

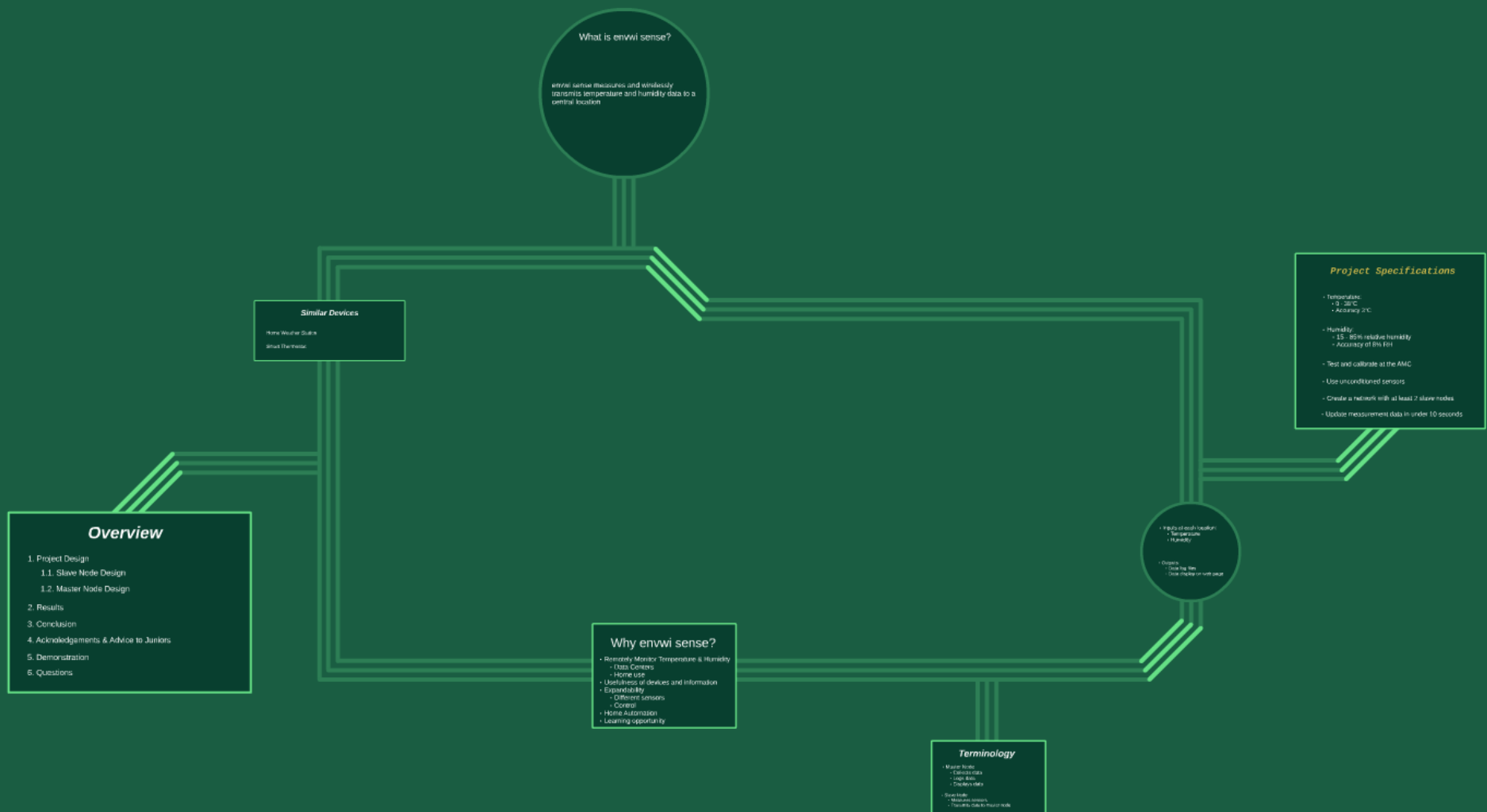
envvi sense  
 Timothy Albur & Ian Maines  
 I/O: 431 Capstone Project Presentation



# envwi sense

Timothy Albert & Ian Maines

ECE 403 Capstone Project Presentation



# What is envwi sense?

envwi sense measures and wirelessly transmits temperature and humidity data to a central location

# *Project Specifications*

- Temperature:
  - 0 - 38°C
  - Accuracy 3°C

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  - 0 - 38°C
  - Accuracy 3°C


- Humidity:

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  - 0 - 38°C
  - Accuracy 3°C
- Humidity:
  - 15 - 85% relative humidity
  - Accuracy of 8% RH
- Test and calibrate at the AMC

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- Use unconditioned sensors
- Create a network with at least 2 slave

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- Update measurement data in u



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  - Accuracy of 8% RH
  
  - Test and calibrate at the AMC
  
  - Use unconditioned sensors
  
  - Create a network with at least 2 slave nodes
  
  - Update measurement data in under 10 seconds
- 

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- Use unconditioned sensors
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# *Project Specifications*

- Temperature:
  - 0 - 38°C
  - Accuracy 3°C
- Humidity:
  - 15 - 85% relative humidity
  - Accuracy of 8% RH
- Test and calibrate at the AMC
- Use unconditioned sensors
- Create a network with at least 2 slave nodes
- Update measurement data in under 10 seconds

- Inputs at each location:
  - Temperature
  - Humidity
  
- Outputs:

- Humidity

- Outputs:

- Data log files

- Data display on web page

# *Terminology*

- Master Node
  - Collects data
  - Logs data
  - Displays data
- Slave Node
  - Measures sensors
  - Transmits data to master node

# Why envwi sense?

- Remotely Monitor Temperature & Humidity
  - Data Centers
  - Home use
- Usefulness of devices and information
- Expandability
  - Different sensors
  - Control
- Home Automation
- Learning opportunity

## *Similar Devices*

Home Weather Station

Smart Thermostat



# *Overview*

## 1. Project Design

### 1.1. Slave Node Design

### 1.2. Master Node Design

## 2. Results

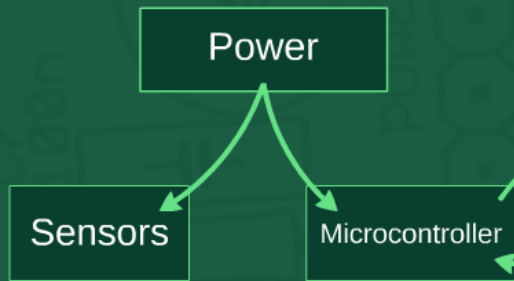
## 3. Conclusion

## 4. Acknowledgements & Advice to Juniors

## 5. Demonstration

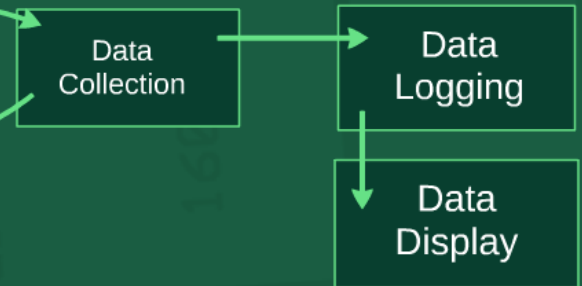
## 6. Questions

# Slave Node

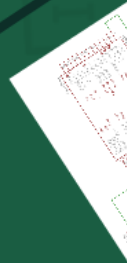


Data Transmission

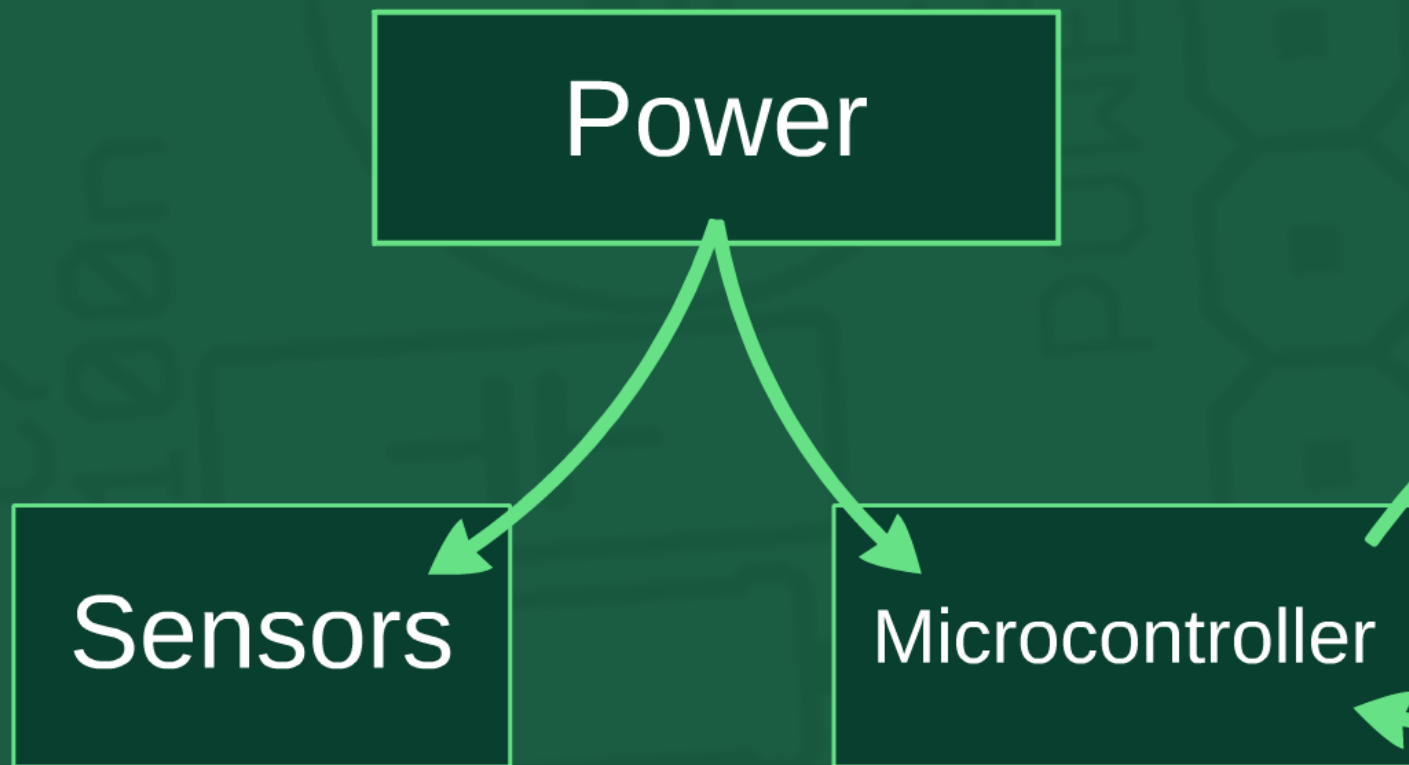
# Master Node



01-2015



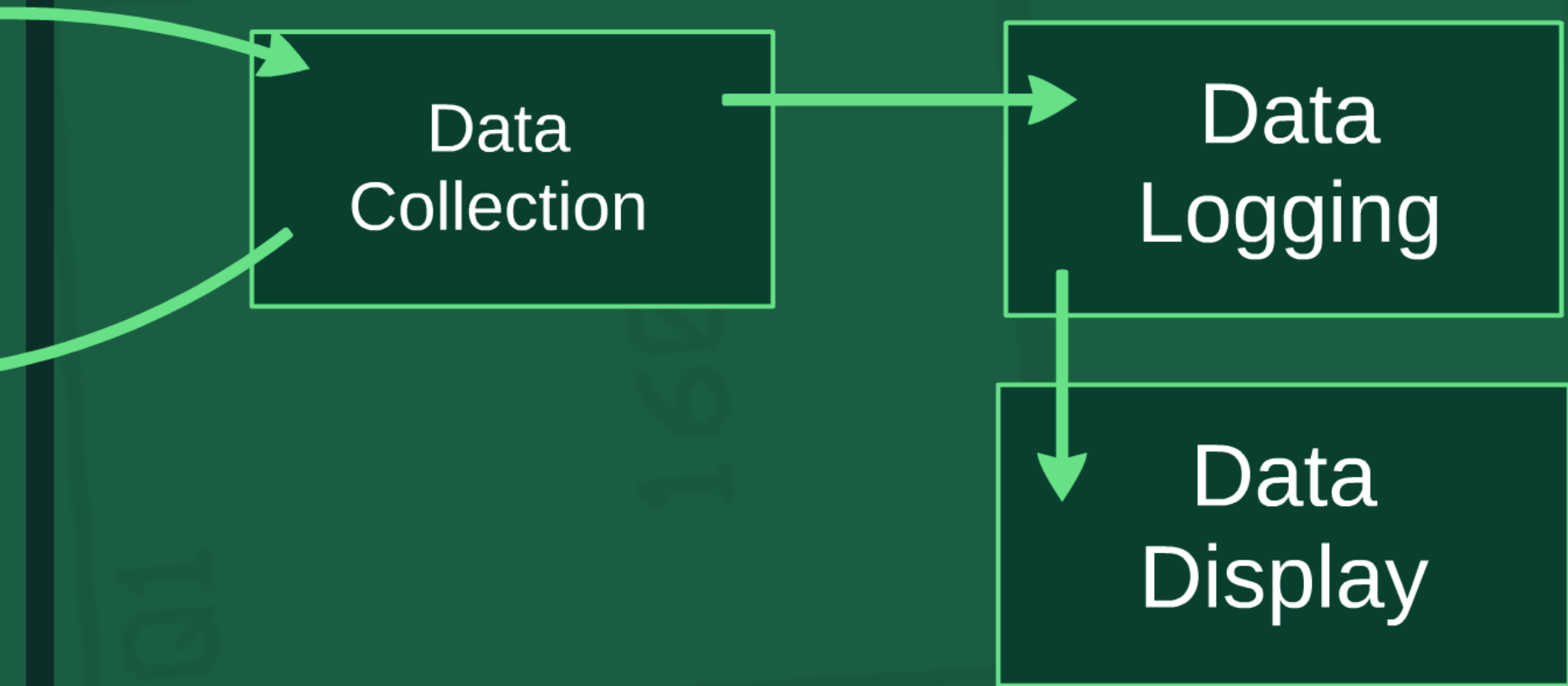
# Slave Node





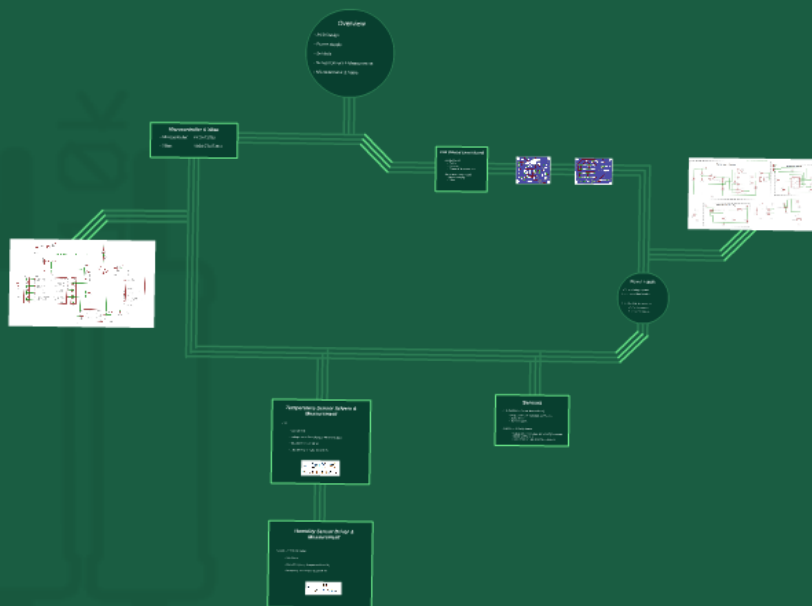
# Data Transmission

# Master Node

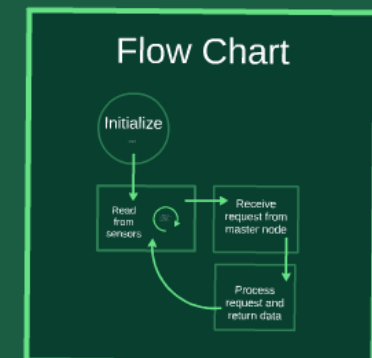
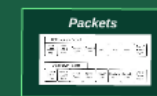


# Slave Node

## Hardware



## Software



# Hardware

## Overview

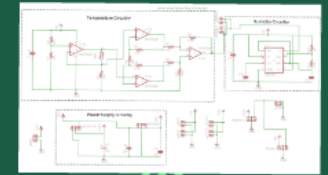
- PCB Design
- Power Supply
- Sensors
- Sensor Drivers & Measurement
- Microcontroller & XBee

## Microcontroller & XBee

- Microcontroller: PIC16F1783
- XBee: XB24-Z75IT-G14

## PCB (Printed Circuit Board)

- General Board
- Sensors
- Drivers & Measurement
- Interconnection Board
- XBee Controller
- XBee



## Power Supply

- 5V Linear Voltage Regulator
- 5V 100mA Voltage Regulator
- Linear Voltage Regulators
- 5V 100mA Voltage Regulator
- 5V 100mA Voltage Regulator

## Temperature Sensor Drivers & Measurement

- RTD
- Current sink
- Voltage across RTD changes with temperature
- RTD sensor amplifier
- ADC (Analog to Digital Converter)

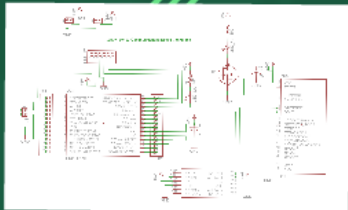


## Sensors

- RTD (Resistance Temperature Detector)
  - ITC (Capacitive Temperature and Humidity)
  - ITC (Capacitive Temperature and Humidity)
  - ITC (Capacitive Temperature and Humidity)
- Capacitive Humidity Sensor
- Capacitive Humidity Sensor (CHS)
  - CHS (Capacitive Humidity Sensor)
  - CHS (Capacitive Humidity Sensor)

## Humidity Sensor Driver & Measurement

- CHS (Capacitive Humidity Sensor)
- CHS (Capacitive Humidity Sensor)



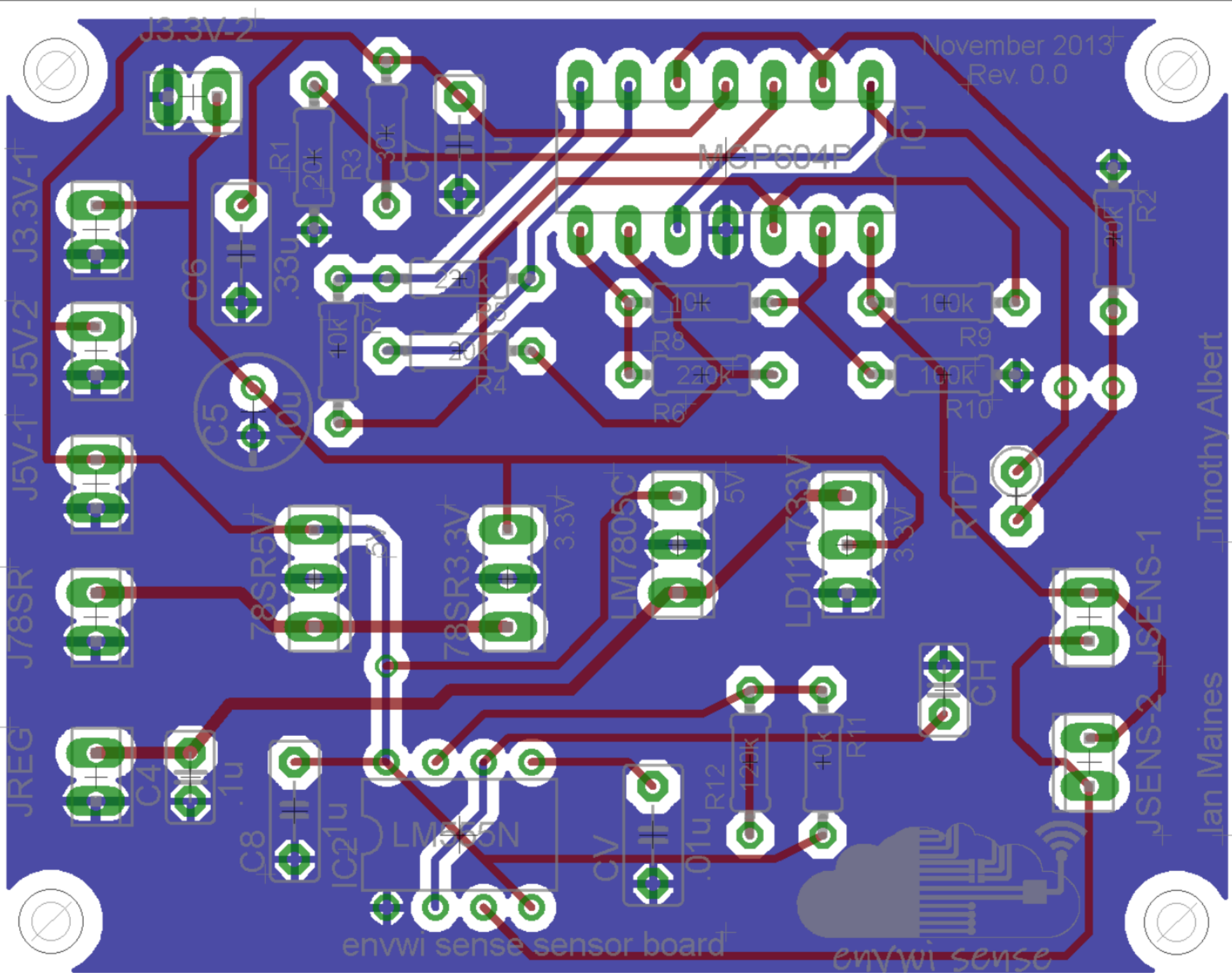
# Overview

- PCB Design
- Power Supply
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- Sensor Drivers & Measurement
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# *PCB (Printed Circuit Board)*

- Sensor Board
  - Power
  - Sensors
  - Drivers & Measurement
- Communications Board
  - Microcontroller
  - XBee



November 2013  
Rev. 0.0

JREG J78SR J5V-1 J5V-2 J3.3V-1 J3.3V-2

JSENS-1 JSENS-2

envwi sense sensor board

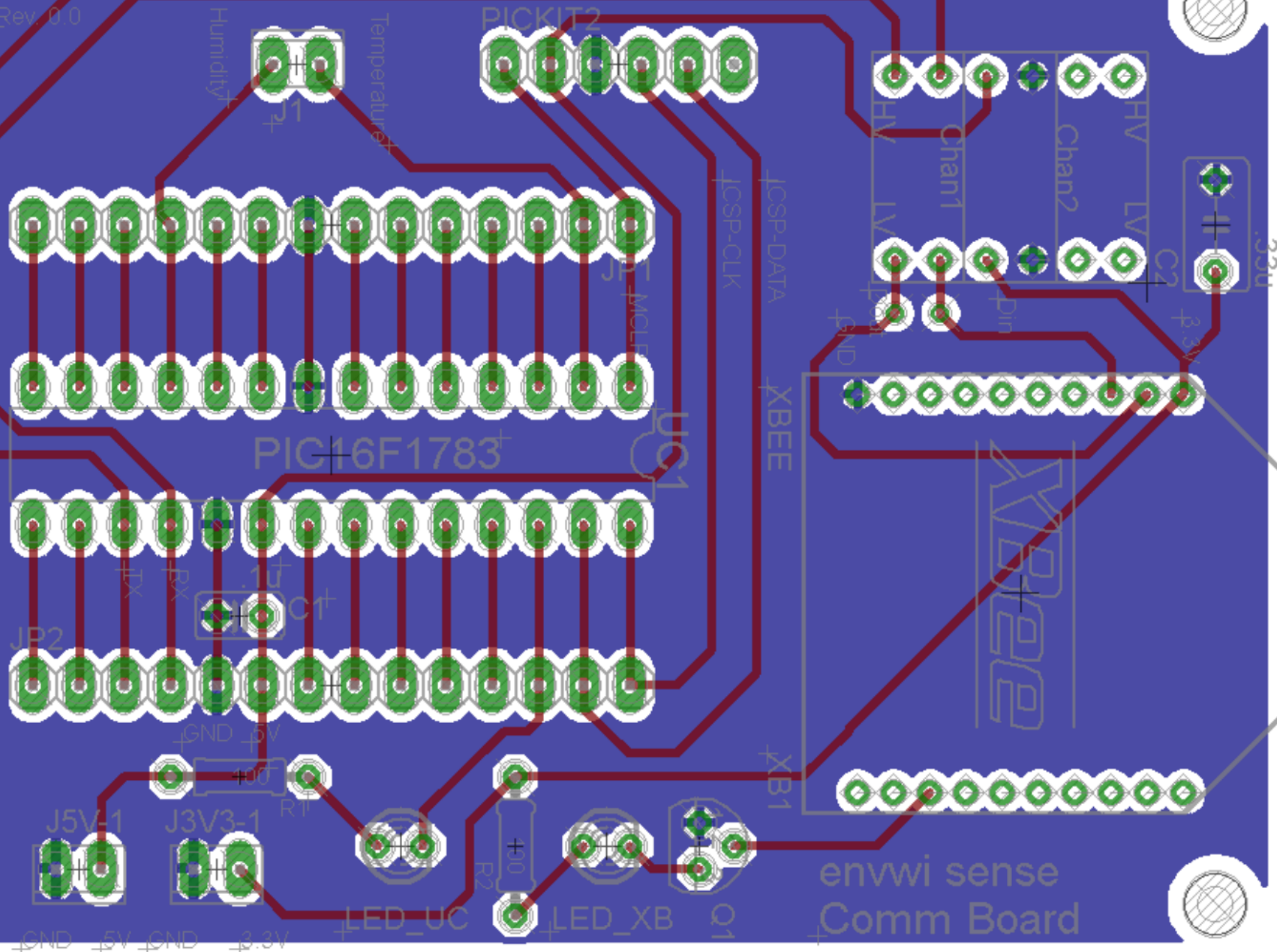
envwi sense

Timothy Albert

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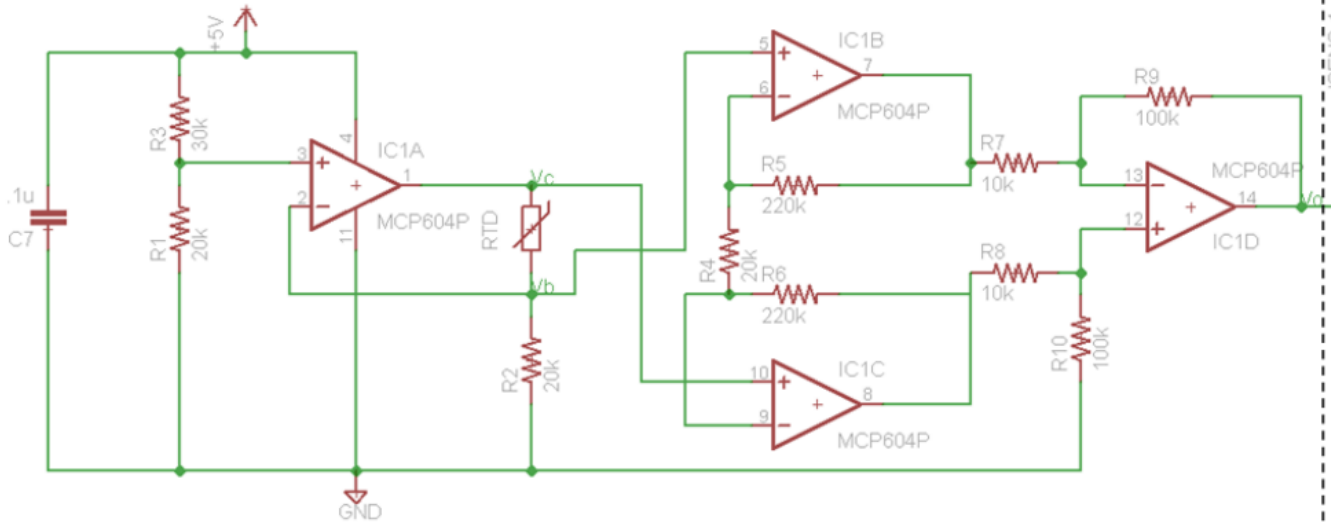
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Jan Maines  
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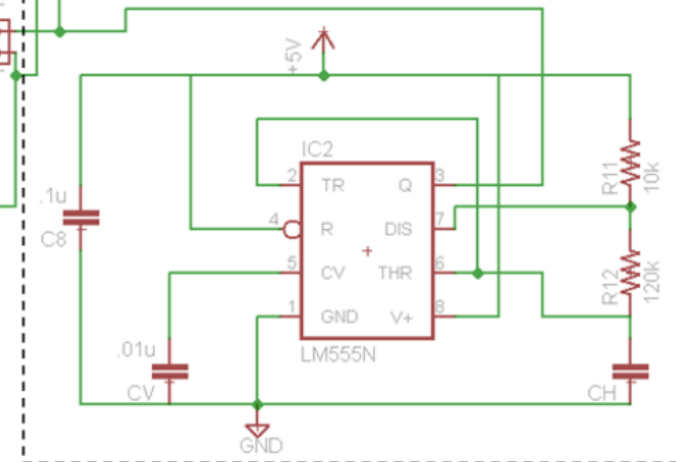


prnwi sense Sensor Board Schematic

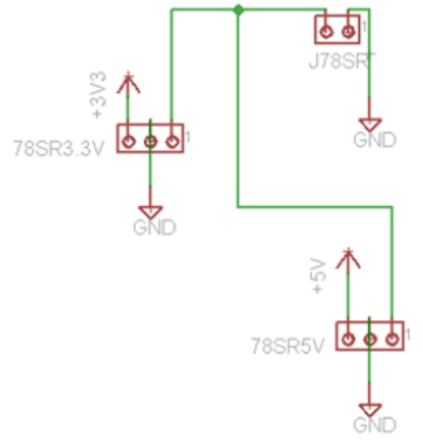
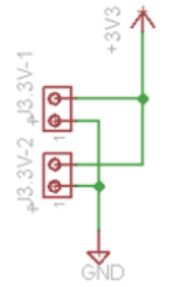
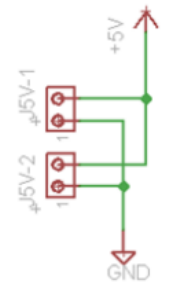
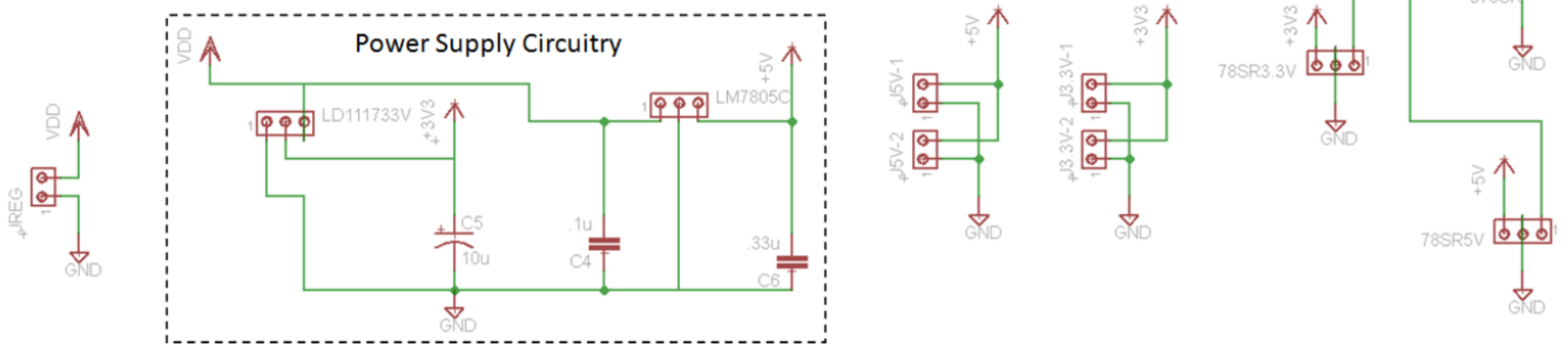
### Temperature Circuitry



### Humidity Circuitry



### Power Supply Circuitry



# Power Supply

+5V Linear Voltage Regulator

+3.3V Linear Voltage Regulator

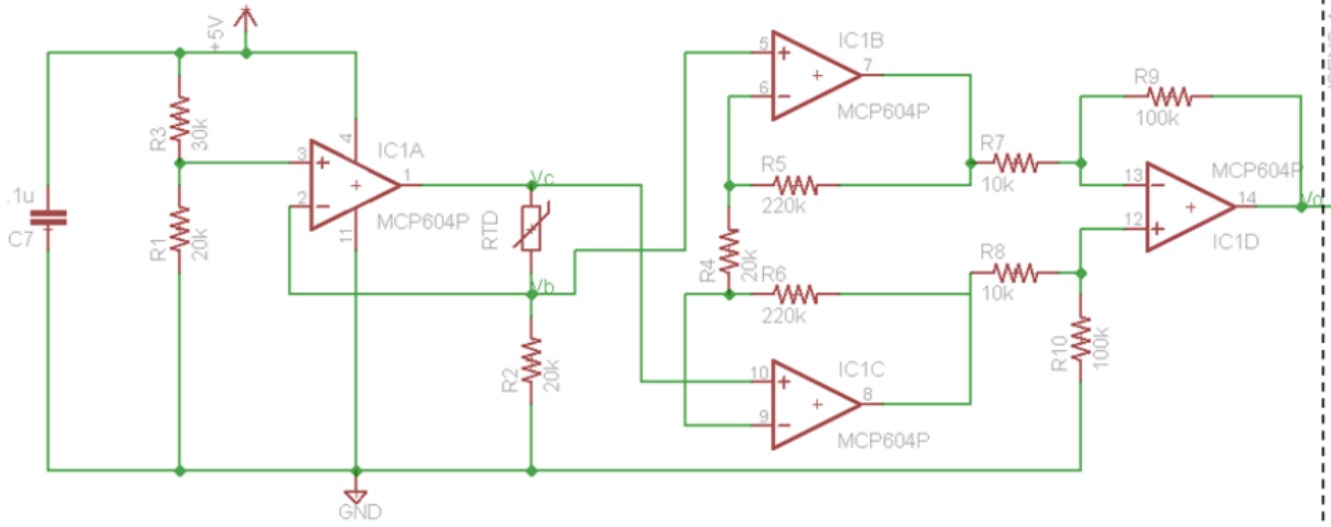
Linear Regulator Replacements

+5V DC-DC Converter

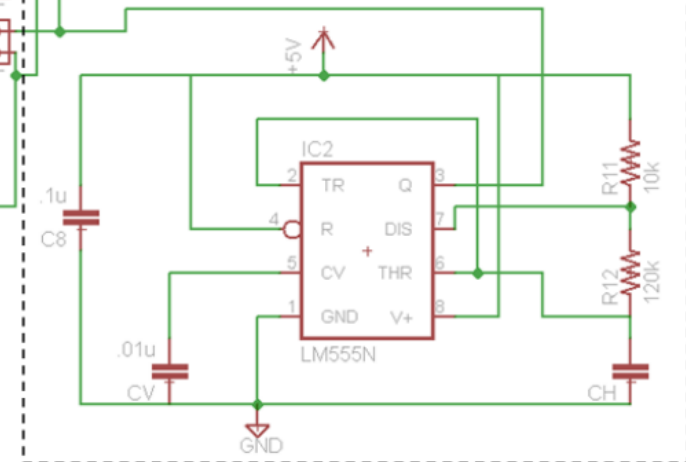
+3.3V DC-DC Converter

prnwi sense Sensor Board Schematic

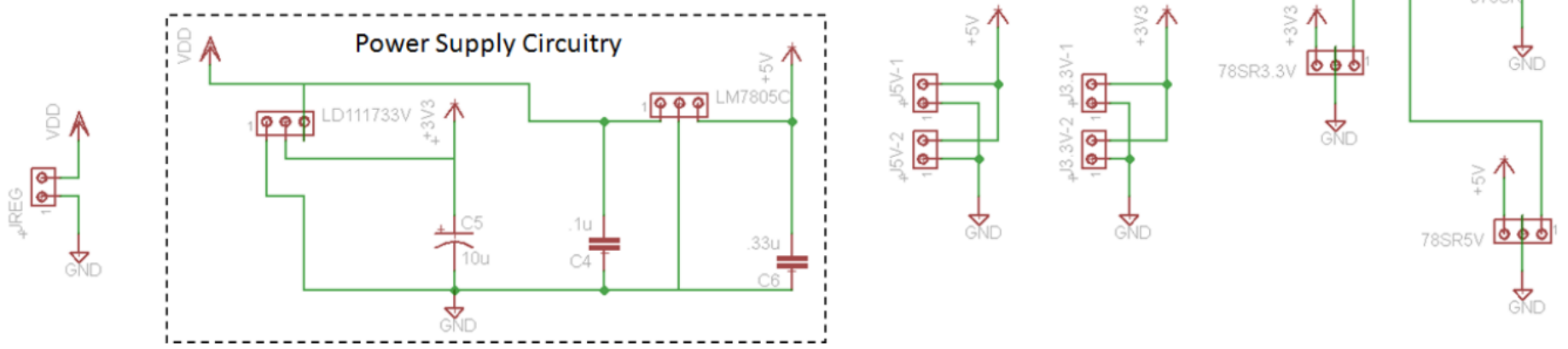
### Temperature Circuitry



### Humidity Circuitry



### Power Supply Circuitry



# *Sensors*

RTD (resistance temperature detector)

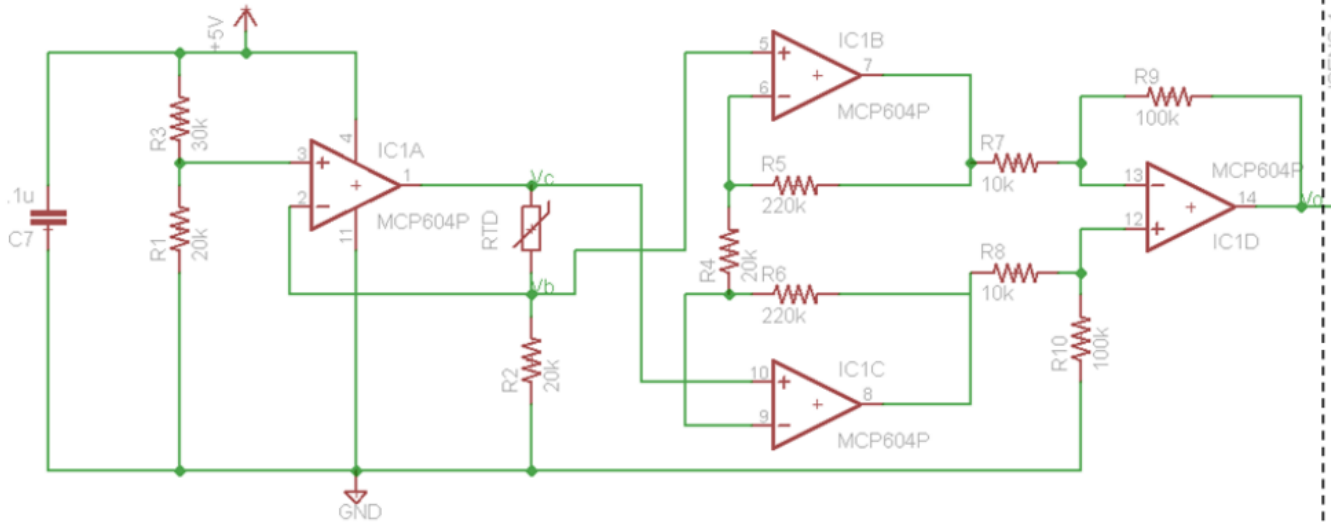
- PTC (positive temperature coefficient)
- $100\Omega$  at  $0^{\circ}\text{C}$
- $-50^{\circ}\text{C}$  to  $500^{\circ}\text{C}$

Capacitive Humidity Sensor

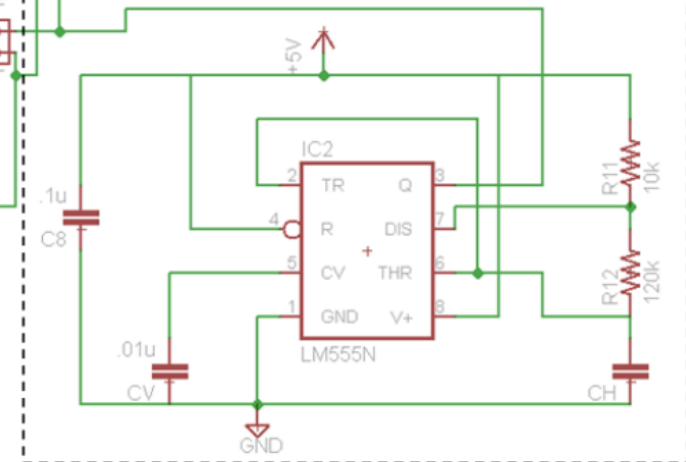
- Capacitance increases as humidity increases
- $330\text{pF}$  at  $55\% \text{ RH}$
- $0.60 \text{ pF}/\% \text{RH}$  from  $10\% \text{ RH}$  to  $95\% \text{RH}$

prnwi sense Sensor Board Schematic

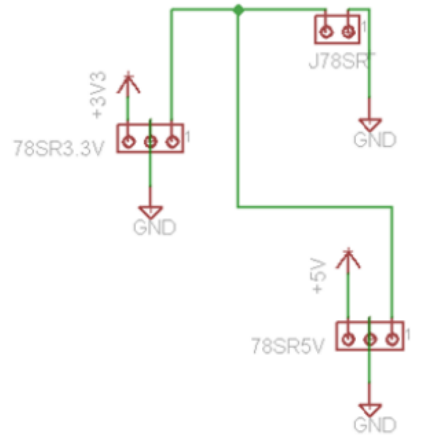
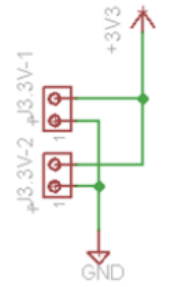
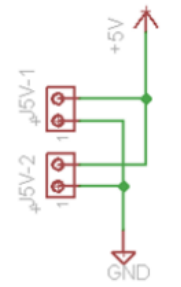
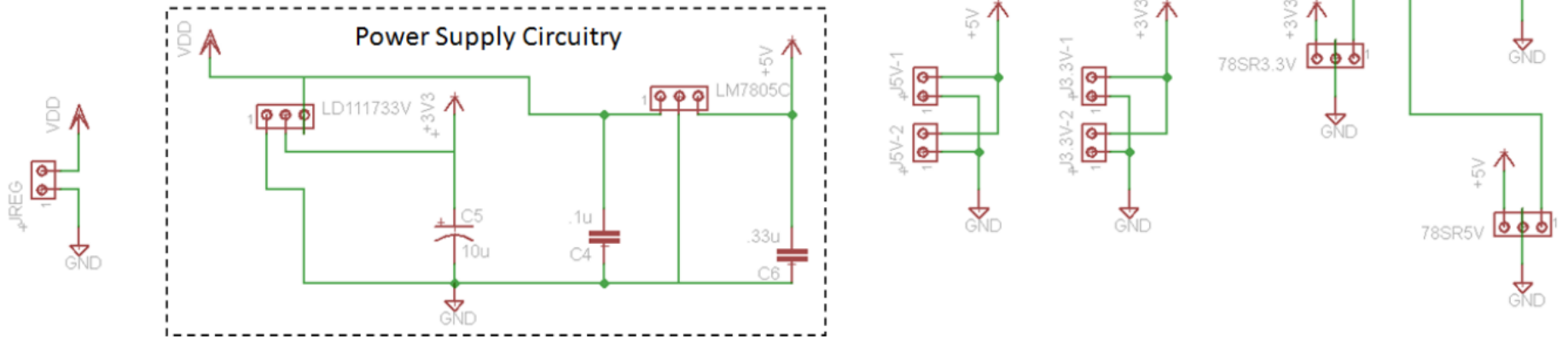
### Temperature Circuitry



### Humidity Circuitry



### Power Supply Circuitry





# *Temperature Sensor Drivers & Measurement*

RTD

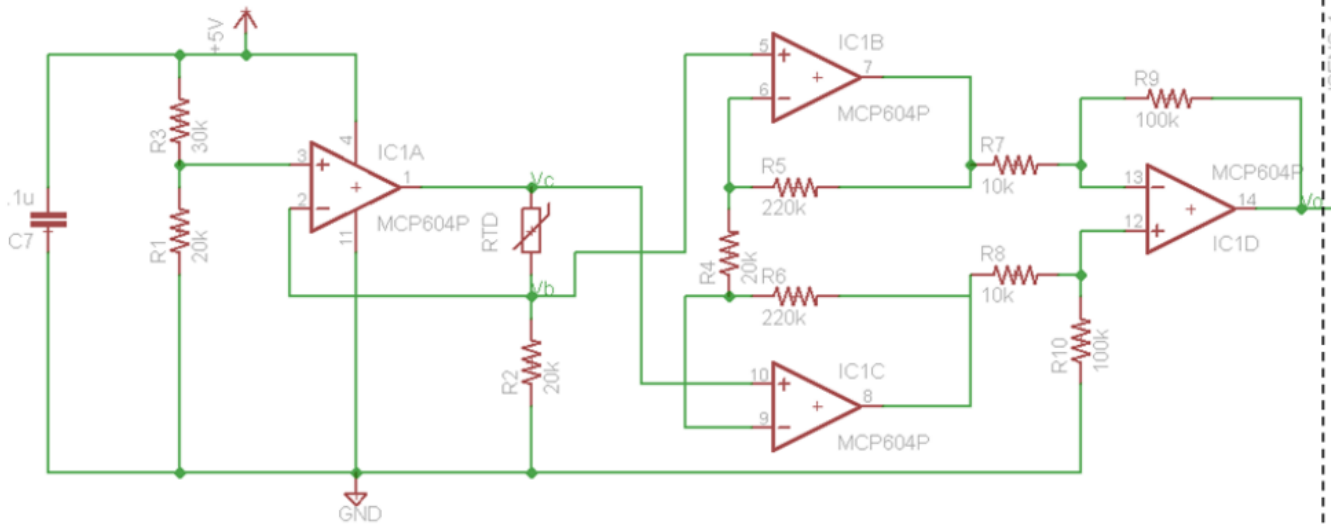
- Current Sink
- Voltage across RTD changes with temperature
- Instrumentation Amplifier
- ADC (Analog to Digital Converter)

$$A_d = \frac{R_9}{R_7} \left( 1 + \frac{R_5}{R_4} \right) = 233 \frac{V}{V}$$

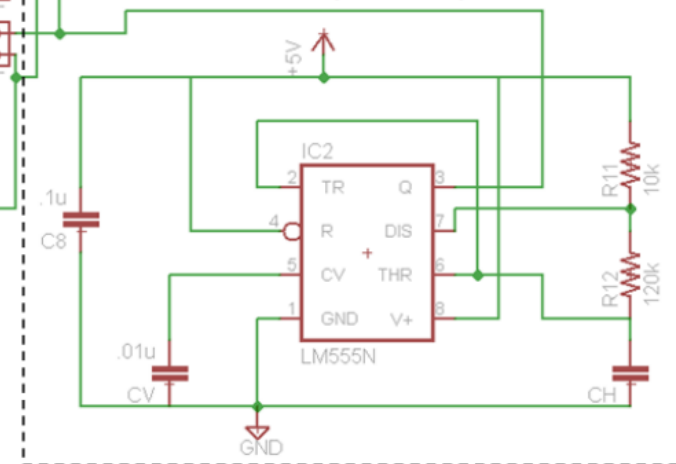
where:  $R_9 = R_{10}$ ,  $R_7 = R_8$ ,  $R_5 = R_6$

prnwi sense Sensor Board Schematic

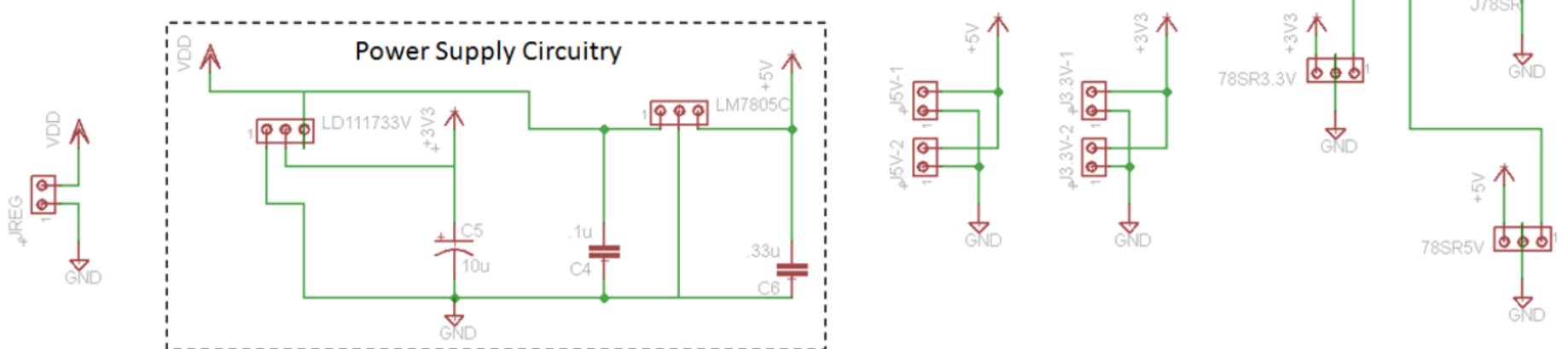
### Temperature Circuitry

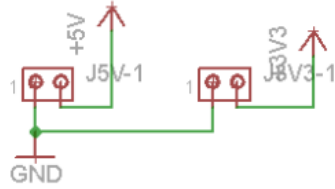


### Humidity Circuitry

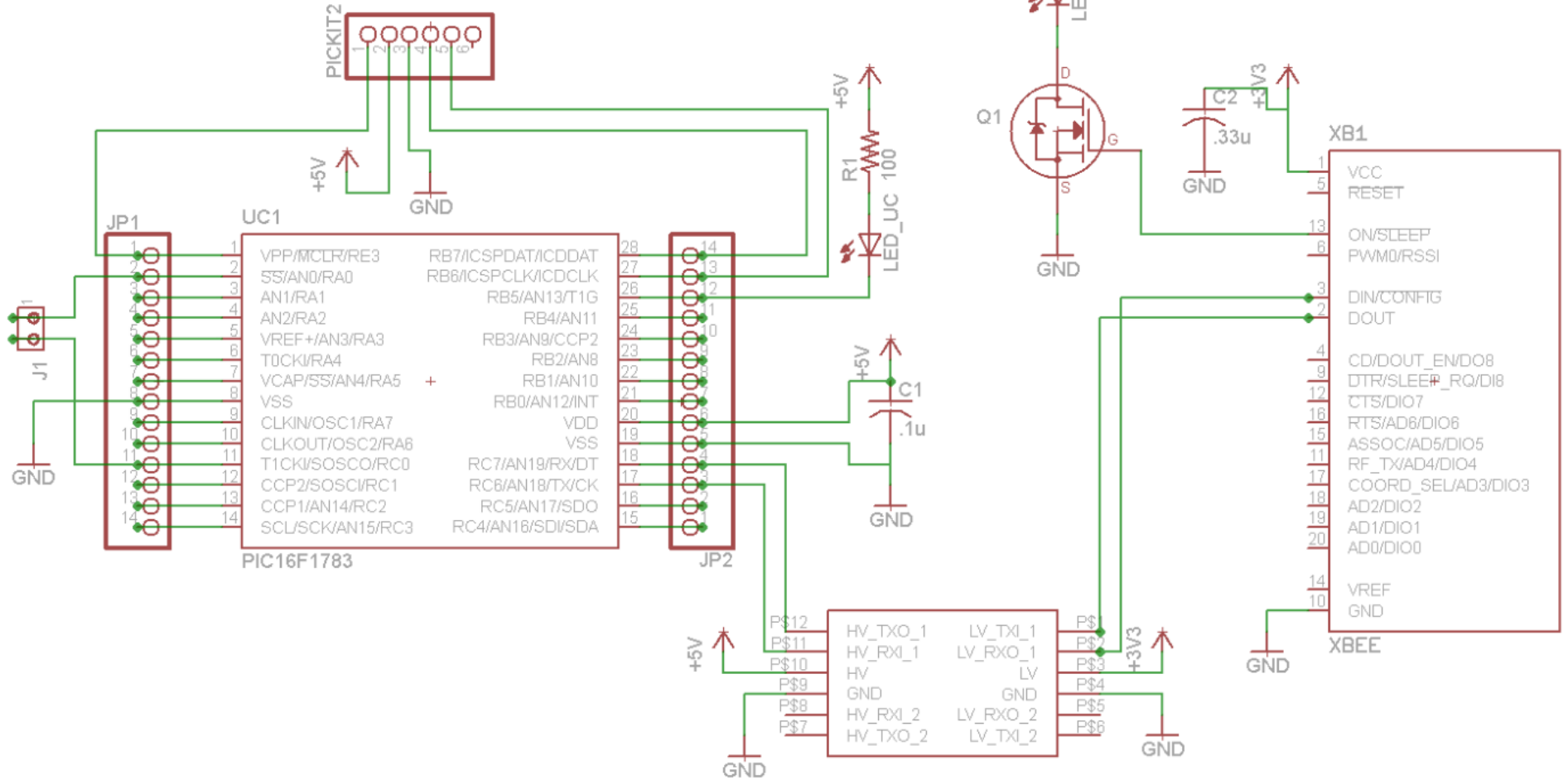


### Power Supply Circuitry





pnvwi sense Communications Board Schematic

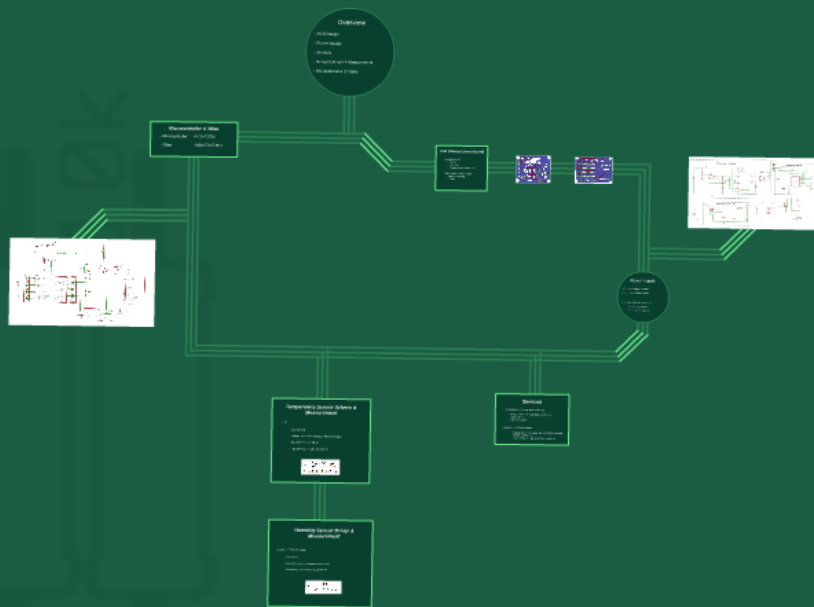


## ***Microcontroller & XBee***

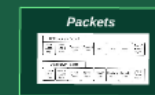
- Microcontroller: PIC16F1783
- XBee: XB24-Z7SIT-004

# Slave Node

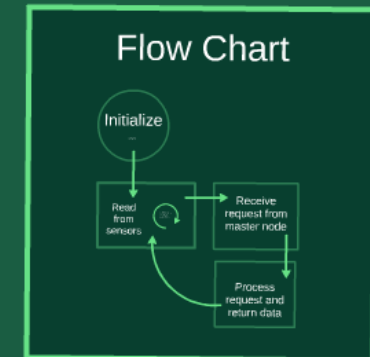
## Hardware



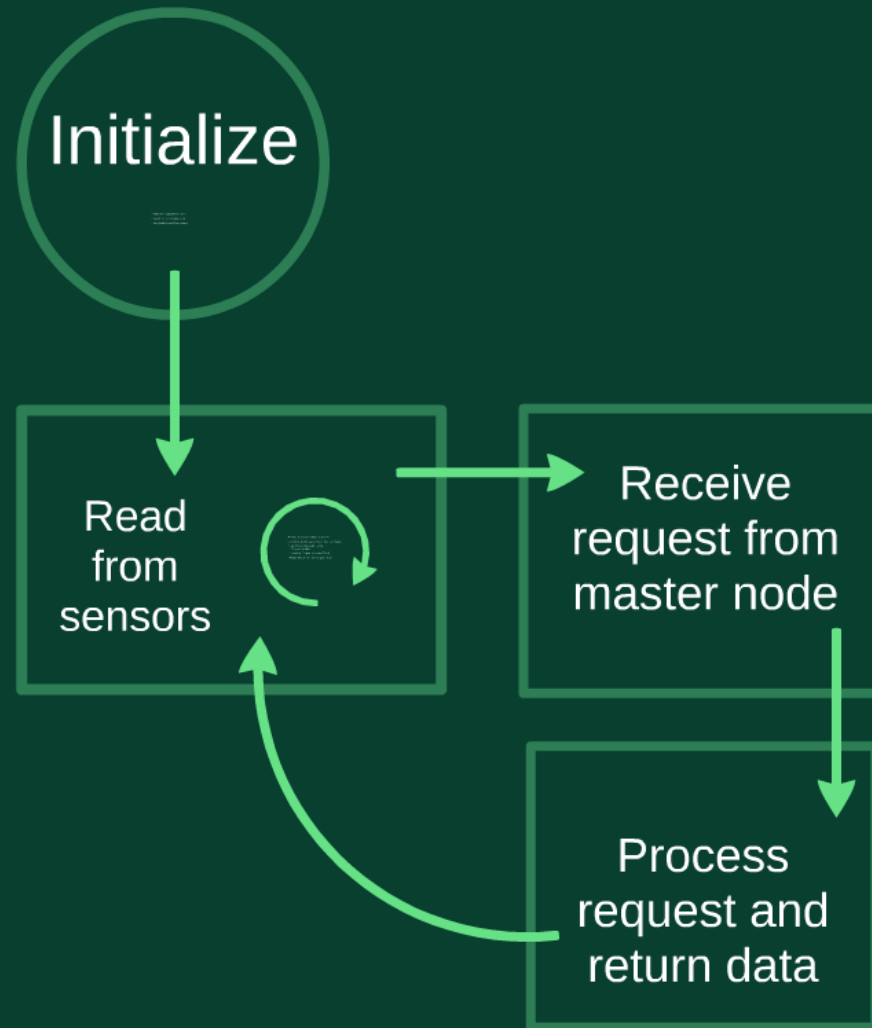
## Software



## Flow Chart



# Flow Chart





# Initialize


- Variables for packets and data
- Serial Port for Communication
- Peripherals to read from sensors

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- Peripherals to read from sensors







# Read from sensors

- 
- Waits for data request from master node
  - Uses interrupts for asynchronous data transmission
  - Reads from sensors while waiting
    - Temperature: ADC
    - Humidity: Frequency Counter (Timer)
  - Minimal delay when master requests data

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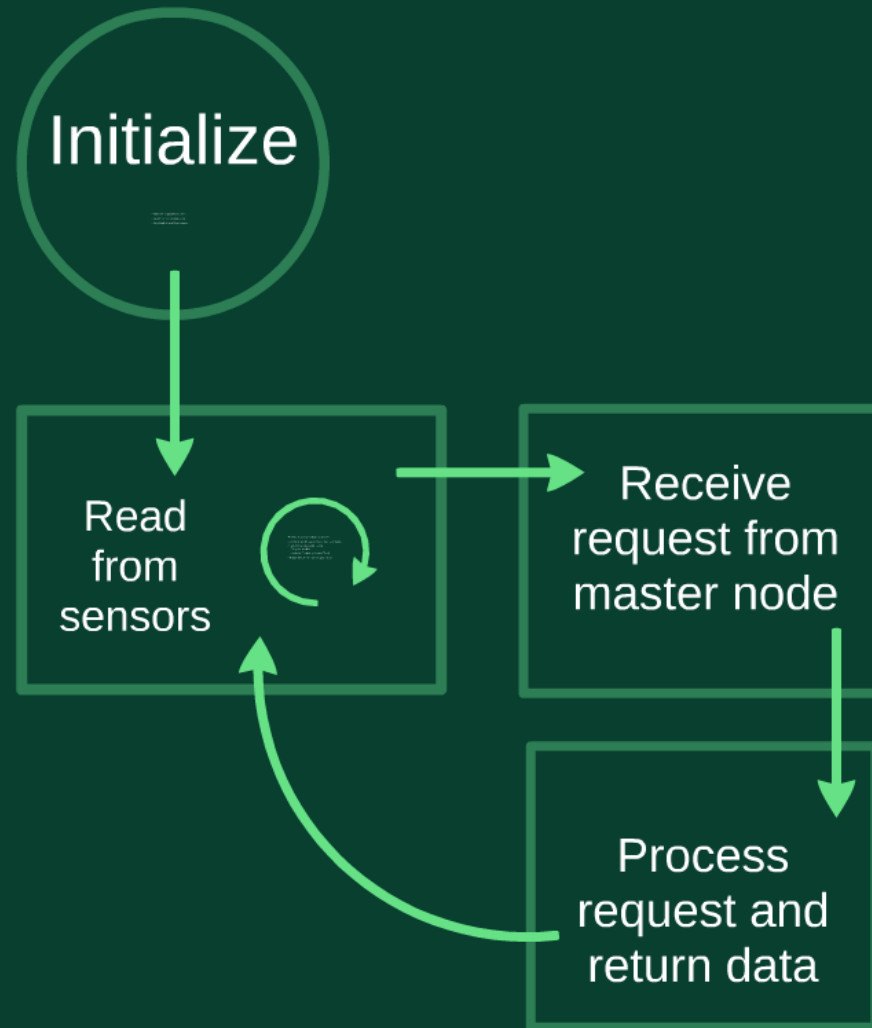
Receive  
request from  
master node





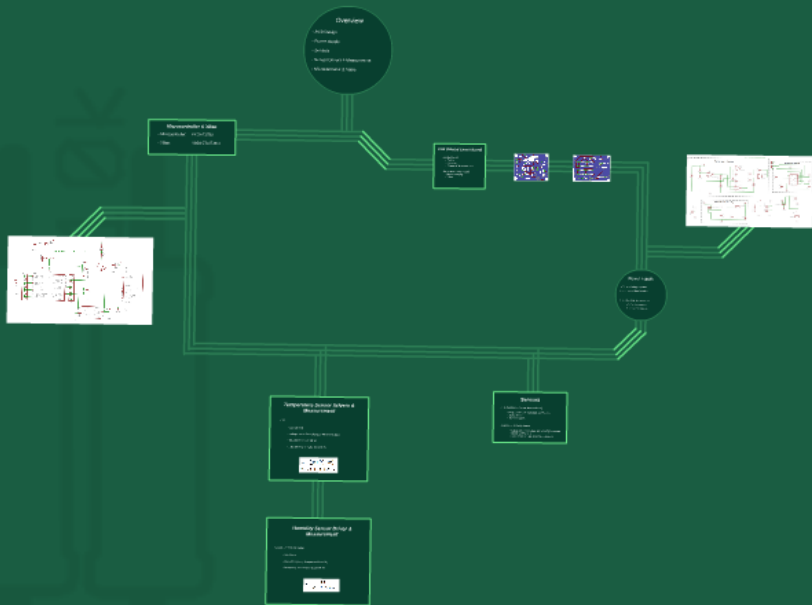
Process  
request and  
return data

# Flow Chart



# Slave Node

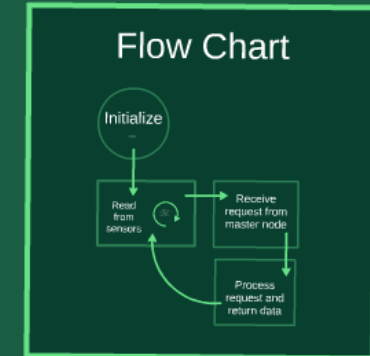
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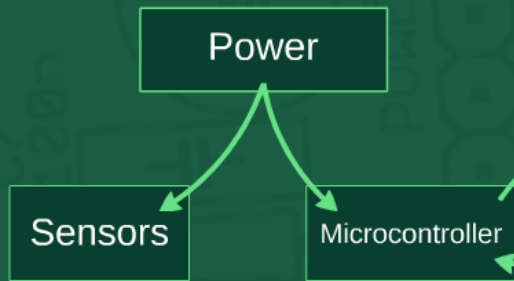
## Software



## Flow Chart

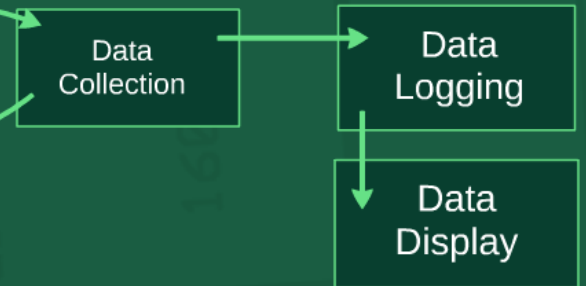


# Slave Node



Data Transmission

# Master Node

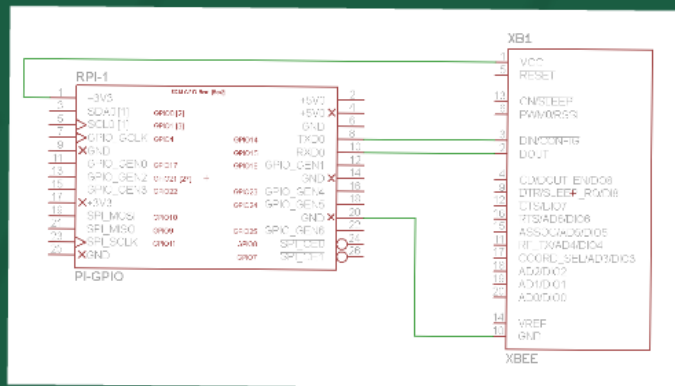


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# Master Node

## Hardware



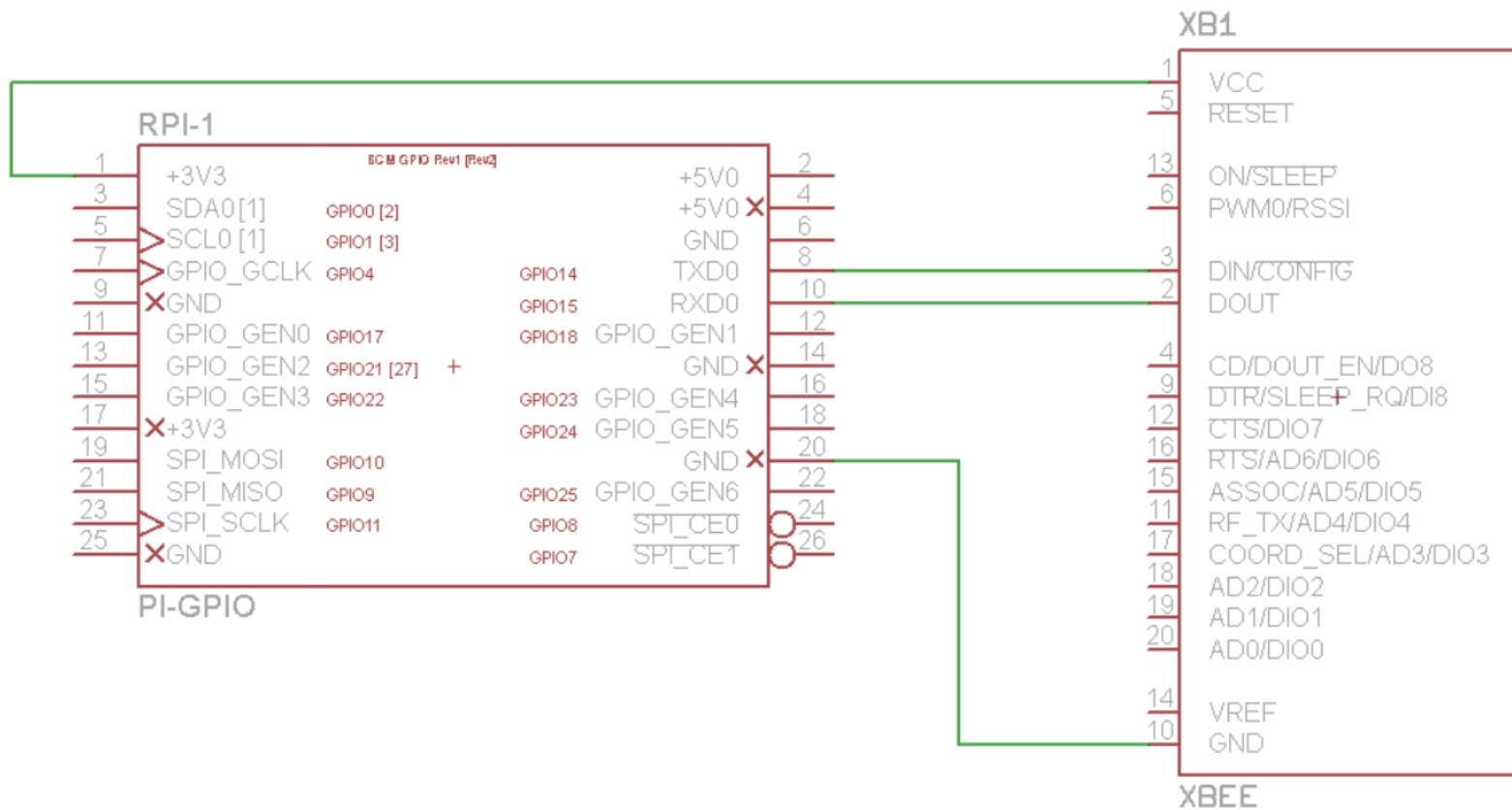
## Software

### Flow Chart





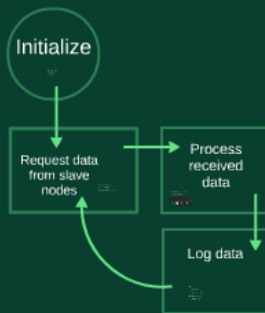
# Hardware



# Software

## Flow Chart

### Main Code



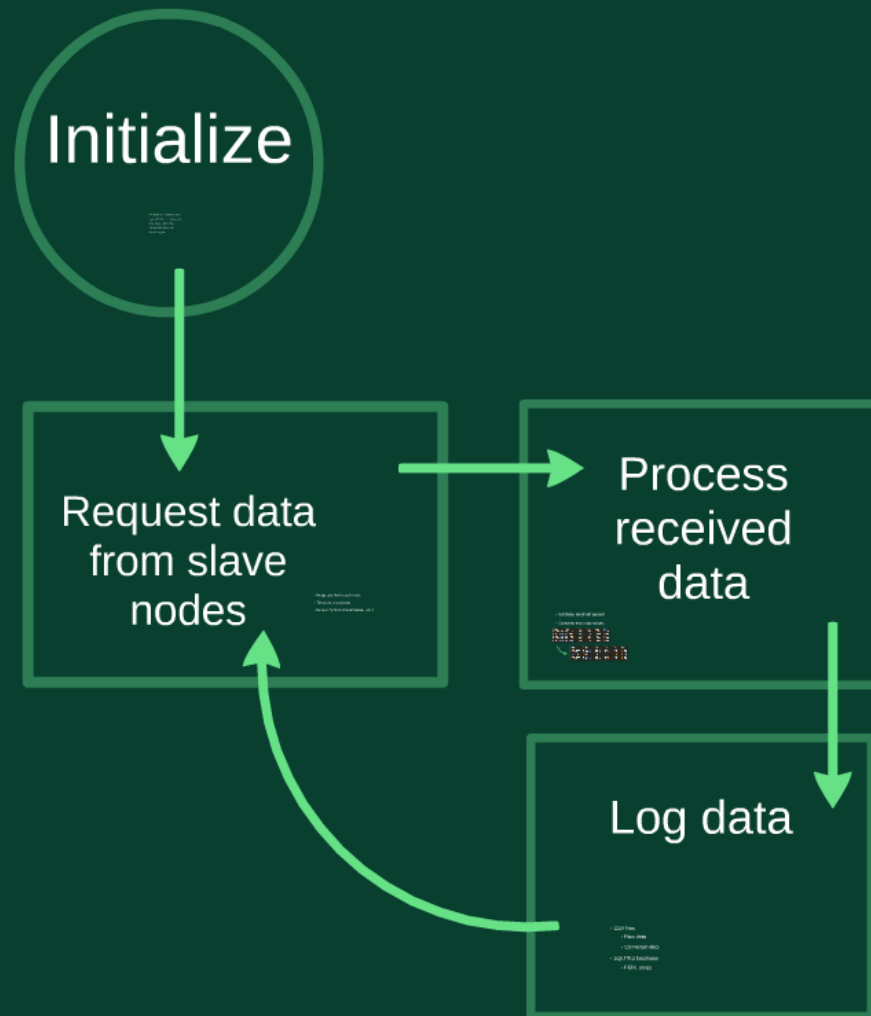
### Perl Script

- Why?
  - Provides interface
  - C library clumsy
- Temperature and Humidity as command line arguments
- SQLITE3 Database
- Date and time

### Website

- Software: PHP5, SQLITE3, lighttpd
- Languages: HTML, Javascript, PHP
- Highcharts chart library
- Project status
- Slave Node status




# Main Code



# Initialize

- Variables for packets and data
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- File pointers for log files
- Strings for logging data
- POSIX signals

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# Request data from slave nodes

- Requests from each node
- Timeout: 2 seconds
- Recovery from transmission error


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- Timeout: 2 seconds
- Recovery from transmission error



# Process received data

- Validates received packet
- Converts from raw values

Date:	Time:	S1T:	S2T:	S1H:	S2H:
11/07/2013	09:04:45	2376	2373	18011	18068
11/07/2013	09:04:49	2376	2372	18009	18057
11/07/2013	09:04:53	2375	2371	18007	18056
11/07/2013	09:04:57	2374	2371	18014	18059
11/07/2013	09:05:01	2376	2370	18012	18065



Date:	Time:	S1I:	S2I:	S1M:	S2M:
11/07/2013	09:04:45	21.89	21.46	41.14	39.14
11/07/2013	09:04:49	21.89	21.31	41.14	40.14
11/07/2013	09:04:53	21.75	21.17	41.14	40.14
11/07/2013	09:04:57	21.60	21.17	41.14	40.14
11/07/2013	09:05:01	21.89	21.02	41.14	40.14



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Date:	Time:	S1T:	S2T:	S1H:	S2H:
11/07/2013	09:04:45	2376	2373	18011	18068
11/07/2013	09:04:49	2376	2372	18009	18057
11/07/2013	09:04:53	2375	2371	18007	18056
11/07/2013	09:04:57	2374	2371	18014	18059
11/07/2013	09:05:01	2376	2370	18012	18065



Date:	Time:	S1T:	S2T:	S1H:	S2H:
11/07/2013	09:04:45	21.89	21.46	41.14	39.14
11/07/2013	09:04:49	21.89	21.31	41.14	40.14
11/07/2013	09:04:53	21.75	21.17	41.14	40.14
11/07/2013	09:04:57	21.60	21.17	41.14	40.14
11/07/2013	09:05:01	21.89	21.02	41.14	40.14

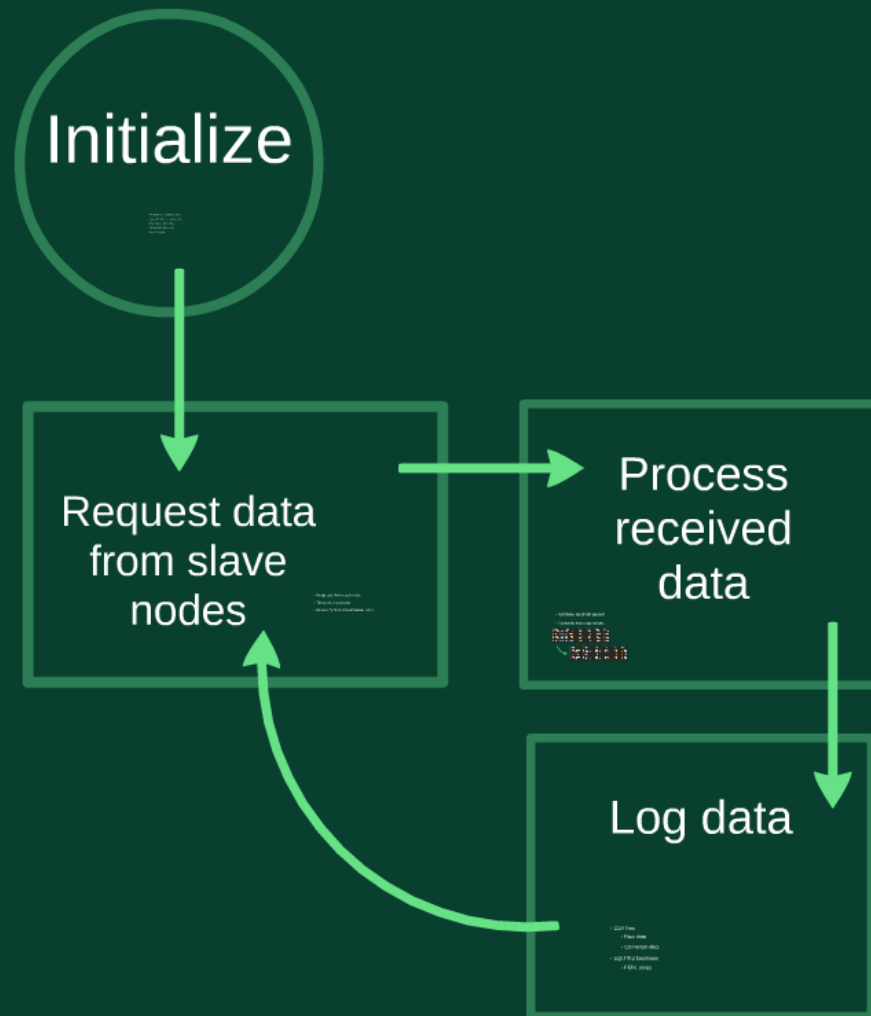
# Log data



- CSV files
    - Raw data
    - Converted data
  - SQLITE3 Database
    - PERL script
- 

- CSV files
  - Raw data
  - Converted data
- SQLITE3 Database
  - PERL script

# Main Code



# Perl Script

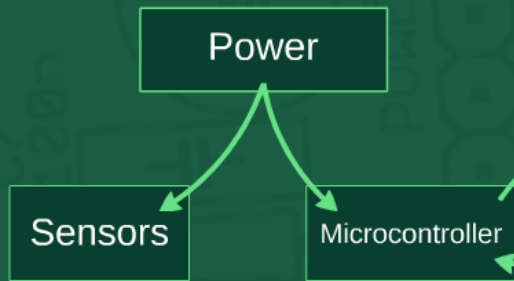
- Why?
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We

# Website

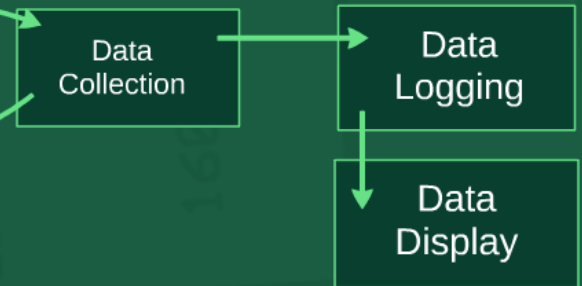
- Software: PHP5, SQLITE3, lighttpd
- Languages: HTML, Javascript, PHP
- Highcharts chart library
- Project status
- Slave Node status

# Slave Node



Data Transmission

# Master Node



01-2015

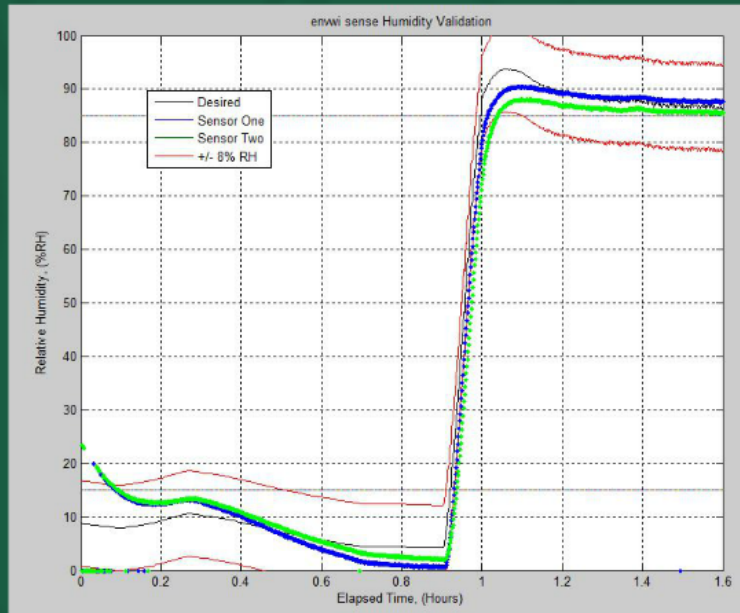


*How envwi  
sense was  
calibrated  
and tested.*





# Results

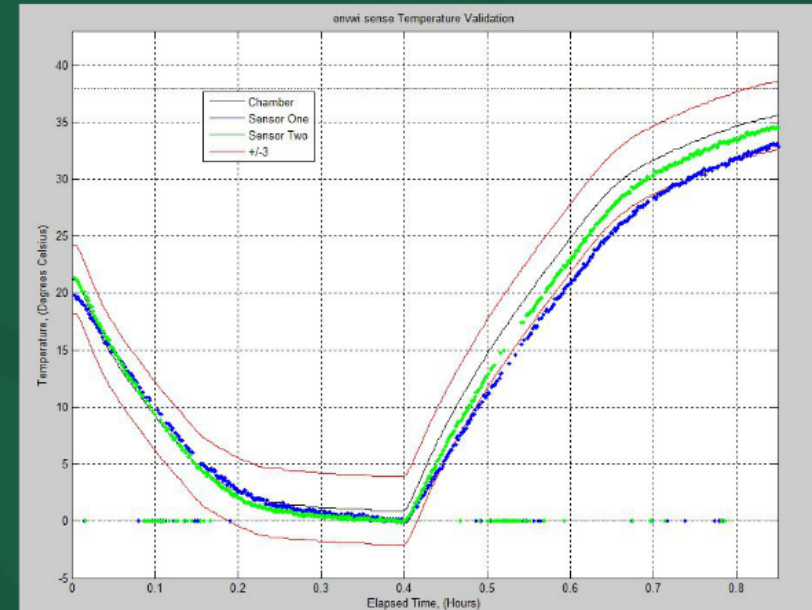


Sensor 1

$$\text{Humidity \%RH} = 770,000 \times (\text{555 Period}) - 384$$

Sensor 2

$$\text{Humidity \%RH} = 770,000 \times (\text{555 Period}) - 381$$



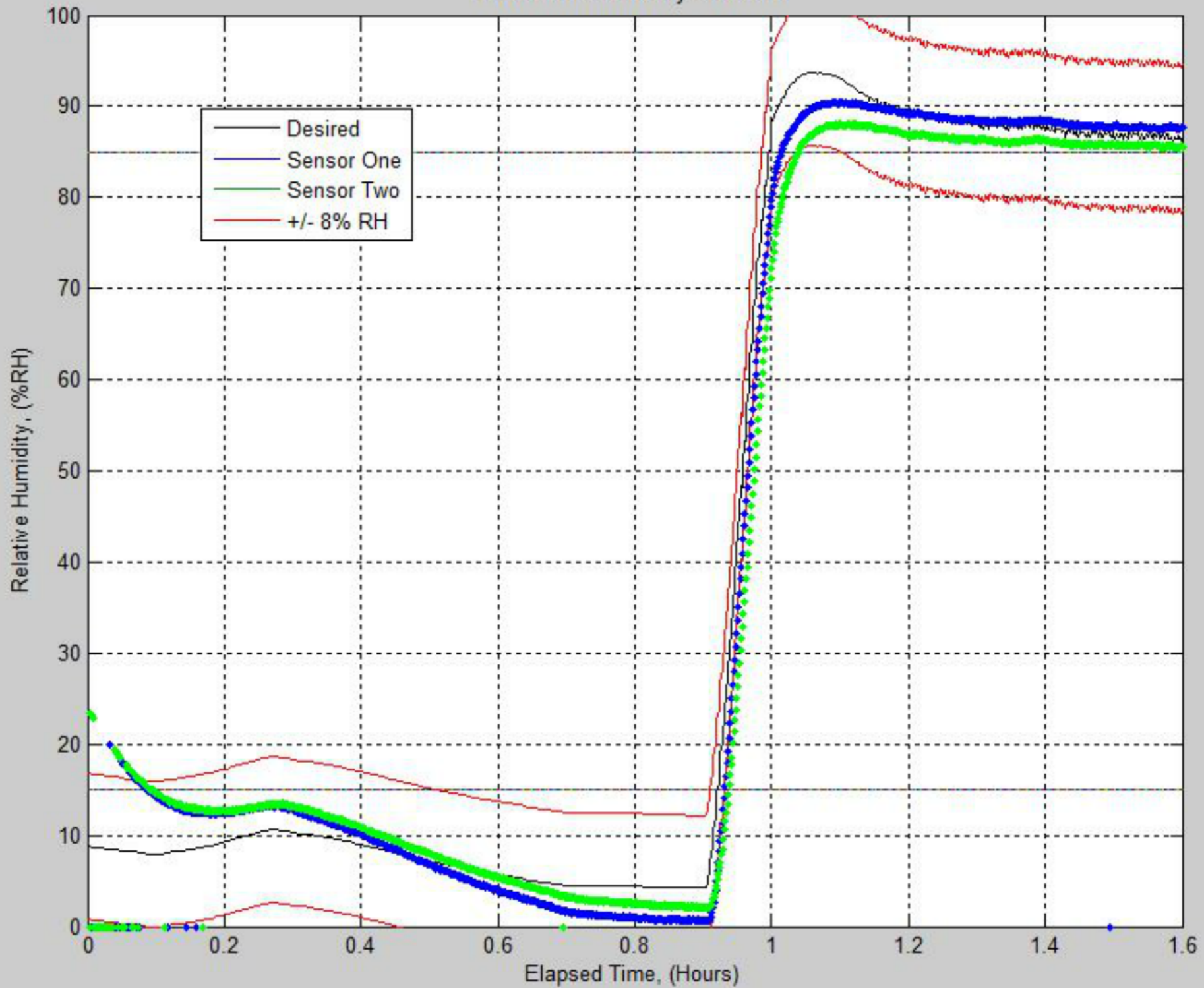
Sensor 1

$$\text{Temperature } ^\circ\text{C} = 0.121 \times (\text{ADC value}) - 214$$

Sensor 2

$$\text{Temperature } ^\circ\text{C} = 0.128 \times (\text{ADC value}) - 266.5$$

enwi sense Humidity Validation



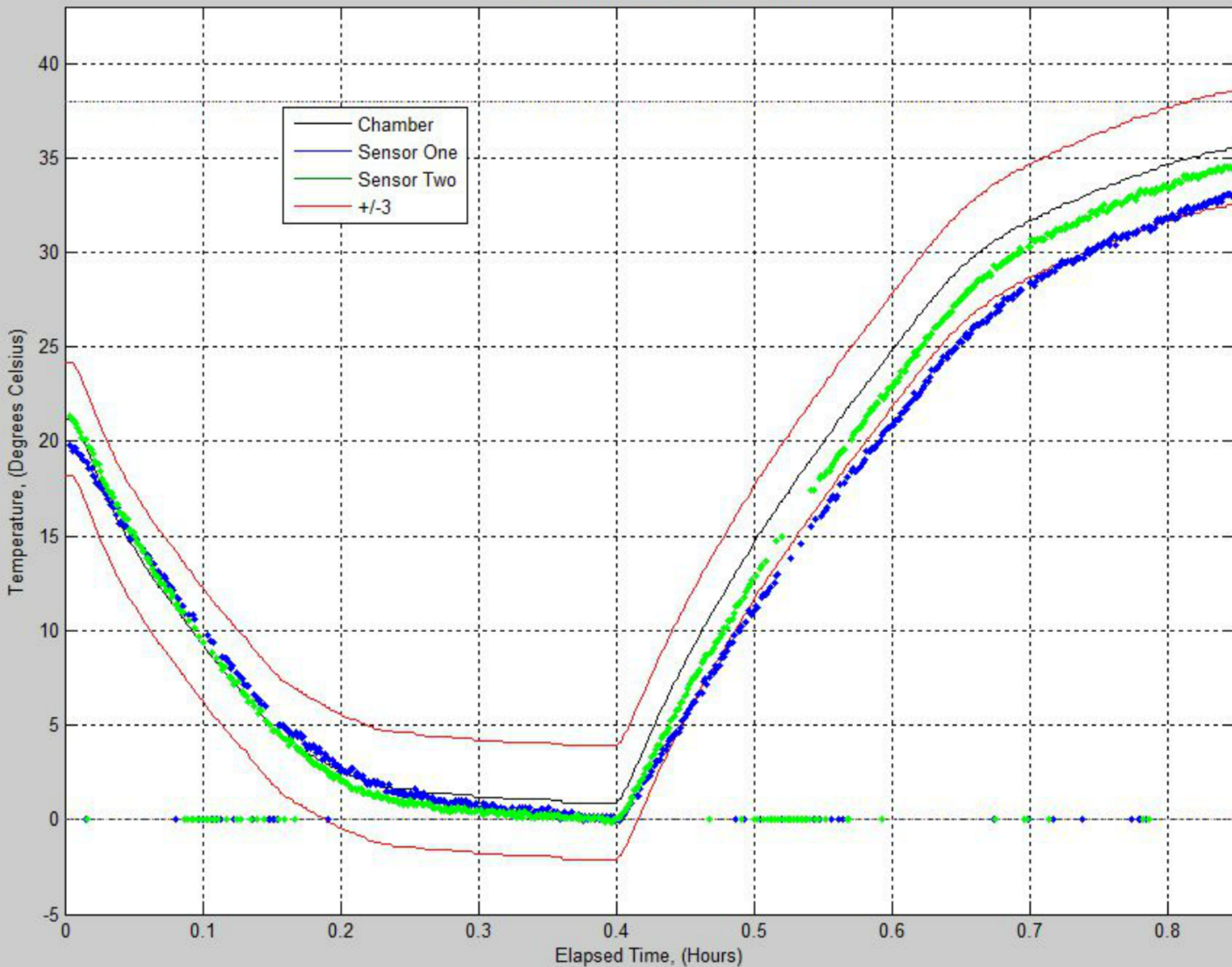
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$$\text{Humidity \%RH} = 770,000 \times (555 \text{ Period}) - 384$$

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$$\text{Humidity \%RH} = 770,000 \times (555 \text{ Period}) - 381$$

enwi sense Temperature Validation



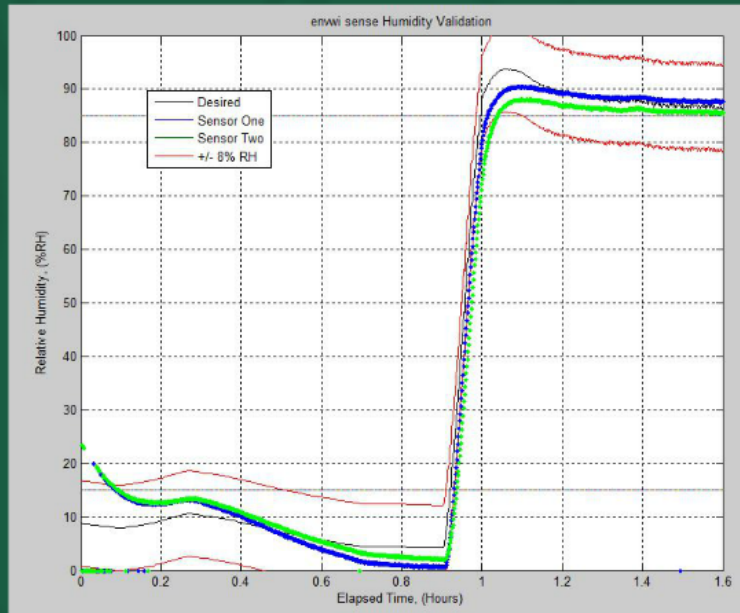
# Sensor 1

$$\text{Temperature } ^\circ\text{C} = 0.121 \times (\text{ADC value}) - 214$$

# Sensor 2

$$\text{Temperature } ^\circ\text{C} = 0.128 \times (\text{ADC value}) - 266.5$$

# Results

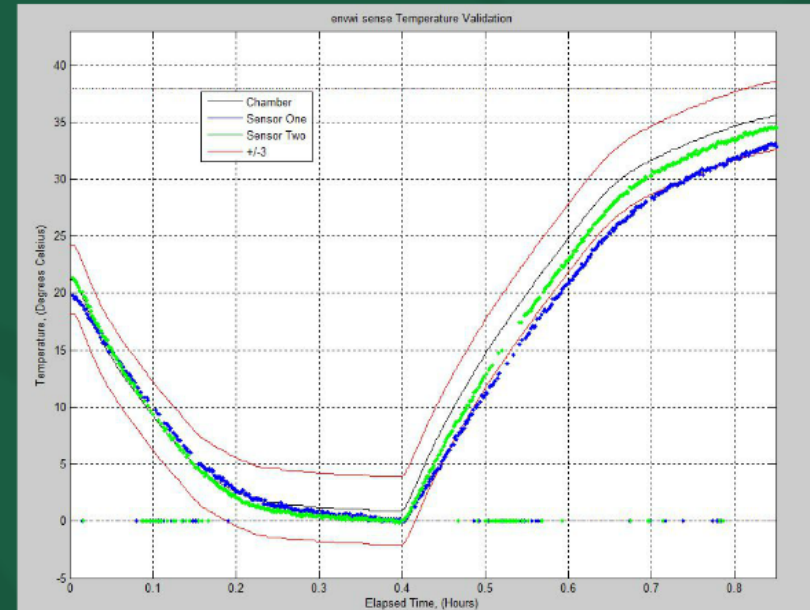


Sensor 1

$$\text{Humidity \%RH} = 770,000 \times (\text{555 Period}) - 384$$

Sensor 2

$$\text{Humidity \%RH} = 770,000 \times (\text{555 Period}) - 381$$



Sensor 1

$$\text{Temperature } ^\circ\text{C} = 0.121 \times (\text{ADC value}) - 214$$

Sensor 2

$$\text{Temperature } ^\circ\text{C} = 0.128 \times (\text{ADC value}) - 266.5$$

## *Conclusions*

- Project met and exceeded proposal specifications
- Wireless communication in a metal box is challenging



## *Advice to Juniors*

- Start early
  - Proof-of-concept by end of 401
- **Never** get rid of a working prototype
- Ask professors and classmates for help

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- Ben Carlson

# *Demonstration*



**envvi sense**

Timothy Albur & Ian Maines

IC: 431 Capstone Project Presentation

