Utilizing Low-Cost Ion-Sensitive FET Sensors

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Abstract

Monitoring water quality is important as it can provide valuable information about aquatic life, contamination, pollution, and much more. One important aspect to measure is the pH level. Ocean acidification is the gradual decrease in the average pH of ocean water, caused by absorbing an increasing amount of carbon dioxide from the air. This can affect sea creature's ability to build and maintain their shells, search for food, or find suitable habitats. We have been working on finding, testing, and implementing low-cost ion-sensitive field-effect transistors (ISFETs) that can be used to measure the pH levels of water.

The Sensors

The first step I took was to research what ISFETs were available to purchase. We were looking for a few key properties:

- low cost
- low overhead
- easy to integrate

Many sensors come with a lot of additional electronics, but we wanted to get the bare minimum so we would be able to integrate the sensor with our own circuitry.

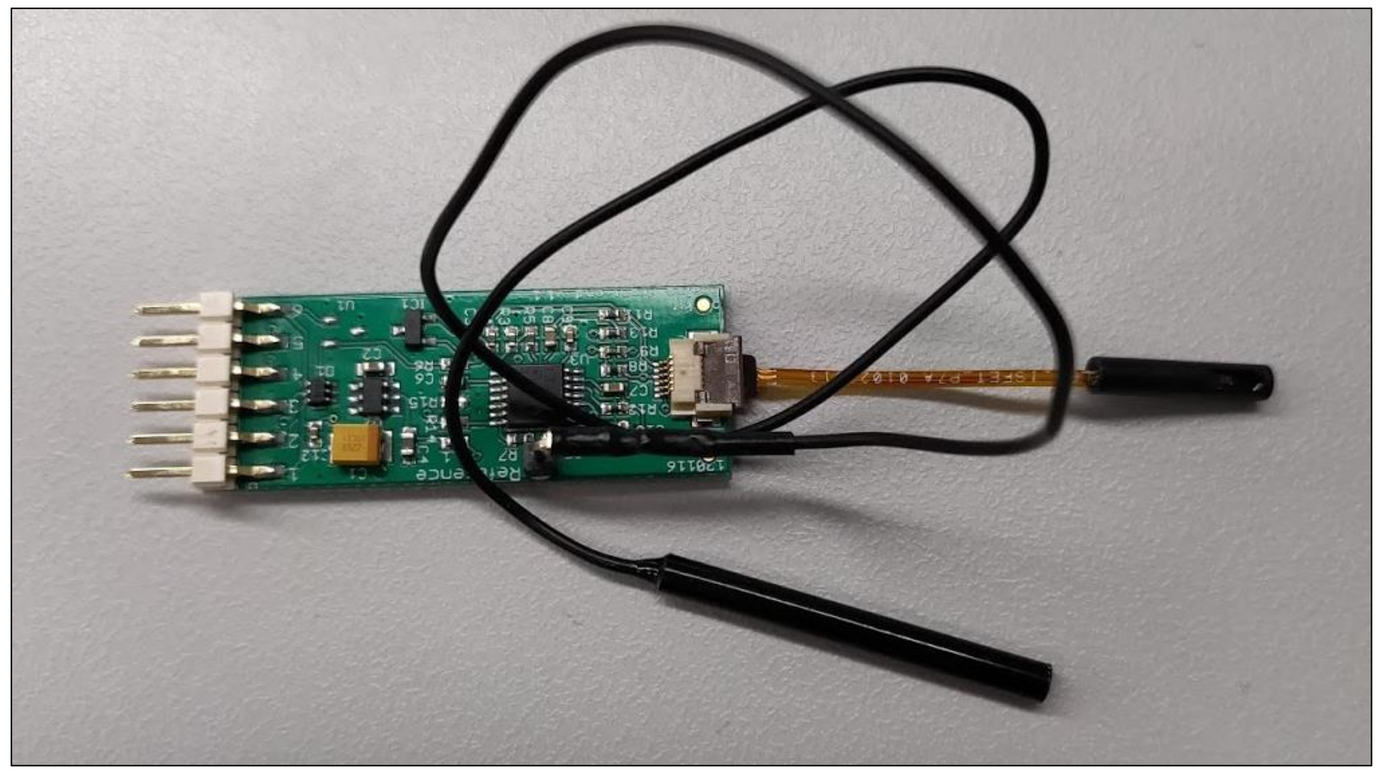

Figure 1: Sentron ISFET, reference electrode, and analog front end

One of the ISFETs, shown in figure 1, was ordered from a company called Sentron. This has the ISFET on a probe, a reference electrode, and an analog front end that connects to both probes. On the end there are 6 pins that include the signal used to calculate pH, power, and an imbedded temperature sensor (not used).

The other ISFETs, shown in figure 2, are from the company MICROSENS SA. These come with the ISFET itself and reference electrode on the same probe that connects to a digital interface board (not shown). Rather than outputting a signal that could be used to calculate the pH, this board did the calculation itself and output the data in a digital format.

Figure 2: MICROSENS SA ISFET and reference electrode

Sensor Usage and Tests

All ISFETs operate in the same way. They act like a transistor, an electrical part in which the current through it changes based on the voltage applied on its gate terminal. In this case, the ion concentration of the solution will affect the current through the transistor. Both our ISFET circuits use a measuring circuit that outputs a voltage that varies linearly with the pH of the concentration.

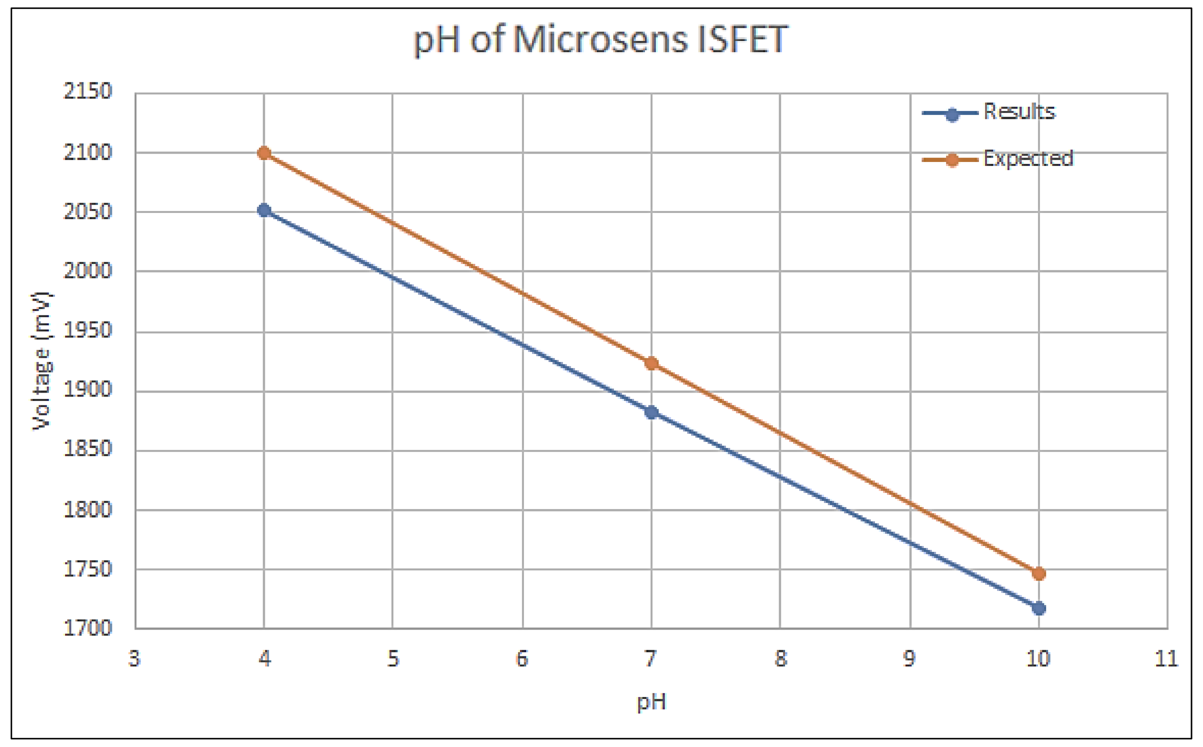

Figure 3: The linear curve used to calculate pH for the MICROSENS SA ISFET

The MICROSENS SA digital interface board takes previous calibration data to form the linear curve of voltage to pH and calculates a pH based on the current measured voltage. This is then converted to a digital signal and output to our microcontroller. This method makes it easier for us to get the pH value directly but gives us little control over the actual measuring itself. Figure 3 shows the linear curve the circuit was measuring versus the curve the manufacturer claimed the sensor had.

On the other hand, the Sentron analog front end simply outputs the analog voltage to one of the output pins. The benefit of this is that we have complete control over how our microcontroller measures this voltage. When analog signals are read by a microcontroller, they are ultimately turned into a digital signal for the processor to read. Since we have access to the analog value here, we can use more precise analog to digital converters to get a better reading of the pH value. This is useful because the pH scale is logarithmic, meaning a small change in the value of pH is a noticeable change, making precision very important. We also have control over the frequency of readings, whereas the MICROSENS SA digital interface board constantly output digital messages to our microcontroller.

Integration and Future Uses

Currently, I am using the Sentron ISFETs to create a payload of sensors to be used to measure water quality that is solar-powered and transmits data wirelessly. Figure 4 shows the water-proof container I created for the ISFET and electronics to be used in this project using PVC piping. This will allow the sensors to be fully submerged in water without damaging the electronics. The ISFETs low cost and customizability makes them very useful and easy to use in projects similar to this one or a lab setting.

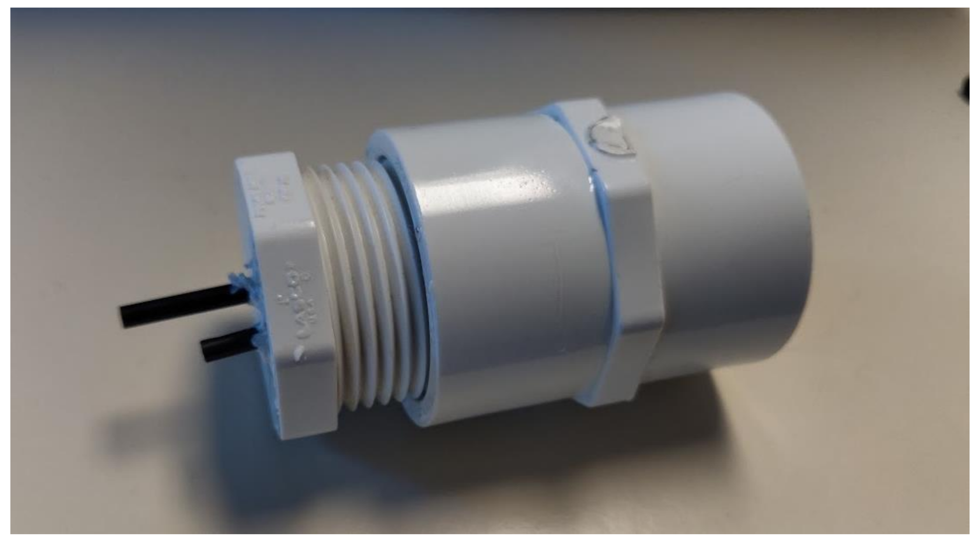

Figure 4: Water-proof container for the Sentron ISFETs and electronics

Acknowledgements

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