ELECOMP CAPSTONE SYMPOSIUM
TUESDAY, DECEMBER 22, 2020

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO℠

BLE-TSTAT

Two-Wire Bluetooth Thermostat Adapter

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Project Motivation

Hydronic heating systems are controlled by thermostats located throughout the home, wired directly to an electronic controller at the heating unit. Older thermostats operate similar to a mechanical switch; when the system calls for heat, a connection is made between two wires, and the unit is powered on. With emerging technology, programmable “smart” thermostats have become increasingly more popular in the marketplace. These thermostats require a third (common) wire for power supply and proper operation. Most of the time when a homeowner is looking to upgrade to a smart thermostat, it is necessary to run new thermostat cable from the unit to each zone, increasing costs and challenges in installation. This is undesirable for the homeowner and the installer. The motivation for this project is to allow for convenient installations of smart thermostats to existing two-wire thermostat configurations, with minimal installation effort and no need for routing wires.

Anticipated Best Outcome

The anticipated best outcome of this design is to develop the hardware to bring power via two existing thermostat wires from an electronic zone controller to a programmable thermostat, pass the heating call signal from a smart thermostat to a microcontroller, and develop firmware to transmit a Bluetooth Low-Energy (BLE) signal from the microcontroller to a hydronic heating unit when the thermostat call state changes. Once all design specifications are met, fabricate a prototype PCB that is functional and ready for lab testing and possible field testing. The device should be cost effective and sized efficiently to simplify the installation process.

Key Accomplishments

Component Selection:

Microcontroller: nRF52805 by Nordic Semiconductor was chosen due to its price, BLE capabilities and Taco’s relationship with Nordic.

Power Management: A 4-diode bridge rectifier followed by a low-dropout voltage regulator (LDO) was designed for AC-DC conversion. The MCP 1792 was selected based on cost and the $55V_{in}$ to $3.3V_{out}$ design specifications. The SOT-223 package with heat sink was chosen for temperature control. To ensure stability, 10uF 50V and 2.2uF 10V ceramic capacitors were selected for the input and output respectively.

Heat Signal: A FOD817 optocoupler was selected to isolate the heat call signal (AC) from the MCU input (DC). A diode and a 100kΩ current limiting resistor for the input and a 100kΩ pull-up resistor on the collector of the optocoupler were selected. Both resistors are sized for 1/4W power consumption.

Prototype Simulation & Design:

A breadboard prototype was created using mostly through-hole components **(Fig.1)**. The 24VAC input was produced via an isolation transformer connected to a Variac transformer for safely isolating earth ground. A load resistor was used to simulate the MCU current during BLE communication. Oscilloscope readings of ±20% nominal voltage were tested in the lab to ensure LDO stability.

PCB Design: Altium Circuit Maker was used for the PCB layout **(Fig.2)**. Board specifications and design rules were based on OSH Park 2-layer board guidelines **(Fig.3)**. Circuitry for proper MCU operation was determined via the nRF52805’s data sheet. The antenna was based on a template for an AN043 Inverted F Antenna (IFA) designed by Audun Andersen from Texas Instruments to have an impedance of 50Ω at 2.45 GHz.

Firmware Development: The firmware development is still in the preliminary stages **(Fig.4)**. The pin configuration is complete with all pins set to output in the beginning. Pin 12 will be configured to accept the input from the thermostat heat call signal. The firmware for BLE communication is in progress. For this, a Hardware Abstraction Layer (HAL) is being used.

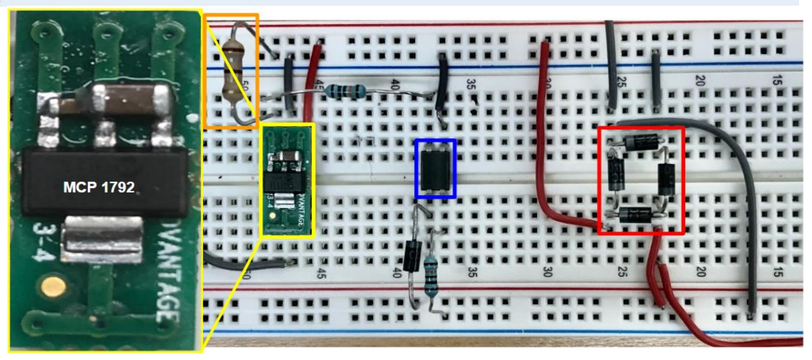

Fig.1: Prototype: Load (orange); LDO (yellow); Rectifier (red); Optocoupler (blue)

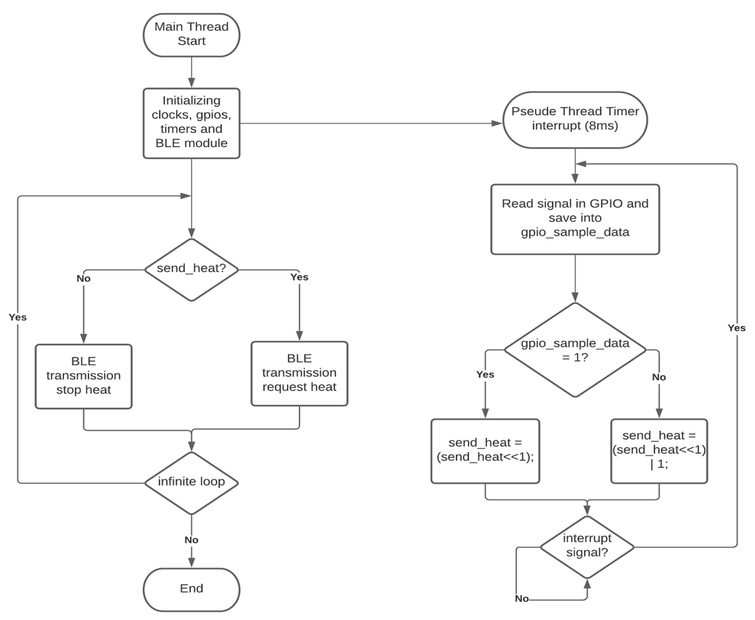

Fig.4 Firmware Flowchart

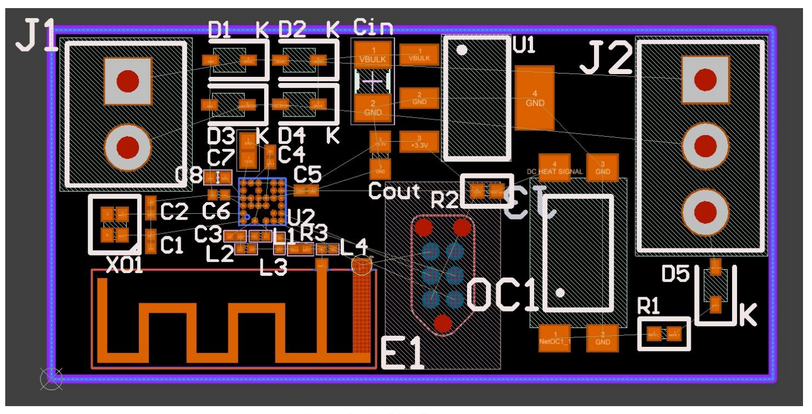

Fig. 3: PCB Footprint

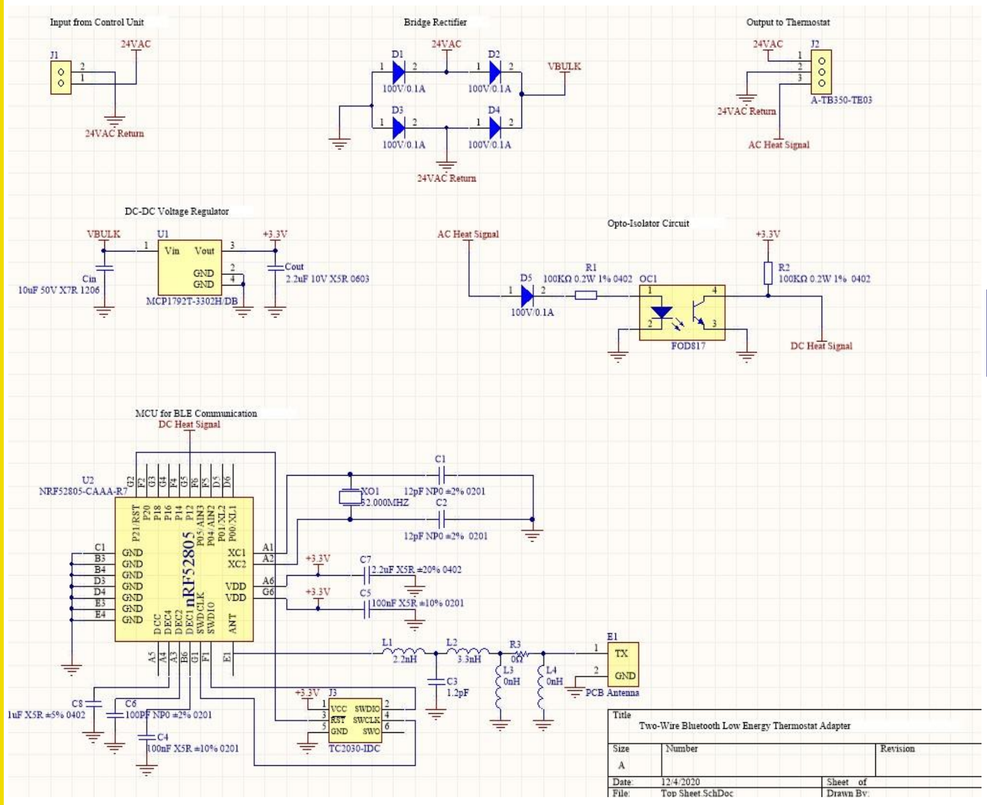

Fig.2: PCB Schematic

Implications for Company & Economic Impact

Taco Comfort Solutions is already at the top of the market when it comes to high-efficiency heating, cooling, plumbing, and irrigation products; and are a market leading manufacturer of hydronic electronic controls. Given the popularity of smart thermostats in households today, homeowners’ demand for simple installations of these devices is at an all time high. The completion of this project will allow for a straightforward transition to smart thermostats, leading to an increase in sales of electronic controls and an advancement to Taco’s position in the hydronic electronic controls marketplace.

Remaining Technical Challenges

Antenna Calibration: The TI AN043 provided a general template for an IFA, however, differences in board thickness, material, and dimensions mean that a 1:1 recreation will not result in the desired performance. The design must be tested and calibrated in order to achieve the correct performance for BLE communication.

Thermal Performance: The current prototype has performed to the desired specifications but the final product will be soldered to a PCB with much smaller dimensions with a plastic shell inside the wall. The decreased gap between components combined with the increased heat retention from the casing and housing insulation may result in altered performance compared to the more open breadboard prototype.

Mounting: The final product must he housed within the wall and thus the case must have some sort of mounting system robust enough to stay in place and be easily accessible but also small enough to be installed without opening up the wall.

Size Constraints: The PCB will sit inside a protective casing with a mounting system while remaining as small as possible. Either aspect could require mechanical additions to the board which would further reduce the already limited space for component placement on the board.

Firmware: The logic behind the firmware is almost entirely idealized and converted into a flowchart. Developing it involves getting a deeper knowledge of how the microcontroller works, its datasheet and the correct path to be used into the hardware abstraction layer. Setting up a timer interrupt associated with the BLE transmission is something that will need to be done carefully to avoid that an interrupt won’t damage or break the Bluetooth signal. Effects caused by timer interruption during BLE transmission will demand attention, even if the execution of the interruption code is less than 1ms.

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