Battery-less Hydrometer

Client Advisor: Henry Duwe

SDDEC20-06: Tilden Chen, Josh Hall, Jensen Mayes, Chris McGrory, Griffin Orr, & Chris Pedersen

Introduction

In the past decade researchers have been exploring the many facets of wireless energy harvesting. In this process an RF signal is used to wirelessly transmit power to a designated electronic platform. This platform uses either a re-chargeable battery or capacitor to store and distribute the signal energy. Many embedded computational systems are beginning to take advantage of this developing technology but there are many issues surrounding its implementation. Such issues include limited power transfer, signal reception quality, signal strength, etc.

Our project will expand the capabilities of these embedded computational systems and reduce some of the limitations associated with wireless power transfer. To achieve this goal, we have developed a device that can measure the specific gravity within an enclosed container with one hundredth precision. The device is powered wirelessly by a commercially produced PowerCast transmitter (tx91501b) at 915Mhz. It remains unpowered until the onboard capacitor is charged to a voltage release point. The stored power is distributed using an appropriate hysteresis model to power onboard instrumentation. The device also wirelessly transmits the sampled data to a collection device. Overall, our design looks to improve upon the typical limitations associated with wireless energy transfer and inspire future applications.

Intended Uses and Users

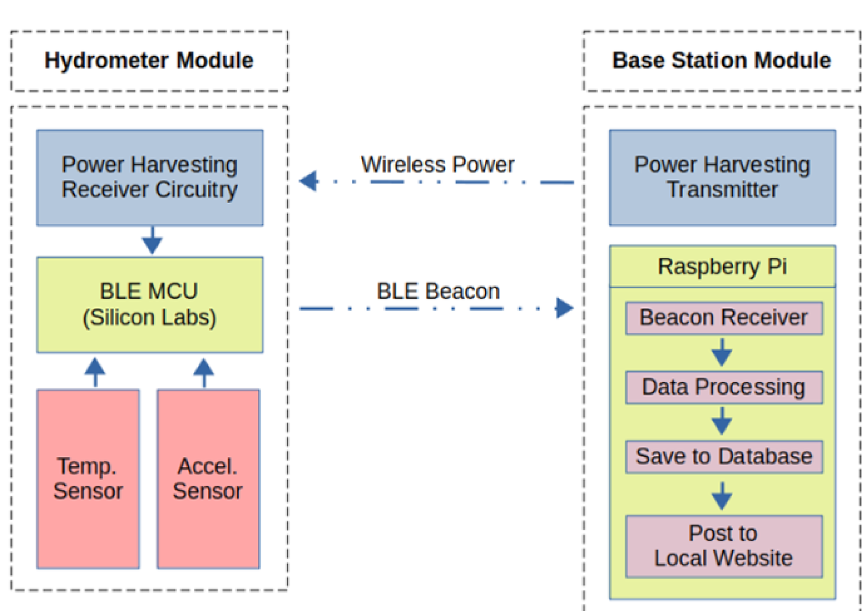
It is our hope that our work will inspire others to explore the wide variety of applications that could benefit from our battery-less design. With our design one could easily modify the base level instrumentation to fit their specific application. Other applications could include, oil & gas monitoring, wastewater treatment, chemical plants, etc. These applications are all inclusive of physically restrictive environments that require regular instrumentation monitoring.

Design Requirements

1. The transmission signal must charge the hydrometer within a days' time without losing signal quality.
2. The transmission signal must provide enough power for consistent data collection and transmission.
3. The data signal must be able to transmit within an enclosed container and possibly submersed in liquid.
4. The design must be completely encapsulated and temperature resistant.

Design Approach

System-Level Diagram



Hydrometer Module	Description
Power Harvesting Receiver Circuity	Receives 915MHz signal from the power harvesting transmitter and powers the hydrometer module.
BLE MCU	Used to gather data from hydrometer sensors and transmit via Bluetooth to the base station module.
Temp Sensor	Acquires the hydrometer's surrounding temperature.
Accelerometer	Acquires the hydrometer's 6-axis tilt.
Base Station Module	**Description**
Raspberry Pi	Receives Bluetooth data transmission and processes the hydrometer's output.
Power Harvesting Transmitter	Transmits 915Mhz power signal to the hydrometer's receiver.
Beacon Receiver	Receives accelerometer and temperature information for data processing.
Data Processing	Raw Data: cartesian coordinates -> Final Result: liquid density
Save to Database	Locally stores information from data processing to later display online.
Post	Posts resultant data to a python web server for user convenience and display.

Technical Details

Hardware	Description
Energy Harvesting	The product will utilize a PowerCast system that operates in the 915 MHz frequency band. The energy har-
Power Management	The power management circuitry exists on the P2110B module. Once the voltage across the capacitor reaches a selected value, the voltage regulator will be activated until either the voltage drops too low or the shutdown flag is activated.
Microcontroller & Sensing	The microcontroller (MCU) selected for this product is the EFR32BG13. This product offers low power consumption along with fast boot times. Additionally, it has an integrated Bluetooth 5 physical layer (PHY) and 2.4 GHz transceiver. The sensors that will be selected will utilize an I2C serial bus for communication with the MCU. There is a 6-axis accelerometer and temperature sensor on the device which will be utilized in the calculation of the specific gravity of the current fluid to within ±0.001 [g/cm3] accuracy.
Wireless Communication	The wireless communication will utilize a connectionless Bluetooth session called a Bluetooth Beacon. In this configuration, the product will transmit the data at 2.4 GHz under the Bluetooth 5 protocol without connecting to the base station.
Software	**Description**
Sensor Data Collection	The software will collect sensor data using the I2C protocol and existing libraries. The libraries used to access the sensor functions will be modified versions of existing code to minimize memory utilization on the device.
Calibration	The calibration of the measurement data will be housed on the base station and not on the product. This will allow for the user to calibrate data in the field without accessing the PCB directly. This calibration process will be designed to be accurate to within ±0.001 [g/cm3].
Computation	The computation of the specific gravity will be performed on the base station. As a result, the hydrometer will transmit
Wireless Communication	The wireless communication will be performed over a Bluetooth 5.0 Beacon and will require all relevant libraries to be stored in on-chip memory.

Project Resources

Hydrometer w/ Base Station

Unit	Amount
Testing Hardware	$30
Initial Prototype	$170
Base Station w/ Power Transmitter	$150
Miscellaneous	$50
Project Total	**$400**

Man Hours

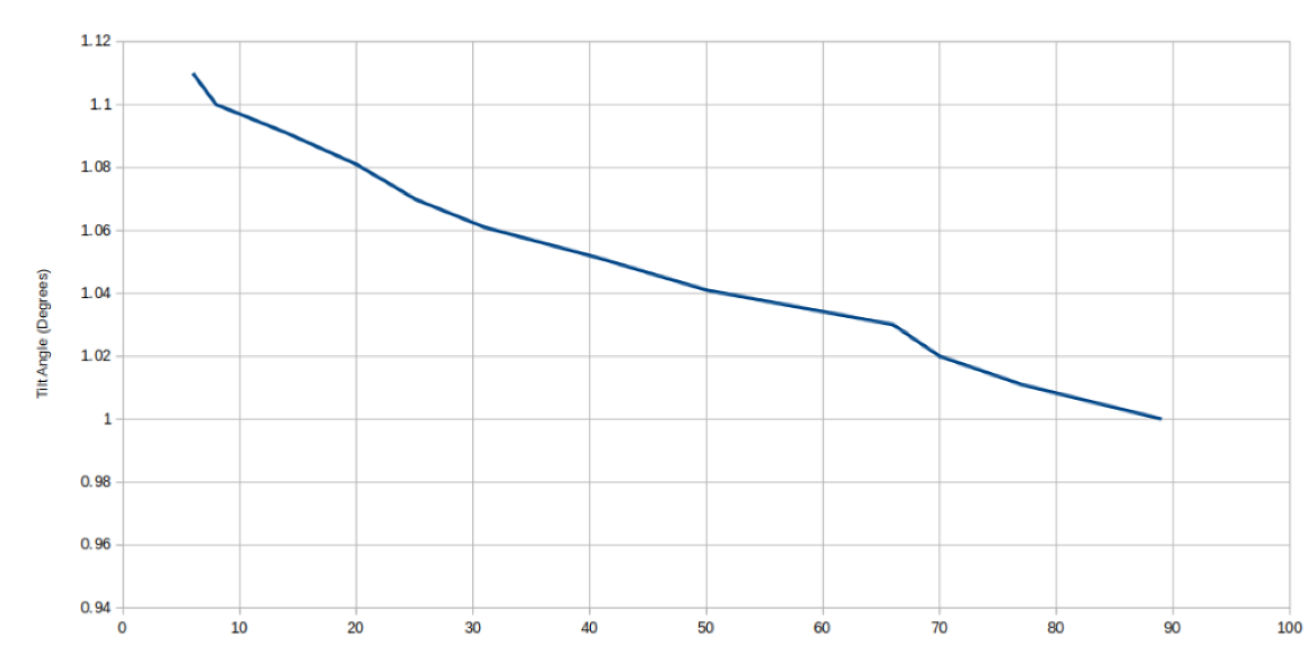
Name	Hrs
Tilden Chen	96
Josh Hall	90
Jensen Mayes	96
Chris McGrory	96
Griffin Orr	104
Chris Pedersen	108
Project Total	**590 hrs**

Testing

3D Encapsulation Progression

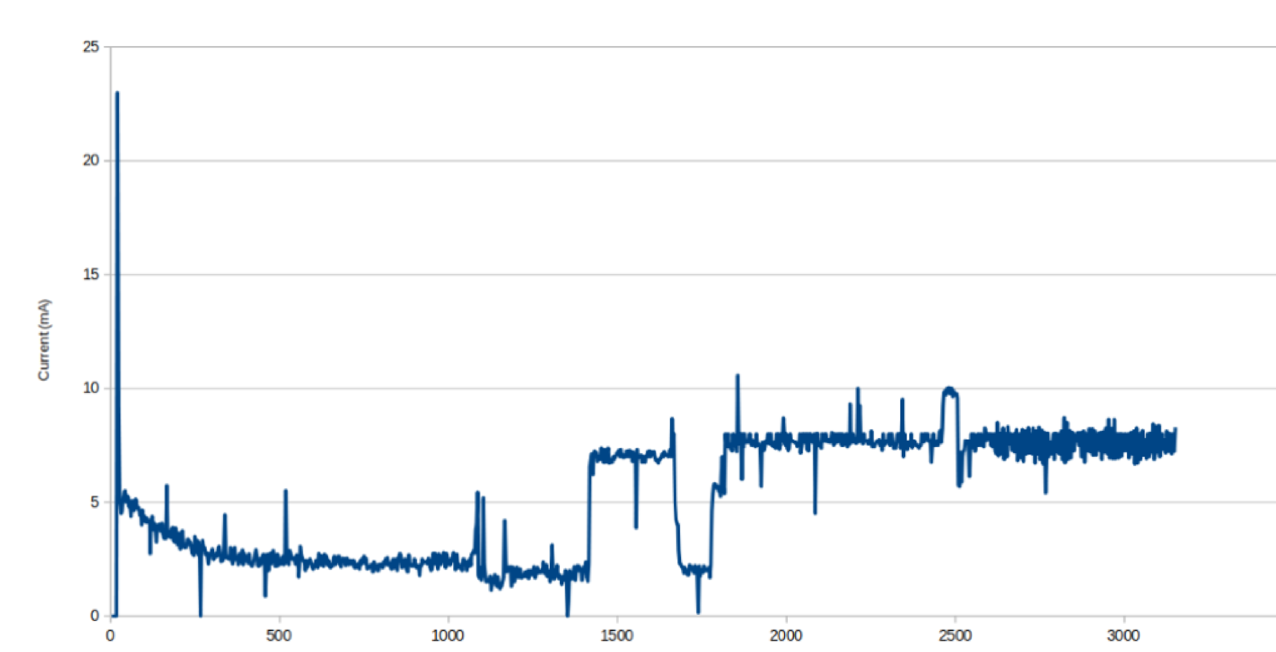
As we gained familiarity with CAD the encapsulation design progressed and increased in complexity. The result is a sleek three-piece threaded structure that makes testing and calibration a lot easier. The final structure shown has room to put weights (quarters) in both the top and bottom sections to vary the center of gravity and overall mass of the hydrometer.

Hydrometer Tilt vs. Specific Gravity of Solution



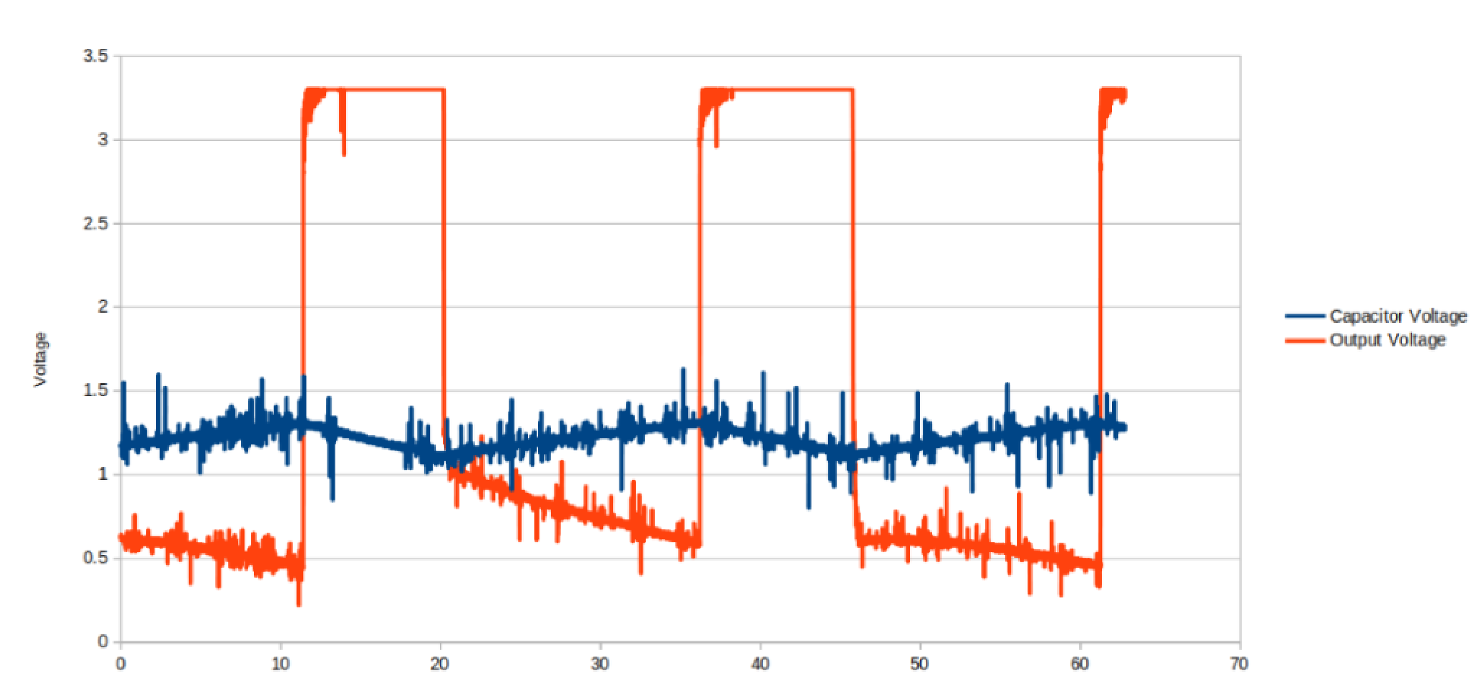
$SP = 6.52331044E\text{-}06\alpha^2 - 0.00184859\alpha + 1.11611406$

Thunderboard Current Consumption



In testing the energy usage of the board running our transmit code, we found the average current usage through the first beacon cycle to be approximately 3.9mA. This matches with our other testing data that found a capacitor over 500mF is necessary for the system to work.

System Cycling Test (1F Capacitor w/ transmitter at 6in)



By using a 1 Farad capacitor we were able to test the system fully cycling several times. We found that the power provided by the capacitor was more than sufficient for the system as it was able to transmit multiple times before shutting back down to recharge which matches with our calculations of only a 500mF capacitor being needed.