Internship Final Paper

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EG490 Internship Course

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Internship Details

This summer, I worked as a Hardware Engineering Intern at Hubbell Incorporated / Aclara Technologies in Portsmouth, NH. My supervisor was Chris Porter, the Director of Hardware Engineering here at Hubbell/Aclara, and my mentor was Rob Snell, a Senior Hardware Engineer. Hubbell is in the advanced metering infrastructure (AMI) market, creating better solutions for utility metering (gas, water, and electric), and comprises 71 brands. I worked for Aclara, the Hubbell electric metering business, which recently developed a level 2 AC charging station for residential use.

Responsibilities, Relevancy, and Experiential Learning

High-Level Communication Project

This summer, I worked on integrating the International Organization for Standardization (ISO) 15118-2 capabilities into Aclara's EV charger (EV2c), alongside my mentor. The ISO 15118-2 standard defines the communication between electric vehicles and their chargers, often referred to as vehicle-to-grid (V2G) communication. This is accomplished using powerline communication (PLC) over the control pilot wire of the Society of Automotive Engineers (SAE) J1772 charging cable and plug standard. The physical and data link layers for this communication are performed by a PLC modem supporting the HomePlug GreenPHY (HPGP) standard, which includes orthogonal frequency division multiplexing (OFDM) modulation in the 2 MHz to 30 MHz band. The PLC modem enabled us to superimpose our high-level communication (HLC) signals onto the control pilot wire, which is already used for basic charging capabilities, thereby eliminating the need for additional cables between the EV and the charger.

When I started my internship, my mentor had already received an EV charging development kit from Dropbeats, a China-based company, that was integrated with a Raspberry Pi. The actual development board, referred to as the HAT, includes a PLC modem supporting HPGP, as well as a 32-bit Qualcomm microcontroller unit (MCU) running a real-time operating system. The development kit arrived with preloaded simulation software and the firmware already loaded onto the MCU and PLC modem. My first task, in addition to learning the basics for the standards I would be working with all summer, was to control the Raspberry Pi remotely using a secure shell (SSH). This step involved my first exposure to Linux and terminal-based commands. The preloaded simulation software allowed us to quickly initiate charging sessions with an EV and identify roadblocks for the future of the project.

The long-term goal of this project is to incorporate the charge session control into the integrated microprocessor on the EV2c main board. To do this, we would have to perform charging sessions independent of the simulation software and rather build our own to serve the same purpose. Without access to the source code of the simulator, I was tasked with creating my own charge controller using the documentation and communication protocols provided by Dropbeats. To demonstrate proof of concept, we moved forward using an ESP32-S2 microcontroller, connected to the HAT, to control charging sessions. This required the use of the Arduino IDE to program the ESP32-S2 using C++. This was a valuable learning experience as I tried to expand my knowledge of C++ coding, including the use of header files, macros, data types I had not been exposed to, bitwise operations, limiting dynamic memory usage, and serial communication. These skills will be valuable to me in future embedded systems work.

With the Dropbeats module, we quickly ran into difficulties in our charge sequence, particularly in the charge parameter discovery phase. In this phase, we hoped to extract information from the car regarding how much energy was expected to be used to fulfill the charging session. By storing this information and providing it to the utility company, the utility can better manage energy demand. Electric vehicles pull a large amount of power from the grid, often doubling or even tripling your household load. As the popularity of EVs continues to increase, the risk of large-scale grid failure also increases. By allowing the utility access to information regarding how much energy is needed to charge the EVs in its area, they can more properly schedule energy release to these chargers for customers participating in the program. EVs generally only take a few hours to charge each night, as they are often not drained to 0% throughout the day, so there is no need to start delivering power to these cars until the middle of the night, when energy demand is lower. However, without being able to access these parameters, this demand scheduling will not work properly.

After careful consideration of our options, my mentor and I decided to move forward with another charge control module, the Chargebyte Charge Module E (CME). The CME supports the DIN70121 and ISO15118-2 charge standards, giving us the ability to perform both AC and DC charging sessions. The DC charging sequence, as defined in the standard, provides several charge parameters that are not accessible during AC charge sessions, including EV state of charge and time to full state of charge, among others that are not relevant to our work on this project. Our hopes were to establish a DC charging session with the car, extract the necessary charge parameters, and then resort to an AC charging session to supply power from our charger.

To accomplish this task, I consulted the documentation and communication protocols for the CME provided by Chargebyte. Similar to my work with the ESP32 and Dropbeats, I built an Arduino program to control a charge session with the CME. The same skills were needed (header files, macros, data types I had not been exposed to, bitwise operations, limiting dynamic memory usage, and serial communication), but with experience from the previous module, this process went a lot smoother. I was able to successfully establish a DC charging session with the Hyundai Ioniq-5 and extract the EV state of charge. While this car could not send us other charge parameters, such as energy request (due to suspected lack of support for full implementation of the ISO and DIN standards), this was an important step forward and showed us what is possible on a wide variety of EVs.

Considering the popularity of embedded systems in industry today, the skills and information I needed in my work this summer would be valuable additions to the curriculum at SNHU. Specifically, the practice of limiting dynamic memory usage for embedded systems where memory is often not very large, as well as the specifics of digital communication buses such as UART, SPI, I2C, RS232, and more. Before this summer, I had minimal practical knowledge of how to use UART/serial communication with an Arduino, let alone no knowledge of other communication buses, and no theoretical knowledge. I think it would be helpful for students to at least be exposed to these protocols and how they operate, so they are aware of them when the need arises.

Microprocessor Swap Out Project

After realizing that we had quickly reached the limitations of our Dropbeats charge control module, and while awaiting our new Chargebyte module, I temporarily switched my focus to our metering business. At our office here in Portsmouth, a large majority of the engineering team is working on our electrical metering products, both for residential and commercial/industrial use. These meters, much like the EV charger, have microprocessors on them to control I/O, monitor different circuits, communicate with peripherals, and most importantly, measure power used by the customer.

Our next-generation residential meter, the I210, uses a newer microprocessor from Microchip with an embedded analog front end (AFE) for metrology purposes. This new processor has several features that are beneficial to us, such as more communication ports, higher clock speed, and others that are not relevant to my work on this project. However, on our commercial/industrial meter, the KV2c, we are still using a microprocessor that has been on the board since about 2015. As we continue to develop our smart metering infrastructure, we are interested in replacing this old processor with a variant of the processor used on the I210. Along with a few other engineers here at Hubbell/Aclara, we were tasked with creating what I call a "paper prototype" to determine if this is a viable option for us.

On the KV2c, the current processor is a 100-pin package that interfaces with an external metrology processor through an SPI bus. The new processor that we were exploring is a 128-pin package that does not include the AFE found in the I210 meter, so it was still necessary for us to keep the SPI bus interface to the external metrology processor. To accomplish this "paper prototype," I referenced Altium schematics for both the KV2c and I210 meters, as well as datasheets for both the old and new processors, making sure to match up pins as best I could and verify that all the necessary signals were mapped onto the new processor. Signals include communication buses (UART, SPI, and I2C), ADCs, GPIOs, LCD control, power rails, debug ports (JTAG and SWD), and clock signals.

Up to this point in the summer, I had not learned much about our metering business, focusing on our EV charger, so I had to learn quite a bit about the various signals and peripheral communications throughout this process. I learned a lot about communication protocols like SPI and I2C, including what signals are necessary for both. While it might not have been necessary, I read about these protocols and how they send data back and forth. I had already had exposure to

UART interfaces both in my curriculum at SNHU and with my work on the EV charger, so I had a good grasp on what I needed to do for these communications when working through this “paper prototype.”

With this new 128-pin package, we now have several extra pins and communication ports that we are considering using for extra peripherals such as real-time streaming to external modules for improved fault detection, and GPS and accelerometer modules to analyze potential tampering. All these additions to this meter are to push the edge of advanced metering infrastructure and improve the business. This project showed me how hardware upgrades can make way for future product features.

Other Internship Tasks

Alongside our main goal of integrating ISO15118-2 capabilities into our EV2c charger, I had several smaller tasks assigned to me. This included schematic and PCB referencing, PCB reworks, and engineering process tasks. On the front panel of our EV2c charger, there are three green LEDs that all light up to indicate that charging has started. In the original design of this board, these LEDs were added without individual control to demonstrate proof of concept as a minimum viable product (MVP). Now that we are moving forward with HLC and production for this product, we hope to gather the state of charge parameter from the EV and individually control the LEDs to reflect this. To accomplish this, I was tasked with reworking our front panel boards to include an 8-bit shift register so that individual LED control could be possible. I was provided with the necessary parts to accomplish this task and received soldering guidance from another engineer here at Hubbell/Aclara. Throughout this mini project, I had to reference the Altium schematic and PCB design to verify that my design did not inhibit the other functionalities of the board. This was a valuable experience, as I had not yet been exposed to PCB soldering with (very small) SMDs, or to Altium PCB and schematic designer.

Beyond technical development, I have been working on engineering process tasks such as qualifying substitute components for our EV2c charger. When production time comes, having substitute parts allows us to source from multiple distributors for cheaper prices or when there are supply chain issues with a particular distributor. The process of qualifying a component involves comparing the component parameters (from the datasheet) and comparing them to the existing component on our boards. If we decide that a component is a viable candidate for substitution, we submit a change order in our Product Lifecycle Management (PLM) system and go through numerous steps to get the component qualified. While not the most exciting task, it is an important one and provided me with exposure to engineering processes that I will inevitably use in the future.

Conclusions from Experiential Learning

Throughout my internship experience, I gained valuable insights into the world of engineering. This includes its challenges, successes, necessary skills, and processes. My technical skills in embedded system development and hardware integration have been significantly improved. I now feel very comfortable in my ability to integrate embedded systems with external hardware components to accomplish specific tasks, while programming more skillfully and efficiently than I had before. My exposure to digital communication buses has expanded my horizons as to what peripherals I can interface with and how to do so, a skill that will certainly be useful in my future coursework and professional career. Even seemingly mundane tasks, like reading datasheets and evaluating component specifications, taught me a significant amount about real-world design considerations.

Besides improving my technical abilities this summer, I also found value in developing professional skills while working in an engineering office environment. I came into this internship slightly nervous, not knowing what to expect, but hoping to be challenged. I was concerned that I would run out of work and be bored, things I had often heard from my classmates who had previously been engineering interns. However, this could not be further from the truth. Here at Hubbell/Aclara, I feel that I have been treated as a real employee, and my opinions and questions are considered with respect. I often worked independently on my projects while also having my mentor's support and direction when necessary. I am grateful for the project I was assigned to this summer, as it challenged and developed my technical skills greatly. I felt that I could understand the necessary information to be successful in this project, or at least have the foundational knowledge to learn the project-specific topics. This experience has helped me to grow as an engineer and employee and will certainly be useful to me in the future.

Applications of Prior Knowledge

My prior knowledge from my curriculum at SNHU has proven to be extremely useful at my internship this summer. As an electrical engineering major, I have taken courses in a variety of topics that I have found useful, including introduction to programming, introduction to autonomous robots, instrumentation and measurements, electrical circuits, digital circuits, analog electronics, and computer architecture.

This internship was primarily focused on embedded system development, relying heavily on my prior theoretical knowledge from computer architecture and digital circuits, and my practical knowledge from Introduction to Programming, Introduction to Autonomous Robots, and Instrumentation and Measurements. Digital logic is a core theme in embedded system development, using both sequential and combinational circuits to accomplish tasks. As I built programs to control charging sessions, I relied heavily on my programming experience from my courses at SNHU, specifically how to interface with the Arduino microcontroller through a serial interface, how to programmatically alter states of GPIO pins to perform digital logic, how to interface with peripheral devices, and C++ syntax to accomplish all the above. When constructing functions to read in or write out serial data between the ESP32 and our peripheral charge controller, I often used bitwise operations such as AND, OR, and XOR, as well as having to convert between decimal, hexadecimal, and binary often. These foundational skills were built up during my time in computer architecture and digital circuits and have proved very useful.

While my experience this summer focused on digital logic and embedded system development, I found use for my circuit design and analysis skills in a variety of contexts. Altium Designer is the PCB designer of choice for Hubbell/Aclara, a software I had not been exposed to previously. Altium allowed me to access schematic and PCB documents of the boards I worked with daily, including the EV2c front panel, EV2c main board, KV2c main board, and the I210 main board. My prior knowledge in analog circuit design and analysis came in handy when determining what each component was doing, such as op-amp buffers and amplifiers, and diode behavior in our circuits. While I have not yet taken Circuits II, where filter design is formally introduced, I independently expanded my knowledge to understand the concept of analog filtering. By applying mathematical knowledge from signals and systems, as well as control systems analysis, I was able to analyze and understand filters in our circuits by constructing a transfer function and plotting the magnitude response in Desmos.

Looking to the Future: Learning and Career Opportunities

This internship experience has ignited my excitement to pursue this vast field of electrical engineering and continue to learn as much as I can about it. While I enjoyed the tasks I handled this summer, my favorite tasks included those that involved the use of Altium for schematic and PCB design consults. My strong interest in circuit design, both digital and analog, has given me excitement for my courses in the coming year, as well as external topics like RF/microwave and mixed signal design, which are not offered in the curriculum at SNHU. Specifically, this fall I am enrolled in the Analog Electronics II course with Professor Monk. This course will be design-focused on an individual project, concluding with actual PCB design, printing, and testing, and I am fortunate to be taking it with an excellent professor.

One of the best qualities of my internship this summer was my work on a variety of engineering tasks, allowing me to get a feel for different parts of the design process. While I particularly enjoyed Altium-related tasks, I find value in seeing a project at all stages of its development, not just board design, and I hope to continue working on projects that span multiple stages of development. In the future, I hope to be respected as an engineer for my experience and knowledge, and I believe that if I work hard and continue to learn as much as I can, I can one day lead my own projects.

Looking to the Future: In the Classroom

This internship experience has made me very excited to return to school and continue to learn about this field. As I continue to learn more about the various topics in electrical engineering, I realize how little I know about this field. There is so much more to learn, but one thing that can’t be taught in the classroom is the importance of design and problem-solving. In school, it is easy to get lost in the equations, problem sets, and exams, but I quickly realized this summer that the engineering world does not operate that way. Instead, the focus is on being presented with or finding a problem that needs to be solved to drive revenue for the business.

To solve such problems in engineering, it is crucial to be intelligent and creative. Creativity is a skill that comes easily to some, and harder to others, and must be practiced and strengthened as an engineer. In my senior year at SNHU, I am excited to strengthen my creativity skills in various design courses. In Analog Electronics II, I will have the opportunity to take on a personal project for the semester that I will hopefully relate to my career interests. In Capstone Design I & II, I will be part of a team that is presented with a problem and creates a solution. This will certainly call on skills, both technical and soft, that I learned throughout my internship experience this summer. Other lecture-based courses will continue to provide me with technical knowledge that I can use in my design courses, as well as to help me find my career interests.

This paper is not enough to express my gratitude for this internship experience. As a young college student entering senior year of college, it is scary to imagine life beyond school. It is all I have ever known. Thankfully, I have fallen in love with what I am studying and am extremely excited for my future professional career, albeit a little nervous. This summer, I have gained confidence in my ability to perform at a high level and to continuously grow and improve as an engineer and employee.