**EENG 4910 Project VII – Senior Design I**

End of Semester Report

Christopher Askings
Nathan Ruprecht
Forrest Gates

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## Introduction:

The purpose of this report is to review what we have learned and accomplished this semester in regards to our final senior capstone project.

To reiterate our project, we are making a development kit for visible light communication (VLC). As of right now, we are making a 1 way communication system where a transmitter sends data (text, pictures, files, etc) using a RGB+W LED. The receiver will be a 3 photodiodes that pick up the individual color spectrums and decode the binary values to retrieve the data. Both the Tx and Rx will use a Raspberry Pi hooked to a GUI for user interaction.

Of the 15 weeks in the semester, we ended up using the first 4 weeks to plan our proposal and get approval from our faculty mentor, Dr. Namuduri. Week 5 is where we started to execute our predetermined plan. Week 5 of the semester (starting on Sunday, 25 Sept) was our Week 1 of work. For the rest of the semester, we numbered our weeks following Week 1 being 25 September. With our conflicting schedules, setting meetings was extremely difficult. We decided to do most of the work on our own time to maximize how much we would actually get done. We sent weekly progress reports to our mentor for review and comments. All reports and referenced materials can be found on the GitHub repository made for our Senior Design project found at the below URL:

https://github.com/NathanRuprecht/EENG4910-4990_SeniorDesign

## Week 1 Summary:

### Work Completed

Research was done on existing luminaire standards for use as street lamps, in particular modern LED fixtures. The *FHWA Lighting Handbook* from 2012 detailed applicable standards for luminaire construction, output, and placement. Although no nationwide standards for LED roadway illumination currently exist The Municipal Solid-State Street Lighting Consortiums *Model Specifications for LED roadway Luminaires V2.0* specifies their ideal standards proposal for modern LED illumination.

### Member Contribution

**Chris** found the *Model Specifications for LED roadway Luminaires V2.0* by the MSSLC and The *FHWA Lighting Handbook* (as well as Nathan).

**Nathan** Researched traffic prediction techniques and how traffic data could be used to improve flow and found the *FHWA Lighting Handbook* (as well as Chris).

**Forrest** researched LED and Li-Fi systems.

## Week 2 Summary:

### Work Completed

Research was done on basic components needed for our system including photo receivers (photodiodes, transistors, or resistors), RGB LEDs and drivers for them, and optical filters. We decided to go with a photodiode since we found it had the best chance to capture the given color spectrum as well as outputting a current that could easily be passed through a transimpedance amplifier and onto an ADC. There are a number of viable options to purchase and all are incredibly cheap. We also decided to go with a RGB+W LED so we effectively have three channels of communication. We found a dichroic cube that separates the incoming light into RGB so we have it as a filter on the receiving side to go to three separate photodiodes for our three channels. For driving the LED, we found two modulation techniques that peaked our interest as explained in IEEE 802.15.7: PWM and CSK.

### Member Contribution

**Chris** found and ordered the dichroic filter so we don't have to try doing BPFs or a software filter. He also found a lot of options we could use for the RGB LED. Chris also found the articles on 802.15.7.

**Nathan** found a good option for a photodiode based off of blue since it was the lowest wavelength.

**Forrest** read documents found by co workers.

## Week 3 & 4 Summary:

### Work Completed

We met with Dr. Namuduri since we were worried about our progress and direction we were heading with the overall project. He suggested we were heading in the right direction with visible light communication, but possibly bit off more than we could chew trying to integrate it into streetlights. He suggested learning as much as we can about this type of communication by either buying a development kit, or making our own. Buying one would mean we could get started understanding how it works and more about VLC itself. Making our own would be a good final product to show that we worked from the ground up to learn about VLC. We spent these 2 weeks pivoting our project to making a development kit instead of a smart LiFi network. We decided to make our own over buying one because of the current market. Of everything that is out there, we only found three viable options that we would consider buying. The best of which was not for sale for academic use.

**Member Contribution**

**Chris** found dev kits that were too expensive to consider. He found 2 of the 3 options we were considering (not the option from India).

**Nathan** found the 3 options we were considering. He followed through with the dead end option by emailing the company and almost allowed to get the schematic for it.

**Forrest** was absent due to sickness.

## Week 5 Summary:

### Work Completed

Having decided to pivot project ideas and focus on VLC we opted to pursue the creation of our own VLC development kit. Research then had to be done to decide which platform our kit would be built around. The MSP430FR2311 by TI was selected as a possible Rx platform due to our familiarity with C programing and the CCS IDE, its integrated photodiode and transimpedance amplifier, and low power consumption. The Raspberry Pi was selected as a possible Tx and Rx platform due to its high speed, internet connectivity, USB support, and display output. Both platforms were purchased along with various other components to begin testing and familiarization.

### Member Contribution

**Chris** did research on photo receivers and led drivers and purchased a Raspberry Pi.

**Nathan** found the MSP430 variant, purchased a Raspberry Pi and ordered a photodiode and led for testing.

**Forrest** did research on photodiodes.

## Week 6 Summary:

### Work Completed

We revamped our project proposal and turned it in. We spent most of the week on this since it is the foundation to what we are doing with 4910/4990. We also spent time familiarizing ourselves with the Raspberry Pi, MSP430, and the components we bought. Chris took lead with the Tx and was using the LED with the Raspberry Pi. Nathan took the Rx using the photodiode with the MSP430FR2311 since it has a built in TIA and given source code to use it all. The source code was well over our heads so it took a while to dissect and understand it.

**Member Contribution**

**Chris** continued to familiarize himself with the Raspberry Pi for the Tx. Now with parts that came in that were ordered during Week 5.

**Nathan** continued to familiarize himself with the MSP430 for the Rx. Now with parts that came in that were ordered during Week 5.

**Forrest**.

## Week 7 Summary:

**Work Completed**

Was a slower week. Nathan began making separate Tx and Rx code based off of the source found from TI for the MSP430FR2311. There were issues compiling it onto boards so most of the week was spent debugging. At the end of the week, Nathan had 2 separate boards the used the source code to show one board transmitting to the other. Chris worked on a constant current driver for the Tx. He used a function generator to simulate the signal being sent so that the LED would not exceed its limits.

**Member Contribution**

**Chris** proved components specs matching tech docs and worked on making a current driver for the Tx LED.

**Nathan** made a Tx and Rx C code that mimicked the source code found from TI.

**Forrest** researched GUI interfaces used on raspberry pi.

## Week 8 Summary:

**Work Completed**

We met to regroup and redefine our tasks and expectations for the remainder of the semester. A working prototype of the Tx side variable constant current driver was tested and proved to work reliably with a frequency range of 0Hz to ~7 kHz and a drive current range of 0mA to 50mA. The MSP430 source code was operational and was able to talk to a TIVA board reliably. More testing had to be done to decide if the MSP430 would be a suitable platform for the Rx side.

### Member Contribution

**Chris** designed the Tx side schematic and tested the physical circuit.

**Nathan** worked on the Rx side and got the MSP430 and TIVA boards talking.

**Forrest** observed project schematics.

## Week 9 Summary:

### Work Completed

We made the decision to have everyone using the Raspberry Pi so we all used Python and could help each other with troubleshooting. We spent the week coding in Python and figuring out what we want to happen depending on its capabilities. We managed to have a standalone GUI on the Tx side and set the foundation for sending data. The Rx also has the base code using FM to receive bits and is set up with the circuit built.

### Member Contribution

**Chris** worked on creating a standalone Python GUI that would accept user input as a text string that could be modulated and transmitted to the Tx board and began initial testing with the newly arrived dichroic cube filters.

**Nathan** worked on the Rx code which would constantly monitor for an FM modulated start sequence from an external ADC and convert the following binary packet into ASCII text.

**Forrest** was busy and couldn't contribute.

## Week 10 & 11 Summary:

### Work Completed

We were able to build a working demo for Dr. Namuduri to see our progress. Chris is able to use a python GUI to communicate with the Tx board to blink an LED at a certain frequency as well as take in a string of characters from the user. Although the Raspberry Pi is capable of outputting a pulse position modulated packet at our target carrier frequency its non real time nature results in stability issues that create an unacceptable amount of distortion. Nathan has a working Rx that outputs a square wave from 0-3.3V that mirrors the incoming data from a blinking light. The rise time is a limiting factor for the Rx. At roughly 15ms rise time, the square wave clips and deteriorates when the light frequency is over 10 Hz.

**Member Contribution**

**Chris** made minor modifications to the Tx circuit to improve stable operation above 5kHz and integrated the raspberry pi into the circuit such that user input modified output frequency and duty cycle.

**Nathan** built a working first stage amplifier for the Rx. We are successfully able to receive light and output a square wave from 0-3.3V of the frequency the light is blinking at (up to roughly 11 Hz).

**Forrest**

## Timeline of Work to be Completed

| *Week* | *Date* | *Projected Goals* | *Comments* |
|---|---|---|---|
| 17 | 1//15/17 | Re-familiarize with past research and code | Potentially retest system and verify points as to how to improve the system. |
| 18 | 1/22/17 | Build Prototype 2<br><br>Code T2:<br>T1 with UART<br><br>Code R2:<br>T2 with UART | Implement UART to choose the bit being sent (hit the 0 or 1 key on Tx) and showing the received bit on the Rx side. |
| 19 | 1/29/17 | Reevaluate Prototype 2<br><br>Code T3 & R3:<br>Multi-channel communication | Reevaluate parts used for prototype 2 and circuit structure<br><br>Modulate all colors (RGB) for multi-channel communication. |
| 20 | 2/5/17 | Code T4:<br>Assign entire ASCII table to bit patterns to send to Rx<br><br>Code R4:<br>Assign entire ASCII table to bit patterns to receive from Tx | Need to hardcode all the values of keys to bit patterns. So when a certain key is hit, it’s equated to a certain bit pattern that we can send. |

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|---|---|---|---|
| 21 | 2/12/17 | Code T5:<br>Send keystroke to Rx<br><br>Code R5:<br>Receive keystroke from Tx | Instantaneously send keystrokes from Tx to Rx |
| 22 | 2/19/17 | “ “ | |
| 23 | 2/26/17 | Prototype 3<br><br>Code T6:<br>Wait to send message until enter key<br><br>Code R6:<br>Receive message and show it in its entirety | Build prototype 3<br><br>Instead of single keystrokes, now an entire message being sent and needing to be processed. Still controlled on which channel (color) it is sent. |
| 24 | 3/5/17 | Other capabilities | Sending audio over a channel, CSK modulation, daylight operations, 2 way communication, etc. |
| 25 | 3/12/17 | *(Spring Break)* | |
| 26 | 3/19/17 | “ “ | |
| 27 | 3/26/17 | “ “ | |
| 28 | 4/2/17 | Completed/constructed system | Verify entire system is working at full capacity. |
| 29 | 4/9/17 | Test/Reevaluate/Big Picture Theory/Deliverables | Final testing and evaluating to confirm it works under all conditions |
| 30 | 4/16/17 | “ “ | |
| 31 | 4/23/17 | “ “ | |
| 32 | 4/30/17 | Project Presentation: Final Semester | After presentation, discuss project preservation. Write formal thank you notes to all staff involved. Pending graduation! |
| 33 | 5/7/17 | Finals Week | |

## Conclusion - Semester Summary:

Our group is set on studying visible light communication (VLC). Although we started with a larger project than we could handle, we narrowed it down so that we could dig in and learn more about the topic. We are making our own development kit for VLC using the Raspberry Pi 3 on the transmitter and receiver side. Our schedule has been updated and we're making good progress to transmit data by using light. Our project proposal, schedule, weekly progress reports, and all other material used in the process can be found on the GitHub repository listed in the opening paragraphs and again in the documentation.

Documentation:
All material pertaining to our project can be found on GitHub:
https://github.com/NathanRuprecht/EENG4910-4990_SeniorDesign

All articles used as references (also on GitHub) are:


FHWA Lighting Handbook. August 2012

MSSLC Model Specification for LED Roadway Luminaires, Version 2.0. July 2014

Design of Wireless Optical Access System using LED, Optics and Photonics Journal. 2013

Integration of Li-Fi System in Street Lights- A future for easy internet access, International Journal of Advancement in Engineering Technology, Management & Applied Science.May 2016

Design and Implementation of Color-Shift Keying for Visible Light Communication, Eric Monteiro. 2013

Design and Implementation of Visible Light Communication System Using Pulse Width Modulation, Angga Pradana, Nur Ahmadi, Trio Adiono. August 2015

IEEE 802.15.7 Visible Light Communication: Modulation Schemes and Dimming Support, Sridhar Rajagopa, Richard Roberts, Sang-Kyu Lim. March 2012

IEEE Std 802.15.7: Short-Range Wireless Optical Communication Using Visible Light. September 2011.