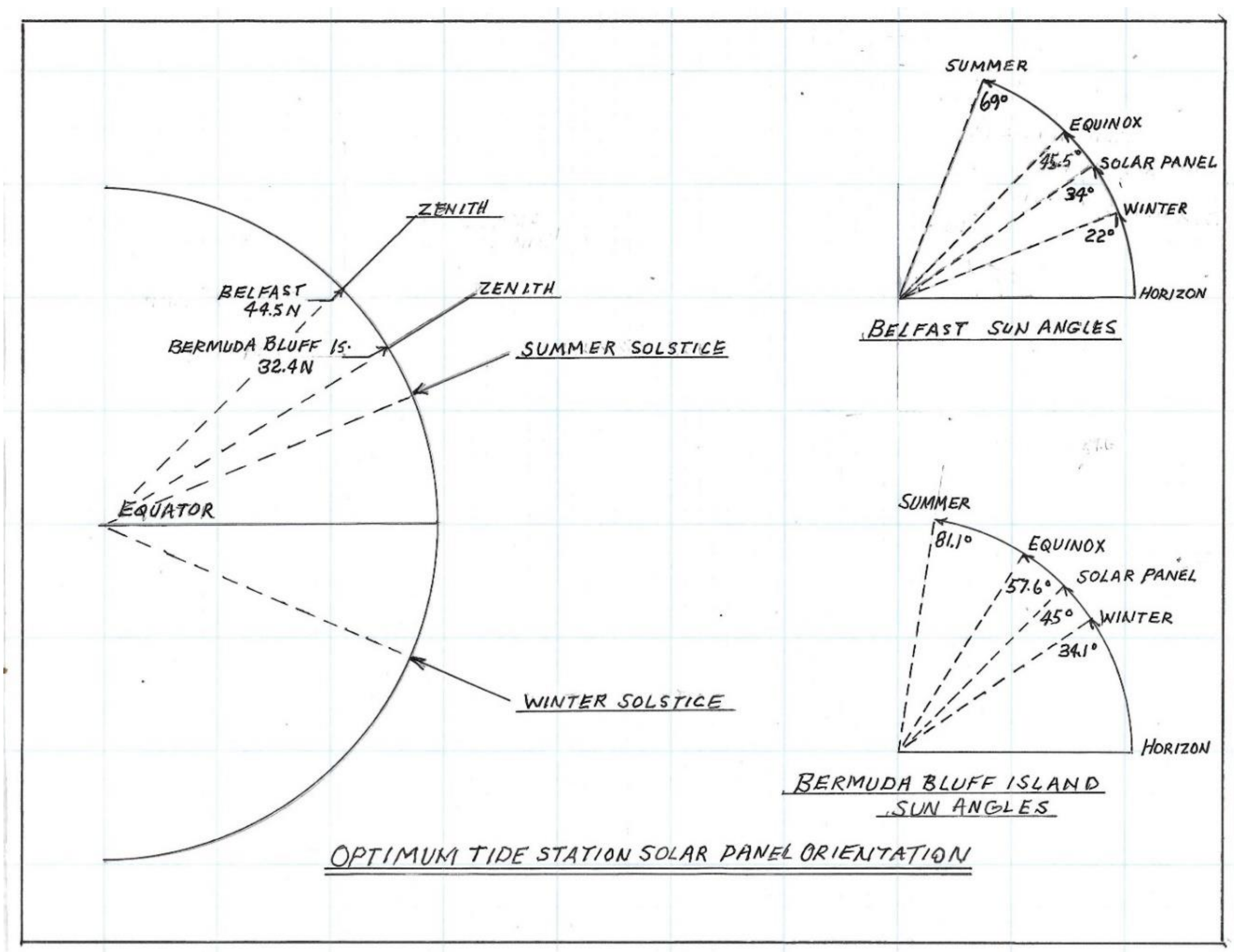
Fabricate a wiring harness to interconnect the MaxBotix sensor with the CubeCell. The harness has a 7-pin header connector on the sensor end, four-pin and five-pin connectors on the CubeCell end, and a single wire that will be attached to one of the 2-position screw terminals to interconnect the temperature sensor, which is installed under the platform. Note that not all header pins are used in the connectors. Refer to the Tide Gauge Wiring diagram below to determine the connector pinouts.





Fabricate and Install Solar Panel

The solar panel mount is fabricated using a section of 1 ½” PVC pipe and Cap. The PVC pipe is cut with the table saw to provide a flat mounting surface for the solar panel. The angle of the cut is determined by the latitude at the installed tide gauge location (refer to diagram below). When cutting the PVC, the work piece should be securely clamped to the angle guide to ensure a smooth even cut.

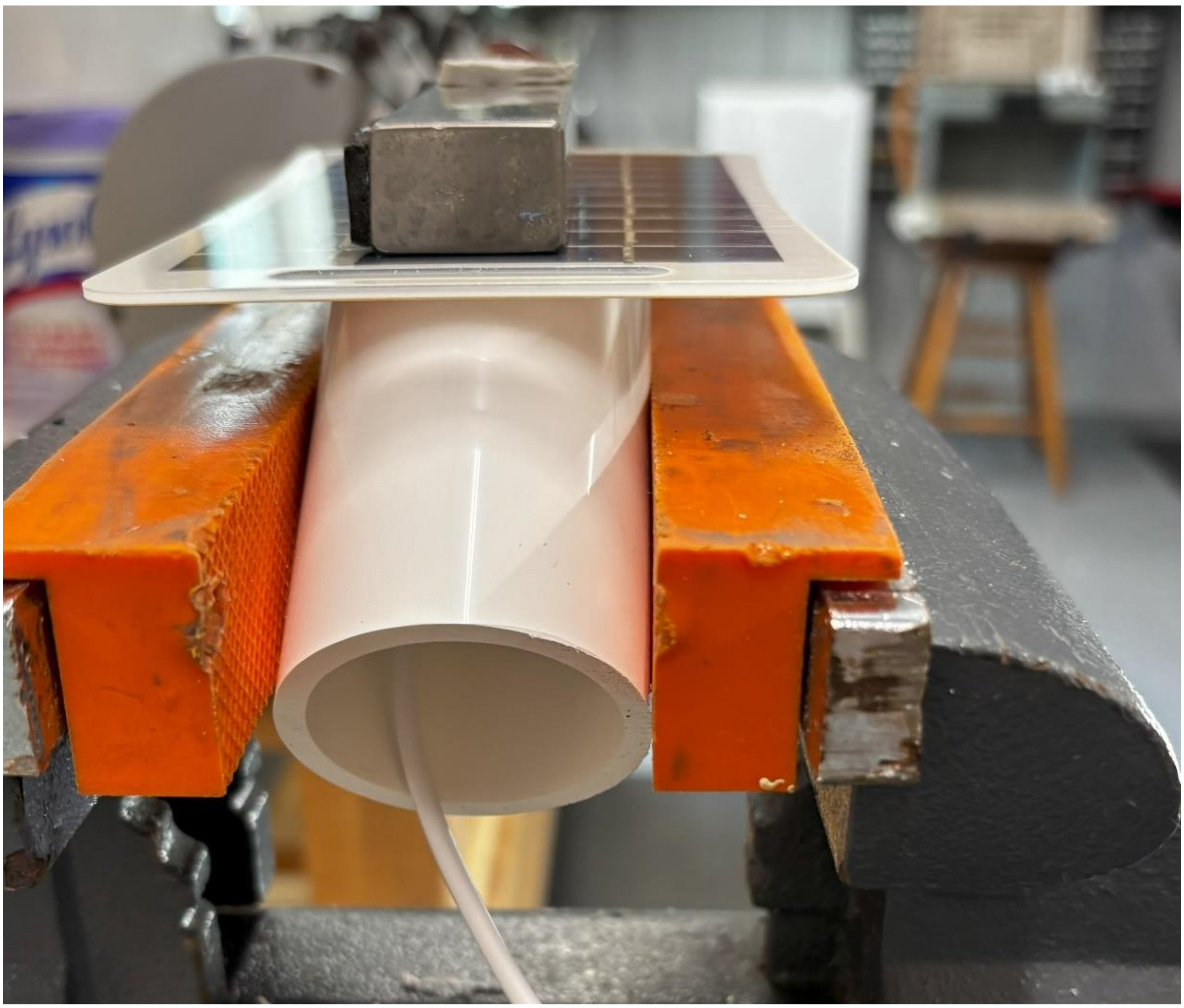


Attaching Solar Panel to Mounting Post

Note: the solar panel is angled about 12 degrees towards the winter solstice sun angle to compensate for the reduction is winter daylight hours.

To prepare the solar panel for installation, the existing cable should be cut about 8” from the panel and a Molex 2-position micro-fit connector installed. The panel is fitted to the PVC with the panel connections closest to the bottom of the angular cut.

The solar panel is attached to the PVC pipe with plastic glue or epoxy. For this installation, a mixture of West System Epoxy and Hardener was used. To facilitate the attachment, the pipe should be clamped in a vice with the mounting surface adjusted exactly level in both dimensions. Using a cotton swab or similar, the mounting surface of the PVC is liberally coated with the glue or epoxy mixture. This will help to ensure a weatherproof connection between the two parts. Carefully place the panel on the PVC and make sure it is aligned exactly with the pipe (the jaws of the vice can be used for this purpose). Note that the panel is offset vertically such that the panel



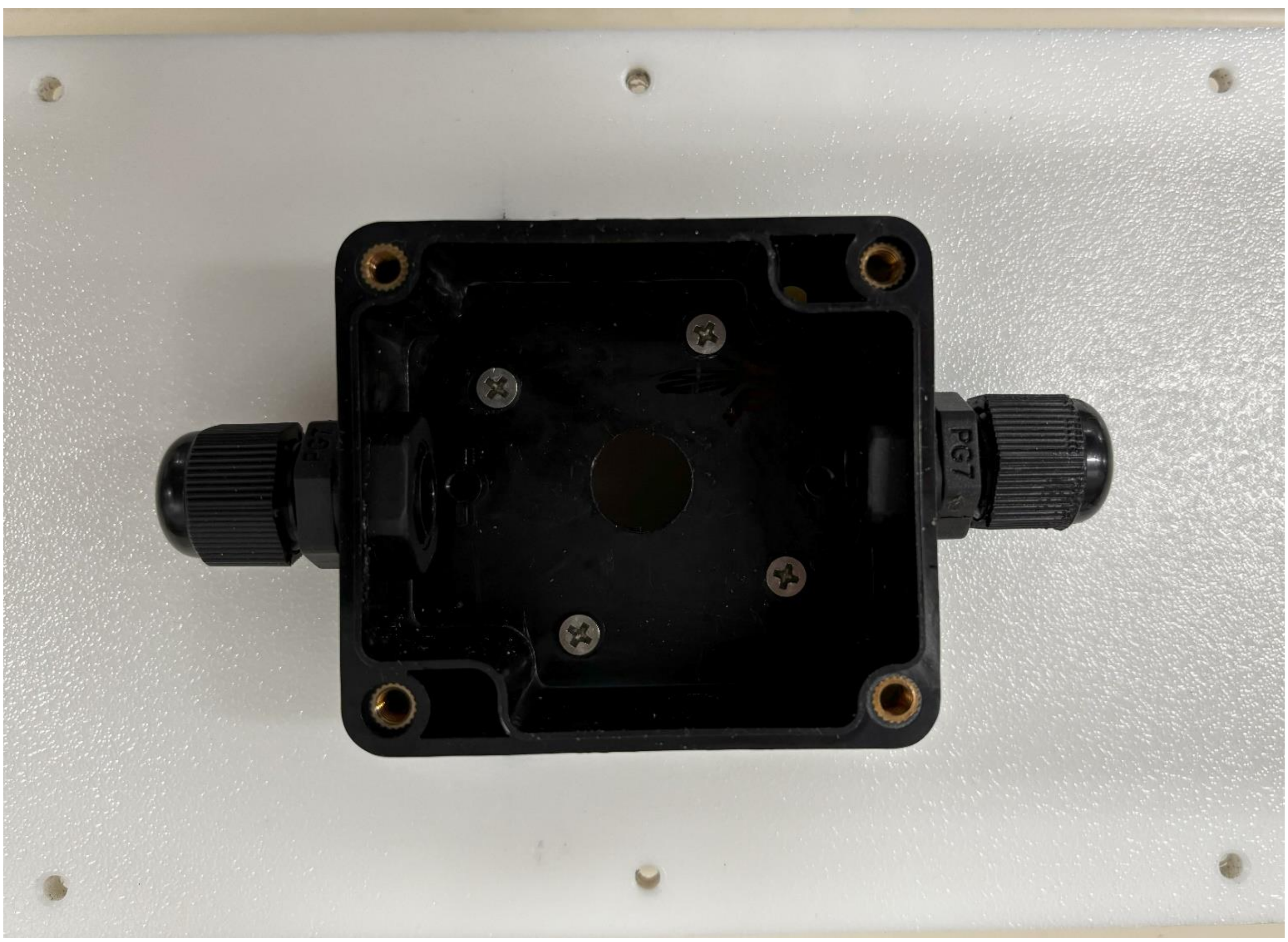
connections are just enclosed within the bottom of the oval mounting surface. Place a small weight on the top of the panel to ensure a good bond while the epoxy is setting up. Allow 24 hours for setup. In the photo, a small bucking bar is used to secure the panel.

Install Solar Panel Mounting Base

Drill a 1/8" pilot hole in the PVC cap exactly centered within the inside diameter. Locate the cap on the platform surface about 4 inches from the edge of the enclosure to ensure adequate solar illumination without shadowing. Use the pilot hole to drill through the platform. Enlarge the holes to 1". Drill the 1/8" mounting holes in the platform surface using the cap as a template. Install the cap using #8 x ½" sheet metal screws.

Prepare and Install Lower Junction Box

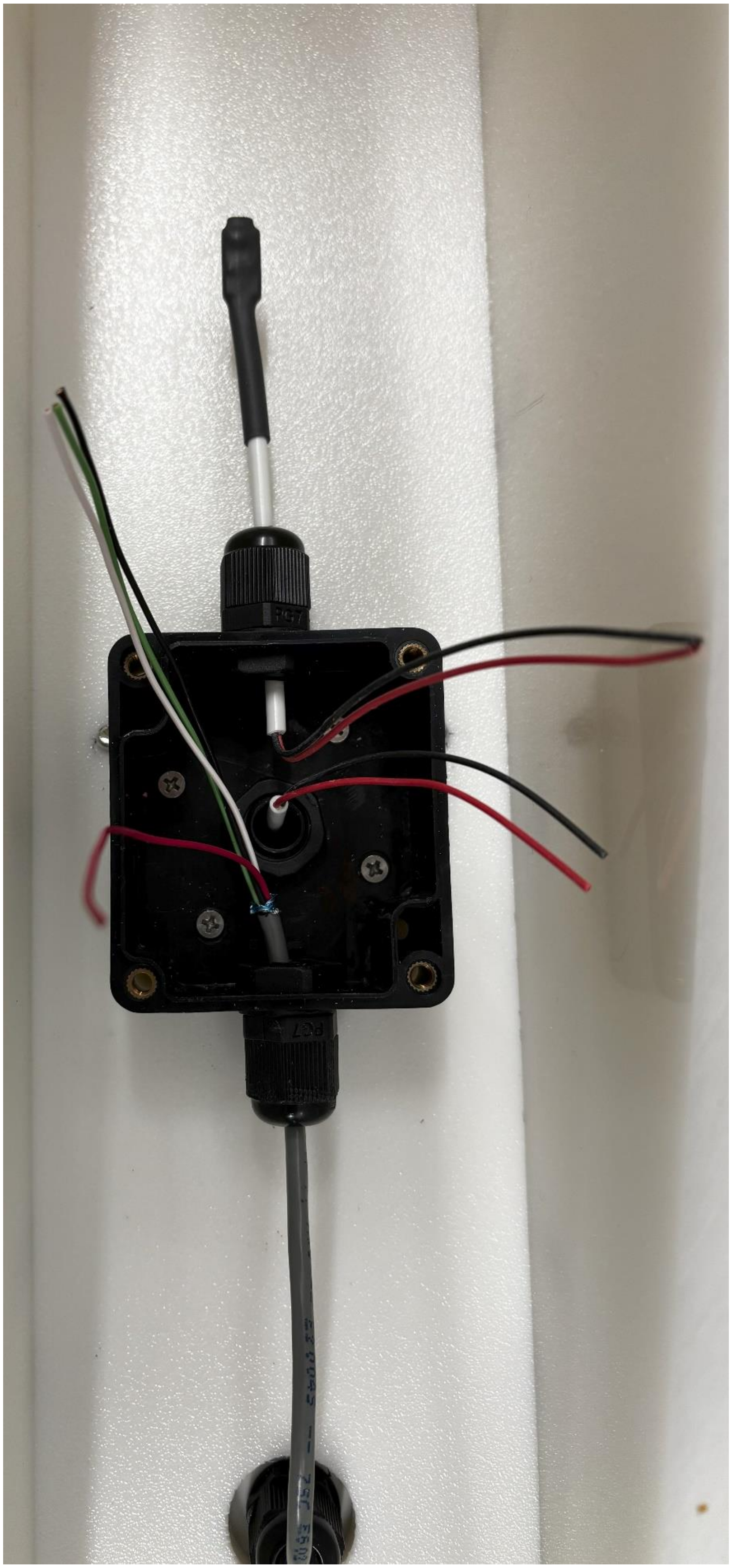
Prepare the small junction box for installation. The box will be attached to the underside of the platform surface, with the center of the box exactly aligned with the PVC cap above. Drill a ½" hole in the bottom center of the box to accommodate a cable gland. With the gland installed, the box should be positioned such that the gland is centered in the PVC cap/platform relief hole. Drill four 5/64" mounting holes as shown in the photo to attach the box to the bottom of the platform surface. Countersink the mounting holes. Drill ½" holes in each side of the box as shown to accommodate the wiring from the temperature sensor and the wiring to the enclosure. Install the cable glands and attach the box to the underside of the platform using #4 x ½" flat head wood screws.



Fabricate Solar Panel Connector Cable

Install a 2-conductor cable to connect the solar panel to the interconnect at the junction box. Leave a few inches extending above and below the gland. The end of the cable on the top side has the Molex micro-fit plug installed to mate with the connector on the solar panel. Having the connector in this position will allow easy replacement of the solar panel, if required.

The solar panel is attached by sliding the PVC post into the cap and seating it as far in as possible. A small amount of lubricant is helpful in seating the post. Later, when the sensor is installed at the dock location, a compass will be used to ensure that the solar panel is oriented so that it is pointing towards South. Once the orientation is established, a small hole can be drilled through the post and cap and a "keeper" screw installed.



Install Temperature Sensor and Interconnect Wiring

Solder the temperature sensor on a short piece of 2-conductor cable and cover the sensor and cable end with a section of shrink tubing. Run the cable through the gland as shown. The sensor and cable are supported by the cable gland and require no further support. Strip back the cable sheath leaving a few inches of wire exposed.

Run the 4-conductor interconnect cable from the junction box to the enclosure through the cable glands. Strip back the cable sheath as above.

Splice the solar panel and temperature sensor wiring to the interconnect cable in accordance with the wiring diagram. For this installation, Hilitchi wire connectors were used.

Underside view of finished Tide Gauge

Programming the Heltec LoRa Modules

Module Description

The Heltec HTCC-AB02 CubeCell and WiFi LoRa 32(v3) modules provide the capability of reading, processing, transmitting and receiving tide level measurements to support the tidal data acquisition process. These modules have a broad range of capabilities, however, only the functions associated with the serial interface, processing, and transmitting LoRa data are utilized. To conserve power the OLED display and WiFi functions will remain inactive.

Module Interconnectivity

The HTCC-AB02 CubeCell connects to the ultrasonic sensor via its serial interface to read, process and forward distance (water level) measurement data to the receiving WiFi LoRa 32(V3) module. To conserve power, the sensor is operated in the “triggered” mode and is activated for only 20 seconds out of every minute, with the remainer of the time being placed in the “sleep” mode. During the active period, 20 measurements are taken at one second intervals. This sampling scheme helps to ensure an accurate measure of the tide level, while averaging out the effects of chop or wave action. The built-in triggering function is activated by applying a signal on Pin 4 on the sensor. Measured values in the form of text messages are output on the sensor serial output pin 5. The CubeCell performs error checking and filtering of the data prior to LoRa transmission. Measurements are transmitted in the form of text-formatted packets containing the measurement values and associated meta data, such as battery voltage, etc.

Module Processing

The receiving WiFi LoRa 32(V3) module receives and outputs the data to a Raspberry Pi 4 (RPi4) processor, which in turn, writes the data to an InfluxDB database for both local and online storage.

Note that the HTCC-AB02 CubeCell module is normally capable of providing both the LoRa transmit and receive capability. However, a problem was discovered which caused the USB interface between the receiving CubeCell and the RPi4 to stop functioning at random intervals. This problem required manual rebooting or restarting the RPi4. The problem was alleviated by substituting the WiFi LoRa 32(V3) module to perform the receiving function.

The Arduino IDE

The Heltec units are among a variety of modules that are supported by the Arduino Integrated Development Environment (IDE). The Arduino IDE is open-source software that can be downloaded and installed under the Windows, Linux, or macOS operating systems. There are also pre-programmed libraries available to support both Heltec modules. During development of the tide gauge, certain incompatibilities were noted between the Heltec libraries and the latest IDE version 2.3.4.   For this reason, it is recommended to download and install the IDE legacy version

2.3.2, which can be found at the URL Release 2.3.2 · arduino/arduino-ide · GitHub. The version corresponding to the platform in use (PC, Mac) should be downloaded and installed.

Module Software Program Format

The software programs that run on the Heltec devices are referred to as "sketches". These are C language programs that have the unique file type of ".ino". Once a sketch has been prepared, it is compiled by the IDE using the appropriate library files and downloaded to the Heltec module via the USB connection between the IDE platform and the module.

Module Framework and Library Description

When configuring the Arduino IDE, the device framework and library modules required to support each specific device are downloaded. Refer to Heltec ESP32 Series Quick Start — esp32 latest documentation for additional information.

For the HTCC-AB02 CubeCell and WiFi LoRa 32(v3) modules, the supporting framework and libraries listed below are required. Some of the libraries may not relate directly to the functions utilized but are required as dependencies of other library modules. The Arduino IDE incorporates two different levels of device support. The device framework is provided by the Boards Manager, whereas additional functional device support is provided by the Library Manager. The Boards and Library Manager utilities are accessed via the IDE menu options.

Module Framework and Library Installation

The Arduino IDE File->Preferences menu option is used to download the CubeCell Development framework and the WiFi LoRa ESP32(v3) framework. This is accomplished by adding the following URL's to the Additional boards manager URL's:

1. https://github.com/HelTecAutomation/CubeCell-Arduino/releases/download/V1.5.0/package_CubeCell_index.json.
2. https://resource.heltec.cn/download/package_heltec_esp32_index.json

When the URL's have been added, the OK button is selected to initiate the download.

Once the download is complete, the Boards Manager panel should show entries for "CubeCell Development Framework by Heltec" and "Heltec ESP32 Series Dev-boards by Heltec", both of which are then installed with the corresponding INSTALL button.

The libraries are then installed through the Arduino IDE Library Manager. From the Library Manager panel, search for and install the following:

1. ESP8266 and ESP32 OLED driver for SSD1306…
2. Heltec ESP32 Dev-Boards by Heltec…
3. Heltec ESP8266 Dev-Boards by Heltec…
4. Heltec_ESP32_LoRa_v3 by Rop Gongrijp

5. Heltec_LoRa_OLED_Examples by GregLee
6. HotButton by Ron Gongrijp
7. RadioLib by Jan Gromes
   Note: Items 6 and 7 are normally
   downloaded as dependencies for other modules.

Module Sketch, Board and Port Selection

With the framework and libraries installed, the Arduino IDE menu option Tools->Board can be selected to view a dropdown menu containing the board types. This menu is followed to select the board framework matching the connected board to be programmed.

The Arduino IDE menu option File->Examples can be used to load board-specific example sketches that are tailored to perform specific functions, for example LoRa transmit and receive. This is a good starting point for sketch development, and the way the tide gauge sketches were initially created.

When the USB connection has been established with the board, the appropriate Comm Port connection should be displayed on the pull-down in the board display area of the IDE.

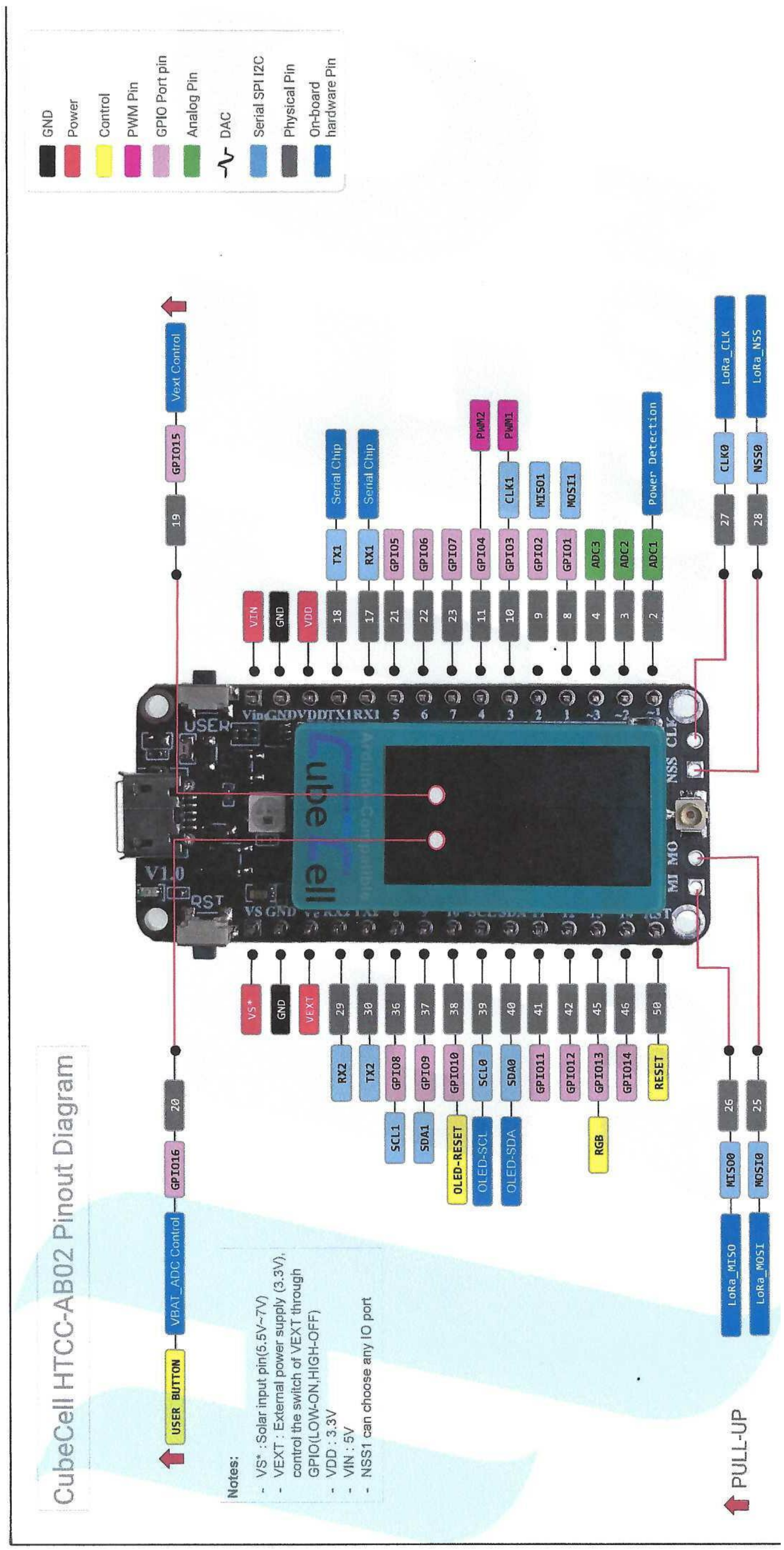
Appendix A – Tide Gauge – Parts List and Cost Analysis

Item Nbr	Description	Total Cost	Percentage used by project	Project Cost	Receiving Station
1	24" x 48" x 1/2" HDPE Panel	87.99	25	22.00	
2	24" x 48" x 1/4" HDPE Panel	65.99	25	16.50	
3	24" x 24" x 1/8" Plastic Sheet	15.36	25	3.84	
4	#4 x 1/2" Flat Head Wood Screws	12.31	10	1.23	
5	#8 x 1" Pan Head Sheet Metal Screws	15.16	4	0.61	
6	#6 x 1 1/4" Deck Screws	14.95	10	1.50	
7	#8 x 1 5/8" Deck Screws	14.49	20	2.90	
8	#8 x 1/2" Flat Head Wood Screws	14.48	3	0.43	
9	#14 x 2" Hex Washer Head Screws	15.99	20	3.20	
10	3/32" Aluminum Blind Rivets	18.43	2	0.37	
11	QILIPSU Outdoor Junction Box (6.9"x4.9"x3")	13.49	100	13.49	
12	Zulkit Project Box (2.48"x2.28"x1.38")	6.59	100	6.59	
13	QILIPSU 1/2" NPT Cable Glands	8.99	33	2.97	
14	PVC Table Leg Cap	7.59	50	3.80	
15	PVC Pipe, 1 1/2"	31.99	5	1.60	
16	Solar Panel	16.03	100	16.03	
17	MaxBotix MB7388 Ultrasonic Distance Sensor	119.95	100	119.95	
18	Heltec HTCC-AB02 LoRa CubeCell Module	15.50	100	15.50	
18	Heltec WiFi LoRa 32(V3)	19.90	100		19.90
19	Raspberry Pi 4	119.99	100		119.99
20	Brass Standoff Kit	15.99	5	0.80	
21	Printed Circuit Board	6.99	5	0.35	
22	18650 Battery Holder	5.99	10	0.60	
23	18650 Battery	19.89	25	4.97	
24	Waterproof Double Pole, Single Throw Switch	13.99	33	4.62	
25	Waterproof USB Coupler	16.99	100	16.99	
26	Micro USB to USB Cable, 6"	7.99	33	2.64	
27	Molex Micro-fit Receptacle, 2 position	0.31	100	0.31	
28	Molex Micro-fit Plug, 2 position	0.33	100	0.33	
29	Molex Micro-fit Connector Socket 20-24AWG	0.15	100	0.15	
30	Molex Micro-fil Connector Pin 20-24AWG	0.19	100	0.19	
31	Header Connector Kit (with crimping tool)	26.99	5	1.35	
32	Screw Terminal Block Connectors	14.99	10	1.50	
Totals		765.96		267.28	139.89

Appendix B - Recommended Tools

1. Good Quality Soldering Iron & Solder
2. Table Saw
3. Drill Press
4. Cordless/Electric Hand Drill
5. Microstop and Hand Countersinking Tools
6. Woodworking Clamps
7. Hand Tools, Screwdrivers, Pliers, Cutters, etc.
8. Appropriate Size Drill Bits, Hole Saw and Drive Bits (Square & Phillips)
9. Hand Rivet Puller

Appendix C – CubeCell Pinout Diagram



Appendix D - MaxBotix Sensor Pinout

General Characteristics

- Low cost ultrasonic rangefinder
- Detection out to 1.5-meters, 5-meters, or 10-meters
- Resolution of 1-mm
- Distance sensor from 30-cm to 1.5-meters, 30-cm to 5-meters, or 50-cm to 10-meters based on model
- Excellent [2] Mean Time Between Failure (MTBF)
- Triggered operation yields real-time range data
- Free run operation with superior noise rejection [3]
- Operating temperature range from -40°C to +65°C [7]
- Operating voltage of 2.7V to 5.5V[7]
- Nominal current draw of 2.3mA (peak ~49mA) at 3.3V, and 3.1mA (peak ~98mA) at 5V
- IP67 Rated

Range Outputs

- Pulse width, 1uS/mm resolution
- Analog Voltage, 5-mm resolution (5-meter sensors)
- Analog Voltage, 10-mm resolution (1.5 and 10-meter sensors)
- Serial, 1-mm resolution
- Available in RS232 (MB736X and MB7375) or TTL (MB738X and MB7395)

HRXL-MaxSonar-WR Pin Out

Pin 1- Temperature Sensor Connection: Leave this pin unconnected if an external temperature sensor is not used. For best accuracy, this pin is optionally connected to the HR-MaxTemp temperature sensor. Some additional information for the temperature sensor can be found on page 12 of the datasheet.

Pin 2- Pulse Width Output: This pin outputs a pulse width representation of the distance with a scale factor of 1uS per mm. The pulse width output is sent with a value within 0.5% of the serial output.

Pin 3- Analog Voltage Output: This pin outputs a single ended analog voltage scaled representation of the distance. This output is referenced to the sensor ground and Vcc. After the ~50mS power up initialization, the voltage on this pin is set to a low voltage. Once the sensor has completed a range reading the voltage on this pin is set to the voltage corresponding to the latest measured distance.

The 5-meter sensors (MB7360, MB7369, MB7380 and MB7389) use a scale factor of (Vcc/5120) per 1-mm. The distance is output with a 5-mm resolution. The analog voltage output is typically within ±5-mm of the serial output.

The 1.5-meter sensors (MB7375 and MB7395) and 10-meter sensors (MB7363, MB7366, MB7368, MB7383, MB7386, and MB7388) use a scale factor of (Vcc/10240) per 1-mm. The distance is output with a 10-mm resolution. The analog voltage output is typically within ±10-mm of the serial output.

Using a 10-bit analog to digital converter with the 5-meter sensors, one can read the analog voltage counts (i.e. 0 to 1023) directly and just multiply the number of counts in the value by 5 to yield the range in mm. For example, a converted value of 60 corresponds to 300-mm (where 60 x 5 = 300), and 1000 counts corresponds to 5,000-mm (where 1000 x 5 = 5,000-mm).

Using a 10-bit analog to digital converter with the 10-meter sensors, one can read the analog voltage counts (i.e. 0 to 1023) directly and just multiply the number of counts in the value by 10 to yield the range in mm. For example, 30 counts corresponds to 300-mm (where 30 x 10 = 300), and 1000 counts corresponds to 10,000-mm (where 1000 x 10 = 10,000-mm).

Pin 4- Ranging Start/Stop: This pin is internally pulled high. If this pin is left unconnected or held high, the sensor will continually measure and output the range data. If held low, the HRXL-MaxSonar-WR will stop ranging. Bring high for 20uS or longer to command a range reading.

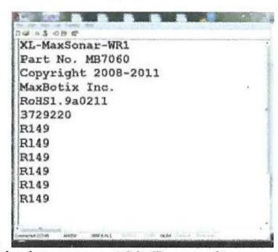
Filtered Range Data: When pin 4 is left high on the sensors, the sensors will continue to range. The data that is output includes a filter for increased accuracy. The sensors will output the range based on recent range information. The filter does not affect the speed at which data is made available to the user but instead allows for more consistent range information to be presented. For sensor specific timing and filter information refer to pages 10 and 11.

Real-time Range Data: When pin 4 is low and then brought high, the sensor will operate in real time and the first reading output will be the range measured from this first commanded range reading. When the sensor tracks that the RX pin is low after each range reading, and then the RX pin is brought high, unfiltered real time range information can be obtained. For timing information please refer to pages 10 and 11.

Pin 5-Serial Output: The MB736X/MB7375 sensors have an RS232 data format (with 0V to Vcc levels) and the MB738X/MB7395 sensors have a TTL outputs. The output is an ASCII capital "R", followed by four ASCII character digits representing the range in millimeters, followed by a carriage return (ASCII 13). The maximum range reported is 4999 mm (5-meter models) or 9998 mm (10-meter models). A range value of 5000 or 9999 corresponds to no target being detected in the field of view.

The serial data format is 9600 baud, 8 data bits, no parity, with one stop bit (9600-8-N-1).

Because the data is presented in a binary data format, the serial output is most accurate .



On power up the sensor will send serial data about the sensor. View an example here.

V+ Pin 6 - Positive Power, Vcc: The sensor operates on voltages from 2.7V - 5.5V DC. For best operation, the sensor requires that the DC power be free from electrical noise. (For installations with known dirty electrical power, a 100uF capacitor and 10ohm resistor placed at the sensor pins between V+ and GND will typically correct the electrical noise.) Please reference page 12 & 13 for minimum operating voltage verses temperature information.

GND Pin 7 – Sensor ground pin: DC return, and circuit common ground.