The OPEnSampler: A Low-Cost, Low-Weight, Customizable and Modular Open Source 24-Unit Automatic Water Sampler

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Abstract

Reliable automatic water samplers allow repetitive sampling of various water sources over long periods of time without requiring a researcher on site, reducing human error as well as the monetary and time costs of traveling to the field, particularly when the scale of the sample period is hours or days. The high fixed cost of buying a commercial sampler with little customizability can be a barrier to research requiring repetitive samples, such as the analysis of septic water pre- and post-treatment. DIY automatic samplers proposed in the past sacrifice maximum volume, customizability, or scope of applications, among other features, in exchange for a lower net cost. The purpose of this project was to develop a low-cost, highly customizable, robust water sampler that is capable of sampling many sources of water for various analytes. A lightweight aluminum-extrusion frame was designed and assembled, chosen for its mounting system, strength, and low cost. Water is drawn from two peristaltic pumps through silicone tubing and directed into 24 foil-lined 250mL bags using solenoid valves. A programmable Arduino Uno microcontroller connected to a circuit board communicates with a battery operated real-time clock, initiating sampling stages. Period and volume settings are programmable in-field by the user via serial commands. The OPEnSampler is an open design, allowing the user to decide what components to use and the modular theme of the frame allows fast mounting of new manufactured or 3D printed components. The 24-bag system weighs less than 10kg and the material cost is under $450. Up to 6L of sample water can be drawn at a rate of 100mL/minute in either direction. Faster flowrates are achieved by using more powerful peristaltic pumps. Future design changes could allow a greater maximum volume by filling the unused space with more containers and adding GSM communications to send real time status information.

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ABSTRACT AND PURPOSE:

Commercially available water samplers can be expensive investments and often provide little(limited, sounds better) customizability. The OPEnSampler was designed to allow direct customization by the user both when choosing parts for assembly and before field use via the programmable microcontroller while preserving the low cost of DIY samplers in addition to the wide range of applications of many commercial samplers.

The OPEnSampler is equipped with 24 foil-lined bags, each storing up to 250mL of sampled water for a maximum of 5.80 L of sample water. The pumps can draw water at a rate of 100mL/minute and solenoid valves, controlled by an Arduino Uno microcontroller, direct the flow into each bag. The pump can be operated in reverse if the bags are oriented upside-down to draw water from specific sample bags for testing. 3D printed mates for mounting components to the aluminum extrusion as well as 3D printed bag caps were designed. All design files are available on our gitHub page, linked in the bottom right corner of this poster.

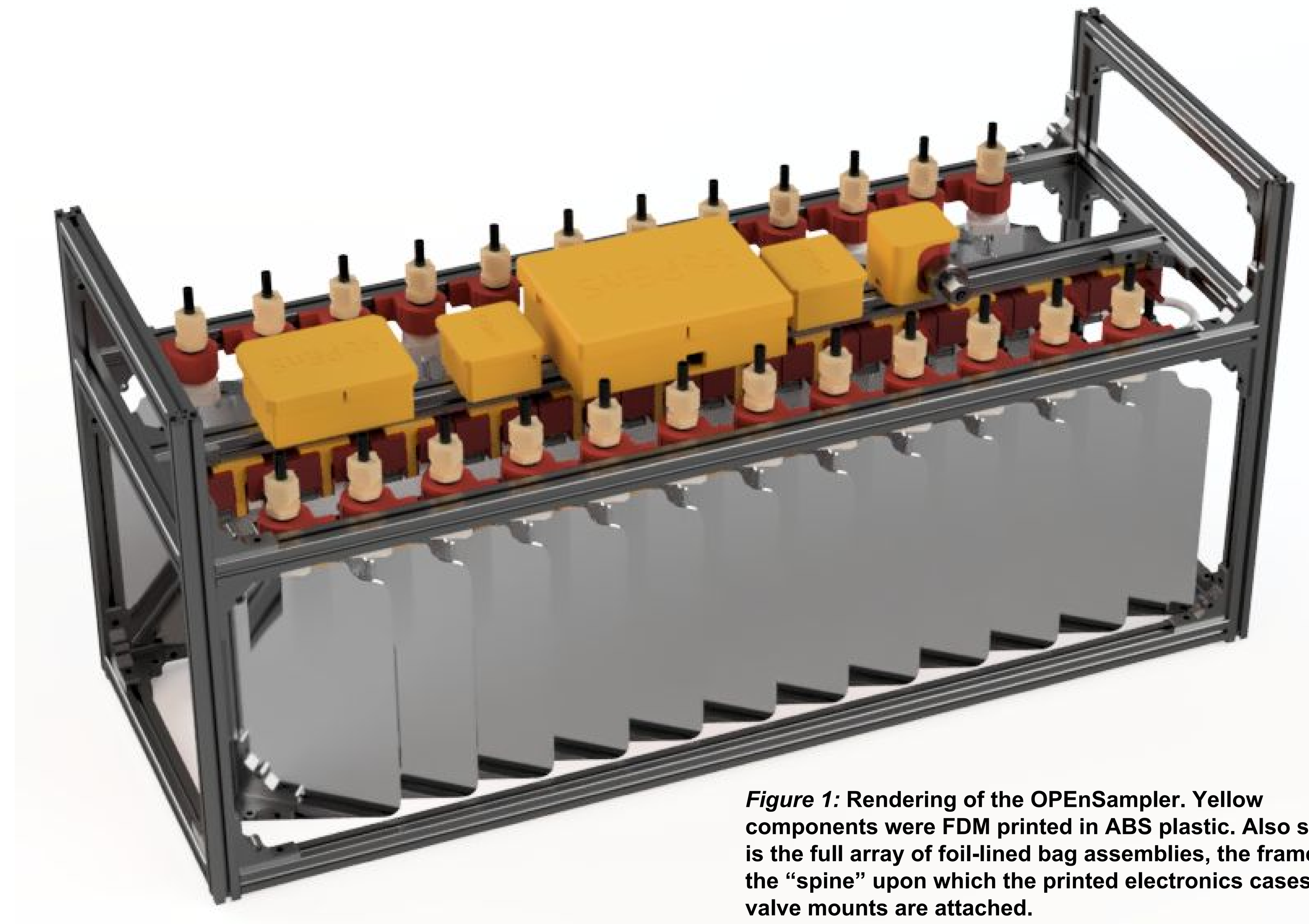
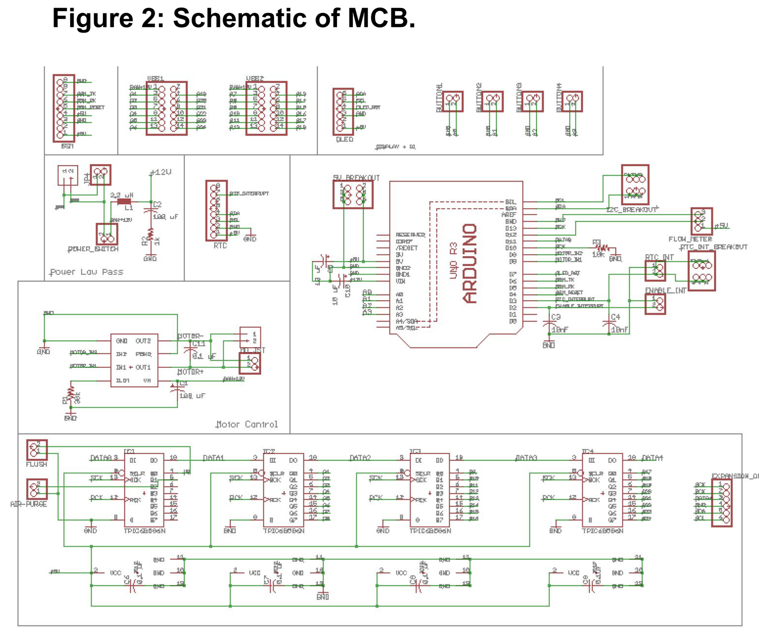


Figure 1: **Rendering of the OPEnSampler. Yellow components were FDM printed in ABS plastic. Also seen is the full array of foil-lined bag assemblies, the frame, and the "spine" upon which the printed electronics cases and valve mounts are attached.**

ELECTRONICS:

The Main Control Board (MCB, *figures 2 and 3*) interfaces the Arduino Uno microcontroller with the rest of the system. A low-pass filter on the power supply limits noise down the line from the motor, and decoupling capacitors stabilize power to the shift registers and interrupt lines. Headers break out the interrupt pins as well as the Arduino's I2C pins for communicating with external sensors.

Figure 2: Schematic of MCB.



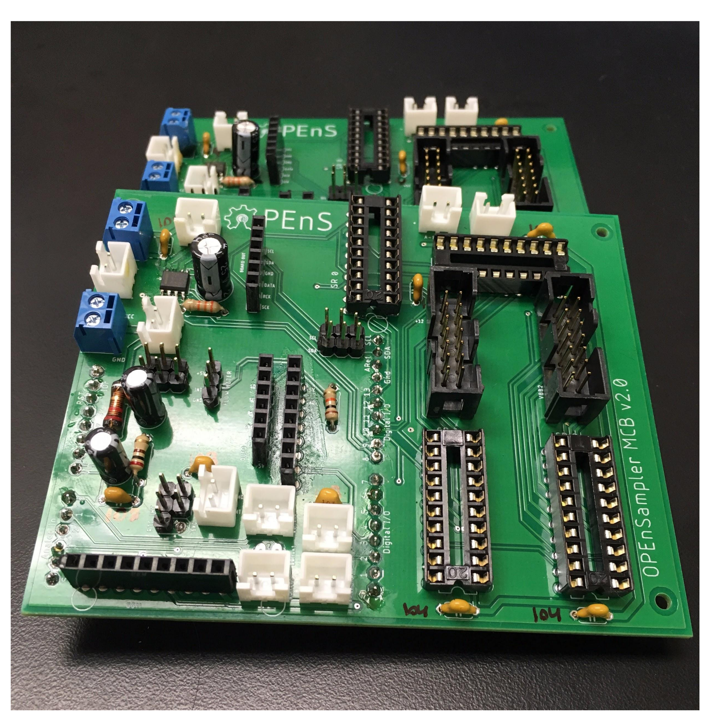
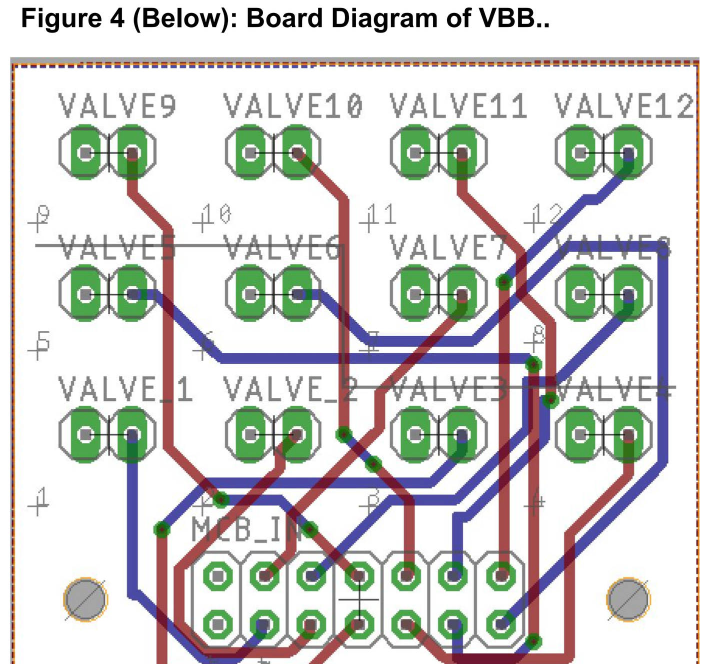


Figure 3 (Above): Finished MCB.

Figure 4 (Below): Board Diagram of VBB..



The Valve Breakout Board (VBB, *Figure 4*) distributes 12VDC to the positive line of 12 valves and connects each valve's ground to an individual pin on a 14-pin rectangular connector. A VBB is positioned on both sides of the MCB, each controlling one half of the sample valves. A ribbon cable connects each VBB to the MCB.

METHODS:

The first concept focused on including as many sample containers as possible in a given space. Bottles were arranged in a foam grid, a cheap peristaltic dosing pump was used to move water, and solenoid valves were controlled by an arduino to direct the flow.

The current design uses a rigid frame made with aluminum extrusion cut to length by an online supplier. SLA printed bag caps hold and seal foil-lined mylar bags. Custom PCBs were ordered and hand-soldered. Arduino code was optimized and improved, allowing the user to enter simple Serial commands to perform tasks such as opening a specific valve, powering the pump forward or reverse, and setting the sample interval. An operator interface consists of several buttons and switches, as well as a usb port. The user is able to set up the settings ahead of time such that field initialization consists of switching the power on and pressing a button, though changing settings with a laptop in the field is possible.

FEATURES:

- 24 individual 250mL sample containers, sealed from the environment
- Arduino controlled PCBs
- Battery operated, 24 hours on 2000mAH 12V battery, one week on 8AH
- Customizable, Openly Published designs on gitHub
- Trigger-based sampling enabled for external sensors
- Fluoropolymer tubing for decreased loss of DOCs due to absorption
- Real Time Clock with separate battery keeps time when device is off

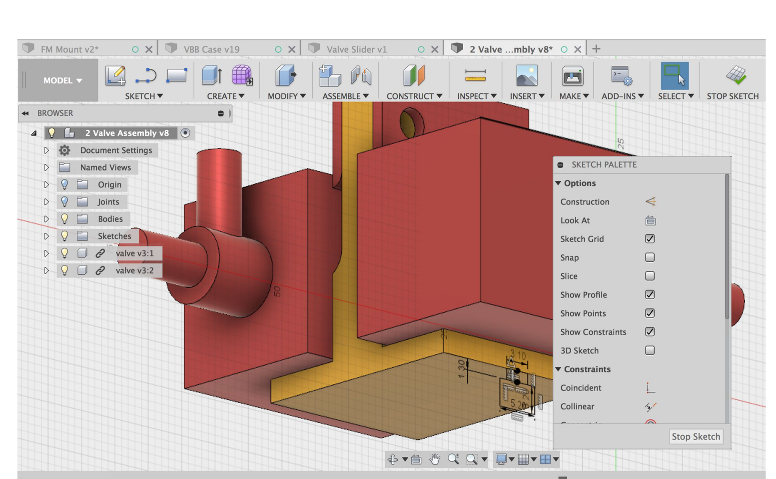
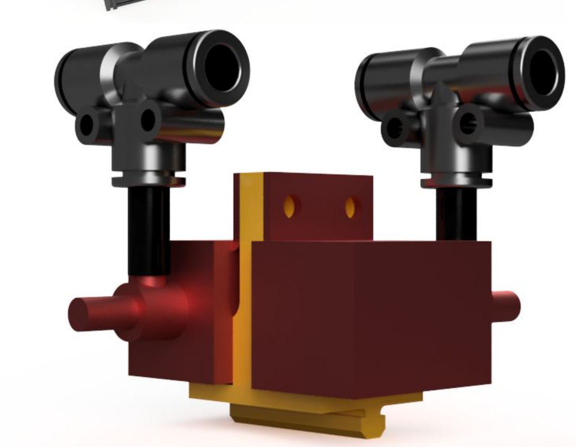


Figure 5: An example of modifying the dimensions of the valve assembly. All components are available on our gitHub as STL files and also as AutoDesk Fusion 360 files.

ASSEMBLIES:

The Frame: The frame is assembled from various lengths of 15mm square aluminum extrusion. Its purpose is to provide a solid mounting system that can be easily manipulated and customized to fit to different containers and applications. 3D printed mounts for components interface with the aluminum extrusion.

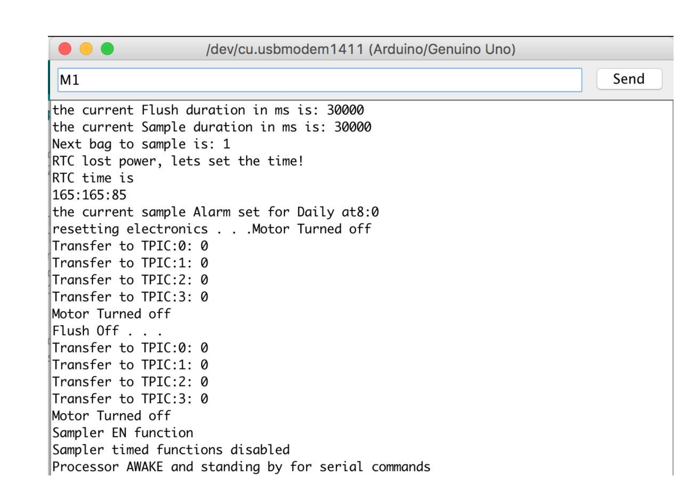
3D Printed Components: Bag caps, valve mounts, and electronics containers were 3D Printed. The caps were printed with an SLA printer and the remaining parts were printed on an FDM printer in-lab. Parts were post-processed with acetone vapor, threaded inserts, o-rings, and Loctite.



The Hydraulics: A peristaltic pump pulls sample water into the device through an inlet port. A flow meter tracks the flow velocity to estimate the net water intake. Water flow is directed into one of 24 sample bags via corresponding solenoid valves or is pushed out of the device if the flush valve is opened. All interior tubing is PVDF, a smooth fluoropolymer. The sample bags are sealed to the environment when their respective valve is closed.

SERIAL INTERFACE:

The Arduino Serial Interface allows the user to operate the device from a computer through a USB cable. Settings can be changed by looking up the preset commands specified in the "Serial Command Defs" file. The device outputs the current settings as well as which valves are open and what is currently enabled, then waits for commands.



CONCLUSIONS:

Each iteration of the OPEnSampler creates additional opportunities for further development. External sensor integration, long-distance device-to-user communication, and flow-proportional sampling are just some of the many improvements we are planning on making to the OPEnSampler. Because the design is available online, anyone can be a collaborator and create their own branch of the OPEnSampler with improvements specific to their own research.

OPEnS Website

GitHub Page

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