FloDar: An Inline Flow Meter for Landslide Drains

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1. Overview

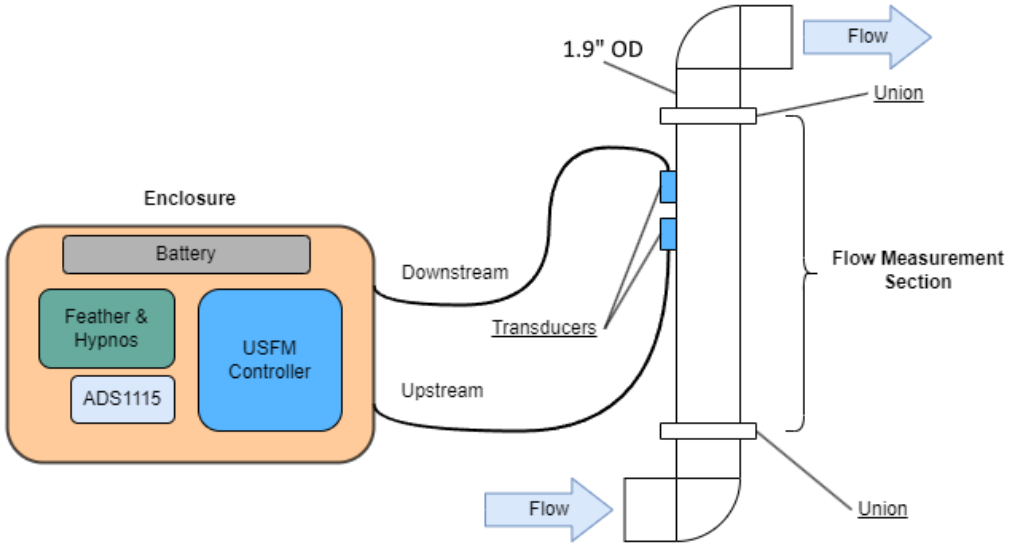

Figure 1: FloDar System Diagram

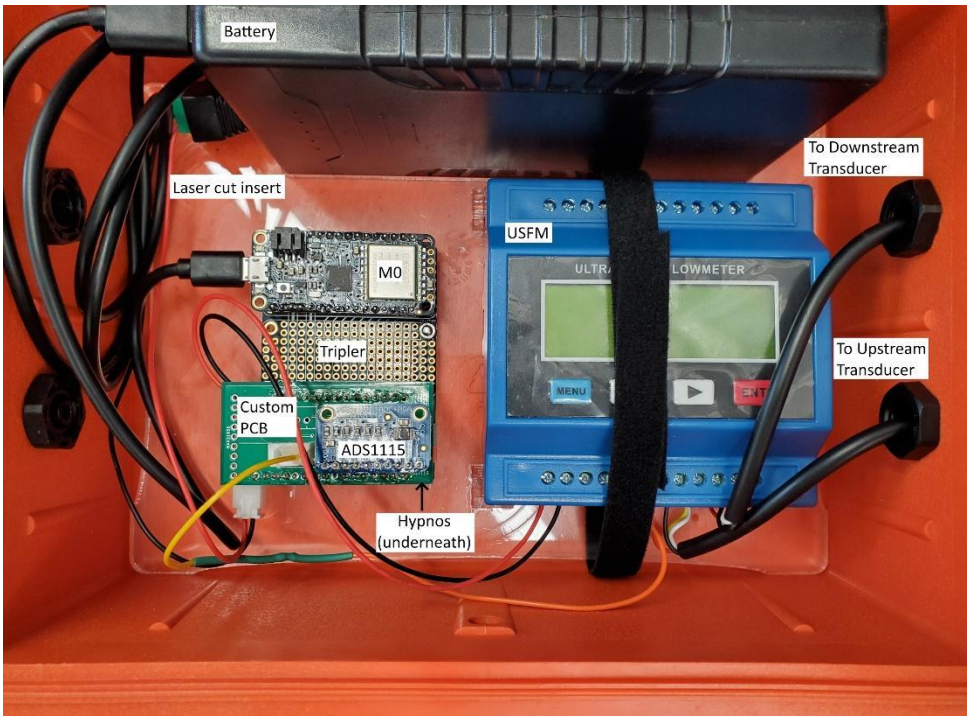

Figure 2: FloDar version 4 with labeled components

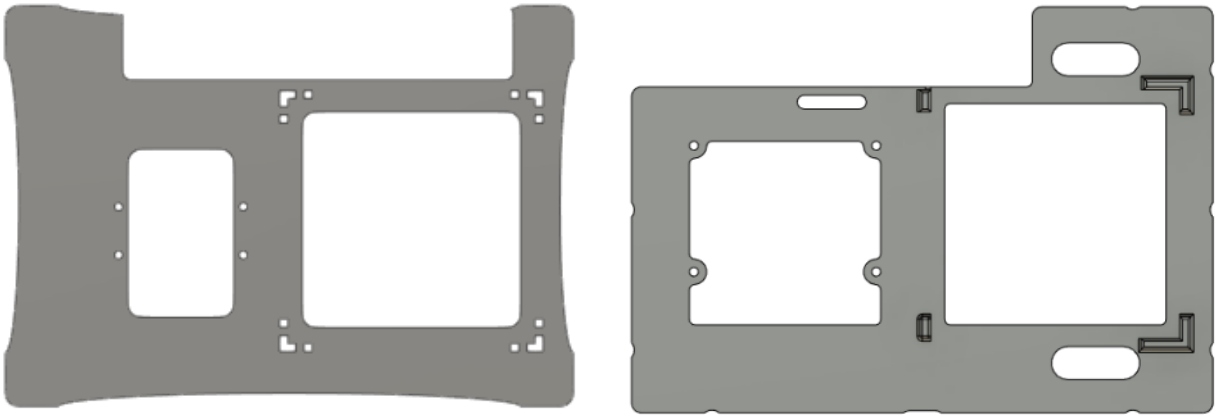

Figure 3: Options for structure inside Pelican case: laser cut insert (left) or 3D printed insert (right).

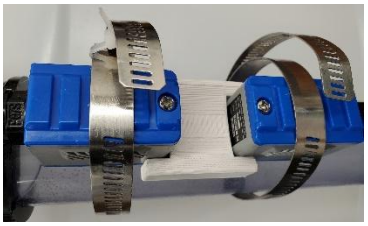

Figure 4: TS-2 transducers with spacer and worm gear hose clamps on 1.5” schedule 40 clear PVC pipe.

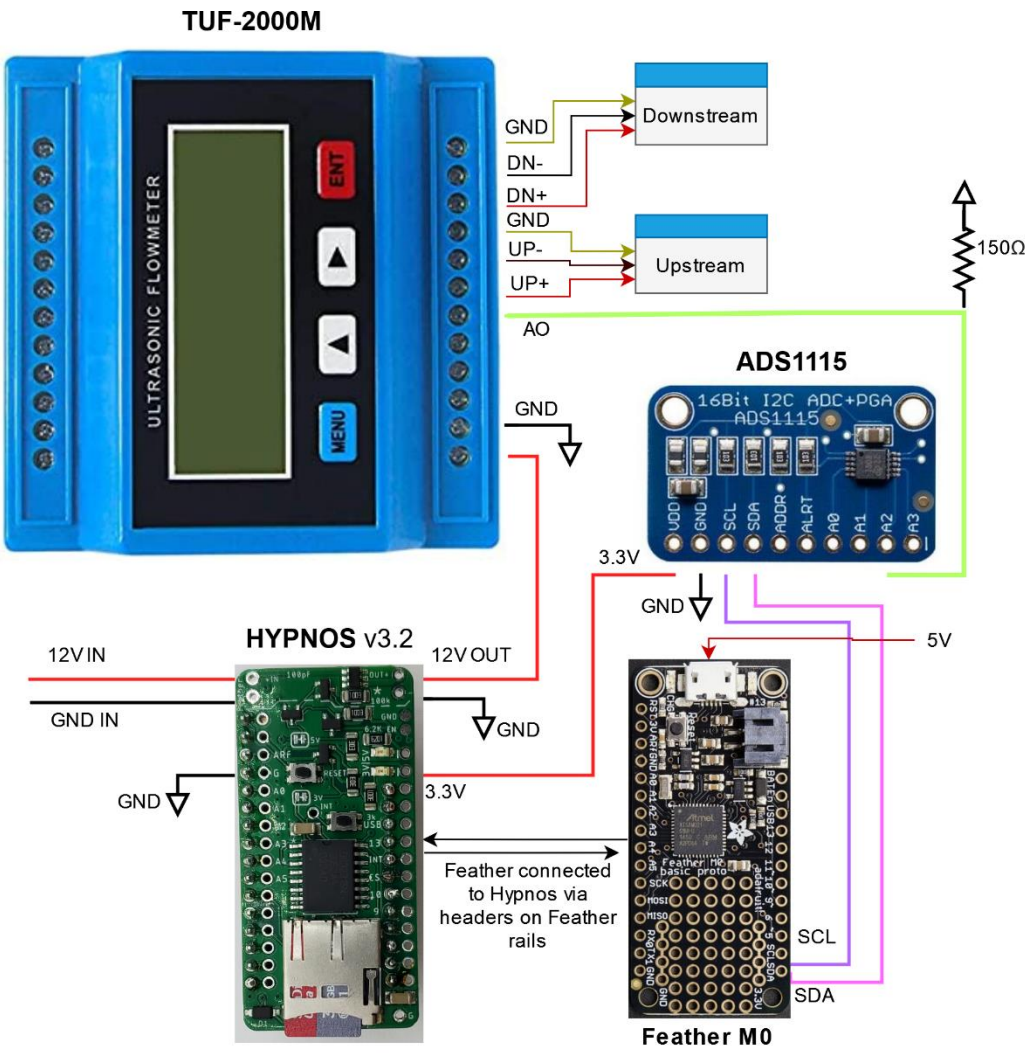

Figure 5: Circuit diagram of major electrical components with connections

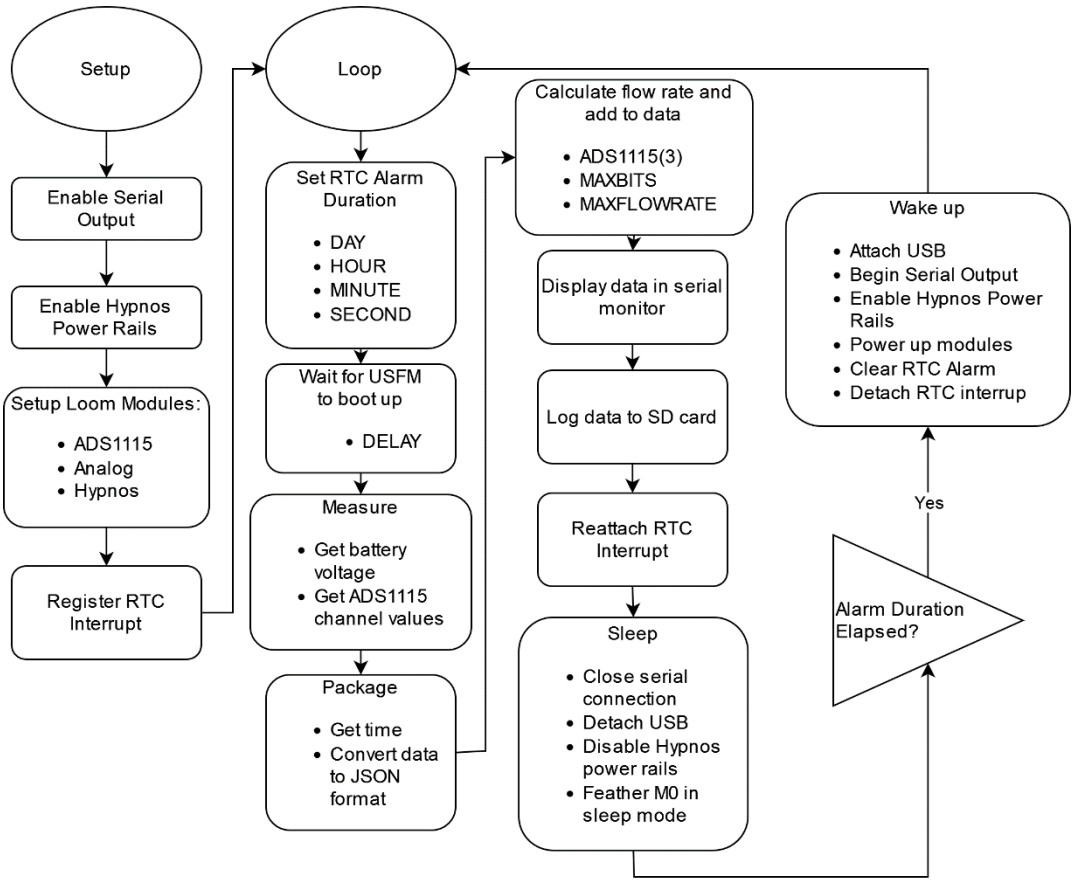

Figure 6: FloDar Loom 4 Software Diagram

2. Design Files

Design Filename	File Type	Description	Source
Pelican Insert Laser Cut	DXF	Acrylic insert option for holding components in place.	Github
Pelican Insert 3D Print	STL	ASA insert option for holding components in place.	Github
Transducer Spacer	STL	ASA spacer for ensuring exact transducer separation for V method installation on 1.5” schedule 40 pipe.	Github
Breakout Board	Gerber	Custom PCB for connecting electrical components.	Github
FloDar_Field_Loom4_1	ino	Arduino code for operating system.	Github

3. Bill of Materials

3.1 Mechanical Components

Designator	Component	Qty.	Cost per Unit	Total Cost	Source of Materials	Notes
Pelican Case	1150 Pelican Case	1	$49.95	$49.95	B&H Photo	
Structure	Acryllic 1/8" x 12" x 12'	1	$4.99	$4.99	Grainger	Each design uses 8.27" x 5.81"
Cable Gland	PG7 Plastic Waterproof Cable Gland Connectors	2	$0.45	$0.90	Amazon	Pack of 20
Drill bit	Multidiameter Drill Bit	1	$21.85	$21.85	McMaster	
12mm M3 Screw	18-8 Stainless Steel Socket Head Screw	4	$0.06	$0.24	McMaster	Pack of 100
M3 Jam Nut	Steel Thin Hex Nut	8	$0.04	$0.34	McMaster	Pack of 100
Velcro	Velcro 3/4 in x 30 ft Roll	25	$0.01	$0.27	Amazon	~25 cm needed for each
PVC Pipe	2.5' 1.5" schedule 40 PVC	1	$18.43	$18.43	McMaster	Minimum order length 10'
Marine Epoxy	Loctite Epoxy Marine, 0.85 fl oz	1	$8.50	$8.50	Amazon	

3.2 Electrical Components

Designator	Component	Qty.	Cost per Unit	Total Cost	Source of Materials	Notes
Feather	Adafruit Feather M0 Basic Proto	1	$19.95	$19.95	Adafruit	
Hypnos	Hypnos V3.2 or V3.3	1	$27.00	$27.00	OPEnS	
2 pin JST right angle socket	2 pin JST XH right angle socket	2	$0.19	$0.38	Digi-key	
Male headers	28 for Hypnos	1	$0.50	$0.50	Adafruit	
Female headers	10 for ADS1115, 30 for Hypnos	1	$2.95	$2.95	Adafruit	
Breakout Board	FloDar Breakout Board	1	$3.87	$3.87	OPEnS	Minimum order of 3
Resistor	SAMD 150 Ohm Resistor	1	$2.12	$2.12	Digi-key	
Tripler	FeatherWing Tripler Mini Kit	1	$8.50	$8.50	Adafruit	
ADS1115	ADS1115 16-Bit ADC	1	$14.95	$14.95	Adafruit	
SD Card	SanDisk 32GB microSDHC Memory Card with SD Adapter	1	$7.95	$7.95	B&H Photo	
Coin Cell	CR1220	1	$0.88	$0.88	Digi-key	

Cable Connector	Waterproof Polarized 4-Wire Cable Set	2	$2.50	$5.00	Adafruit	
USB Cable	Micro USB Cable	1	$1.60	$1.60	Amazon	Pack of 5
3-pin JST plug cables and sockets	3 PIN JST XH plug 200mm 26 AWG cable, socket	1	$0.75	$0.75	Amazon	Pack of 20
2-pin JST cables	22 AWG 2 Pin JST XH2.54 Connector Plug	2	$0.50	$1.00	Amazon	Pack of 20, 10 usable
Battery	TalentCell Rechargeable 12V Lithium Ion Battery	1	$39.99	$39.99	Amazon	
DC Power Jack	DC Power Jack Plug Adapter	1	$1.00	$1.00	Amazon	Pack of 10

3.3 Flow Meter

Designator	Component	Qty.	Cost per Unit	Total Cost	Source of Materials	Notes
USFM	TUF-2000M	1	$253.00	$253.00	Amazon	
Transducer	TS-2 Pair	1	(included)	-		
Transducer Cable	Transducer Cable	5 m	(included)	-		
Hose Clamps	Hose Clamps	2	(included)	-		
Heat Shrink	Heat Shrink	8	(included)	-		2x Red 2x Blue 4x Black small
Spades	Fork Spade U-Type Connectors	6	(included)	-		
Large black heat shrink	1/4" 3:1 adhesive lined heat shrink	5	$0.05	$0.25	Amazon	20 ft, each cable needs 2.5"
Solder seal connectors	Marine grade solder seal connectors 18-22 gauge	6	$0.20	$1.20	Amazon	Pack of 50, 1.5" long
Silicon Lubricant	Dow Corning 111 O-Ring Silicone Lubricant	1	$7.95	$7.95	Amazon	

4. Build Instructions

4.1 FloDar printed circuit board (PCB) assembly

Tools: soldering iron, solder, solder paste, reflow oven or heat gun, hot glue gun and glue, fan for solder fumes (optional), fume hood (optional)

4.1.1 ADS1115

Components:

- ADS1115 (with included male headers)

Procedure:

1. Solder provided male headers on to the ADS1115 with the short end of the pins sticking up through the top of the board (Figure 7).

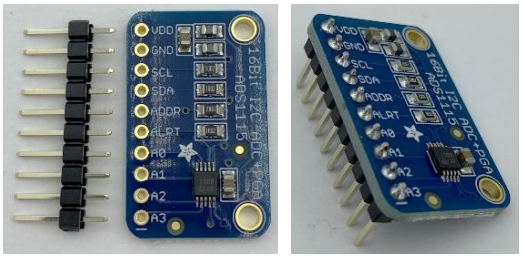

Figure 7: ADS1115 top with male headers separate (left), and with headers attached (right).

4.1.2 Custom PCB

Components (Figure 8):

- Custom PCB
- Female headers (10)
- Male headers (14, 16)
- Resistor
- 3 pin JST XH socket
- 3 pin JST XH plug with wires

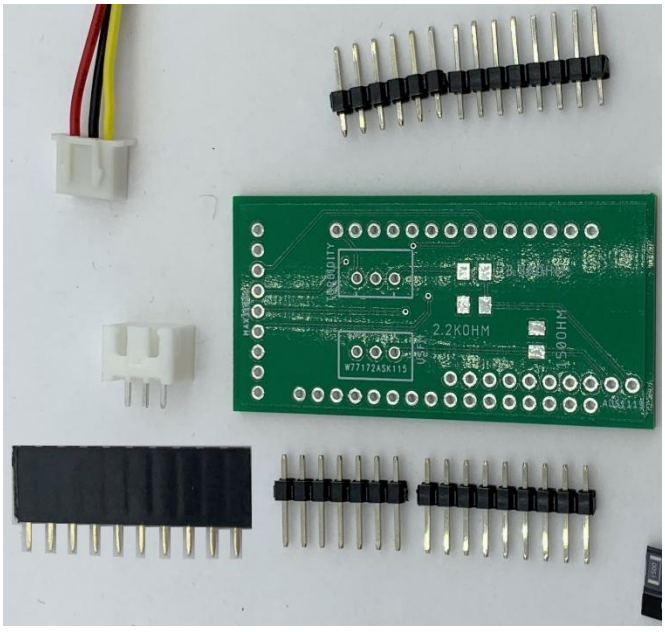

Figure 8: Components for breakout board assembly.

Procedure:

1. Apply solder paste to pads adjacent to 150 Ohm label (Figure 9, top)
2. Place the resistor across the two pads (direction does not matter).

3. Use either a reflow oven or heat gun (~350°C) to heat the solder paste enough to connect the resistor to the PCB (Figure 10). Paste should go from looking grainy to shiny.
4. Insert the short side of the 14 and 16 long male headers from the bottom of the board into the holes labeled for Hypnos Control in Figure 9, and solder them into place from the top (Figure 10).
5. Insert the pins for the female header into the board from the top side in the holes labeled ADS1115, flip over the board, and solder into place (Figure 10).
6. Insert the pins for the JST socket into the through holes labeled USFM from the top of the board, flip over the board, and solder into place (Figure 10). For consistency, align the side with the cutouts toward the center as indicated by the two lines inside the rectangle for the JST socket on the PCB silkscreen.
7. For the JST plug with cable, plug into the JST socket to determine which wire will be closest to the USFM label. Remove the socket and remove with tweezers or cut flush all wires except the one that will be closest to the USFM label (Figure 10). Plug back into the socket and hot glue wire into place.

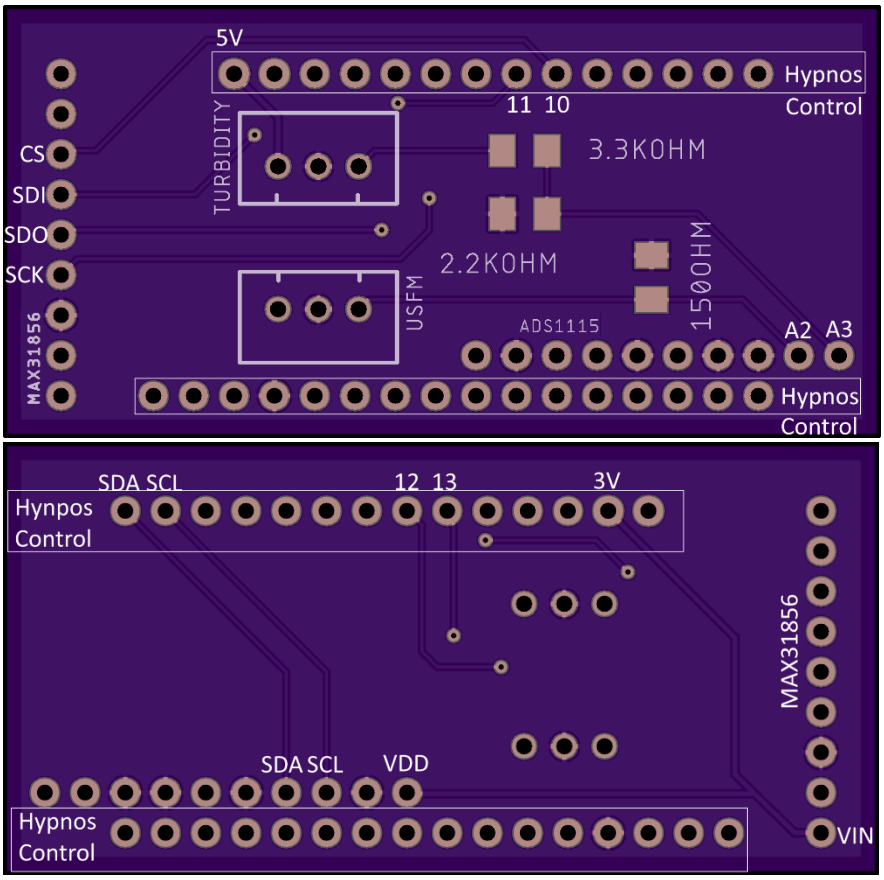

Figure 9: Custom PCB front (top) and back (bottom) with added labels. Note through holes labeled for MAX31856 are for implementation with a thermocouple. Through holes labeled for turbidity and 3.3 kOhm and 2.2 kOhm resistors are for implementations with a turbidity sensor.
Credit: OSHPark rendering of Gerber file.

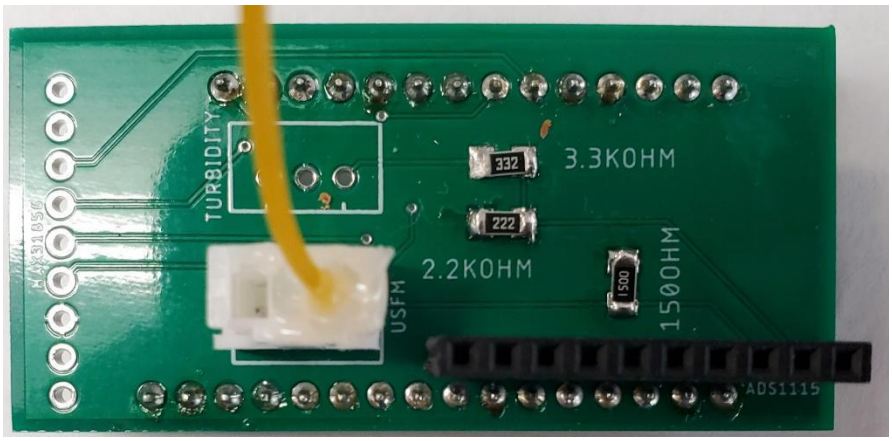

Figure 10: Assembled breakout board. Note 3.3 kOhm and 2.2 kOhm resistors are only used for implementations with the turbidity sensor.

4.1.3 Tripler

Components (Figure 11, left):

- Tripler
- Include female headers (2 x 12, 2 x 16)

Procedure:

1. Insert pins of female headers into outer most holes for the first and third board outlines as shown with the added red outlines in Figure 11 (left).
2. Flip the board over and solder each pin into place (Figure 11, right).

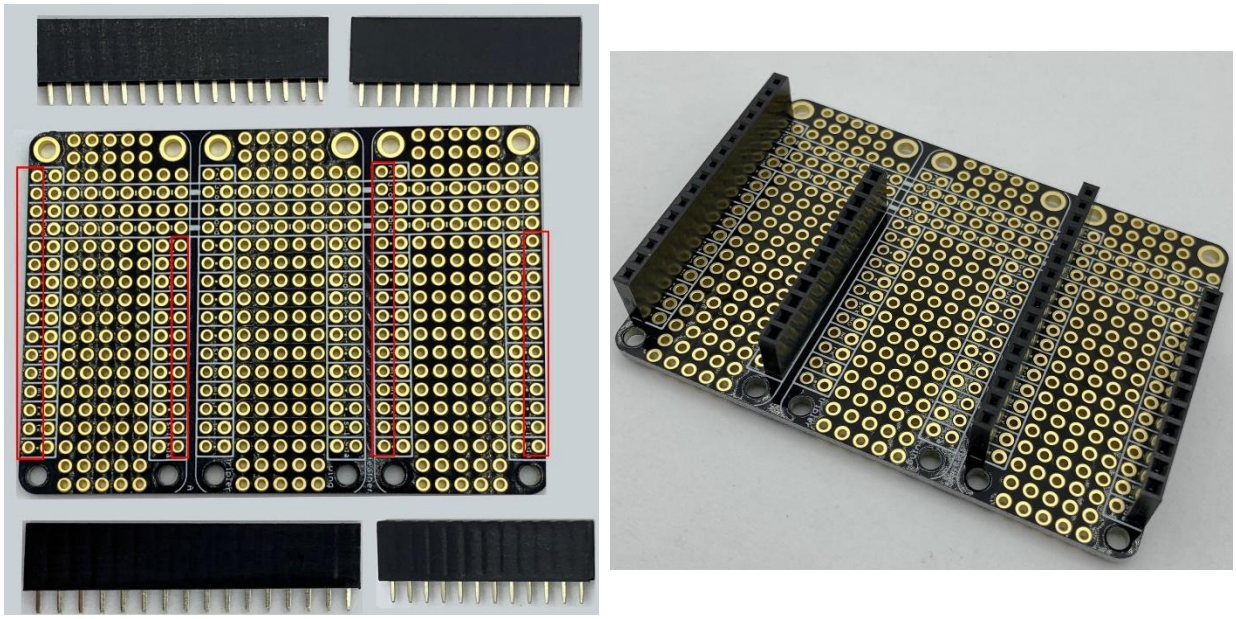

Figure 11: Tripler with headers separate and placement shown with red outlines (left) and assembled (right).

4.1.4 Hypnos

Components (Figure 12):

- Assembled Hypnos PCB (Nguyen et al. 2021)
- Male headers 12, 16
- Female headers 14, 16
- 2 2-pin right angle male JST sockets
- 2 2-pin female JST plugs with wires
- CR1220 coin cell
- microSD card

Procedure:

1. Insert the short side of the male headers from the back side of the board into the through holes labeled Feather starting with the holes closest to the end with the microSD socket (Figure 13, left). Flip over the board and solder each pin into place.

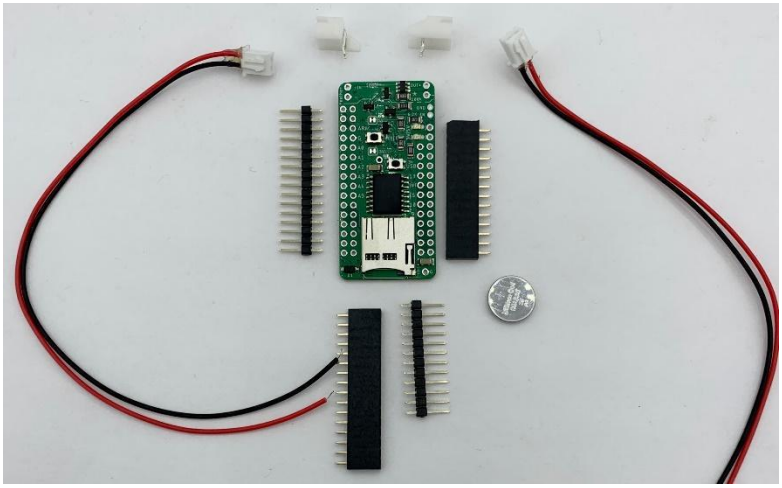

Figure 12: Top of assembled Hypnos PCB with components to be added. Note 2 pin JST on left has a clipped fin and microSD card is not shown.

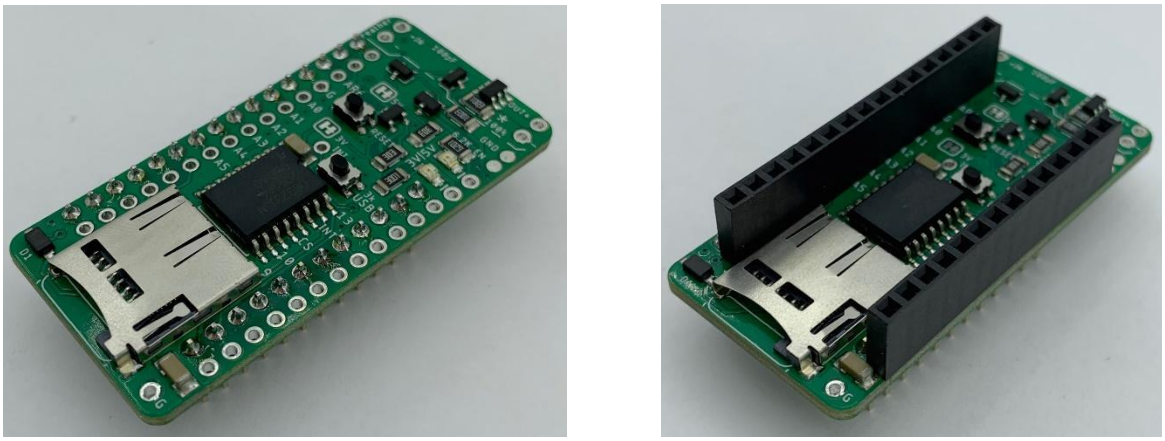

Figure 13: Top of assembled Hypnos PCB with male headers attached (left), and male and female headers attached (right).

2. Insert the pins of the female headers into the through holes on the PCB labeled control from the top side (Figure 13, right). Flip over the PCB and solder each pin into place.
3. Clip the right fin off of one of the 2 pin right angle JST sockets (Figure 14). Insert from the top into the top of the board in the two through holes labeled “In” so that the entry is facing out from the board. Flip over the board and solder into place.
4. Insert the other 2 pin right angle JST socket from the top into the top of the board in the two through holes labeled “Out” so that the entry is facing out from the board (Figure 14). Flip over the board and solder into place.

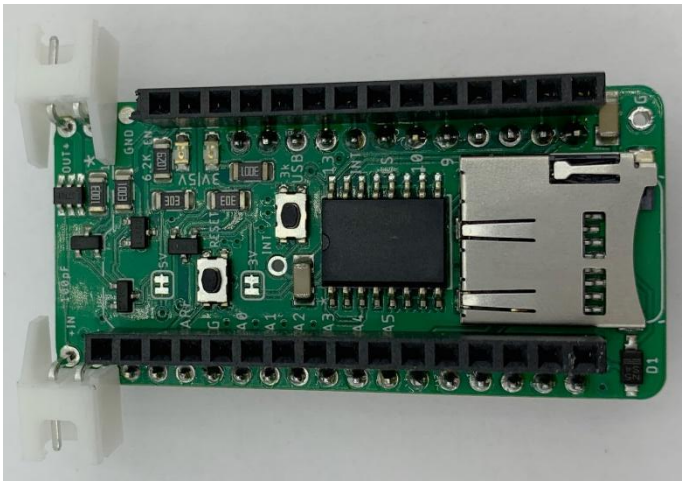

Figure 14: Top of assembled Hypnos PCB with headers and 2 pin right angle JST sockets.

5. Insert the JST plugs into the sockets. Verify the polarity matches the board for both: red wire at the end where the + symbols is on the board, black wire closer to the headers (Figure 15). If it does not match, use tweezers to gently pull up the plastic tabs holding the crimped connectors inside the case for each wire, pull out the wires, and insert on the appropriate side. Add hot glue to where the wires come out of the case to help hold in place.

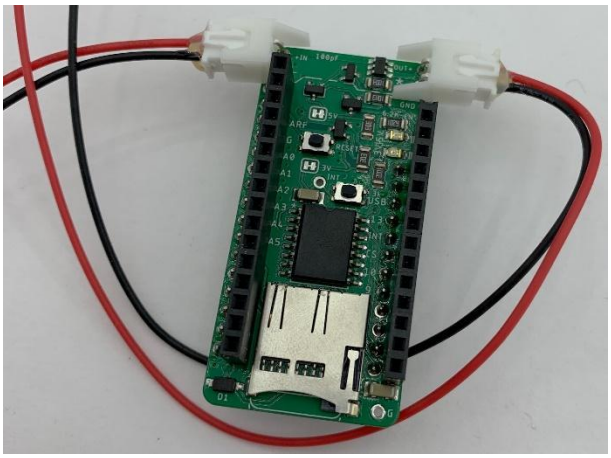

Figure 15: Fully assembled Hypnos showing correct wire positions.

6. Insert the coin cell into the coin cell holder on the back of the Hypnos board.
7. Insert the microSD card into the microSD socket on the front of the Hypnos board.

4.1.5 Feather M0

Components:

- Feather M0
- Included male headers (12, 16)

Procedure:

1) Insert the short end of the male header pins into the Feather M0 board from the bottom (Figure 16, right).
2) Flip the board over, and solder each pin.

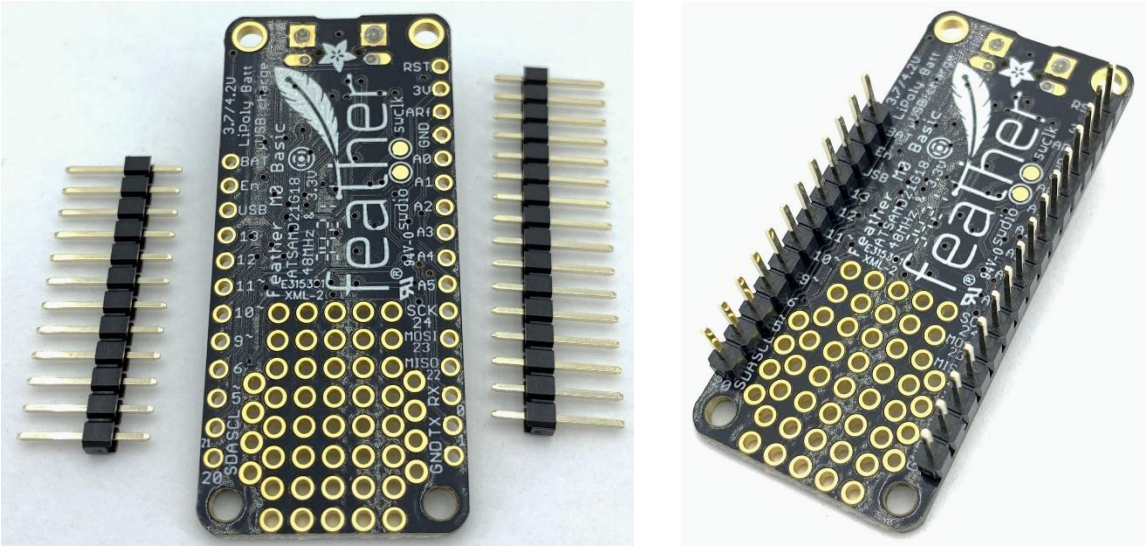

Figure 16: Feather M0 bottom with separate headers (left) and assembled (right).

4.1.6 Conformal coating

In a well-ventilated area or fume hood, coat all surfaces on all PCBs with conformal coating except 1) the unsoldered side of male header pins, 2) on and around buttons, 3) the microSD socket, and 4) the coin cell holder. Leave to dry for up to 48 hours.

4.2 FloDar transducer assembly

Tools: Phillips Screwdriver, Flush Cutters, Wire Strippers (22 Gauge, 10 or 12 Gauge), Soldering Iron, Heat Gun (1500 W recommended), Crimpers, Fan for Solder Fumes (Optional)

Components (Figure 17):

- Transducers
- 5 m Transducer Cable
- Electrical Tape
- 2x Large Heat Shrink
- 2x Large Blue and Red Head Shrink
- 2x Waterproof Cable Connectors
- 6x Fork Spade U-Type Connectors
- 6x Solder seal connectors

Figure 17: Materials for assembling transducers

4.2.1 Transducer heads

1. Measure and cut each transducer cable in half to have two cables approximately 2.5 m in length (or less depending on location of transducers vs. pelican case).
2. Split all the components into two equal piles.

Repeat steps 3 through 21 for each transducer:

3. Strip back the outer jacket of the transducer cable at one end using the larger gauge strippers, about 3 cm (Figure 18). Note there is a copper wire casing - do not remove this - as well as a thread strand.

Figure 18: Transducer cable with outer jacket stripped back.

4. Unwind the copper, keeping it as intact as possible.
5. Isolate the thread, and cut it out using the flush cutters.
6. Twist the copper tightly to form a cleaner and more usable wire.
7. Strip the black and red cables using the smaller gauge wire strippers for about 0.5 to 1.25 cm (Figure 19).

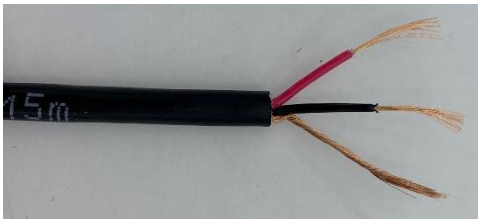

Figure 19: Transducer cable with outer jacket and individual wire jackets stripped back.

8. Twist the copper in the black and red wires so they are neat as well. Set aside.
9. Unscrew the screw in the lid on the transducer head and remove the lid (Figure 20).

Figure 20: Transducer head with lid removed.

10. Take off the cable gland cap on the transducer head.
11. Poke a hole in the cable gland either using the flush cutters or other sharp object.
12. Use a round blunt object such as your screwdriver to loosen the hole in the cable gland. Be careful not to rip the gland. If the gland comes out of the housing but is undamaged, it is acceptable to place the gland back in its housing.
13. Slide the cable gland cap over the transducer cable such that the side with the threads is facing the stripped end (Figure 21). If you do this step backwards, you are still able to take the cap off the other end of the transducer and flip it around. This will NOT always be the case.

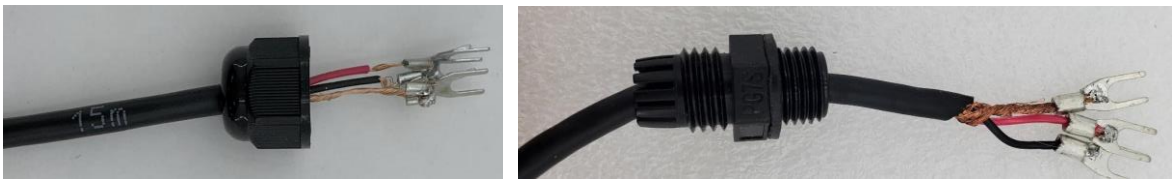

Figure 21: Transducer wire with cable gland nut (left) and cable gland body (right). Note that the cable gland body right side should still be screwed into the transducer head unlike as shown.

14. Feed the stripped wires into the cable gland body and pull it through such that the stripped wires are on the inside of the transducer and the outermost casing of the transducer wire is through the cable gland (Figure 21). It may help to fold the exposed metal back on itself.
15. Slide a fork spade onto the end of each wire.
16. Optional: Solder each wire end to the fork spade just after the crimp section. Ensure the fan is on prior to soldering.
17. Crimp each fork spade onto each wire. It may help to note the sequence that the wires are placed into the transducer and orient the fork spades so that they are facing up (Figure 20, 22). Ensure that each crimp holds tight.
    a. Red goes to the (+)
    b. Black goes to the (-)
    c. The bare copper goes to the ground ⏚.
18. Unscrew each connection without fully taking the screw out. Place the fork spades under the screw and the square washer. It may be necessary to pull or push the transducer cable through the cable gland more to adjust where the fork spades land due to the small space.
19. Screw each of the contacts back down, ensuring that each one is tight and does not move (Figure 22).

Figure 22: Wires with fork spades attached inside transducer head. Note the cable gland nut is not shown but should already be on the cable in orientation shown in Figure 21 (top).

20. To seal the container, apply RTV silicone to the top of the outer edge of the grey body part where it will interact with the blue lid. Ensure that the top side of inside nut of the cable gland is horizontal so it does not interfere with the lid.
21. Place the transducer top back on the transducer and screw it back down. Be careful not to screw back in at an angle as you are screwing directly into the plastic. Also ensure that the top forms a tight seal against the transducer body, cracks could allow water to seep into the transducer and cause shortage.
22. Screw the cable gland cap that was already on the transducer cable tightly onto the cable gland to grip the transducer cable.
23. If this is the first transducer, repeat for the second transducer.

4.2.2 Transducer cable to waterproof connector cable

Repeat steps 1 to 10 for each transducer:

1. Slide a 6 cm long piece of the large black heat shrink over the untouched end of the transducer cable.
2. Strip the outer jacket of the transducer cable back about 4.5 cm: enough to fit a solder seal connector with 1.5 cm of wire exposed (similar to Figure 18).
3. Same as before, unwind the copper casing and isolate the thread, cutting it off. Twist the copper neatly together.
4. Strip back the jackets of the red and black wires using the smaller strippers about 1.5 cm (similar to Figure 19). Twist the copper strands for each wire together.
5. Slide the large black heat shrink at least 10 cm away from the end of the transducer cable.
6. Switching to the waterproof connector cable, identify whether this is the up (red) or down (blue) transducer, and place the respective color heat shrink on the wire end of the each side of the connector cable and slide to next to the threads or connector. Use a heat gun to shrink on to each cable (Figure 23). This is a critical step; if forgotten, you may not be able to place the heat shrink on after further steps are completed.
7. For remaining steps, use the side of the connector cable that has threads for the transducers. Set aside the side that the cap goes over. It is used for the pelican case.

Figure 23: Waterproof connector cable with blue heat shrink to indicate down transducer, and heat shrinked connections to transducer cable (completed in step 10).

8. Strip the jackets about 1.5 cm of all four wires on the connector cable using the smaller gauge wire strippers (Figure 24).

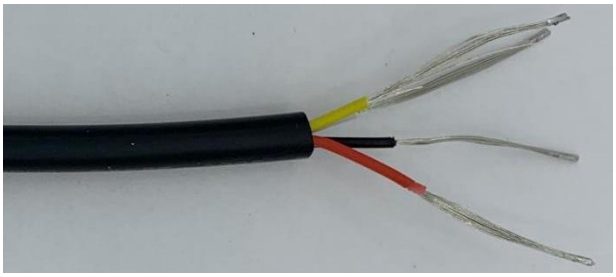

Figure 24: Waterproof connector cable with wire jackets stripped.

9. For each of the three transducer wires:
    a. Slide on a solder seal connector.
    b. Twist the wire from the waterproof connector cable around the appropriate transducer cable wire:

Waterproof connector cable wire color	Transducer cable wire color
Red	Red
Black	Black
White, Yellow	Bare

    c. Slide the solder seal connectors so that the metal ring of solder is on top of each of the combined wires (Figure 25).
    d. Make sure the fan is on, if using, and use a heat gun at ~200°C or the highest setting for a 1500 W heat gun to first melt the solder and then shrink the surrounding tube one side at a time.

Figure 25: Waterproof connector cable and transducer cable wires with solder seal connectors prior to heating (left) and after heating (right). Note directions indicate putting on and heating each connector individually, not all together as shown on the left.

10. Slide the large black heat shrink over all three wire connections, and use the heat gun to shrink the heat shrink (Figure 23).
11. If this is the first transducer, repeat for the second transducer.

4.3 Pelican case assembly

4.3.1 Cable glands

Tools: drill or drill press, drill bit

Components:

- Pelican case
- 2x cable glands
- Marine epoxy

Procedure:

1. Take out the bottom foam piece in the case, and discard.
2. Use the drill and drill bit to drill two 1.25 cm diameter holes in the right side (when looking at the pressure valve) of the pelican case at 4.5 cm from the bottom and 4.4 cm from each side (Figure 26). Hole locations do not need to be exact, but ensure that the cable gland nuts will sit on top of the vertical ridges inside, and centers will be above the flowmeter to allow for each cable to pass above the flowmeter. Alternatively, the holes could be drilled in the front of the box to align with the connections for the flowmeter.

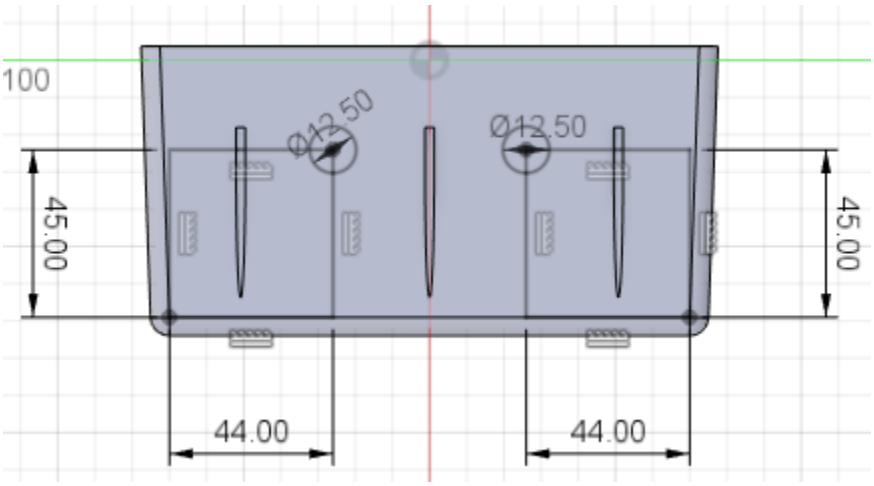

Figure 26: CAD rendering of the side of the pelican case showing hole placements with measurements in mm.

3. Unscrew the flat nuts. The rubber gaskets can be used if the nut is put on backward inside the box or the rubber gasket can be removed and epoxy used to seal the gland instead.
4. Mix the two parts of the epoxy, and apply to the base of the threads of each cable gland on the side for the flat nut. Insert cable glands into the holes in the pelican case from the outside, and fasten on the inside with the flat nut (Figure 27).

Figure 27: Cable gland in pelican case shown from outside (left) and inside (right).

4.3.2 Insert

Tools: 3D printer or laser cutter

Components:

- acrylic or ASA filament

Procedure:

1. 3D print or laser cut the insert. If using the acrylic insert, after cutting, glue the four flow meter tabs into place with Acrylic Plastic Cement (e.g. Weld-On 3).
2. Insert the 2-4 bolts for the tripler into the 3 mm holes in the insert from the bottom (see orientation in Figure 3) and fasten in place with nuts.
3. Put the insert into the case with the flow meter section on the right and the bolt threads up (Figure 2, 3).

4.3.3 Final Assembly and Wiring

Tools: Small screwdriver, scissors

Components:

- Pelican case with insert
- PCBs: ADS1115, custom breakout board, Hypnos, Feather M0, tripler
- Unattached waterproof connector cables
- USB cord
- DC power jack
- Flow meter
- Battery (fully charged)
- Velcro

Procedure:

1. PCBs
    a. Set the tripler on the bolts in the insert, and use one nut on each to fasten in place.
    b. Stack the Hypnos board on the headers on the left side of the tripler (Figure 28).
    c. Stack the custom breakout board on top of the Hypnos board (Figure 28).
    d. Stack the ADS1115 board on top of the custom breakout board (Figure 28).

e. Stack the Feather M0 on the headers on the right side of the tripler (Figure 28).
f. If the male and female headers are switched (male for control and female for Feather) on the Hypnos, the Hypnos will need to be stacked under the M0 instead of the custom PCB.
g. Connect the USB cable to the USB port on the Feather M0.

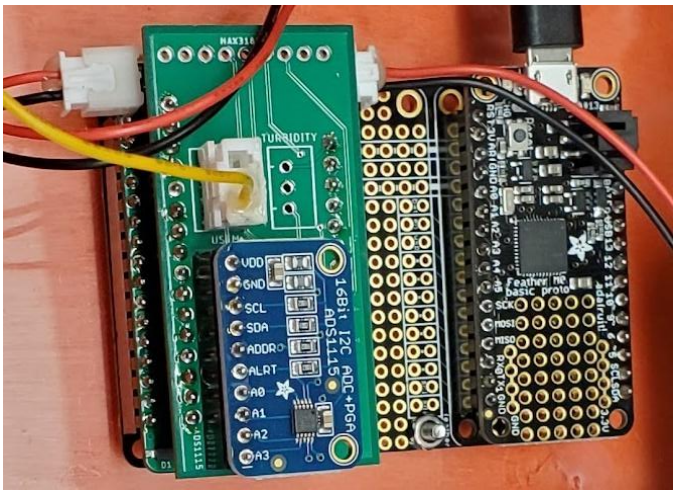

Figure 28: PCBs stacked with connections.

2. Battery
    a. Put the battery upright in the case in the long slot against the back so that there is room to make connections (Figure 2, 3).
    b. Connect the other end of the USB cable to the battery. Make sure any excess cable length will not get closed in the case seams.
    c. Unscrew the terminals on the DC power jack, insert the ends of the wires (red to + and black to -) from the JST connector in the “In” location on the Hypnos, and screw back down.
    d. Insert the DC power jack into the battery barrel jack socket.
3. Flow meter
    a. Cut a ~25 cm long piece of velcro, and slide it under the insert. For the 3D printed insert, the velcro comes up in the oval holes above and below the flow meter. For the laser cut insert, the velcro comes up in the battery slot and the narrow space between the insert and case wall (Figure 2).
    b. On the flow meter, unscrew the terminals for 24+, 24-, A0, UP+, UP-, GND, DN+, DN-, and GND (Figure 29).
    c. For each of the waterproof connector cables, slide the nut onto the unthreaded side with the threads facing away from the bare wires (Figure 30).
    d. Loosen the nuts on the outside of the cable glands in the pelican case.
    e. Insert, bare wires first, the waterproof connector cable with the red heat shrink for the upstream transducer in the cable gland closer to the handle (Figure 30).
    f. Insert, bare wires first, the waterproof connector cable with the blue heat shrink for the downstream transducer in the cable gland closer to the hinge (Figure 30).
    g. For the upstream cable, insert the end of the red wire into UP+ terminal, and tighten down the screw. Insert the end of the black wire into the UP- terminal, and tighten down the screw. Insert the ends of the white and yellow wires into the

GND terminal between the UP- and DN+ terminals, and tighten down the screw (Figure 29).

h. For the downstream cable, insert the end of the red wire into DN+ terminal, and tighten down the screw. Insert the end of the black wire into the DN- terminal, and tighten down the screw. Insert the ends of the white and yellow wires into the farthest right GND terminal, and tighten down the screw (Figure 29).
i. Insert the end of the red wire from the “Out” JST of the Hypnos into the 24+ terminal, and tighten down the screw.
j. Insert the end of the black wire from the “Out” JST of the Hypnos into the 24- terminal, and tighten down the screw.
k. Insert the end of the wire from the 3 pin JST on the custom breakout board into the A0 terminal, and tighten down the screw.
l. Rotate the flow meter and set into place, and secure with the velcro (Figure 2).
m. Tighten the outer nuts on the cable glands.

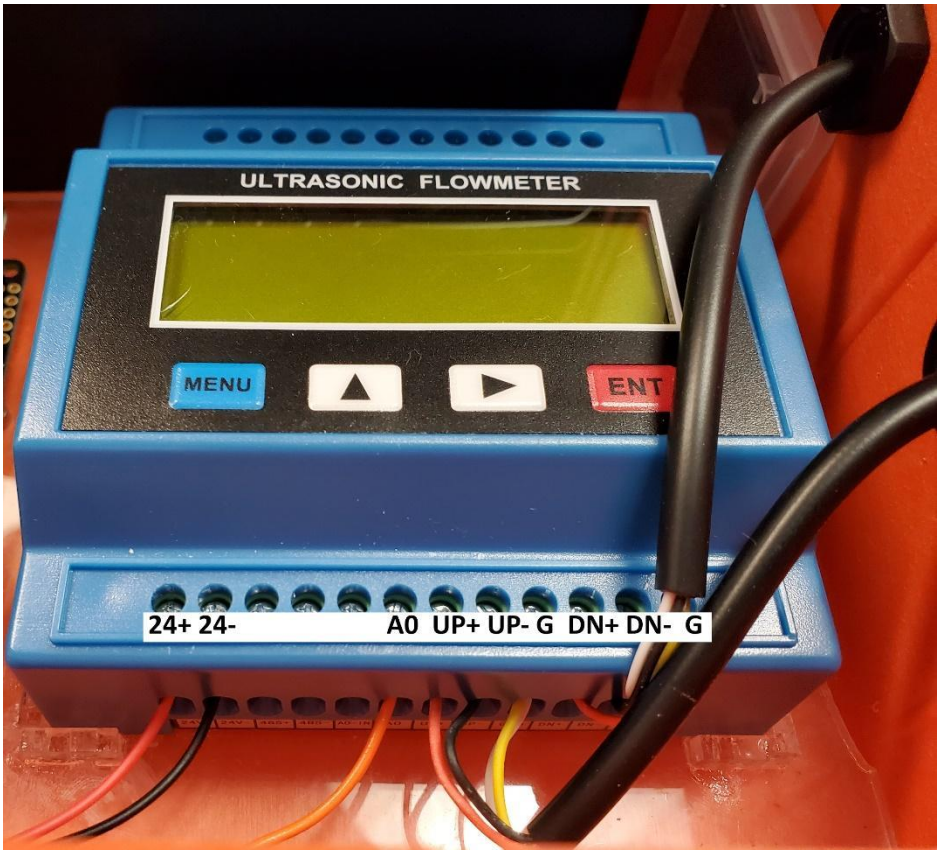

Figure 29: Flow meter with all wire connections. Note labels are below the ports for the wires, so in the image labels have been duplicated next to the screw terminals for clarity.

Figure 30: Pelican case with waterproof connector cables, battery, and flow meter.

4.4 Program Feather M0

1. Follow the directions on the Loom Wiki for installation of the Arduino IDE and Loom 4.1 Board profile: https://github.com/OPEnSLab-OSU/Loom-V4#Install
2. Download the FloDar_Field_Loom4_1.ino, and place in a folder with the same name (FloDar_Field_Loom4_1).
3. Open the .ino file with the Arduino IDE.
4. Adjust constants as desired:
    a. Time period between measurements: DAY, MINUTE, HOUR, SECOND on lines 21-24
    b. Maximum flow rate: MAXFLOWRATE on line 31 (Must match flow rate for 20 mA set in flow meter menu 57 in Section 4.5.2).
    c. Time zone: Line 36, third variable for Hypnos object creation. See Loom_Hypnos.h lines 31-53 for options.
5. Follow the directions for selecting a board profile, port and compiling code on the Loom Wiki under "Run an example", but use the FloDar code instead of an example. See also guidance from Adafruit.
6. Once the code has successfully compiled, open the serial monitor: Tools\Serial monitor or magnifying glass like icon in upper right corner.
7. Follow the prompts in the serial monitor to set the clock.

4.5 Flow meter setup

For the correct speed of sound, and output from the flow meter, many settings need to be changed from the default (see Ultrasonic Flow Meter User Manual for more information). During normal operations, the flow meter is turned on for just long enough to capture a reading. In order to keep the flow meter on for long enough to change parameters, either reprogram the Feather M0 with software to keep the whole system on (e.g. FloDar_Lab.ino which includes data logging), or directly wire the 24+ and 24- to the DC power plug for the battery. Turn on the battery. Remember to change the program or wiring after setup is complete.

There are four buttons for navigating and changing parameters on the flow meter:

1) MENU: Allows input of a specific menu number
2) ▲: Increments to greater menu item, or with menu button pressed or changing a parameter cycles through 0-9, +, -, .
3) ▶: Decrements to a lesser menu item or moves the cursor over
4) ENT: Finishes menu number input or enters into a sub menu

4.5.1 Speed of sound related parameters

Optional: Menu 30: Set unit system to English (all values below will be in English units)

1. Menu 11: Outer diameter of pipe: 1.906 in
2. Menu 12: Pipe wall thickness: 0.145 in
3. Menu 14: Pipe material: (5) PVC
4. Menu 16: Lining parameters: (0) none, no liner
5. Menu 20: Liquid type: (0) water(general)
6. Menu 23: Transducer type: clamp-on Ts-2
7. Menu 24: Transducer mounting type: (0) V
8. Menu 25: Transducer installation distance: Set by flow meter - verify it is 1.01 in

4.5.2 Output and display related parameters

1. Menu 31: Flow rate unit: L/min (or other desired unit that is consistent across the flow meter and Arduino code parameters)
2. Menu 55: Analog output mode: 0-20 mA
3. Menu 56: Value corresponding to 0 mA current: 0
4. Menu 57: Value corresponding to to 20 mA current: 150 (or value that is consistent across the flow meter and Arduino code parameters)

4.5.3 Save parameters

Press enter twice in Menu 26 to “solidify settings”: save to internal flash memory. Without this step, none of the parameter changes will remain after power is removed.

5. Operation Instructions

5.1 Transducer installation

The transducers should be installed on a clean section of pipe that is free of debris or scaling on the outside and inside where there will be steady, full pipe flow with minimal bubbles and suspended sediment. See the Ultrasonic Flow Meter User Manual for more information on transducer placement in a pipe system. Apply lubricant to the oval transducer faces, set the upstream transducer face against the cleaned pipe location with the label on the downstream side, and use the clamp to fasten securely with the clamp band in the gap between raised sections on the back of the transducer (Figure 4). Place the spacer against the upstream transducer and slot the downstream transducer into the spacer, label touching the spacer, or

measure and place the downstream transducer at the distance indicated by Menu 25 exactly in line with the upstream transducer, and use the clamp to fasten securely (Figure 4). The spacer can be removed or left in place. Attach the upstream waterproof connector cable from the transducer to the upstream cable attached to the flow meter, and the downstream waterproof connector cable from the transducer to the downstream cable attached to the flow meter.

5.2 Flow meter calibration

For the flow meter to accurately calculate fluid velocity, it must have a zero flow reference. Fill the pipe the transducers are attached to with water, and wait until there are no bubbles or fluid movement. Turn on the flow meter and select menu 42 (see Section 4.5). Select ENT to start the zero flow calibration. When calibration is complete, solidify settings in flash memory using menu 26 (see Section 4.5.3).

5.3 Deployment

After the transducers are installed, place the pelican case in an adjacent location and open it. Switch on the battery, and wait up to 30 seconds for the flow meter to turn on: initial setup waits for a serial monitor connection for 20 seconds, then the flow meter takes up to 10 seconds to boot up. If the flow meter does not power on, check all wire connections and battery voltage. When the flow meter powers on, check that the flow meter display shows signal quality values greater than 60 for each transducer, and then a flow value within the expected range, and “R” (normal) for the system error code in the upper right corner of the display. If not, consult the Ultrasonic Flow Meter User Manual for troubleshooting. Close and latch the pelican case, ensuring that there are no debris or wires between the gasket in the lid and the bottom lip.

6. References

Nguyen, B., Goto, B., Selker, J.S., Udell, C. 2021. Hypnos board: A low-cost all-in-one solution for environment sensor power management, data storage, and task scheduling. HardwareX, 10: e00213. https://doi.org/10.1016/j.ohx.2021.e00213

Ultrasonic Flow Meter User Manual. Type: TUF-2000M. Accessed from https://m.media-amazon.com/images/I/A12ZQnE3uEL.pdf. Accessed 2023-03-22.