IoT Implementation for a Harsh Temperature Monitoring System

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Department of Electrical Engineering

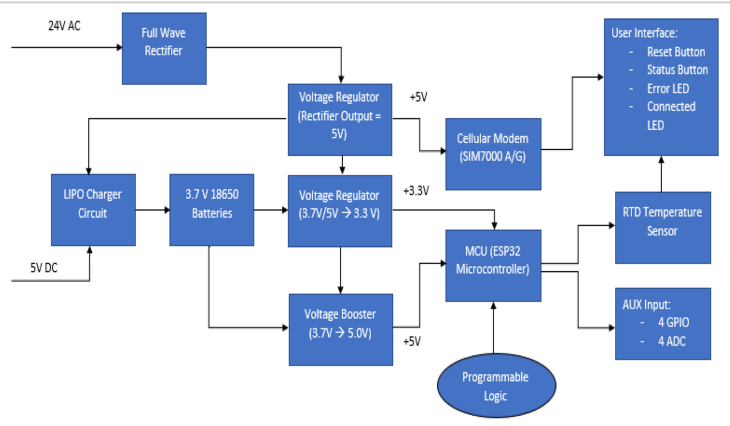
Problem Definition

Many construction companies use large industrial equipment, such as concrete crushers and excavators, on their job sites to accomplish large-scale tasks. However, on-site personnel are unable to monitor the internal temperature of this equipment to know if it is operating outside of the desired temperature ranges. When the internal temperature of the equipment fluctuates out of normal temperature ranges, this could potentially make for a dangerous environment.

Motivation

We wish to devise an innovative system that will allow companies to maintain and improve the longevity of their operational equipment by monitoring and alerting onsite personnel if components on equipment are operating outside their desired temperature range. This data can then be sent back to a server to be analyzed and provide real time measurements for operators.

Proposed Design



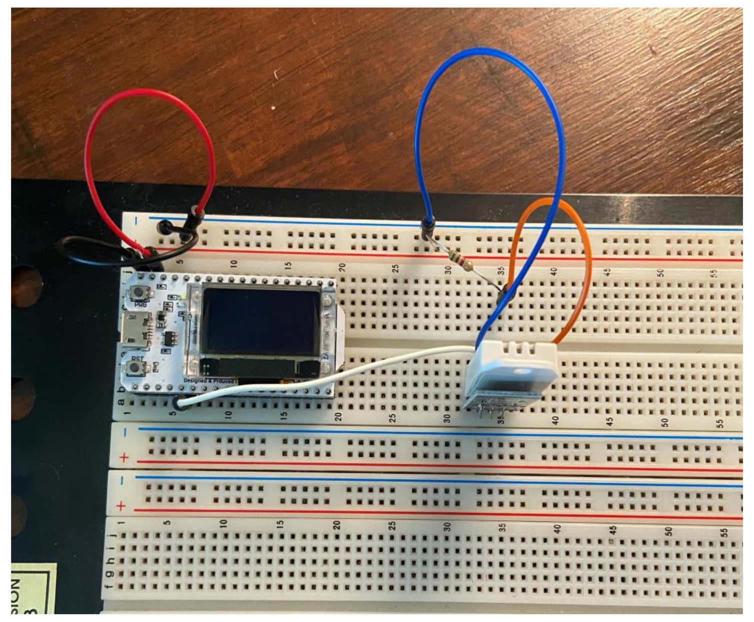
For our device, we designed a PCB that utilizes the ESP32 microcontroller to gather and interpret data from the thermistor temperature sensor. The device is powered by either (2) 5V DC LiPo batteries and LiPo charger or 24V AC. The device is initially configured via Bluetooth from ESP32 and Wi-Fi through an app developed by Software Logistics using react-native and C code. The device alerts on-site personnel through the use of LEDs on the PCB and through text/email alerts to those who have created an account with the associated app.

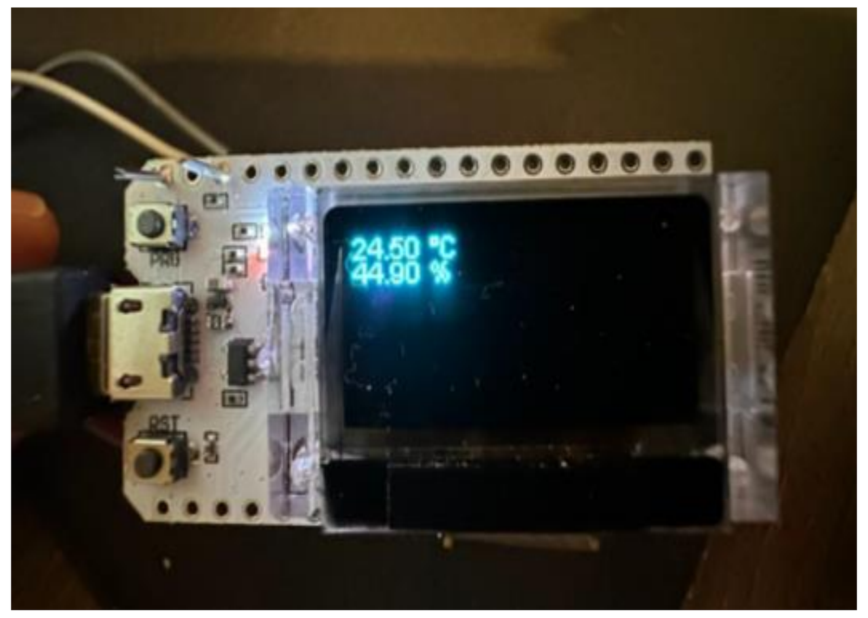
Design Considerations/Methodology

While designing the PCB, we were able to assemble the Heltec ESP32 Wifi Kit and the DHT22 temp sensor on a breadboard to develop the firmware and get accurate temperature readings from the microcontroller and sensor. We kept developing the firmware using Visual Studio code until it was time to program the ESP32 on our PCB. The major design considerations included:

- Device operating on either 5V, 24VAC, USB-C, or on battery power
- Device can sustain itself strictly with batteries for 6 months
- Configurable by a Bluetooth connection
- Associated app to monitor the temperature and the device
- Device can operate in harsh environments such as dust, heat, cold, etc.

For the enclosure, we developed a CAD design that would fit our PCB and meet the correct IP68 rating. Ultimately, we decided to order an enclosure that met our design requirements and make the correct cutouts for the temp sensor and LEDs.





Requirements and Specifications

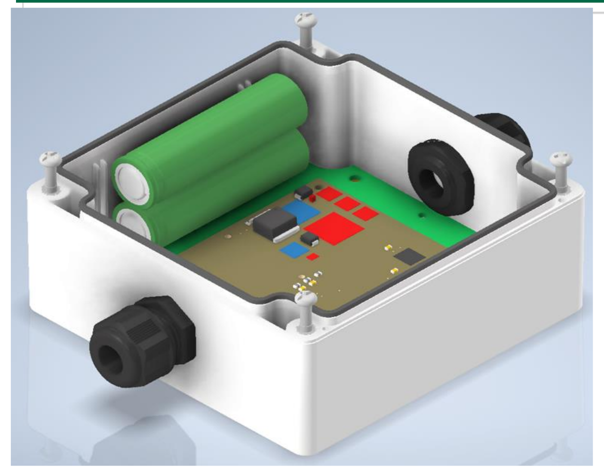
Hardware:

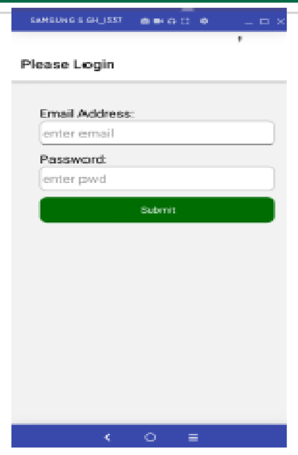
- The device will contain a temperature sensor, LEDs, microcontroller, SIM card, and batteries with 6-month lifetime
- The device will be contained within a durable enclosure to withstand sustained exterior temperatures of 250°F and mechanical shocks of 3g
- LED will be placed within the device that will be visible for on-site personnel to alert them of dangerous conditions with respect to temperatures being out of range
- The device requires to be surface mounted to the surface of interest and will remain there for the duration of the job

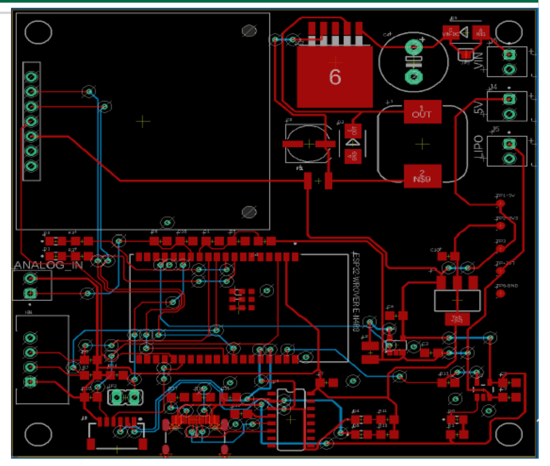
Software:

- Initial configuration of device using Bluetooth from the project manager's phone/laptop via the app
- Temperature sensor will read the internal temperature of the concrete crusher and relay this data back to the server at a user defined interval, with a minimum time of at least 30 seconds
- Pre-configured ranges for acceptable temperatures within the concrete crusher will be programmed into the device
- A text/email alert will be sent to relevant personnel to notify them of the condition and will be notified via the associated app

Simulation Results







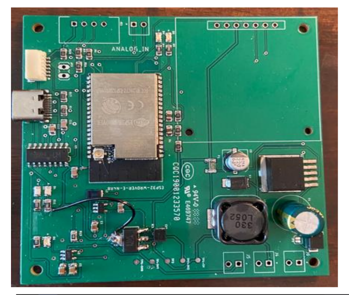
Left: CAD simulation design for the enclosure of the device

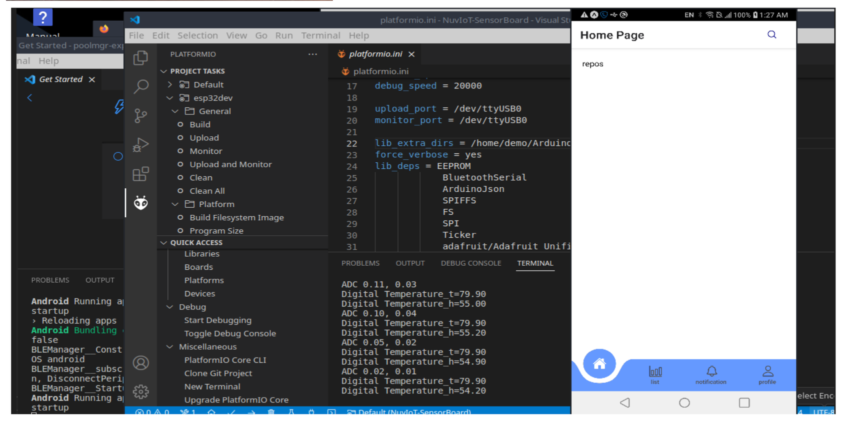
Middle: A preview of the sign in page of the associated app (created by *Software Logistics*) for personnel to monitor the device

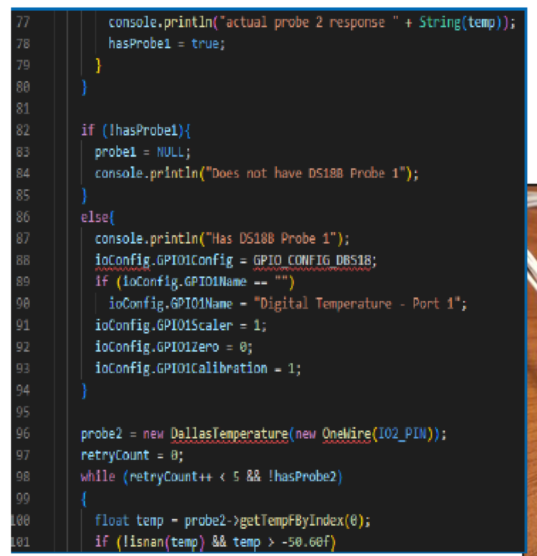
Right: PCB schematic for device

Prototyping

- Three revisions of our PCB were designed using Eagle CAD to produce a successful final product
- Firmware was developed step by step, adding in necessary functions to suffice all requirements
- Further developed app by *Software Logistics* to meet needs of our device







Testing

For battery, we performed 3 types of discharges to gauge battery life, including idling, constant use/constant upload = 1 upload/sec, and realistic upload rate of 1 upload/10 mins. Time to failure was measured by the time from initiation of test until failure to broadcast data or ESP32 shutdown. For temperature, device was placed in a controlled temperature environment for 30 seconds and tested after removal to ensure integrity. The temperatures tested ranged from -10°– 250°F. For durability, device was tested in harsh environments with regards to abrasion, impact resistance, vibrations, and dust.

Analysis of Results

- Device is initially configured via Bluetooth from the app on associated users' phones as specified
- Device accurately detects temperature of operational equipment using thermistor
- App quickly alerts associated personnel when temperature fluctuates out of range
- Data from thermistor is sent to ESP32 to be analyzed, then sent every 30 seconds to server, then displayed on app as required
- All components interface as specified with ESP32
- Appropriate LEDs on device illuminate to alert on-site personnel of a condition, such as a successful Bluetooth connection, an error, etc.
- Firmware allows device to go into deep sleep when not collecting data to save power
- Enclosure protects device from harsh conditions with required IP68 rating

Timeline

January	February/March	April/May	June/July
- Industry partner introduction - Discuss device	- Design system requirements - Conduct research	- Finalize requirements - Finalize design	- Summer break

August	September/October	November	December
- PCB Design - Subsystem Development	- Begin firmware development - Develop app	- Finalize PCB - Finalize app - Finalize enclosure	- Prepare and submit all final docs

Conclusion

The IoT device operates and meets all developed requirements after completing final PCB design, device enclosure, firmware, and the associated NuvIoT app. Future improvements include expanding the areas of use for the device and improving the alert method. In addition, user friendliness of app will be further developed. PCB will be altered to meet these improvements.

Work Division

Brandon Collins: Firmware, Enclosure, Technical Design Lead
Ashley Porter: Firmware, Cost and Schedule Lead
Steve Lambropoulos: App configuration, Mechanical Design, Test Software
Paul Polgar: PCB Design, Testing, Team Coordination Lead

References

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[2] "NuvIoT by Software Logistics." *Nuviot*, Software Logistics, Sept. 2022

[3] "What Is a Thermistor Used for & How Do They Work?" *What Is a Thermistor?*, Pyrosales, 12 Apr. 2019

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