April 13, 2010

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Post Mortem for Smart House with Power Line Communication Network

Dear Dr. Rawicz:

The attached document, Post *Mortem for Smart House with Power Line Communication Network*, outlines the progress of our project and any digression made to its original description. We have researched and implemented a programmable power line modulation system, called Prometheus, which enables users to remotely check and control the status of the lights inside their buildings, through the structures existing power grid.

This document describes the current state of our project and its functionalities, any digressions applied throughout the implementation and manufacturing stage, and suggested future upgrade plans. Furthermore, the companies' budget and time constraints throughout the term will be discussed. Moreover, group dynamics and personal experiences of all company members are mentioned describing each person's point of view of the project and what they learned from it.

The Nexus team consists of five intellectual, highly motivated, and talented fourth-year engineering students: Kia Filsoof, Pranil Reddy, Yalda Hakki, Mike Kubanski, and Kevan Thompson. If you have any questions or concerns about our design specification report, please feel free to contact me by phone at (604)910-5747 or by e-mail at kjthomps@sfu.ca

Sincerely,

Kevan Thompson

Kevan Thompson
Chief Executive Officer
Nexus Technologies

Enclosure: Post *Mortem for Smart House with Power Line Communication Network*

Post Mortem for

Smart House with Power Line Communication Network

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Glossary

CGI:	Common Gateway Interface
FSK:	Frequency Shift Keying
PIC:	Programmable Interface Controller
PLCM:	Power Line Communication Modem

1. Introduction

Nexus Technologies has been working since January 2010 to develop a system which provides users with a practical low cost implementation of a smart home. Our smart home design will allow users to control the lights of their house from either a local computer, or any computer connected to the internet. The building's master controller determines what device the user intends to control by the data received and sends control signals to the corresponding device controller via the Power Line Communication Modem (PLCM). The control signals are processed by the PLCM and sent through the electrical grid. These control signals are then recovered from the electrical grid by the corresponding device controller's PLCM located near the light that is to be controlled.

Our current prototype system, named the Prometheus, incorporates most of its proof of concept functionalities proposed previously by Nexus Technologies in our functional specification requirements report.

1.1 Scope

This document provides information on the current state of the Prometheus system. Moreover, changes in the scope of the project, not documented previously, will be stated as well. Future improvement, budget, and timelines are also discussed. Finally, a brief reflection of each group member's personal experience is also included within this report.

1.2 Intended Audience

This document is intended for the ENSC 440 professors as a reference towards evaluating Nexus Technologies' success in completing the project.

2. Current State of the Project

As proposed in the project proposal, the Prometheus system controls home or business electrical devices through a power line communications network on the building's power grid. A user can log onto a website hosted by the master controller, which will send control signals through the power grid to the corresponding device controller. The master controller and device controllers each consist of one power line communication modem (PLCM) which allows for their transmitting and receving of data over the power grid. Figure 1 below shows the overall system block diagram for the Prometheus system.

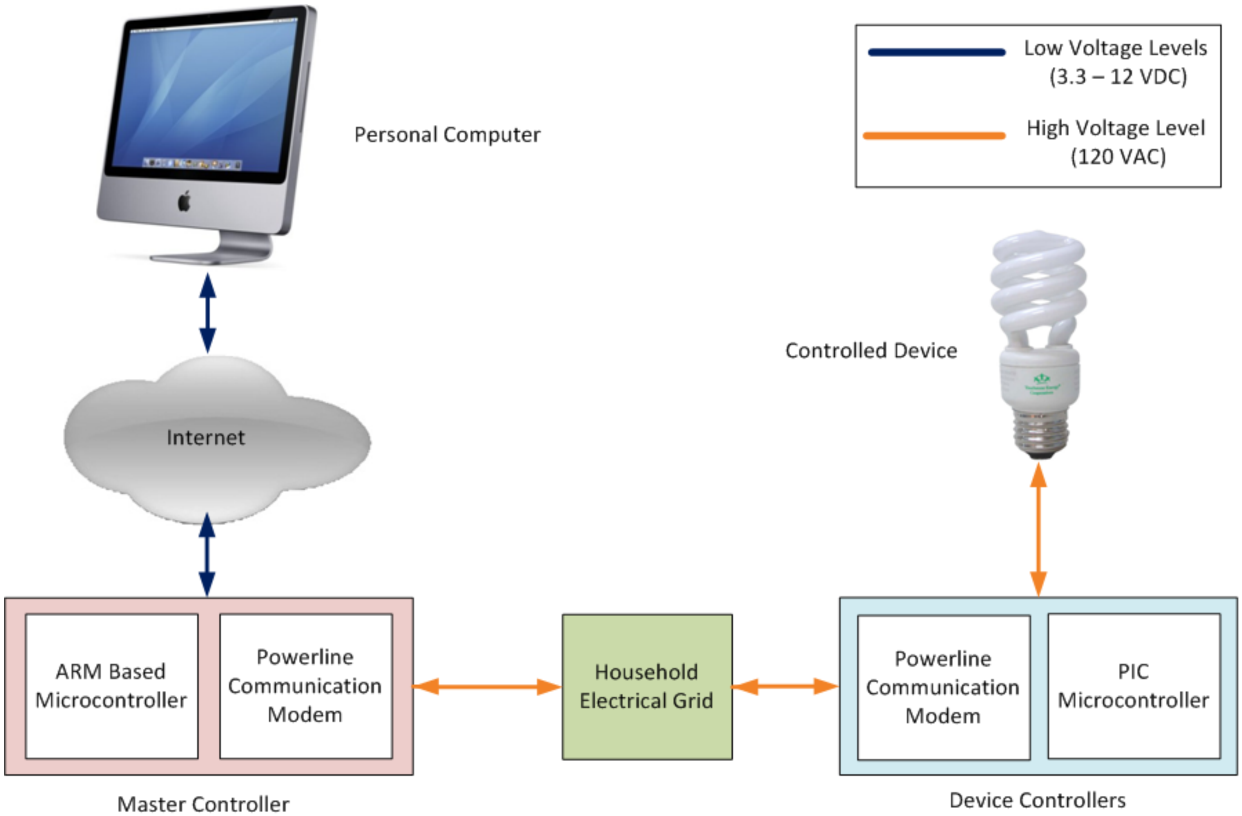

Figure 1: Overall System Block Diagram

Currently the Master Controller uses a TS-7200 SBC with a Debian Linux operating system. The master controller can use an Apache webserver to create a dynamic CGI webpage that can communicate with a static process which runs the network. This static process, called master_controller, sends and recieves data from the CGI program and also controls the device controller network. Currently this network is only configured to operate with a maximum of two device controllers. Each device controller must connect to the network, and will then recieve data as the user uses the website. In order to communicate with the device controllers, the master controller uses an RS-232 interface in cominbation with GPIO. The GPIO is needed to turn on or off the transmitter on the PLCM.

As of to date, the PLCM is meeting majority of its most critical proof-of-concept requirements as mentioned in our functional specification report. The PLCM is capable of sending and receiving digital data reperesented in RS232 format over the power line at any desired baud rate. It can be connected to any microcontroller device and grant it communication over the power line. In other words, it is not dependent on any specific required microcontroller. The PLCM's interface to the power line consists of a high frequency coupling transformer with two filtering capacitors sitting on the hot and neutral lines of the power line. The purpose of these capacitors in conjunction with the transformer is to prevent the 60-Hz AC power signal from getting through to the low voltage secondary side of the PLCM. There are also two 250 mA fast blow fuses sitting onwards these capacitors to provide protection of our circuitry from any current surges on the power line.

When transmitting, the PLCM takes the RS232 control signals from a microcontroller, modulates them into their corresponding FSK format, and passes them on to an H-bridge circuitry which drives the coupling transformer with the required amount of current. Conversely, when receiving, the PLCM extracts the FSK formatted control signals from the coupling transformer, passes them on to a band-pass filter which will further filter out the 60-Hz power signal and the high frequency noise signals. After filtering is done, the control signals are passed on to a pulse-shaping circuitry and then a phase-locked loop which will demodulate the FSK signals into their corresponding RS232 format and output them to the receiving input of the microcontroller.

The device controller consists of a PIC mircocontroller connected to the PLCM through an RS232 line driver/reciever and an external device control circuitry used to control devices connected to 120 VAC power line. The device controller communicates with the master controller via RS232 packets which are passed to and from the PLCM and controls devices based on the control packets it recieves. The PIC drives an output pin high to turn a device on, and holds it low when the device is off. When the pin is driven high, it powers the optoisolator's LED, which drives the other side of isolator. This in turn provides just enough base current to switch a NPN power transistor on and switch a 12 VDC relay on. This closes the device circuit and allows the 120 VAC source to power the device.

3. Digressions to the Project

3.1 Overall System

Overall, we have developed a system which functions as we desired, even though it still does not meet some of its final-product functional specification requirements. There were a few requirements which we had to change around due to our time and budget constraint. However, these digressions barely affected the functionalities of our project as of to date.

Our proof of concept system is currently implemented on breadboards, and uses power supplies which we had designed in our previous engineering courses. These power supplies are not designed specifically for our purpose but can be set to provide the power levels we need. Ideally, the power supply will need to be implemented on the same platform as the rest of the circuitry, but due to time and budget constraints we refrained from doing that.

Another general digression to our original functional specification requirement is that our system is not compactly built within an enclosure and is not very portable as every module currently consists of three units. One unit is the microcontroller circuitry placed beside its PLCM. The second unit contains the coupling transformer with the filtering capacitors and fuses. The second unit was separated from the first unit since the SFU lab faculty advised that we enclose our high voltage circuitry as soon as possible before progressing with our project. Finally, the third unit is the power supply to all of the circuitry in our system. As for our final product, we will need to combine all these three units into one compact enclosure to make it more portable and easily installable.

The details of our project's digressions are given below in the following sections for the three main sub-modules.

3.1.1 Master Microcontroller

Currently the Master Controller is designed to operate with two device controllers instead of a complete network of Device Controllers. This was a design change for the prototype only, in order to save development time. Moreover, the Device controller network is not implemented exactly as designed. This is due to the limited scope of the network with two Device Controllers.

In addition, the web interface only allows users to turn on or off devices, and not to set timer or alarms. This is due to the TS-7200's lack of a Real Time Clock Chip and lack of development time. The time required to develop the Device Controller network to its current was longer than anticipated, so the alarm and timer functionality had to be removed.

3.1.2 Power Line Communication Modem

The PLCM has not yet met many of its final-product functional specification requirements. The PLCM has not yet been placed within a mechanical metal chassis for professional appearance, heat dissipation and grounding purposes from the casing. Currently, it is neatly wired on a breadboard which allows for easy troubleshooting and demoing.

As for the power consumption of the PLCM, it actually draws much less current than initially expected. In our functional specification report we had specified for a 7.5 W power consumption of the PLCM, but our current system only draws a maximum power of 2.0 W. As stated before, the PLCM and the master/device controller's power usage are all currently supplied from a portable power supply designed before. The final product will need to include its own specific power supply implemented on the same platform as the other circuitry.

Due to time constraints, the PLCM has not yet been designed around any of the required standards as mentioned in the functional specification report. For later improvements, these standards could be taken into account.

3.1.3 Device Controller

There have been some deviations from the original design of the device controller, mostly in the hardware design. For the device controller software the only major change was to remove the network address that the device controller would request when connecting to the master controller. Instead, since our network is a local one, we have chosen to have the device controller request access to the network with its own unique MAC address, and further communication uses the MAC address to distinguish device controllers. This makes the software easier to implement, as the network address is not necessary unless there are multiple networks involved, which is not the case in our system.

For serial communication we had to introduce a Maxim MAX232 driver/receiver between the PIC's RX/TX ports and the RS232 In/Out from the PLCM. The reason for this is that the PIC runs on a 5V V_{DD} and a 0V V_{SS}, and cannot generate an actual RS232 signal which requires at a minimum ±3V swing. The MAX232 chip runs on the same 5V V_{DD}, but it is designed to generate ±10V internally and convert the PIC's TTL signal to an actual RS232 signal, and vice versa.

For the external device control circuit, when we went into detailed design and construction of the circuit, we found we had to make some changes to our initial design. The opto-isolators we purchased have a maximum rating of around 1V on the LED side, requiring voltage division to reduce the PIC's output voltage to around 1V. The current outputted on the phototransistor side is small, although it is proportional to the input current on the LED side. Thus, we opted for a 12V DC relay which can be powered with the same power supply the PLCM uses. The 12V DC relay requires only 75mA of current, and using a power BJT, it can be controlled with a 12V DC power supply powering the opto-isolators phototransistor side. Enough current is outputted from the opto-isolator to trigger the relay. An updated circuit schematic of our device controller is shown below in Figure 2.

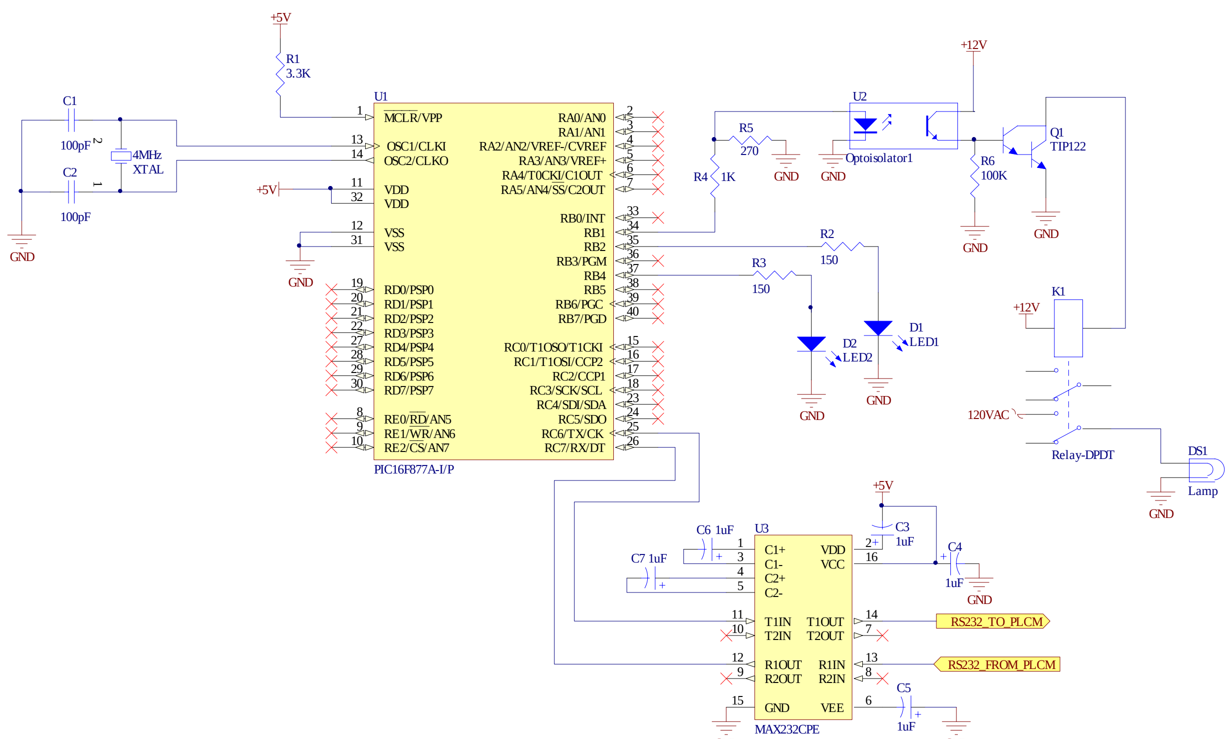

Figure 2: Redesigned Device Controller Schematic

4. Future Plans

The Prometheus system can be expanded and improved in many areas before it reaches the market. Based on our experience gained from developing our proof-of-concept system, we have gained much insight as to what can be done to improve our product and, thus, provide the following suggestions for future improvements.

4.1 Overall System

One of the critical improvements which can be made to our system towards having it ready for market would be to compactly enclose all current three units into one for every module. This enclosure will allow for more safety, easier installation and portability of our system by the user. The intended final enclosure is to be made of metal to allow for making use of grounding and heat dissipation purposes.

Another improvement to our overall system would be to reduce the overall power consumption of our system, leading to a less costly and more efficient device. All three of the master microcontroller, device controller, and the PLCM include circuitry which can be optimized more towards increasing the system's efficiency.

Lastly, our final product will need to be capable of controlling more complex devices. Currently, our system can only control the on/off state of the corresponding electrical devices. As for future improvements, we are aiming to interact further with the internal circuitry of more complex devices. For example, we could use our system to control the overall operation of an electrical oven such as controlling its temperature, the corresponding heating pads, its internal clock, and timer.

Detailed description of the improvements which could be made to the Master controller, PLCM, and device controller are all described below.

4.1.1 Master Microcontroller

Future plans for the Master Controller are to expand the network capabilities to allow a larger number, and a greater range of Device Controllers to connect to the network. This will include devices that can do more than simply turn off and on.

Additionally we plan on adding timing and alarm functionality to the web interface. This will allow devices to be turned on and off at a specific time. This will require the purchase and interfacing of a Real Time Clock Chip. Additionally we plan on making the web interface more aesthetically pleasing.

4.1.2 Power Line Communication Modem

The PLCM is currently working at an extremely satisfactory state. However, small improvements can always be made to it towards having it ready for the market. Its power consumption is certainly one of the most critical and easiest factors which could be improved upon further.

Currently, one of the disadvantages of the PLCM is that it continuously attempts to transmit FSK modulated signal even when the microcontroller has turned off the transmitter output's enable signal. This inefficiency results in the PLCM consuming power which is unnecessary and wasteful. For future improvements, we could make use of the FSK modulator's inhibit signal to enable/disable it appropriately to make it more efficient.

On the receiving side of the PLCM, one of the possible improvements would be to advance its band pass filtering techniques. The band pass filter currently used is constructed of a 1^{st} order high-pass filter and a 1^{st} first order low-pass filter cascaded together. For future improvements, we could advance our filtering circuitry by making using of higher order filters to completely eliminate any unwanted frequencies.

4.1.3 Device Controller

One of the improvements which can be possibly made to the device controller is its external circuitry. The device controller's external control circuit can be redesigned more compactly and efficiently for placement on a PCB. This would decrease the cost as currently our proof of concept design makes use of different discrete parts that we could purchase easily.

Another improvement which could be made to the device controller is its power supply design. The device controller in the proof of concept system makes use of two different power supplies that were modified for our purposes. Ideally the device controller should have one 120V AC input and have this transformed into the necessary DC voltages required internally, and have it provide the power to the device when it is switched on.

5. Budgetary and Time Constraints

5.1 Budget

All of the funding required for our project was provided from IEEE and ESSEF. Table 1 and Table 2 summarize the estimated and actual cost of the prototype development respectively. The actual cost was $150 more than the estimated one mainly due to the fact that shipping costs and taxes were not included in the initial estimate. The added tax and shipping costs significantly affected the cost of TS-7200 SBC (ARM9 Processor). Table 3, Table 4, and Table 5 illustrate detailed costs of the prototype PLCM, device controller, and chassis.

Equipment		Estimated Cost
TS-7200 SBC (ARM9 Processor)	$	120.00
Powerline Communication Modem	$	70.00
Controlled Devices	$	20.00
Appliance Interfacing	$	30.00
System Chassis	$	22.00
15% Contingency Plan	$	38.00
Total Cost	**$**	**300.00**

Table 1: Estimated Cost

Equipment	Quantity	Unit Cost	Actual Cost
Master TS-7200 SBC (ARM9 Processor)	1	$228.85	$228.85
Power Modulation Modem	3	$21.14	$63.43
Device Controller	2	$28.78	$57.56
Controlled Devices	1	$0.00	$0.00
High Voltage Enclosure	3	$34.32	$102.97
Total Cost		**$313.10**	**$452.81**

Table 2: Actual Cost

Description	Supplier	Quantity	Price		Extended Cost	
Phase Locked Loop - CD4046	Texas Instruments	6	$	0.54	$	3.24
H-Bridge - L298	STMicroelectronics	3	$	4.34	$	13.02
5V Regulator - LM7805	Fairchild Semiconductor	3	$	0.60	$	1.80
Votlage Feedback Amp - LM6171	National Semiconductor	3	$	2.83	$	8.49
Op Amp - LF356	National Semiconductor	15	$	1.09	$	16.35
Zener Diode (4.7V) - 1N4732	Fairchild Semiconductor	3	$	0.51	$	1.53
General Purpose Diode - 1N4148	Fairchild Semiconductor	9	$	0.12	$	1.08
Fast Acting Fuses - 120V @ 250mA	Cooper/Bussmann	6	$	0.31	$	1.86
Inline Fuse Holders 30mm	Cooper/Bussmann	6	$	1.14	$	6.84
Pulse Transformers - 10mH	Schurter	3	$	2.74	$	8.22
Various Resistors (Lab Stock)	Panasonic	60	$	-	$	-
Various Capacitor (Lab Stock	Panasonic	21	$	-	$	-
					Total $	**62.43**

Table 3: Prototype PLCM

Description	Supplier	Quantity	Price	Extended Cost
PIC16F877	Microchip	2	$ 6.72	$ 13.44
Optoisolator Darlington - 4N33836Q	Fairchild Semiconductor	2	$ 0.64	$ 1.28
Switching Transistor - TIP122	Fairchild Semiconductor	2	$ 0.61	$ 1.22
RS-232 Interface - MAX232	Maxim	2	$ 3.31	$ 6.62
Crystal Oscillator	ECS	2	$ 0.50	$ 1.00
Relay Socket	N/A	2	$ 8.50	$ 17.00
Relay 12VDC - 5A/250VAC	Song Chuan	2	$ 8.50	$ 17.00
Light Socket - (Free)	N/A	2	$ -	$ -
Various Resistors (Lab Stock)	Panasonic	18	$ -	$ -
Various Capacitor (Lab Stock)	Panasonic	12	$ -	$ -
			Total $	57.56

Table 4: Prototype Device Controller

Description	Supplier	Quantity	Price	Extended Cost
3 Prong Chassis Plug	Generic Brand	3	$ 1.99	$ 5.97
PCB Terminal Blocks 10 / PKG	Generic Brand	3	$ 6.74	$ 20.22
Metal Chassis	Hammond	3	$ 16.98	$ 50.94
Nylon Standoffs 10 / PKG	Generic Brand	1	$ 4.73	$ 4.73
Prototype Boards	Generic Brand	1	$ 8.51	$ 8.51
Binding Posts - Black/Red Pack	Generic Brand	3	$ 4.20	$ 12.60
			Total $	102.97

Table 5: Prototype High Voltage Chassis

5.2 Time Constraints

Table 8 is the project Gantt chart. The estimated time schedule is shown via blue bars, and the actual time for each stage is illustrated with red bars. The actual implementation of most stages required more time than expected primarily due to the complexity of certain phases of the project.

Despite discrepancies between estimated and actual time required to complete each phase of the project, except for the design specification, all deadlines were met, as all team members thrived to adhere to the initial schedule to the best of their ability.

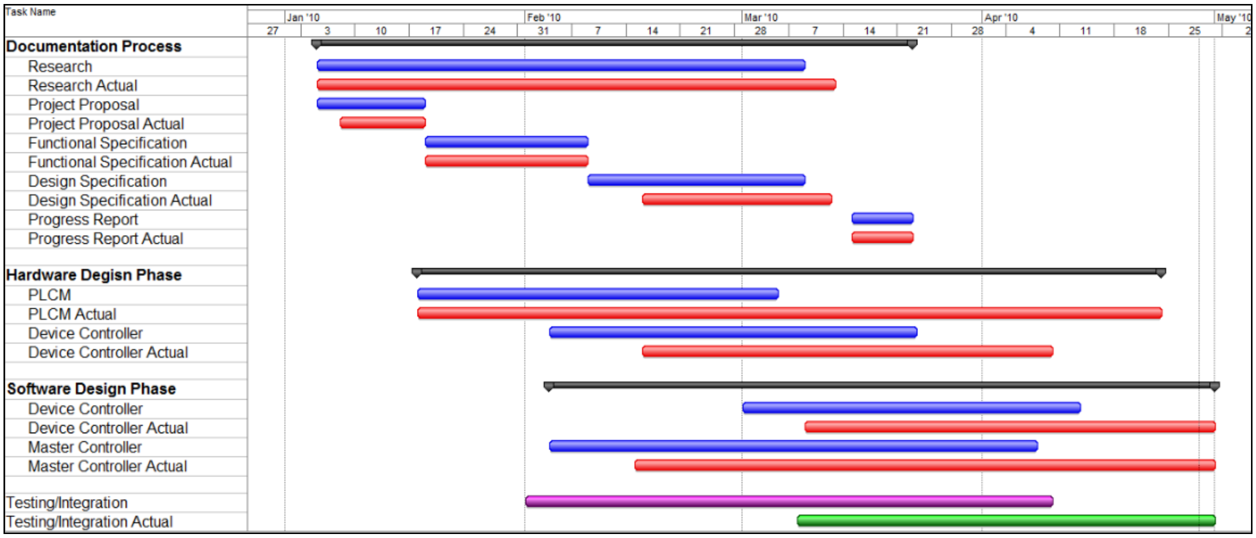

Table 6: Project Completion Gantt chart

6. Personal Experiences

Kevan Thompson

Our group is perhaps unique among most ENSC 440 groups in that every member is taking a full course load this semester. While one could argue about whether this was a wise decision, it is my personal opinion that people perform at their best when times are at their worst. However this situation did require that each individual team member had to manage their own time. Once decisions were made, and protocols established, each member would go their own separate way, and perform their own tasks as they saw fit and when time allowed. Many meetings needed to be casual and would consist of group members giving quick updates or possibly small groups tackling a specific problem. This lack of micromanagement allowed each team member to flourish and display their own strengths.

Over the course of the project I learn a great many things. Beginning when we first acquired the TS-7200 I had to learn how to use the Linux command line to format a compact flash card, using very specific options to install a custom Linux operations system. Following that, I had to learn how to boot the TS-7200 from the compact flash card.

The next hurdle was to learn how to use the POSIX standard “termios.h” to read and write from the TS-7200’s second serial port. As well as learning how to create, and run CGI programs. Once this was done, we had to define the packets that would be used in our power line network. The final thing to be done before integration was to determine a way to make the dynamic CGI program to communicate with the static master controller program. This was solved by using a Linux message passing queue. This allows for the exchange of data between the two programs without having to mutual exclusion.

New lessons were learned once we began to integrate. Both the master controller and device controller had to have code alterations done. Packet headers needed to be changed in order to compensate for errors produced by the PLCM.

Kia Filsoof

Throughout the ENSC 440 project, I learned a great amount about my colleagues, faculty members, myself, and most importantly, the secrets behind communication through the power line. I am very satisfied with where our project has reached. At the start, it was all a black tunnel and the end seemed ages away. Although our project has not yet reached its final ready-for-sale stage, all of its secrets have been unfolded and the remainder of work is just for appearance and safety.

This course taught me group dynamics and team work skills. I think one of the most important things I learned about group work is to respect and consider every member's insight and suggestion towards any problem. Each person has a different point of view of the project and has his/her own unique strengths. There were numerous times throughout the project that a huge problem was fixed by just a group member saying out a word. Sometimes that member was not even specializing in the particular field of the problem. In regards to these incidents happening number of times, I learned that it is critical to have every group member always involved in what you are working on and any problems which you are currently facing, because each member's past experience could be used towards progressing the project from every aspect.

On a technical level, I have to admit I loved what I worked on. I had chosen hardware circuit design as my future field of specialization back when I was studying in BCIT, and this is exactly the type of work I had in mind. This project helped me advance toward my field of specialization in many ways. I got the opportunity to become familiar with many sub-circuits which will certainly assist me with my future projects. I think the PLL chip which we used for our project is extremely versatile and can be used for many applications as it gives the user full controllability over the input and output frequency of the corresponding signal. Also, I got familiarized with different techniques of driving transformers, or more exactly, inductors. The H-bridge was used in our project to properly drive the high frequency transformer with square signals and provide the transformer the necessary amount of current desired.

Pranil Reddy

Over the course of four months during the development of the power line communication system, I increased my knowledge in various aspects of hardware design. The extensive use of the phase locked loop circuitry also gave me an appreciation of how smaller sub blocks within the integrated circuit (VCO, Phase Comparator, and Loop Filter) are combined to create such a versatile electronic circuit. The unique opportunities in circuitry design for this project allowed me to apply theoretical concepts from previous and current courses, bringing my ideas to realization in the physical world.

The hardware design process, at the beginning of the project, taught me that there are many ways to solve a problem. During the development phase for the FSK modulator we came up with four different designs, and slowly analyzed how each worked before coming to the optimal solution. Another major learning outcome from the project was the involvement of higher voltage circuitry and that researching a topic that you do not understand can sometimes be difficult as you are sorting through many different sources trying to find the relevant information.

One of the most important attributes I gained from this experience is how to function effectively in a group. In all types of teams there are ideas that other present that we might not agree with, however, having patience and understanding the point of view of the individual presenting the new idea is important and creates good group dynamics. It is also good to criticize and analyze each other's ideas since it allows the person to see potential flaws with the idea and allows them to learn from their mistakes. I also learned that if I didn't understand a concept or some aspect for a design the engineering faculty are always willing to help with problems, yielding their experience in their respective fields to help aid in completing our projects.

I also learned that planning and setting goals is vital for the success of any project. Working on a strict deadline I found to be very challenging, however, it provides drive and motivation for starting on work early and allows room for improving on design, documentation and other aspects when the group is ahead of schedule. One of my biggest regrets this semester is taking a heavier course load in conjunction with ENSC 440 as the project seemed to take away time and resources away from my other classes.

Michael Kubanski

I increased my knowledge in many areas while doing this project. In terms of technical aspects, I learned how to use PIC microcontrollers and how to design hardware circuitry which is used by them. I also learned how the RS-232 protocol works and how to communicate between a PC and microcontroller using serial communication. I also got to learn the uses of opto-isolators, relays, line drivers/receivers, and gained experience in designing circuits with them. There were a few changes I had to make to the design of the device controller portion of the project as I gained more knowledge and understood better how the different circuit elements needed to be connected. In this project I learned how important the hardware underlying the software is.

In terms of software I learned more about low level C programming in a single threaded PIC with one interrupt service routine available. I also got to increase my level of experience with programming in C++ in Windows by developing a test program for serial communication between my laptop and the PIC. I learned how to work with Windows code and make use of Windows dynamic libraries to control a COM port. It was a great feeling when I got my Windows program on my laptop to control a light bulb via the PIC microcontroller.

During this project I also learned the importance of documentation and planning, and that a good project requires a lot of time devoted to research and design. I also found that experience is very useful in designing hardware. I was personally inexperienced in hardware design and had no experience with PIC microcontrollers. The initial learning curve for me was very steep, and getting the PIC microcontroller to even run took a lot of time. After the initial learning curve, it was much easier to see what needed to be done for the device controller and resulted in me having to redesign the device controller once I got to the implementation stage. I learned a lot about good documentation practice and, also, how to draw out schematics properly for documentation using Altium Designer.

I developed better group working skills and also a better understanding of group dynamics throughout this project. I learned that even if everyone has their own tasks you still have to work as a group as most tasks are related and influence the others. Design changes have to be discussed as a group, as not only can group members give input on your design change, but can also come up with better solutions. I learned that talking with group mates about different issues I ran into made it quicker to find a solution to my problem, instead of bashing my head against the desk trying to figure out the problem is myself. We had a very hard working group and this project took a lot of time and effort to complete, but it was a very rewarding experience for us all and we gained a lot of experience that we can use in our future endeavours.

Yalda Hakki

From technical point of view, this project helped me have a better understanding of the importance of the applications of many hardware devices and techniques. I have also learned the importance of breaking a large system into several sub-systems and perform thorough testing to examine the satisfactory performance of a sub-system before moving on to the next stage and building the next sub-system. Most importantly, I have gained an extensive and valuable knowledge about the building blocks and performance of transmitters, receivers, and power line coupling circuitry. Throughout this project I have also obtained a better understanding of power electronics.

One invaluable experience I gained while working on this project was the importance of putting good ideas into practice without spending countless hours on research. Despite the fact that at every stage of the project, it was vital to carry out research in order to progress and succeed, I found out emphasizing on research to be very time consuming and confusing. I learned that the best approach to perform a task at every stage of the project was to balance out the amount of research done on the topic and the time spent to implement the ideas obtained by doing research. Although some topics might be difficult to understand at some point, implementing the ideas step by step is very helpful to understand any unclear points encountered during the research.

Throughout this project I have learned to be considerate, understanding, and patient in order to fully understand my team members' point of view and incorporate their ideas into the project. I have also learned to not take any criticism personally, and criticize others only if the project is being negatively affected or the project will suffer significantly from a wrong decision. I have also found that supporting other team members usually has a great impact on the successful completion of the project.

7. Conclusion

In less than 4 months, through close collaboration between team members, Nexus Technologies was able to carry out extensive research and design to develop a functional prototype incorporating the majority of functional specifications promised in a timely manner. Any digression to the project was outlined in this document. Related possible future improvements towards the project were also included. The functional prototype indicates a potential for the product to be marketed due to its reasonable price and desirable functionality.