Universal Sensor Interface

A Mission Statement

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Introduction

I have lived in the mid-Columbia Basin for over 35 years and have kayaked hundreds of miles along the main Columbia River as well as its tributaries. I have frequently taken a quick dip in the river after a long mid-summer run. The Columbia and most of its tributaries are clean enough to support a major recreation industry as well as being the primary source for drinking water.

In the summer of 2021, we had a record heatwave that reached 115 F, meteorologist introduced us to the term "Heat Dome", water levels in the Columbia dropped and our first ever toxic algae bloom occurred in the main river. Toxic algae blooms have been issues in smaller water bodies like Scooteney Reservoirs and Crab Creek but never before in the Columbia proper. Dogs died, Sturgeon died, people got sick and had skin rashes. Signs went up warning people not to enter the water and to keep dogs away.

I inquired with professional biologists, ecologist and hydrologist of the Army Corp. of Engineers, the Washington Dept. of Ecology and Washington State University. The general reaction was one of surprise. The professionals in the area were not prepared for such an event. I also reviewed the water quality analysis data and found that it was sparse both in time and space. However, it is a fairly safe assumption that nitrogen and phosphorous nutrients are the root cause of this eutrophication event and that the obvious sources are irrigated farmland and residential landscaping and septic systems. Because we get so little rain (~8"/yr), stormwater runoff is probably not a great factor.   But to drive change the data has to show where and when nutrients enter the river. Effectively one needs daily monitoring at dozens of locations from Priest Rapids Dam to McNary Dam. As well as up the Yakima and Snake Rivers.

Ideally, we would like a 4-dimensional space-time map of eutrophicate plumes as they enter into and disperse across the river system for all our waterways. But chemical analysis is expensive and time consuming. What is needed is an inexpensive, portable and open-source, water quality monitoring system that anyone can build and operate with minimal technical experience.

What is Available

Options for off the shelf water quality instruments range from industrial devices costing well over $2,000 to the Arduino and Robotics hobby sensors that come as individual modules that plug into a microprocessor. For example, Hanna Industries sells a hand-held probe with pH, Oxygen Reduction Potential, Electrical Conductivity and Dissolved Oxygen sensors. These four measurements are then converted to 12 different water quality measurements. Turbidity is apparently not included but, somehow, they report total dissolved solids from these measurements. This is just one such provider of industrial quality instruments and a few of these might be used at waste treatment facilities and firms or government agencies involved in environmental monitoring where sampling is limited and labor costs, not lab analysis costs, are the driving factor.

The electronics hobbyist can find many individual sensor modules that come with a bottom quality probe and unknown electronics allowing direct connection to a microprocessor. While inexpensive integrating these individual components into a complete system of sensors would be a hodge-podge of both electronics and software.

It is clear in reviewing the field that water quality is expressed by a variety of parameters but which are derived from a handful of actual sensor devices. There is a clear need for an exposition on the terminology of water quality and how these terms relate to specific or combined sensor responses. But this is a whole other rant beyond our immediate scope.

The Universal Sensor Interface (USI) Concept

All sensors can be considered as electronic black boxes with 2 current electrodes and 2 voltage probes. In many cases, one or more of the connections is missing but a careful examination of the sensor operation reveals that many operate at zero current or fixed voltage. A pH probe for example operates at zero current and only a voltage is measured. Hence only two wires are required. A photodiode is set at a fixed potential and current response is measured. Hence only two wires are required. A resistance temperature detector (RTD) generally has 3 leads but when integrated into a Wheatstone bridge requires 4 wires. A water conductivity probe needs an AC voltage excitation and a current measurement resistor. Hence 4 wires are needed but the two for current measurement are hidden in the test circuit. In addition, each type of sensor will need different signal conditioning to eventually be compatible with an Analog to Digital Converter (ADC) whose signal can then be recorded by a computer.

What would be helpful is a universal interface for each of these sensors – the Universal Sensor Interface (USI). A multitude of sensors could be hooked up to the same basic control and measurement circuit and interfaced with a microprocessor to control the switching between sensors and the actual measurement.

The USI is based upon a potentiostat/galvanostat (PGStat) combination along with various subcircuits for signal amplification, noise damping, level shifting and AC to DC conversion ending with an ADC. The USI is controlled by a microprocessor that determines the PGStat configuration, routes the signal through the analog signal conditioning steps and collects and stores data. It could also provide wireless communication and Global Positioning System information. The objective is to make this portion of the system field portable. The microprocessor would be in wireless communication with a data center through which data is recorded and analyzed and potentially reported in a Geographic Information System (GIS) format. The USI should be open-source in all aspects from hardware to software and a small team of modestly technically astute, concerned, citizen scientists should be able to construct and operate a system of USIs.

Concluding Remarks

Our purpose here is to introduce the need for inexpensive water quality analysis instrumentation and to present the concept of the USI based upon a PGStat. The end device should be field portable. It is a major aspect of but not the entire end goal. In many cases such as the detection of nitrates and phosphates some sample preparation or chemical reaction is necessary. The USI cannot achieve this and some tentative plans based upon flow injection analysis equipment and chromatography pieces have been sketched out. A rant on those ideas is needed.