BEGN 186B Final Project

Temperature and pH sensing electrode

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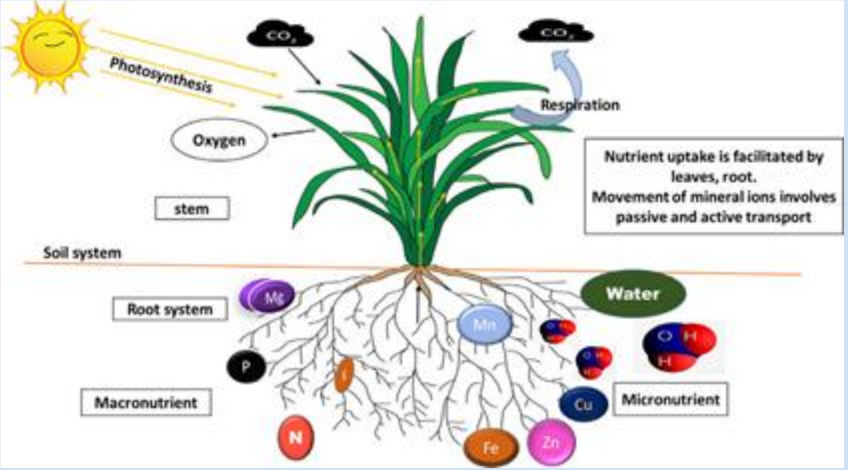
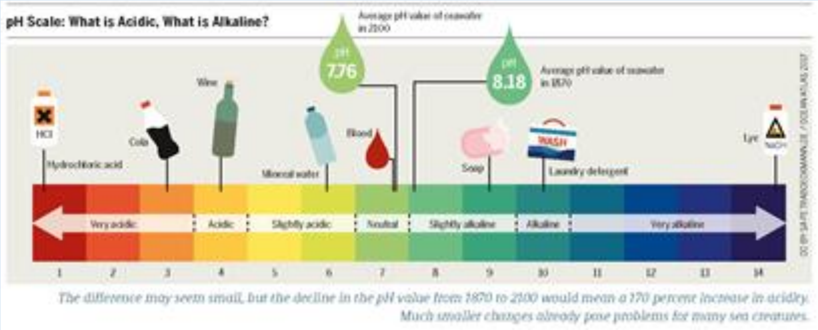
Significance

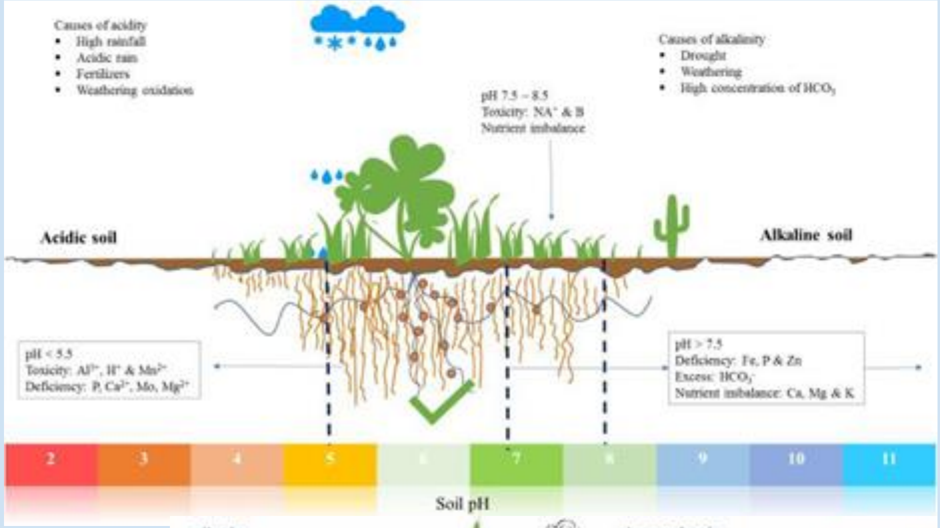
- Soil pH controls many chemical and biochemical processes that take place in the soil itself, and therefore can regulate the nutrient availability and crop productivity
- The optimum range of soil pH for most agriculture is between 5.5 and 7.5 (moderately acidic to slightly alkaline respectively), and temperature from 50 to 75°F (10-24°C).

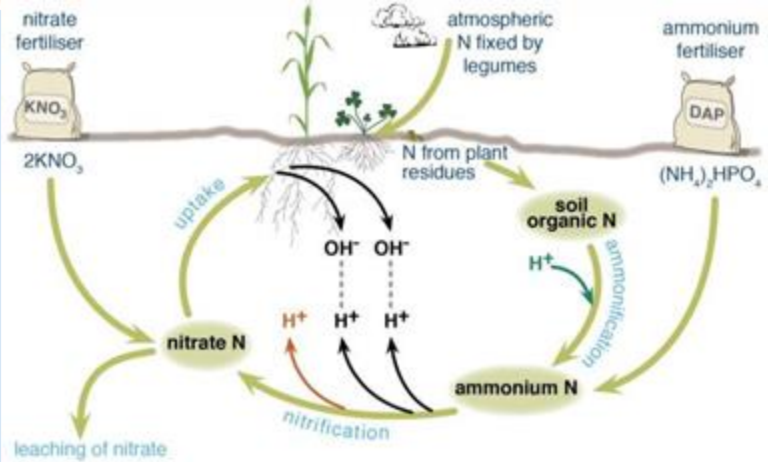




Significance

Most crops in soil outside this range end up with less yield and nutrients due to the unideal conditions for necessary chemical reactions to take place





Current risk factors that may alter soil pH:

- Waste and runoff into agricultural areas
- Fertilizers of varying compositions

Background/Assumptions

- We can calculate the pH through the Nernst Equation:

$$E_{cell} = E^0 - \left(\frac{RT}{nF}\right) \ln Q \qquad pH = -\log [H^+]$$

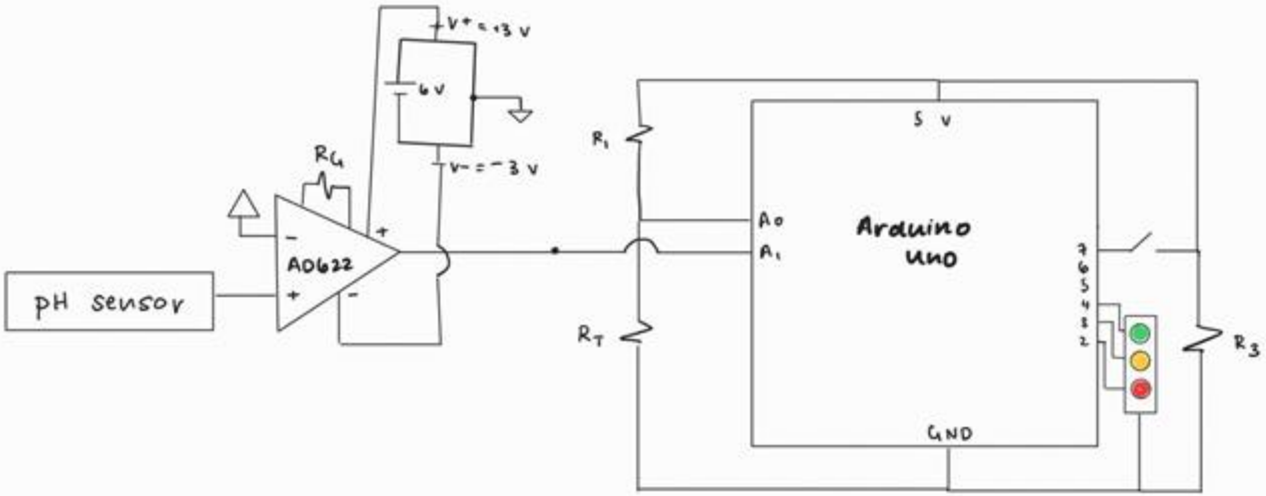
With E_{cell} as the pH and E^0 as the standard cell potential

- Temperature and pH have a direct relationship - High soil temperature show higher cation exchange capacity, and therefore pH level acidity rises to a greater degree due to organic acid denaturation.
- The sample of soil taken and measured will be representative of the condition of the general area
- Efficiency of the electrode is 100%

Specific Goals → Circuit Inclusions

Specific Goals		Circuit Inclusions
High accuracy and high precision pH sensing capabilities	→	Initial calibration based on both thermistor acquired temperature readings and initialization with buffer solutions of known pH
Low-cost, automatic signal analysis	→	Arduino UNO board
Easily comprehensible readings of transformed signals	→	Tri-colored LED displaying output

Device Overview



User instructions:

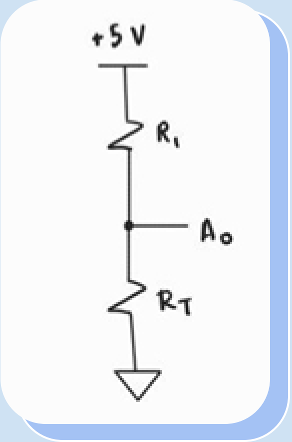
1. Press button once for pH 4 buffer calibration
2. Press button again for pH 7 buffer calibration.
3. Press button 3rd time for sample pH acquisition
4. Recieve color output:

- Red = outside of 5.5- 7 pH range
- Yellow = unable to properly acquire signal
- Green = Within pH range

Device Specifics (Signal Acquisition) - thermistor and pH electrode

-thermistor specifications:

- $T_0 = 25℃$
- $R_0 = 10\ k\Omega$
- $\beta = 3977\ K$



$R_T = R_0 * e^{\beta(1/T - 1/T_0)}$

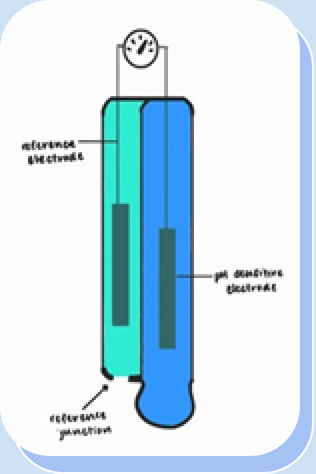
$V_{out} = V_{in} * (R_T/R_T + R_1)$

-commercially available options:

- Hannah Instruments (Gel Filled PEI Body pH electrode with BNC connector) -HI1230B
- METTLER TOLEDO InLab Solids pH Electrodes

-pH electrode specifications:

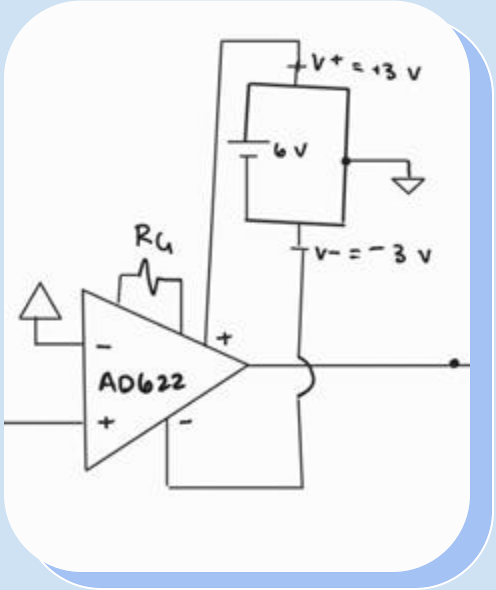
- gel electrolyte
- double junction



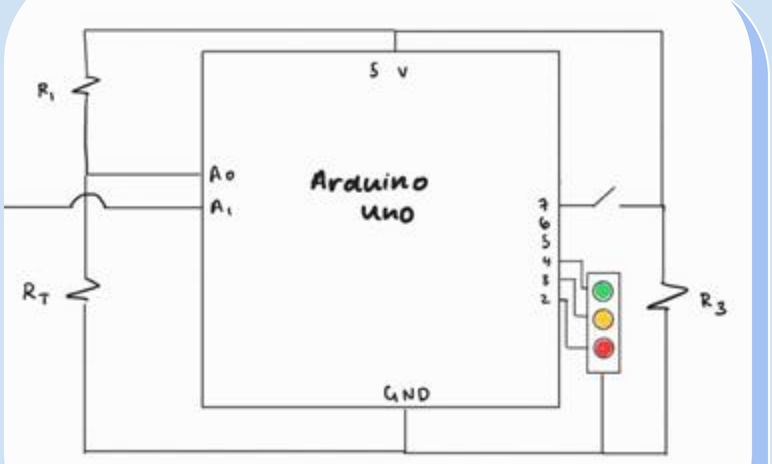
Device Specifics (Signal Filtration) - Op-Amp

-AD622 Operational Amplifiers

- Theoretical input voltage range: -200 mV to 200 mV
- Theoretical desired output voltage range: -2 V to 2 V
- $G = 1 + (50.5\ k\Omega)/R_G$
- Desired gain ≈ 10
- $R_G = 5\ k\Omega$



Device Specifics (Signal Conversion) - Arduino




```
    If (switchState == HIGH) {
      //calculating temperature
      Vo = analogRead(thermistorpin);
      RT = R1 * ( 1023.0 / (float)Vo - 1.0 );
      logRT = log(RT);
      T = ( 1.0 / (c1 + c2 * logRT + c3 * logRT * logRT * logRT ) ) - 273.15; //Steinhart-Hart equation, T in C
      measurementThermistor[i] =  T;

      //calculating pH
      sensorValue = analogRead(signalpin);
      pHValue = map(sensorValue, 0, 1023, 0, 14.00);
      measurementEV[i] = sensorValue;
      measurementpH[i] = pHValue;
    }
    lastswitchState = switchState;
    buttonCounter = buttonCounter + 1;
  }

  //Calibrating slope
  float slope_calib = (measurementEV[2] - measurementEV[1]) / (measurementpH[2] - measurementpH[1]);

  //pH reading
  float pHsample = measurementpH[2] + (measurementEV[3] - measurementEV[2]) / slope_calib;

}
```

$$\frac{1}{T} = A + B \ln R + C(\ln R)^3,$$

Steinhart-Hart eq (for thermistor-temperature interactions)

$(Y - Y_1)/m + x_1 = x$
$m = (EV_{7.0pH} - EV_{4.0pH}) / (7 - 4 \text{ pH})$ [V/pH]
$(x_1, y_1) \approx (7 \text{ pH}, 0 \text{ V})$

Limitations

-Possible Error Sources

- Buffers expire
- Electrolytic solution surrounding reference electrode contaminated
- User's steps must be specific to match Arduino code

Limitations

-Future improvements

- Allow user to specify pH range of interest based on specific agricultural interests

Table 1. Typical desirable soil pH ranges for select garden plants

Plant	pH range
Temperate fruit and nut trees	6.0–8.0
Citrus	6.0–7.5
Blueberries	4.5–5.5
Avocados	5.0–7.0
Azaleas	4.5–5.5
Herbaceous ornamentals	6.0–8.0
Most woody landscape species	5.5–8.0
Vegetables	6.0–8.0
Lawns	5.5–8.0

Sources: Locke et al. 2006; Pittenger 2015.

- Scalability/portability - must find different microcontroller and parts in order to make portable
  - Not Arduino Uno

Conclusions and Questions

Questions?

And big thank you to:

- Our BENG 152 TA's Carter and Jeffrey
- Our BENG 187A TA's Vikrant, Samira, and Adyant
- Dr. Cauwenberghs and Dr. Taylor

Thank you for listening!