OCN 479-001

Sensor communications

(Wireless edition)

Today’s plan

- Short group activity/lecture
- Your presentations
- Build sensors!

Kayaking plans

Nov. 17 tentative

Teams

- Team Chlorophyll:
  - Jessie
  - Mia
  - James
- Team Turbidity:
  - Nick
  - Braeden
  - William
- Team Water Level:
  - Ashley
  - Matt
  - Summer
- Team Water Quality:
  - Jack
  - Mitch
  - Grace

Today’s topics

Sensor Communications:
(Wireless edition)

Think, pair, share

THINK (3 MINS): LIST OUT AS MANY WIRELESS DATA TRANSFER TECHNOLOGIES AS YOU CAN THINK OF

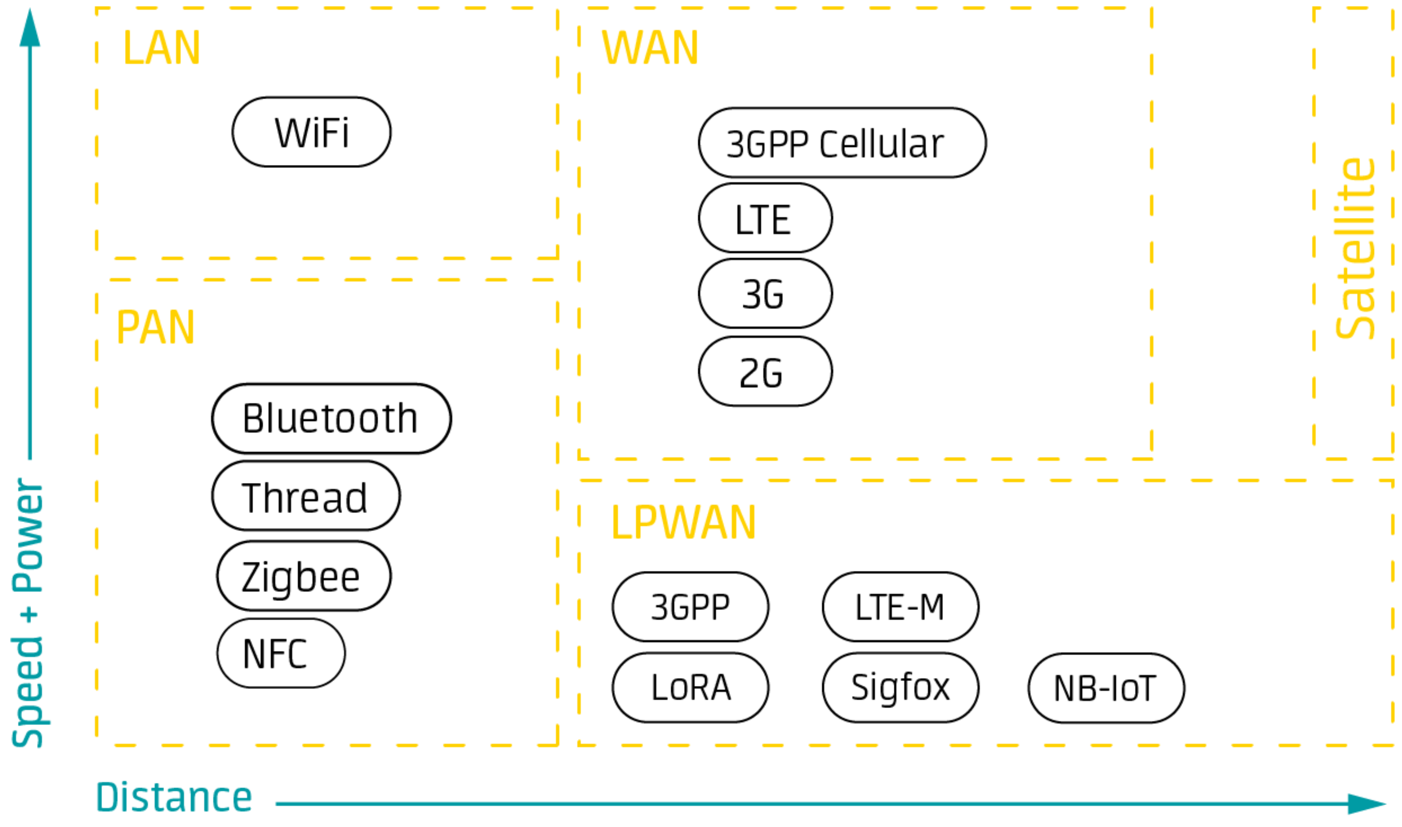
PAIR (3 MINS): PAIR UP WITH ONE OTHER PERSON AND DISCUSS

SHARE (5 MINS): SHARE YOUR THOUGHTS WITH THE CLASS

Comparison (Note the url…)

Attribute	Bluetooth® Low Energy Technology	Wi-Fi	Z-Wave	IEEE 802.15.4 (Zigbee, Thread)	LTE-M	NB-IoT	Sigfox	LoRaWAN
Range	10 m – 1.5 km	15 m – 100 m	30 m - 50 m	30 m – 100 m	1 km – 10 km	1 km – 10 km	3 km – 50 km	2 km – 20 km
Throughput	125 kbps – 2 Mbps	54 Mbps – 1.3 Gbps	10 kbps – 100 kbps	20 kbps – 250 kbps	Up to 1 Mbps	Up to 200 kbps	Up to 100 bps	10 kbps – 50 kbps
Power Consumption	Low	Medium	Low	Low	Medium	Low	Low	Low
Ongoing Cost	One-time	One-time	One-time	One-time	Recurring	Recurring	Recurring	One-time
Module Cost	Under $5	Under $10	Under $10	$8-$15	$8-$20	$8-$20	Under $5	$8-$15
Topology	P2P, Star, Mesh, Broadcast	Star, Mesh	Mesh	Mesh	Star	Star	Star	Star
Shipments in 2019 (millions)	~3,500	~3,200	~120	~420	~7	~16	~10	~45

https://www.bluetooth.com/blog/wireless-connectivity-options-for-iot-applications/



https://www.avsystem.com/blog/iot-connectivity/

Summary: what's the best option?
It depends…

- Satellite: global coverage, more power, more $
- Cellular: distributed but not truly global coverage, medium power, medium $
- BLE: requires a mobile device with an app, very low power, low $
- WiFi: requires a WiFi network, low power, low $
- Others: typically not sufficiently available for global deployments, but can work for local needs

Assignment (due Sep. 29)
1 per group

- Short presentation on your instrument
  - ~5 minutes, just a couple slides
  - Most critical: methods/principles of operation—how does it work?!
  - Methods: how is it built, what does it do?
  - Principles of operation: how does it convert some physical (chemical, biological) quantity (e.g., conductivity) to a voltage (e.g., it transmits a voltage across the water and measures current flow, enabling the calculation of resistance and therefore conductance)?
  - What accuracy, precision, stability, and response time can we expect?

Order (alphabetical by team name, this time only)

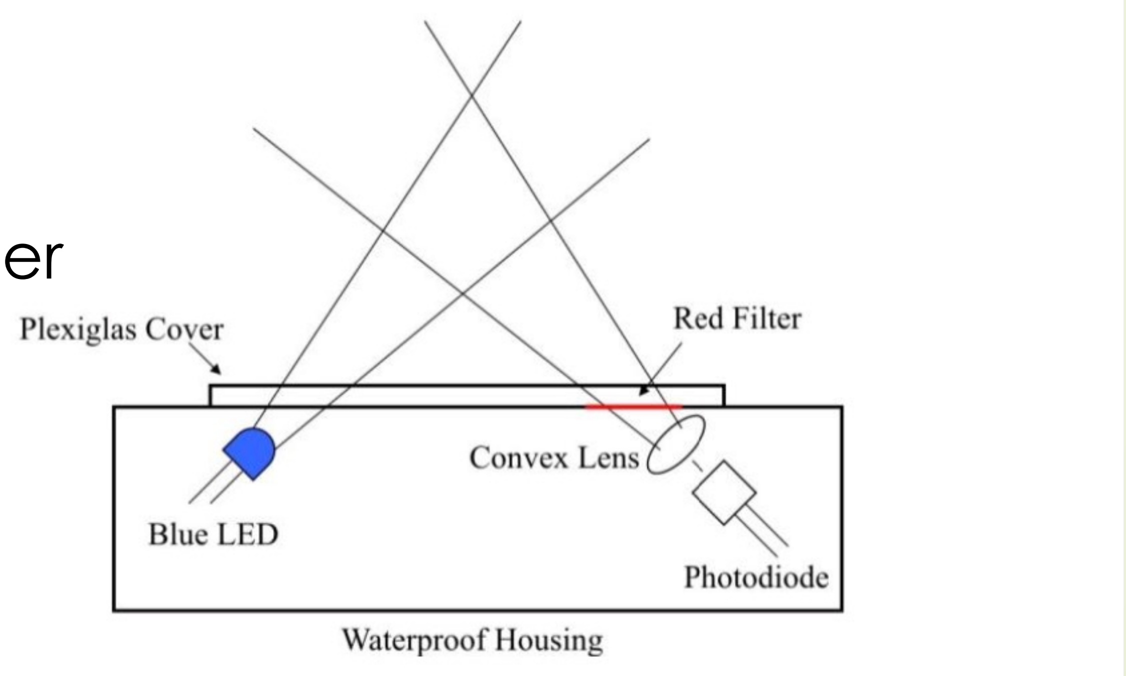
- Team Chlorophyll
- Team Turbidity
- Team Water Level
- Team Water Quality

Chlorophyll a Fluorometer

By: Mia Carulli, James Lockwood and Jessie Wynne

How is it built?

- Waterproof box with a plexiglass window
- Excitation light source
- Detector
- Transimpedance amplifier
- Arduino Duemilanove microcontroller
- SD Card
- Calibration



Accuracy, precision, and response time

- Two 9v batteries provide power for 24 hours
- LED light needs 1.5 minutes to warm up

  - allows the LED to stabilize

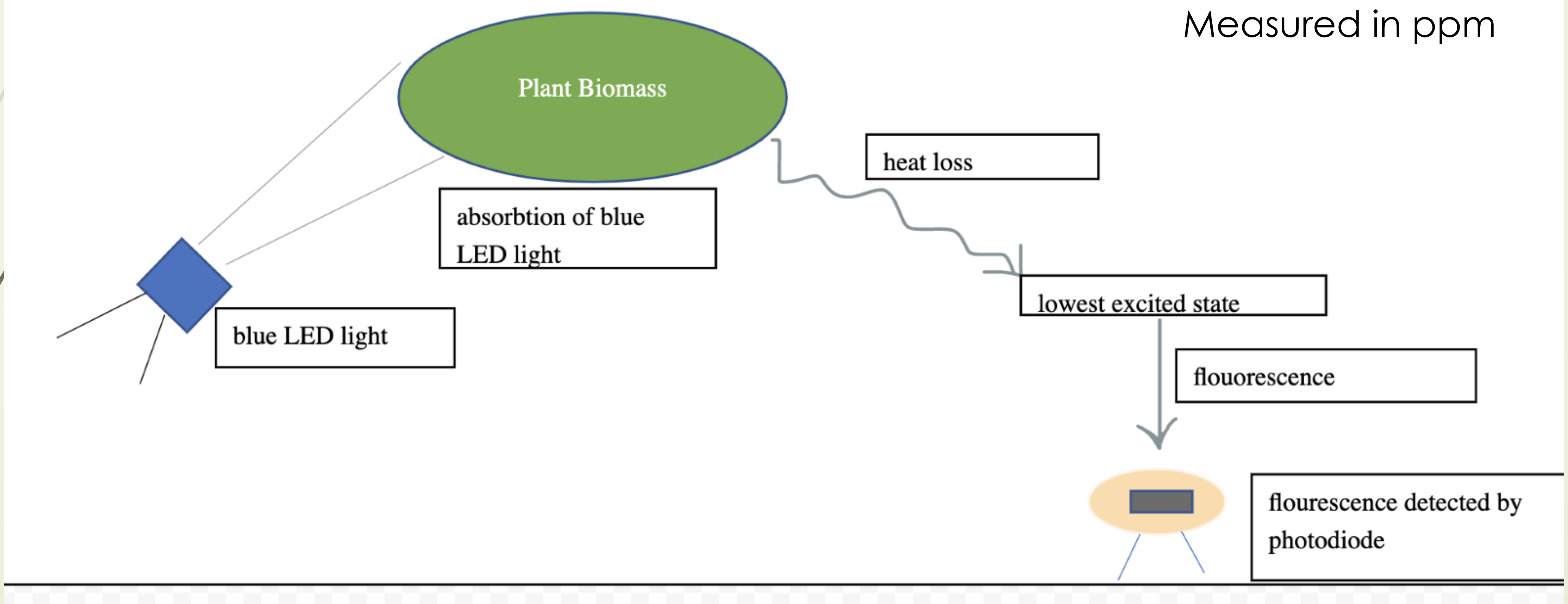
  - saves battery
- Sampling interval of 10 minutes
- Accuracy of sample depends on turbidity
- Ambient light can also affect data collection

  - opaque tube can be used to create a flow through sensor
- Error of sensor measurement compared to commercial device +/- 4%

Chlorophyll Fluorescence

Light absorbed by the chlorophyll molecules causes an increase in energy state, when the molecules return to their lower state they fluoresce.

Measured in ppm



Citations

- Maxwell, K., & Johnson, G. N. (2000). Chlorophyll fluorescence—a practical guide. *Journal of Experimental Botany*, *51* (345), 659–668. https://doi.org/10.1093/jexbot/51.345.659
- Leeuw T, Boss ES, Wright DL. *In situ* Measurements of Phytoplankton Fluorescence Using Low Cost Electronics. *Sensors*. 2013; 13(6):7872-7883. https://doi.org/10.3390/s130607872

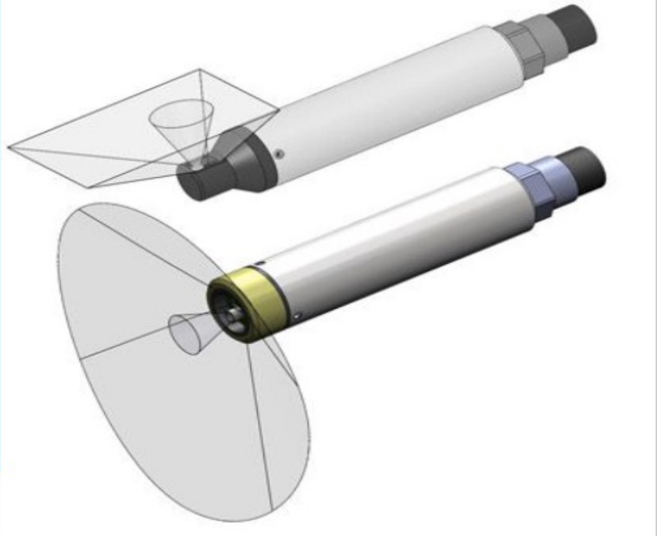
Optical Backscatter Sensor

Braeden Craddock, William Rueh, Nick Porter

Methods

- Optical backscatter sensors are used to measure turbidity in freshwater and marine environments.
- Some key components:
- Infrared light emitting diode to illuminate the water. (Peak wavelength 870 nm)
- The photodetector, which measures the intensity of light scattered back to the sensor from particles in water column. (Peak sensitivity 900 nm)
- The light backscattered can be used as a proxy for amount of particulates in the water.
- This is then converted to a measurement of turbidity, total suspended solids (TSS).

Principles of operation



- The OBS emits an infrared light
- The reflected light is read by a photodiode
- The photodiode then sends the data as voltage to an ADC (Analog to Digital Converter)
- Data is then recorded with a microSD card
- The sensor will always take measurements when turned on
- A clock module is used to turn the sensor on and off for measurements
- An OBS runs on an open source microcontroller and single board frameworks making it more affordable to build your own.

Accuracy, Precision, Stability, and Response Time

Accuracy

- Date and Time: +/- 2 min per year
- +/- 3 degrees celsius
- Data: Comparable to commercial turbidity sensors

Stability

- Good but varies depending on sediment size, depth, and light

Response Time

- Instantaneous, data is read as soon as the sensor is turned on. Recording stops when the sensor is turned off

References

- *OpenOBS: Open-source, low-cost optical ... - wiley online library*. (n.d.). Retrieved September 28, 2022, from https://aslopubs.onlinelibrary.wiley.com/doi/10.1002/lom3.10469
- Campbell Scientific. (2010, March 31). *New turbidity probe helps avoid obstructions*. New Turbidity Probe Helps Avoid Obstructions: Campbell Update 2nd... Retrieved September 28, 2022, from https://www.campbellsci.com/obs300-article

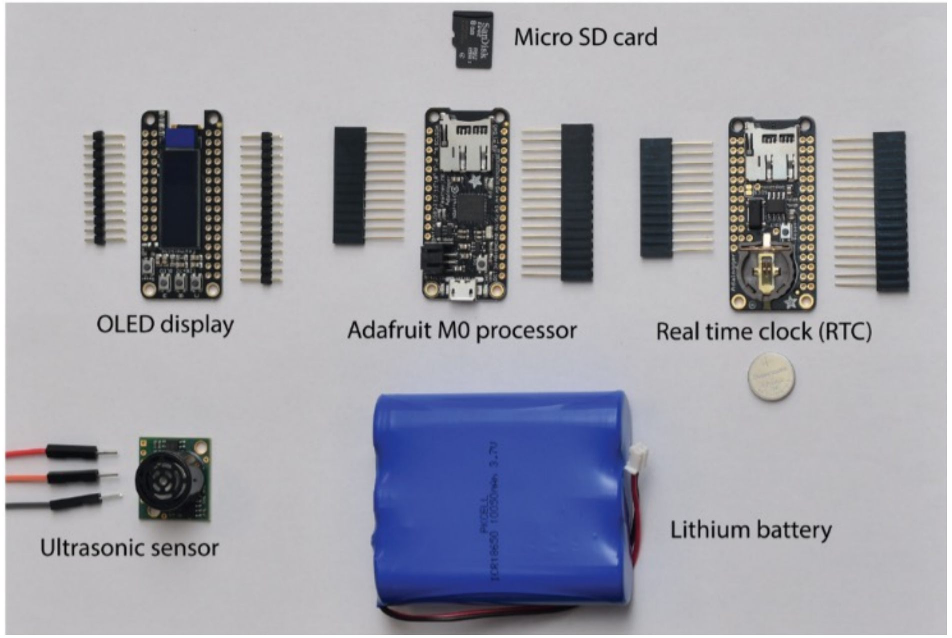
Low-Cost Water Level Sensor

Ashley Holsclaw, Matt Larson, & Summer Banning

OCN 479 – Smart Coasts

Methods

- Water level sensor – measures the elevation of water relative to some known datum (e.g., NAVD88, MSL)



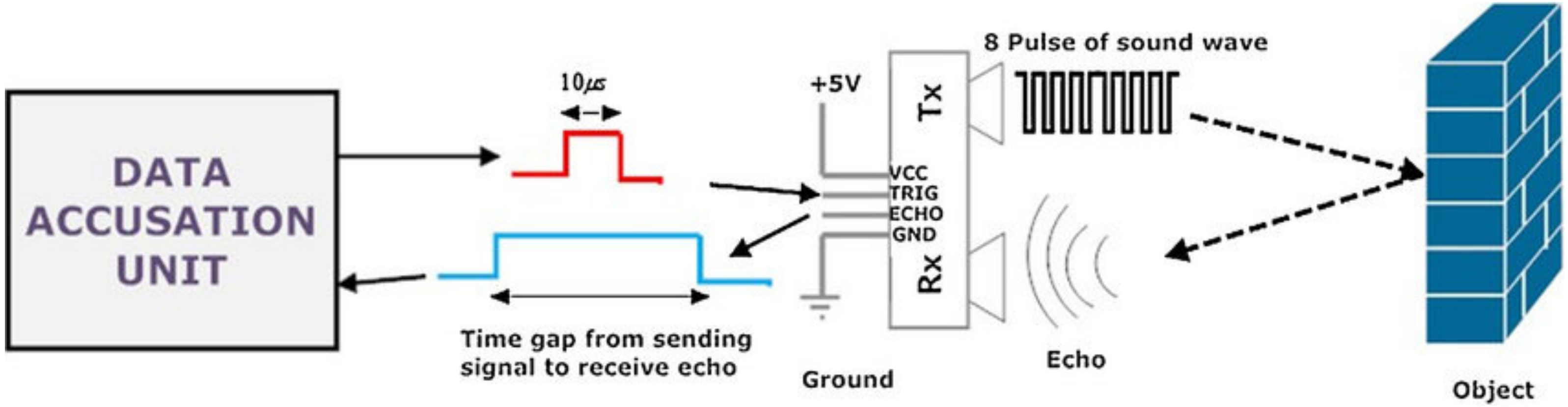
Source: Bresnahan et al., 2022

- Components:
  - Microcontroller/Data Logger
    - Adafruit Adalogger or Particle Boron
  - Maxbotix LV-EZ4 ultrasonic rangefinder
  - Adafruit FeatherWing OLED screen
  - Adafruit FeatherWing Real-Time Clock
  - Rechargeable lithium-ion battery
  - Enclosure
    - Upcycled plastic or custom design

Principles of Operation

- Ultrasonic sensor emits high frequency sound waves that reflect off water
- Sensor measures the time it takes for the sound wave to travel to the water surface and reflect back
- Time is converted to distance
  - Velocity = speed of sound = 343 m/s
- Analog to digital converter (ADC)
  - Analog output → digital counts → physical distances

$$\boxed{\boldsymbol{Distance = \frac{Velocity * Time}{2}}}$$



Source: Panda et al., 2016

Specifications

- Accuracy: 5 cm
- Range: 15 – 645 cm
- Resolution: 2.5 cm
- Response Time: 1 / (speed of sound * distance * 2) s
- Required voltage: 3.3 V
- Max sampling frequency: 20 Hz
- Output frequency: 42 kHz

Water Quality Testing Device

Mitch, Grace, Jack

Principles of Operation? How does it measure it?

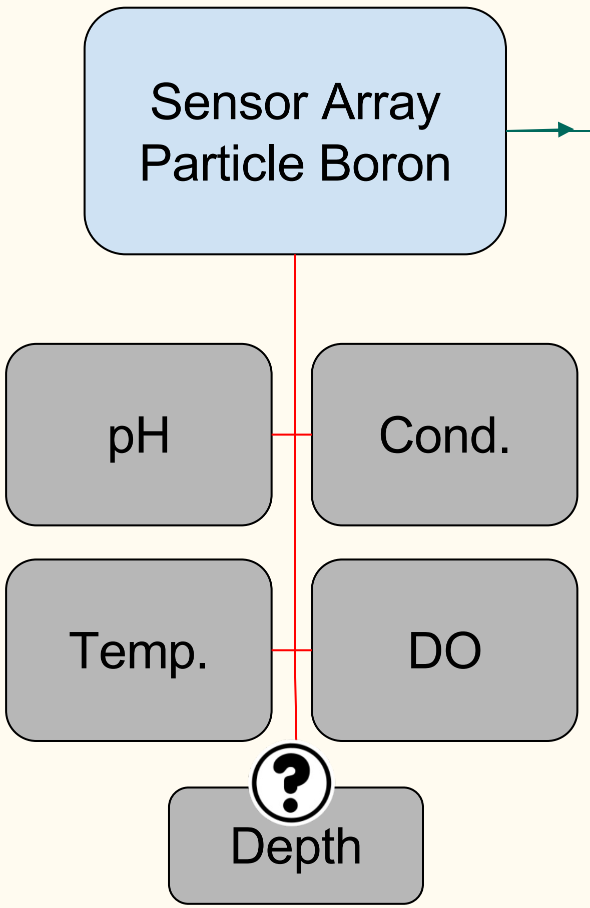
- **Temperature**: uses resistance and the Steinhart equation to map a temperature curve (can be digital or analog) as temperature increases, resistance drops.

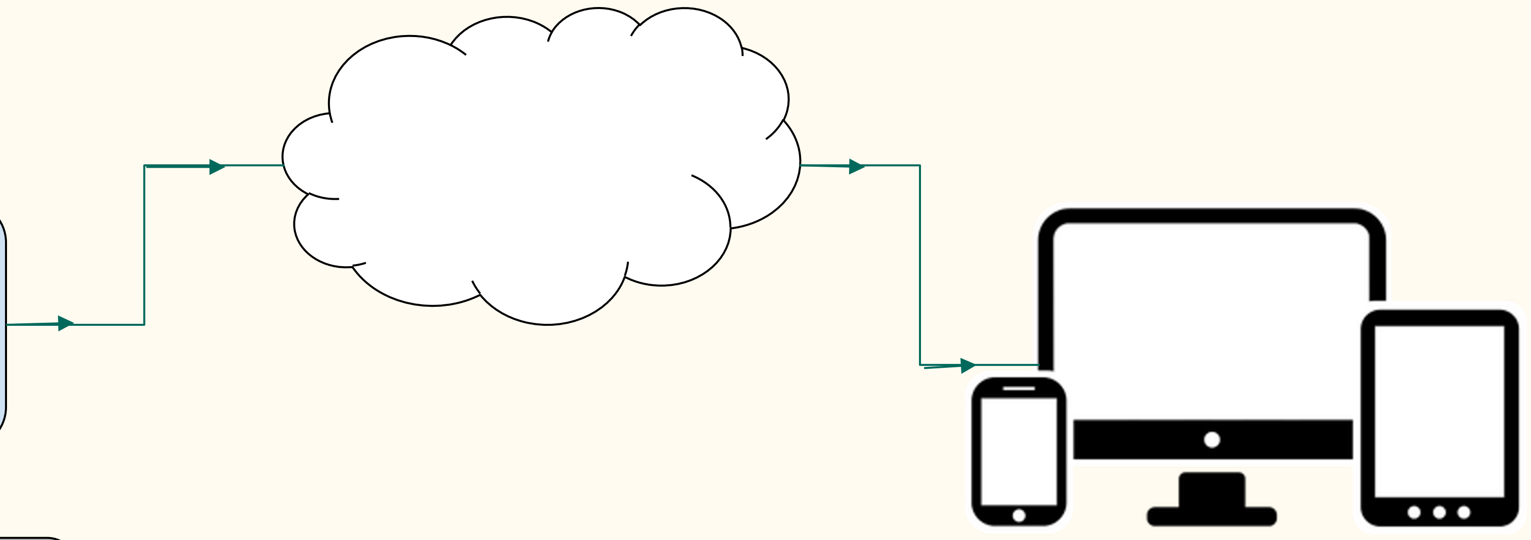
- **Conductivity**: measures salinity based on the electrical current from the major ions of seawater, by applying an alternating electrical current between two electrodes

- **pH**: measures based on the level of free Hydrogen ions [H+]; with an increase in the concentration of [H+] there is a decrease in pH.
    - A KCl solution is used and based on the testing solutions reaction to that KCl and the movement of protons, a current is created which is then relayed to the microchip and analyzed with the Nernst equation

- **Dissolved Oxygen**: measures the amount of oxygen that passes through the semipermeable membrane, and then gets reduced to OH, the sensor measures the amount of reduction taking place from an electrical current. This current is fed back to the microchip to measure it in a percentage.

Data Flow





Array Components:

- Particle Borons microcontroller
- GPS Featherwing add-on
- Adalogger Featherwing RTC + microSD card
- Atlas Scientific Tentacle T3 Shield
- Whitebox T2 Mini MKII
- [DO EZO + Atlas Scientific Probe] for measuring Dissolved Oxygen
- [EC EZO + Atlas Scientific Probe] for measuring conductivity
- [RTD EZO + Atlas Scientific Probe] for measuring temperature
- [pH EZO + Atlas Scientific Probe] for measuring pH
- [Device] for measuring depth (echosounder, pressure) (YSI EXO2)

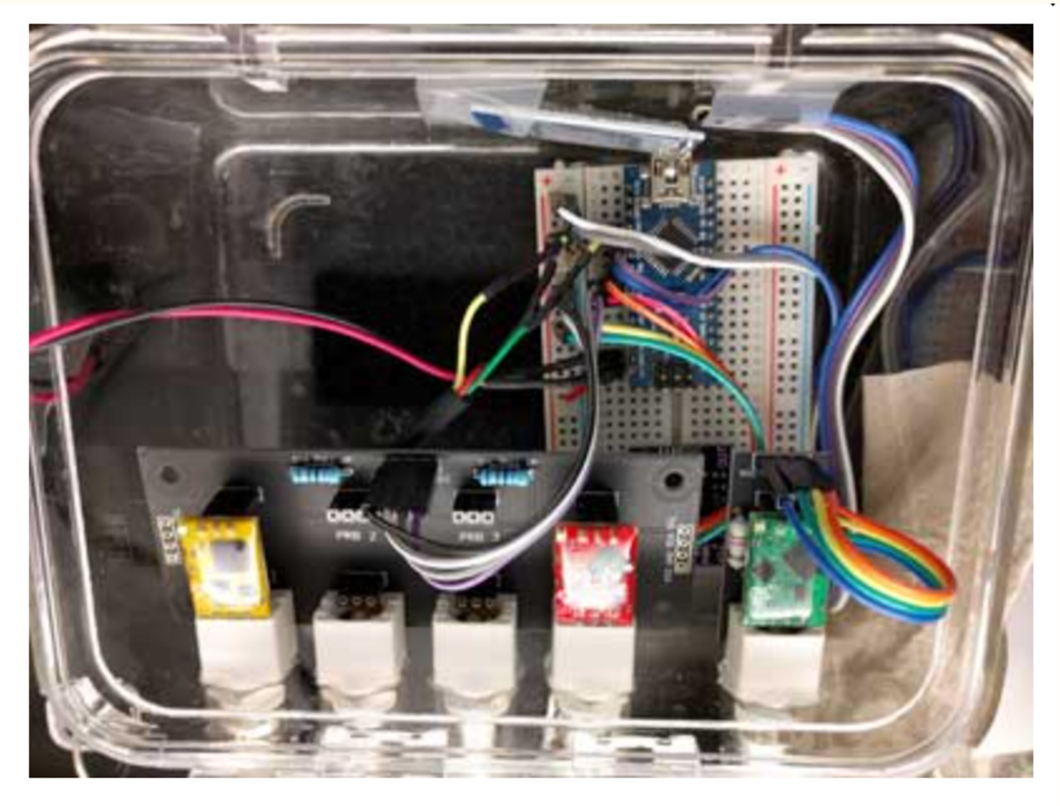
Accuracy, Precision, Stability, and Response Time

- **DO EZO** - Accuracy: +/- 0.05 mg/L ; Response Time: 1 reading per second
- **EC EZO** - Accuracy: +/- 2%; Response Time: 1 reading per second
- **RTD EZO** - Accuracy: +/– (0.1 + 0.0017 x ˚C); Response Time: 1 reading per second
- **pH EZO** - Accuracy: +/– 0.002; Response Time: 1 reading per second
- **GPS Featherwing** - Accuracy: Position = 1.8 meters, Velocity = 0.1 meters/s; Response Time: 10 Hz update; Stability: -165 dBm sensitivity
- All EZO devices have high accuracy and stability
- They also have high precision, except when electrical noise is interfering with the readings it is common to rapidly fluctuating readings or readings that are consistently off

EZO™ pH Circuit | Atlas Scientific (atlas-scientific.com)

Housing Design

- PVC piping with o-ring/silicone sealants
- Pelican case



https://acwi.gov/methods/sensors/field_deploy/index.html

Work Cited

DO_EZO_Datasheet.pdf (atlas-scientific.com)

EC_EZO_Datasheet.pdf (atlas-scientific.com)

EZO_RTD_Datasheet.pdf (atlas-scientific.com)

pH_EZO_Datasheet.pdf (atlas-scientific.com)

Overview | Adafruit Ultimate GPS featherwing | Adafruit Learning System

https://www.ysi.com/ysi-blog/water-blogged-blog/2019/02/anatomy-of-ph-electrodes

https://group.chem.iastate.edu/Holme/augmented-reality-in-educational-laboratories/conductivity/

https://atlas-scientific.com/blog/how-do-dissolved-oxygen-probes-work/#:~:text=Dissolved%20oxygen%20probes%20work%20by,is%20displayed%20on%20a%20meter.

https://atlas-scientific.com/blog/how-do-temperature-sensors-work/#:~:text=Temperature%20sensors%20work%20by%20providing,increases%2C%20the%20temperature%20also%20increases.

https://oceanographyforeveryone.com/project/openctd/

https://github.com/IanTBlack/CTDizzle

https://theoryandpractice.citizenscienceassociation.org/articles/10.5334/cstp.124/