May 1622: Wireless Embedded Roadway Health Monitoring Network

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Project Scope

What are we doing?

Why are we doing it?

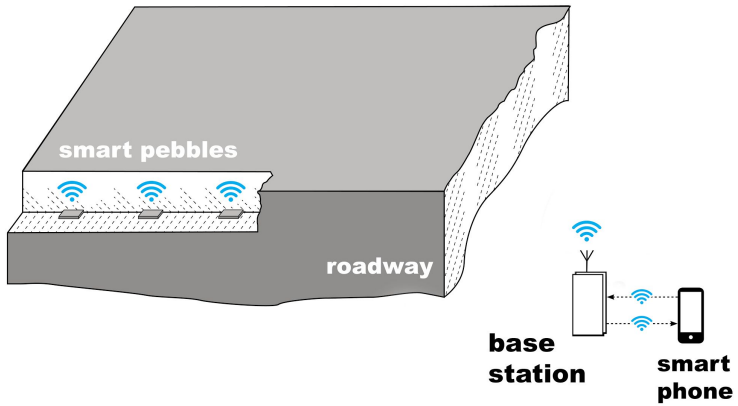
Past efforts

Project Scope - What are we doing?

This is Phase II of a network of nodes which measure humidity and temperature within roadways

Requirements of this network are:

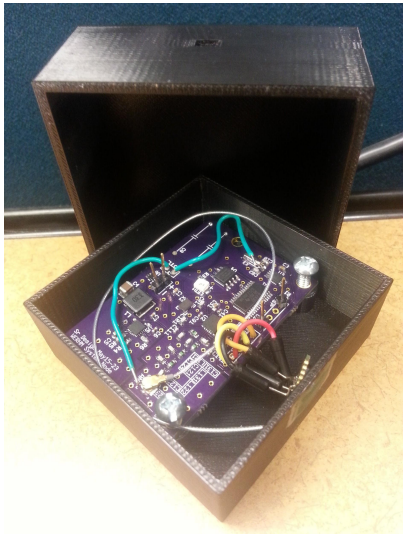
- ➔ Wireless communication between “smart pebbles” and a base station that stores data to transmit to smartphone
- ➔ Low power consumption for extended life
- ➔ Able to withstand harsh environment- temperature, chemicals, stress, etc.
- ➔ Node size must be small enough to minimize impact on road integrity



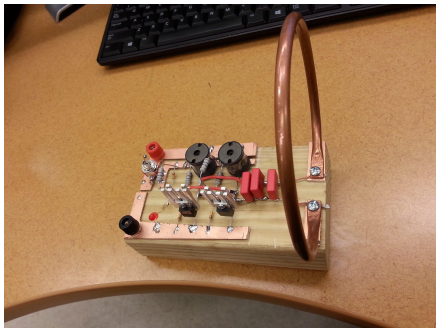
Project Scope - Why are we doing it?

- ➔ Provides a feasible method of monitoring the status of roadways and other structures throughout their lives
- ➔ Directly observes the condition of the roadway at different parts as often as desired
- ➔ Determines more accurately when a roadway needs to be replaced

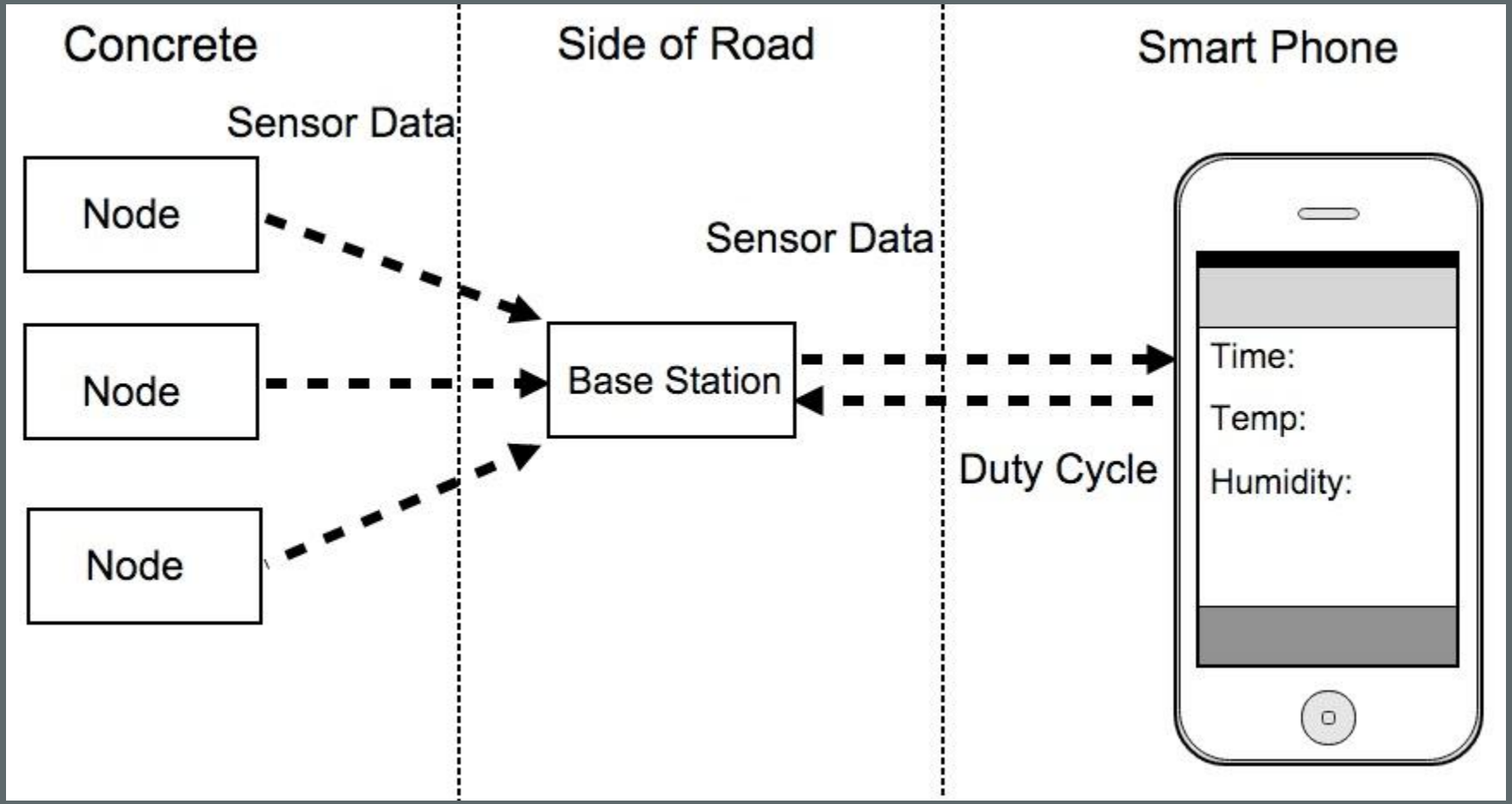
Project Scope - Past Efforts



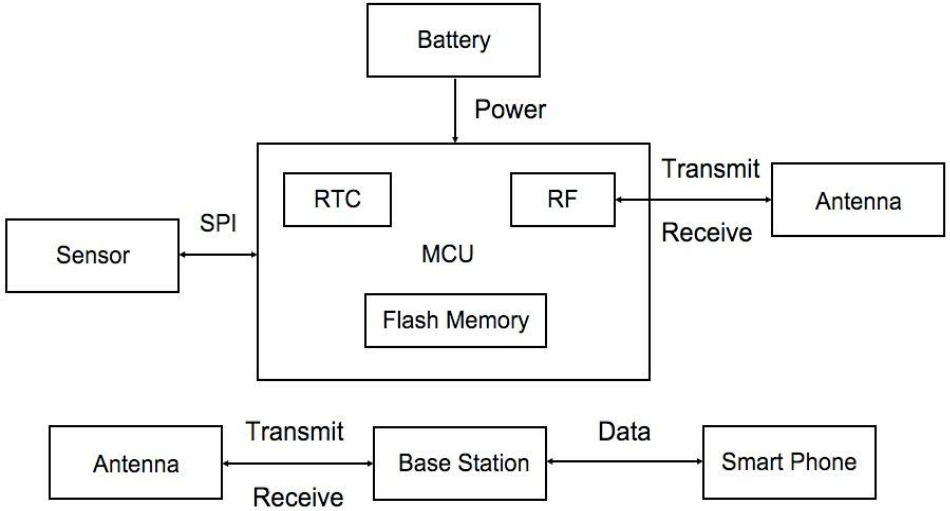
- **Wired Communication:** Delicate - connections destroyed during pouring and curing process of concrete
- **Wireless Communication using Zigbee operating at 2.4GHz:** Frequency too high to penetrate concrete
- **Phase I:**
  - Charging circuitry prohibitively large and expensive
  - Enclosure too large and unwieldy to feasibly be poured with concrete



Conceptual Sketch in Phase II

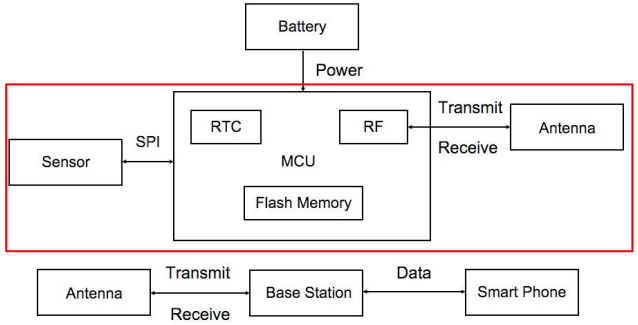


Current Design



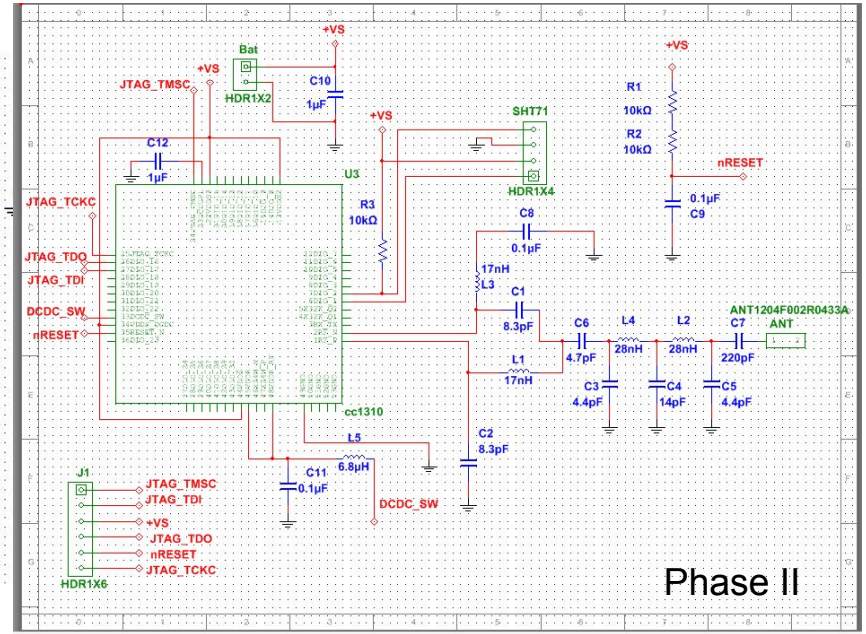
- Hardware
- Digital Circuit Layout
- Software / Networking
- Battery
- Enclosure
- Base Station
- Data extraction

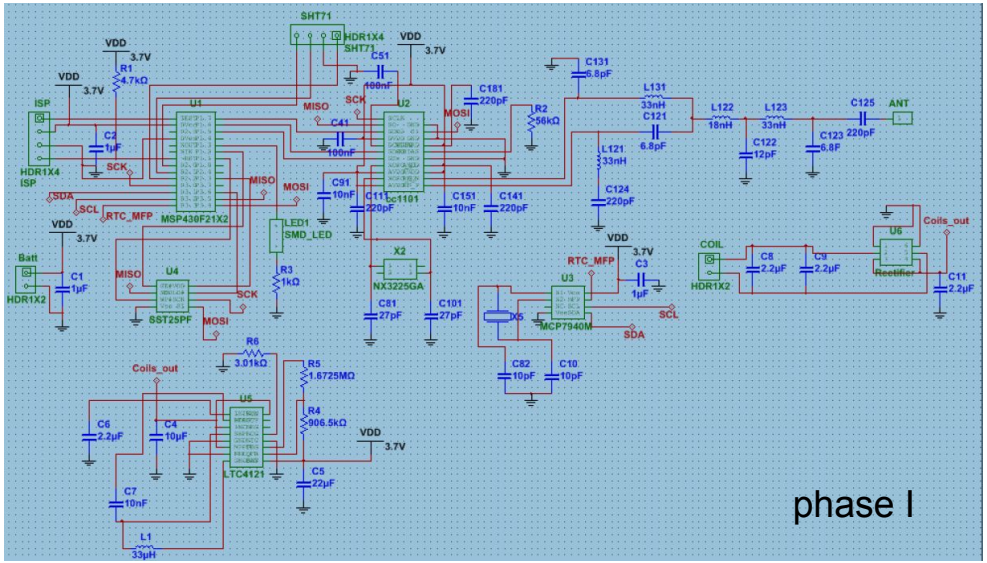
Current Design - Hardware



- Powered by TI CC1310 Microcontroller
  - Low-power radio frequency (RF) transceiver
  - 128KB programmable flash memory
  - Real-time clock (RTC) for accurate timekeeping
  - Low active current
- Sensirion SHT71 temperature and humidity sensor
- Yageo FR4 433MHz chip antenna
- Overall PCB size: 1” x 1”

Current Design - Digital Circuit Layout

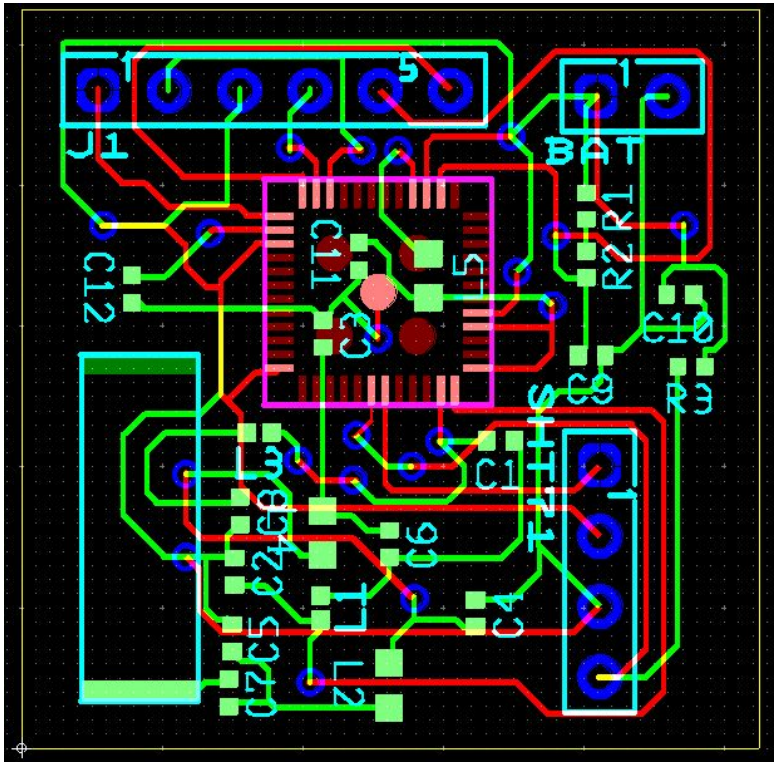


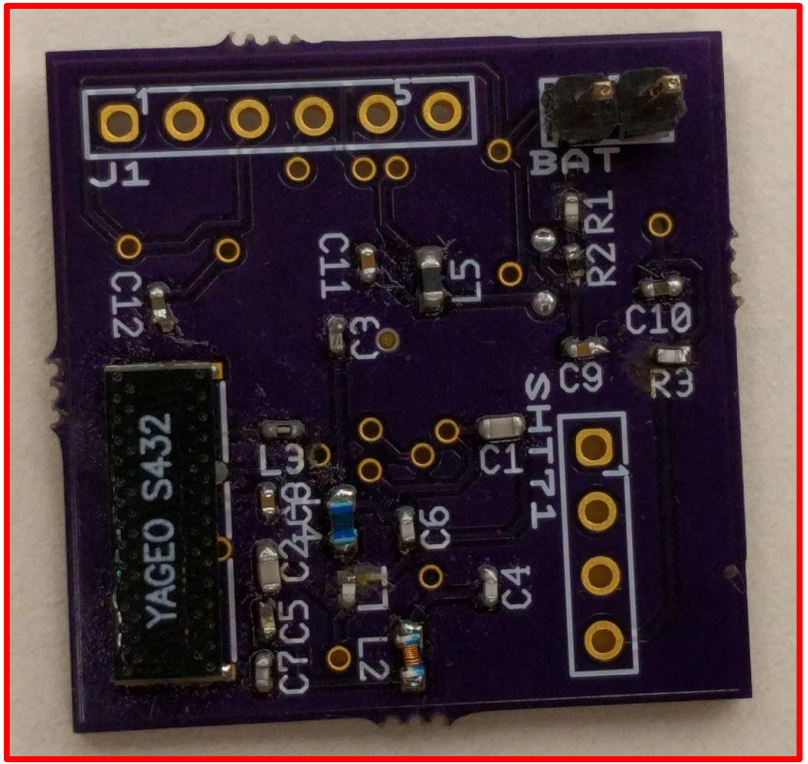


Current Status - Hardware

- ➔ Digital circuit design and PCB design completed
- ➔ All parts received, evaluation boards assembled and being tested
- ➔ Testing/debugging bread board assembled
- ➔ Prototype PCB assembled

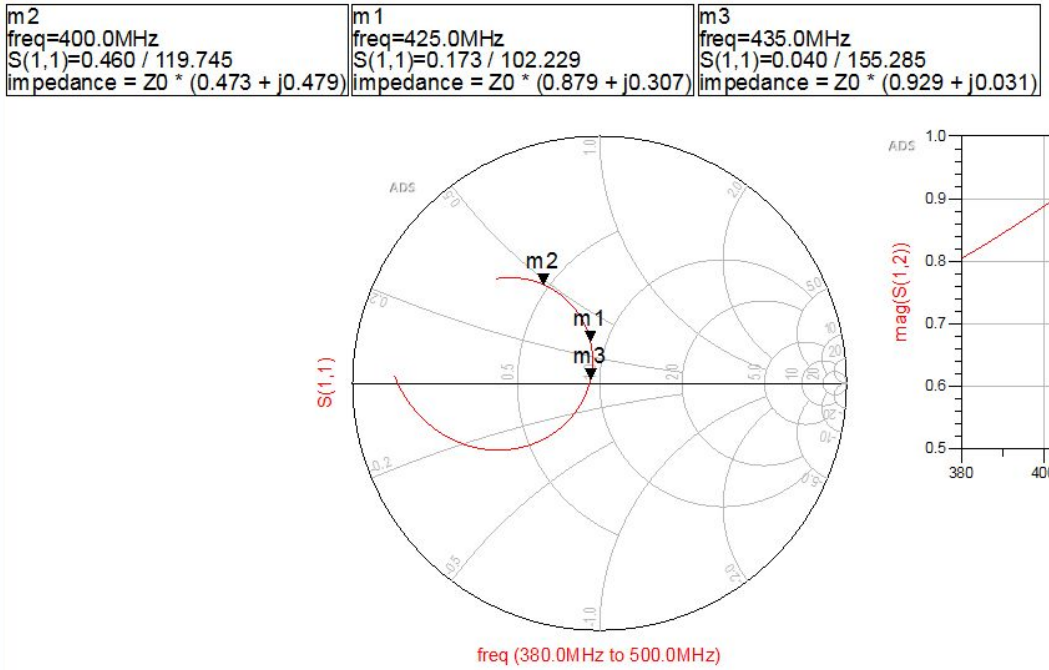
Final PCB Layout and Prototype





RF circuit physical simulation in Advanced Design Device

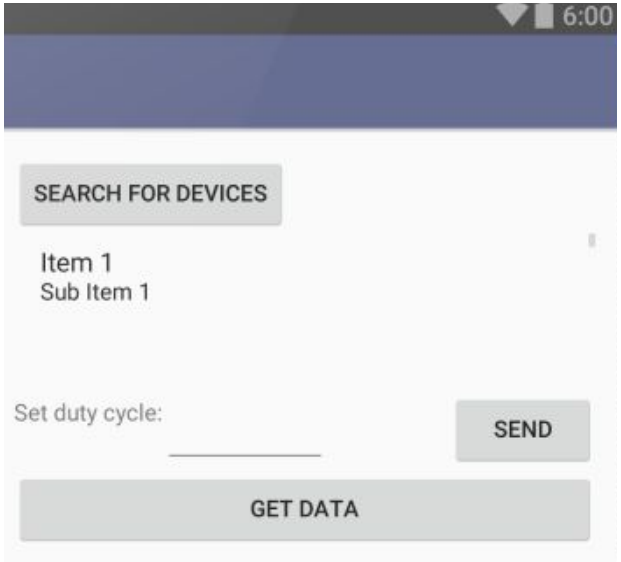
Impedance testing



Power flow testing

Current Design - Software / Networking

- ➔ Wireless sensor network will utilize directed flooding technique
- ➔ Embedded code will be optimized for low power consumption
- ➔ Android applications for smartphone and base station

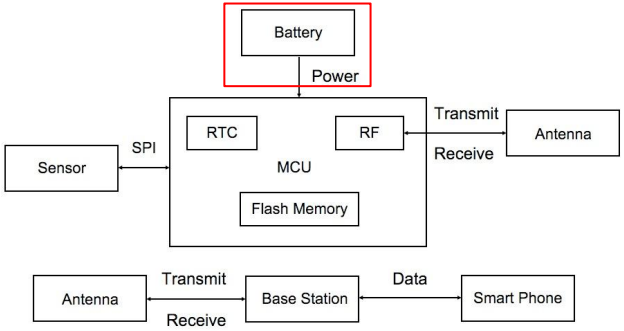


Current Status - Software

- ➔ Bluetooth client Android app (for smartphone) connects to base station(s)
- ➔ Base station acts as Bluetooth server and sends data upon connection
- ➔ Software for the communication between sensor and MCU is finished
- ➔ Software for inter-node communication is finished

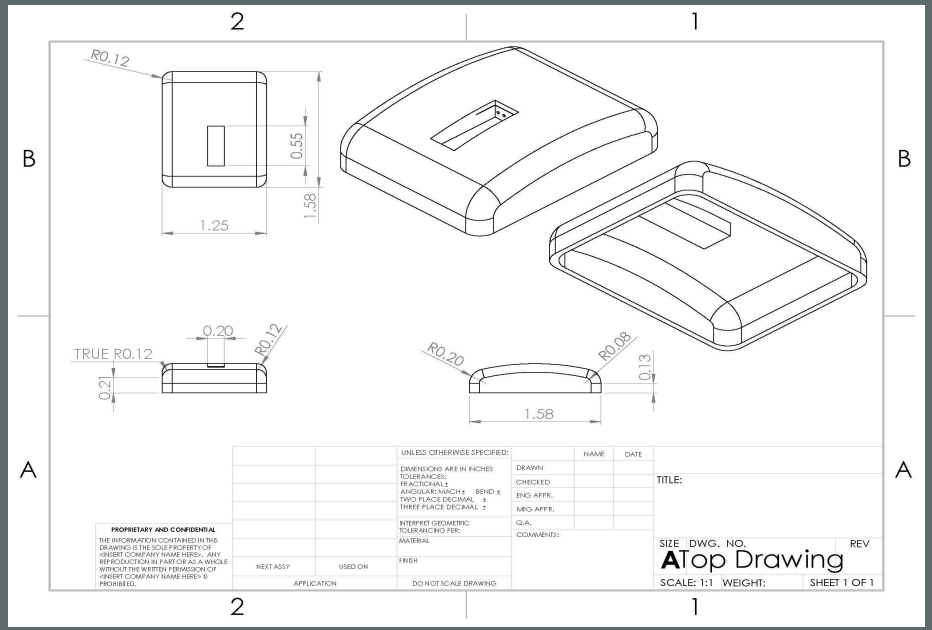
Current Design - Battery

- Small, space efficient design
  - CR2477 coin cell battery
- 1000 mAh capacity
- Lithium battery can survive harsh temperatures



Current Design - Enclosure

- 3D printed, dimensions: 1”x1.5”x0.8”
- Material used: ABS plastic
- Withstands the heat, pressure, acidity of curing concrete
  - While allowing the sensor to accurately take measurements
  - Protects circuit from corrosion


R0.12
0.55
1.58
1.25
TRUE R0.12
0.20
R0.12
0.21
R0.20
R0.08
0.13
1.58
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
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MFG APPR.
Q.A.
COMMENTS:
TITLE:
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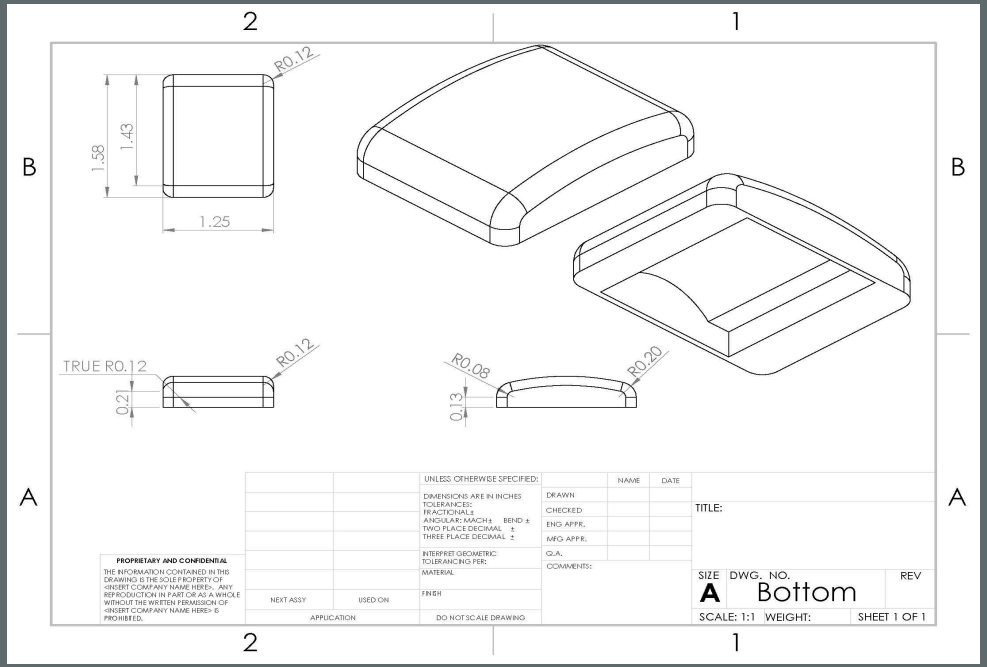
R0.12
1.58
1.43
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TRUE R0.12
R0.12
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
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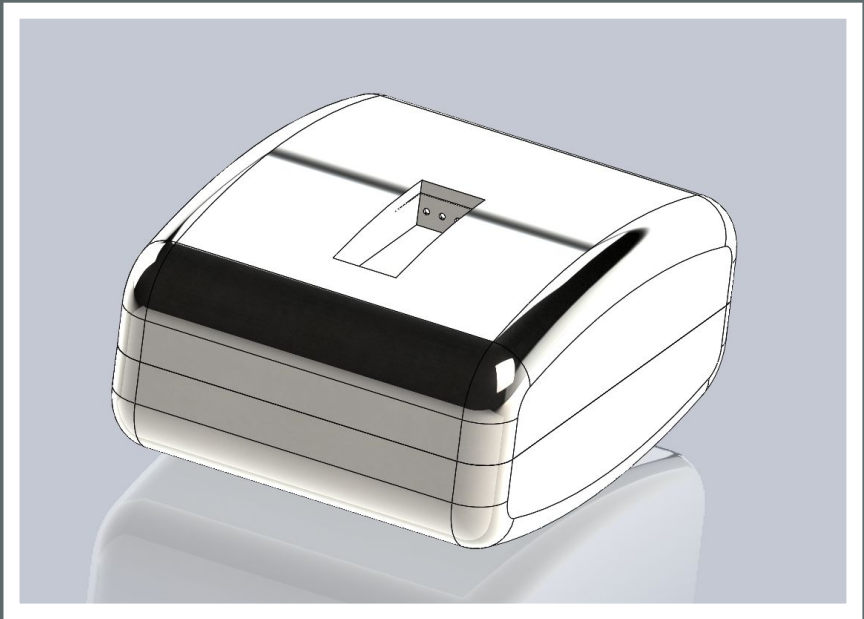
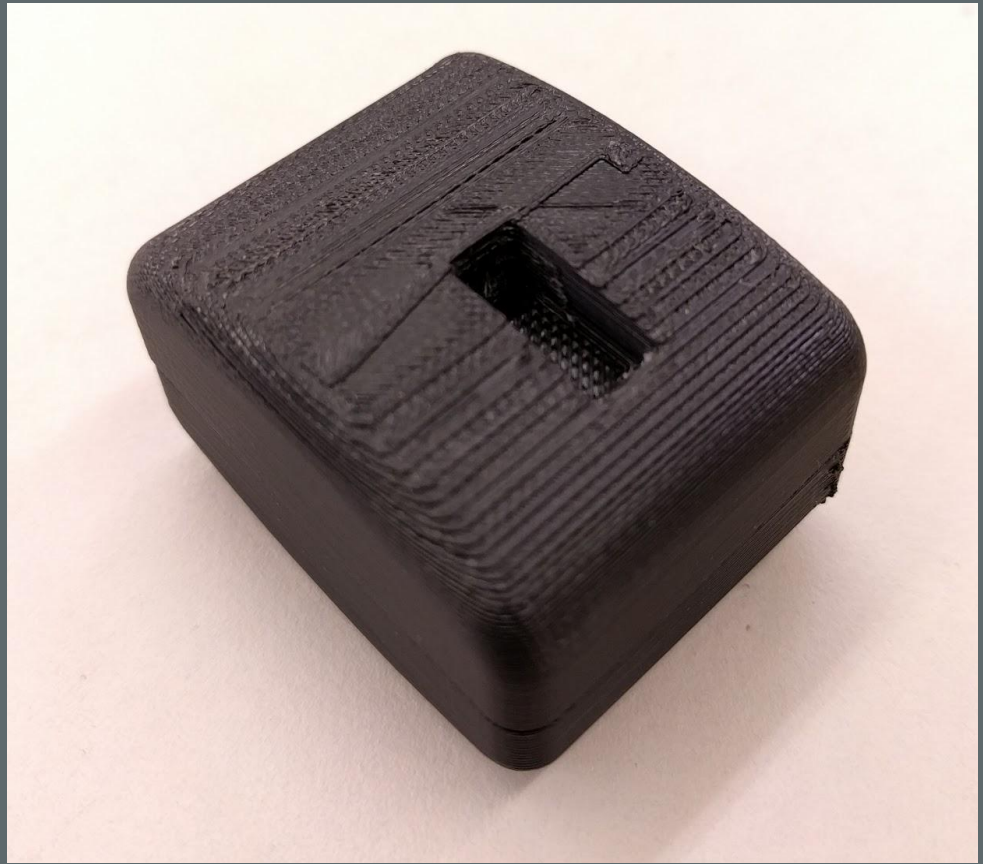


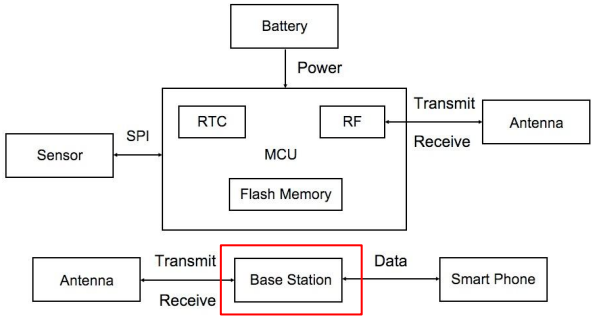


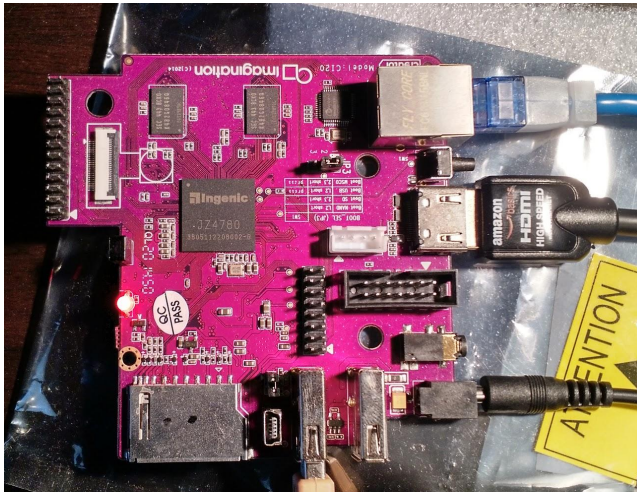
Enclosure Challenge

- Had to use battery holder for coin cell battery
  - Takes up a lot of space
- Our enclosure design is larger than ideal
- Design software difficult to learn quickly

Current Design - Base Station

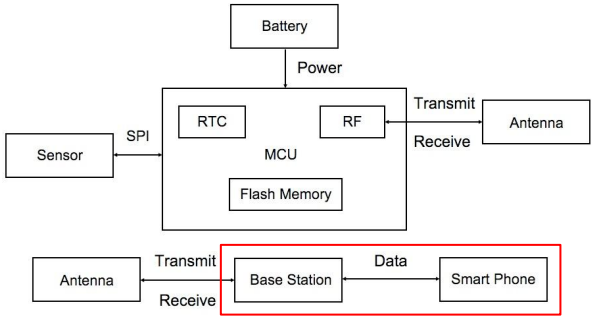
- Base Station is the system's access point
  - Collect readings from network
  - Configure duty cycle
- Creator CI20 microcomputer

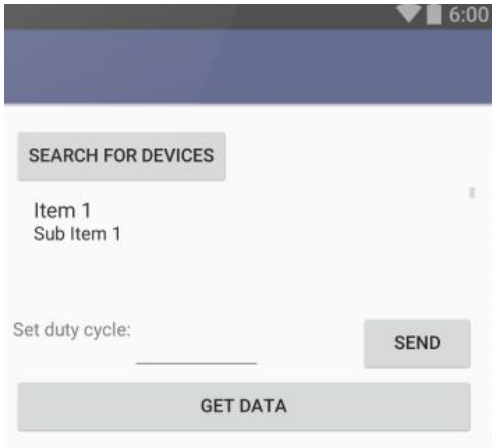




Current Design - Data Extraction

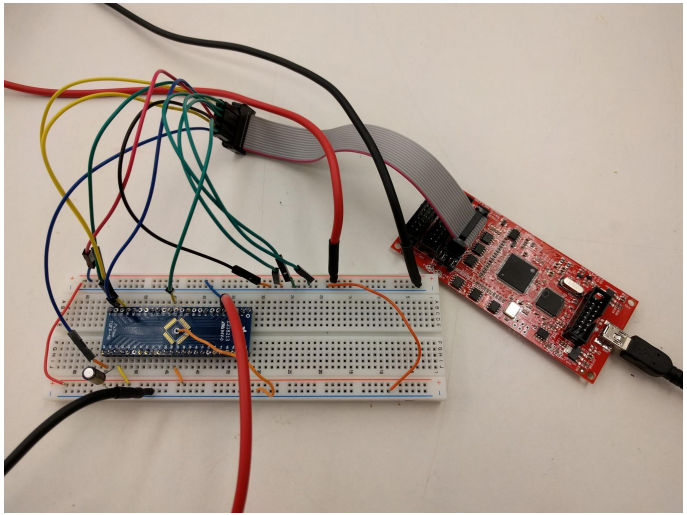
- ➔ Smartphone automatically connects to base station via Bluetooth via Android app
- ➔ Base station server sends smartphone all of its nodes' data
- ➔ User can define duty cycle for nodes to take readings





Testing

- ➔ Soldered MCU and pins to breakout board for testing
- ➔ Connected debugger to MCU to try to load our code
- ➔ Found some problems with the MCU ground pin connection and adjusted the PCB layout

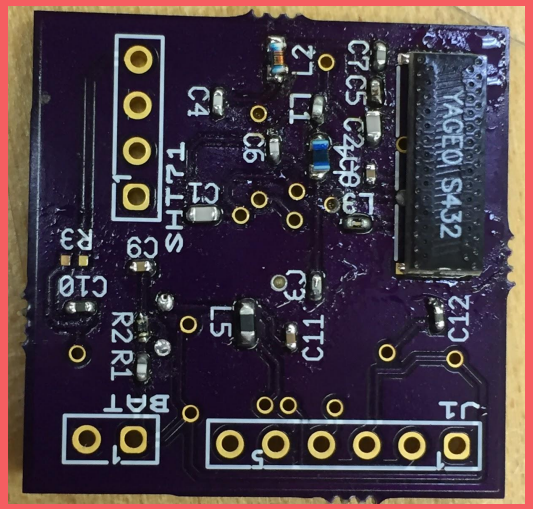


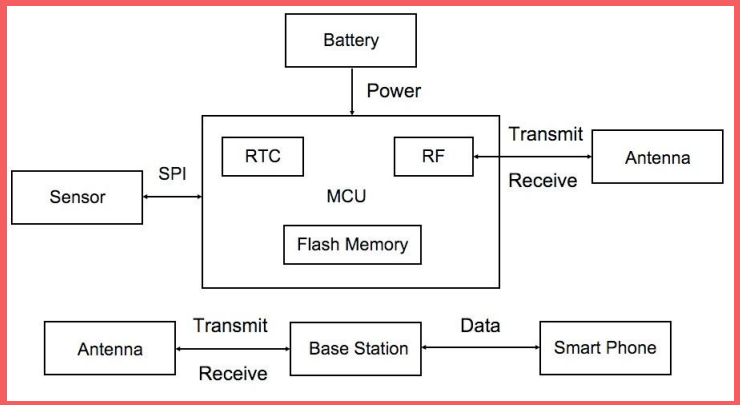
Hardware Challenges

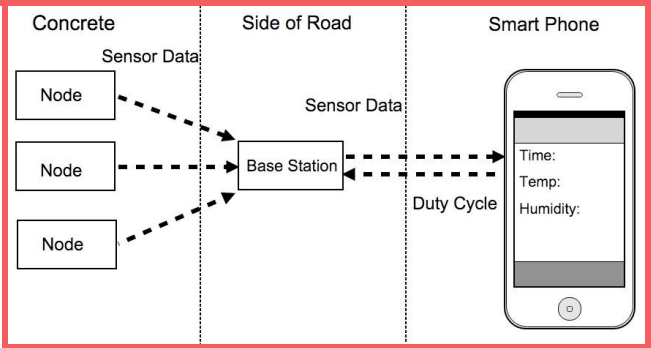
- ➔ Debugger was found to be incompatible with our MCU
  - ◆ Advertised to work with CPU
- ➔ Took several weeks to discover
- ➔ Set our schedule back greatly, had to order new debugger
- ➔ More problems getting new debugger to connect to MCU
  - ◆ Can’t successfully test embedded software

Other Technical Challenges

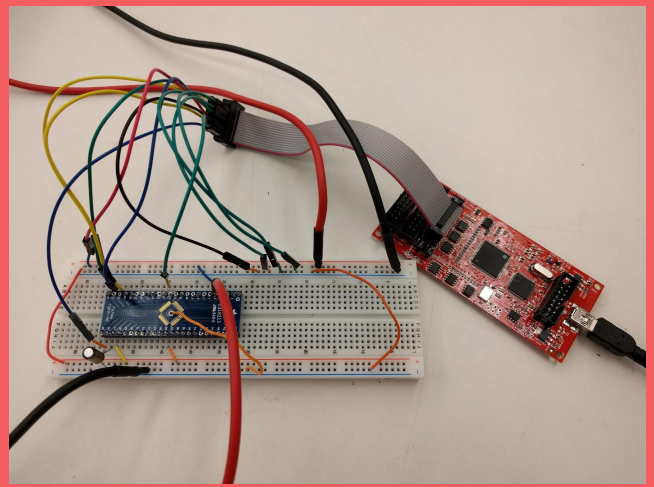
- Sensor Exposure
  - Expose sensor indirectly to concrete environment
  - Protect circuit from outside
- Temperature
  - Exposure to Iowa summer/winter temperatures
- Communication
  - Frequency must be able to penetrate concrete

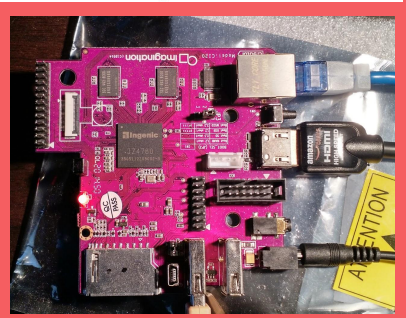



Battery
Power
RTC
RF
Transmit
Receive
Antenna
Sensor
SPI
MCU
Flash Memory
Antenna
Transmit
Receive
Base Station
Data
Smart Phone


Concrete
Side of Road
Smart Phone
Sensor Data
Node
Node
Node
Sensor Data
Base Station
Duty Cycle
Time:
Temp:
Humidity:

Questions?






6:00
SEARCH FOR DEVICES
Item 1
Sub Item 1
Set duty cycle:
SEND
GET DATA