Lumen Medical Technologies Inc.

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1154 Harold Rd. North Vancouver, B.C. V7K 1G3

April 20, 2006

Dr. Andrew Rawicz
Simon Fraser University
8888 University Drive
Burnaby, BC
V5A 1S6

Re: ENSC 440 Project Post-Mortem for a Noninvasive Glucose Measuring Device

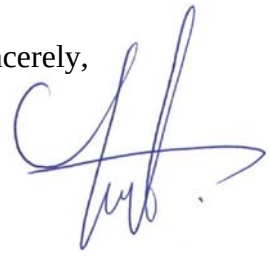
Dear Dr. Rawicz,

Attached, you will find the Lumen Medical Technologies' Post Mortem Report for a Non-Invasive Glucose Measuring Device. This document illustrates the engineering design process that we have carried out for our ENSC 440 project over the past four months.

The goal of this document is to explain the current condition of the device and explore the differences between the final design and our original plans. It also summarizes some of the financial and time constraints we encountered and describes the technical experience we gained from working on the project.

Lumen Medical Technologies Inc. comprises of six highly motivated and innovative senior level undergraduate engineering students. The team members include Mehdi Abdollahi, Deema Annyuk, Jeff Chen, Connor Gillan, Graham Laverty and Tony Tsai. Please feel free to contact me by phone at (604) 319-4726 or by email at mehdi@lumen.co.ca should you have any questions or concerns.

Sincerely,



Mehdi Abdollahi
Chief Executive Officer
Lumen Medical Technologies Inc.
http://www.lumen.co.ca

Enclosure: Post-Mortem for a Noninvasive Glucose Detection Device

Lumen Medical Technologies Inc.

Post-Mortem Report for a

Noninvasive Glucose Measuring Device

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Submitted to: Dr. Andrew Rawicz – ENSC 440
Steve Whitmore – ENSC 305
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Executive Summary

The state of diabetes in Canada has been categorized as “an epidemic” by the Canadian Diabetes Association. In its 2005 report, the Canadian Diabetes Association counts the number of knows diabetics in Canada to be more than two million. This report projects this number to increase to over three millions by 2010[1].

Diabetic patients are required to monitor their blood sugar level constantly. The monitoring devices currently available in the market today require patient blood samples. The inconvenience and pain of taking blood samples makes these solutions very undesirable. This presents an opportunity for improved and innovative solutions that can help those suffering from this condition. We, at Lumen Medical Technologies Inc., are in the process of designing and developing a non-invasive device that can measure the concentration of human blood simply through skin contact.

With this document, we present a summary of the completed design and outline the Glucose Measuring Device described above. Our group consists of 6 engineering science students with skills that were essential in making this project a reality.

[1] Canadian Diabetes Association, Diabetes Report, 2005.
Available: http://www.diabetes.ca/files/diabetesreport2005/CDA-diabetesreport-2005-en.pdf

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1. Introduction

Since January of 2006, we, at Lumen Medical Technologies, have been working hard to show that with innovative thinking, it is possible to come up with a non-invasive glucose measuring device to help the many who suffer from a disease which has been recognized as an epidemic by the Canadian Diabetes Association in its 2005 report[2]. This report will look at the process that took this vision from concept to reality. It will also explore the experiences that each member of our group has had throughout this project.

1.1 Glossary

A/D: Analog to digital
CCD: Charged Coupled Device
DSP: Digital Signal Processing
GUI: Graphical User Interface
LCD: Liquid Crystal Display
LED: Light emitting diodes
PCB: Printed Circuit Board
TTL: Transistor-Transistor Logic

1.2 Intended Audience

This document is intended to be a description of the progress and future directions of Lumen Medical Technologies Inc. Its audience is the supervising instructors/professors and the engineers/management of Lumen Medical Technologies Inc.

2. Current State of the Device

As described in our project proposal, *gSense* is initially going to be used to detect glucose in a solution. In the proof of concept prototype stage we wanted to be able to use RF spectroscopy to measure and compare different levels of glucose in a solution. A system block diagram is shown in Figure 1. The block diagram illustrates the process that we have used to measure glucose levels.

[2] Canadian Diabetes Association, Diabetes Report, 2005.
Available: http://www.diabetes.ca/files/diabetesreport2005/CDA-diabetesreport-2005-en.pdf

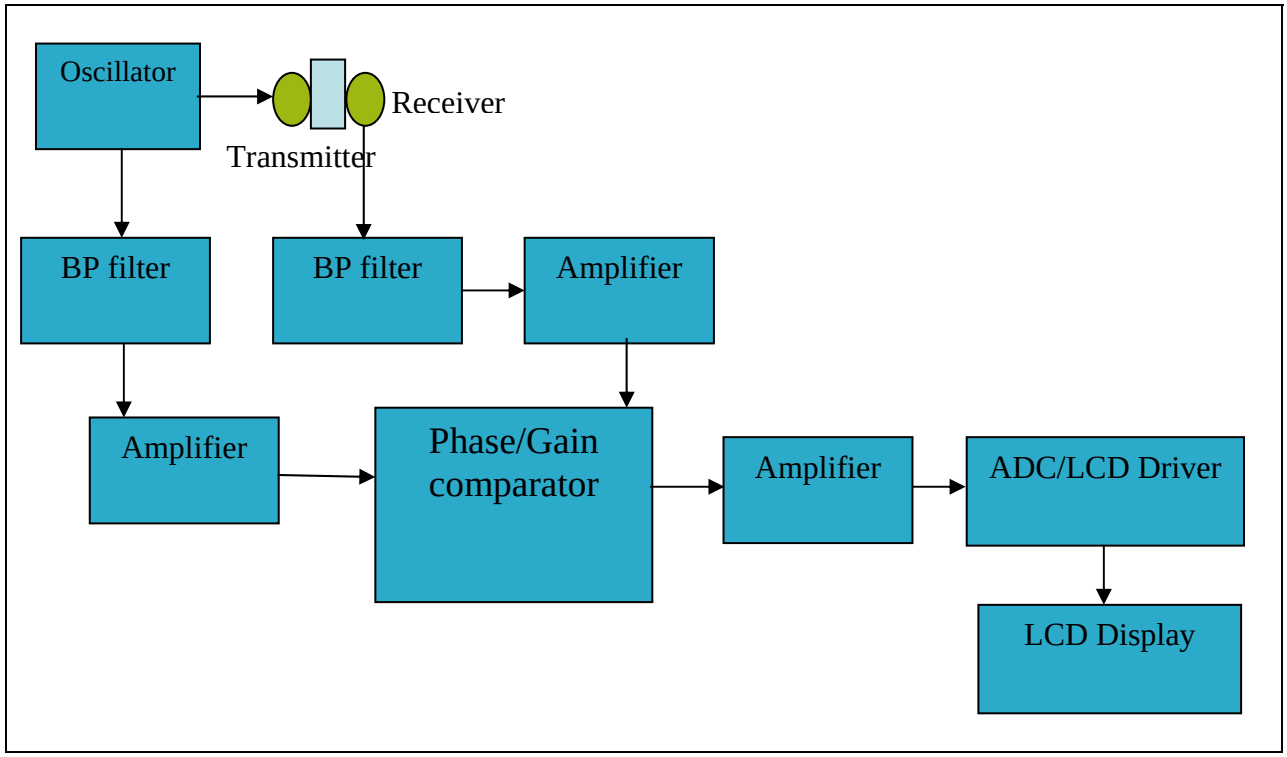

Figure 1 - System Block Diagram

This system description of *gSense* shows that it is divided into a variety of subsystems. We will discuss the current state of each subsystem.

gSense currently uses a clock oscillator to generate a square wave signal. This signal is split and transmitted to two separate paths, a reference and a sample path. The clock oscillator does not provide a good enough signal for our purpose. We needed a sharp square to provide a nice comb spectrum, the square is too round and does not provide a wide enough spectrum. With a more narrow spectrum, we do not need the BP filter to narrow the signal more, thus currently the BP filter is not employed. The BP filter also does not have the proper parameters with regards to bandwidth and center frequency required in the design specification.

Instead we used a non-inverting Buffer /Amplifier is used to reduce loading on the oscillator.

The Phase/Gain Comparator is single chip that is able to compare two oscillating signals from DC to 2.7 Ghz and determine differences in amplitude and phase between them. It produces a DC voltage output for each measure of phase and gain.

Initially it was thought that we would need an interstage amplifier between the Phase/Gain comparator and the ADC/LCD Driver, but that is not the case. The Phase/Gain Comparator is able to output 0-1.8V and the ADC is set up with a 0-2V range, so they are nearly perfectly matched.

The other functions of the ADC such as displaying a low battery voltage condition, and continuity of the probe circuit are also working properly.

Currently *gSense* requires more than one power source to function properly. Actually it requires a ±5V and a 9V battery. The battery is required because the ADC/LCD driver requires a differential input, we used one of the inputs grounded, and had to float the power to the ADC/LCD driver with a battery to display an output.

3. Deviation from Design Specification

3.1 Elimination of BP filters

The bandwidth of the signal generated by the TTL 30MHz clock oscillator is 35 KHz. On the other hand, the bandwidth of our 3rd order Chebychev band-pass filter was bigger than the signal so noise will still be present after passing through the band-pass filter. To achieve a 35 KHz bandwidth, we need capacitors at the scale of femtofarad, which we currently do not have access to.

Furthermore, the purpose of the band-pass filter was to filter out the noise and the other frequencies that are brought by the bones, skins and materials other than the blood when we are doing the non-invasive glucose measurement. In our stage of design, we test the device with pure glucose solution; therefore, there is no need to have the band-pass filter.

3.2 Elimination of amplifier with gain of 3

During the design state, the purpose of the amplifiers is to amplify the signal so the there will be sufficient amount of signal to let the LCD display values properly. However, during assembly of each part, we realized that without amplification we still have a good signal for LCD to display. Finally we decided the take out the amplifier with gain of 3 to reduce the cost of the final product.

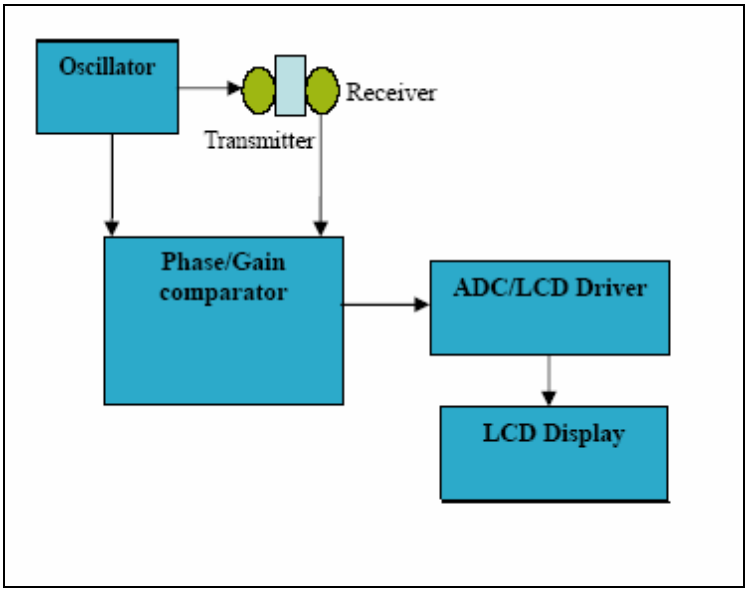

Figure 2 - The new deviated system overview

4. Future Expansion

The *gSense* is a great innovation and most definitely should be developed further. The desired improvements to the proof of concept (current) design which will be first steps into prototyping stage are listed below:

4.1 Overall System

- *Circuitry* – one of the first improvements that have to be done to the current design is to replace the development board that we have used to solder our components to with a printed circuit board (PCB). This modification will improve the quality of our system in terms of reliability and signal generation and acquisition.
- *Packaging* – the current device is a proof concept and has completely no external protection. One of the ways to protect our device is to enclose it in a plastic case.
- *Portability* – currently our proof of concept device is using a 9V battery and power supply for operation. The next step of design improvement will be to completely convert it to be battery powered. This will create a completely portable device.
- *Usability and interface* – at the current stage the devise operation is limited and it constantly taking measurements. One of the solutions would be to integrate a switch that would activate the measurement procedure.

4.2 Data Acquisition

- O*scillator* - the oscillator that we have chosen for our proof of concept design did not fully meet our requirements. So one of the main changes to the design has to be creating a signal generation unit.
- *Measurement probes* – another step towards the final design is the change of the wire probes to measurement pads. In the current proof of concept model we have used pair of wires to analyze the solution. The design should be modified to use of a two conductive low resistance pads which will be part of the PCB. This change will eliminate long wire which introduce unnecessary noise and will make the design smaller.

4.3 Data Processing

- *Microcontroller* – one of the important changes to our current design should be additional processing unit between phase gain comparator and display. With the microcontroller we would be able to process the received signal easier and to present glucose concentration in a standard format that is used in current devices.

5. Budgetary and Time Constraints

5.1 Budgetary Constraints

The expensive costs of lasers completed precluded any attempt to use Raman Spectroscopy or the other optical measurements we had hoped to employ using the human eye as a medium. During our research, we found that the price of suitable components could be very high and easily cost several thousand. Although many labs across campus may have had suitable lasers, their high cost would outright restrict our ability to "borrow" one, and fear of misuse or equipment damage would limit our access (and desire to freely access) available lasers. This also nearly halved our budgetary estimates. Most of the "sensory" components (see table below) now belong as part of the "Electronics" section (since there were effectively RF technologies), making that section of our budget no longer applicable.

We experienced a number of unexpected cost overruns with our IC purchases – caused mainly by ordering chips that weren't high-frequency enough to do our desired spectrum, and even prototyping boards that weren't high-frequency enough not to cause their own interference. Fortunately for us, our chemical supplies proved a great deal cheaper than expected, mostly because we were able to buy most of our lab equipment from SFU Science Stores at a great deal less than internet-quoted prices.

We did, however, have to compromise a bit with our glucose source. Ideally it would have consisted exclusively of pure glucose and high-purity water. This would have cost between $30-

50. Instead we used an “instant glucose” solution containing relatively high purity (33%) glucose, intended to be administered to diabetic patients experiencing a diabetic shock.

Overall, we still managed to remain within our modified budget, but only “just”, and only because we were able to save money in other departments in order to mitigate our cost overruns.

Table 1 - Budget Breakdown

Category	Description	Original Estimate	Amount Spent
Development Kits	(borrowed)	$ 0.00	$ 0.00
Electronics	Prototype/testing requirements: General chips/PCB components (including LED/LCD’s, etc)	$ 300.00	$368.00
Sensory	Radio Frequency/Visual Light/IR transmission and sensory equipment and devices	$ 300.00	N/A
Misc.	- Glassware - Chemistry Regents/Solutions - Misc. Testing Supplies	$ 70.00	$ 20.00
Administrative	Postage/Mailing in applications/Printing costs/Business cards/Misc. small marketing	$ 30.00	$ 0.00
Total		**$800.00**	**$388.00**

5.2 Time Constraints

Immediately setting up a website, mailing list, and so on proved a great way of improving efficiency. The website provided a convenient centralized place to store files, such as various draft versions of documents, emails and so on. Although the forum wasn’t used much, the convenience of the mailing list made mass emails to team members far easier. Overall, the infrastructure investment paid off in terms of simplifying organization. While this did not directly reduce development time, it did increase the efficiency of which deliverables could be handled, and improved the organization and communication of the group as a whole.

Generally speaking, we kept to our posted timeline (the original Gantt chart is shown below). Some items (such as the Company website) were done largely in advance. Most of them, especially where deliverables are concerned were kept stringently. It was mostly the project prototype itself that proved greatly more “last minute” than desirable. The chart should perhaps have been revised to enforce an earlier date for “prototype completion”, or broken the prototype development into sub-phases.

There were a number of areas of the prototype we could have improved upon had it been designed earlier – such as more research into the exact frequency bands and signal strengths, the ratio of volume to glucose when the probes were connected to different amounts, and so on. We were partly constrained by the bandwidth of our initial design – more development and testing time would have improved on all of these, and ideally gotten us a more advanced prototype.

We really should have tried more aggressively to order, assemble and build the demo unit earlier on. It would have greatly saved "last minute" difficulties, stress, and problems. We were one of the first groups to demo – this was partly a constraint brought about by our final exams (we didn't want to risk having prototype development time and final exam study time conflict to the mutual detriment of both). Still, it would have been nice if we could have had a "pre-demo" earlier on. Overall, considering our time constraints, we feel we did a fairly good job of adhering to all of them.

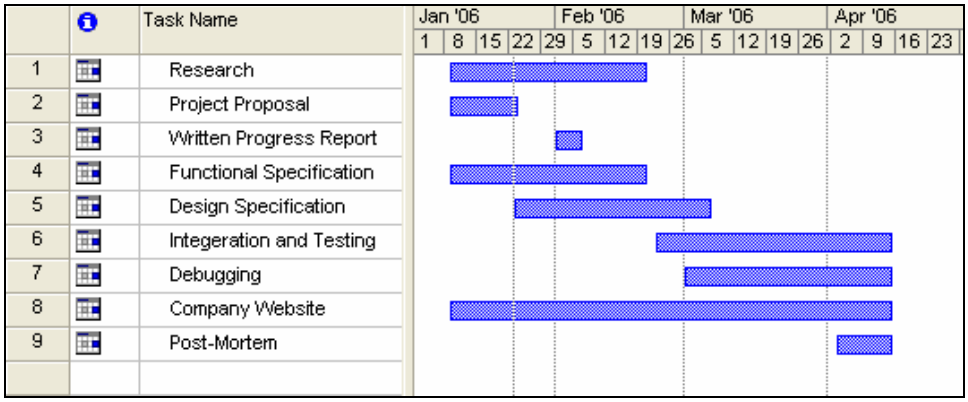

Figure 3 – Original Gantt chart

6. Group Dynamics and Personal Experience

Mehdi Abdollahi

My personal experience with this course was both pleasant and stressful. I did learn a lot about how a project evolves, most likely into something unanticipated. The rather large size of our team presented various communicational and organizational challenges. I however do think that we, as a team, maintained our team cohesion throughout the project even though there were points where we experienced friction within our group. I wanted to be the team leader from the beginning because I was planning to apply for an MBA program in Technology Management. This will most likely happen after I have gained some experience in the work force.

From a technical point of view, I learned a lot about designing analog systems for high frequency operations. I worked with clock oscillators and operational amplifiers. I also learned a thing or two about human physiology. Something that posed an ethical quandary for me was the fact that

through out the project, I had to look at people who are suffering from an incurable disease as opportunities to make money.

The one thing I would suggest to improve the quality of this course is to make the course a bit more structured. I think there should be feasible targets that each group should meet at specific times. These should be demonstration of components and not just a progress report. I also think the length of the course doesn't permit a meaningful product at the end. I personally experienced that a lot of time was spent on the documentation and not on the actual project. I understand the importance of having quality technical documents. That is why I think we needed some time that we can focus solely on the project itself after all the documentation is done.

Deema Annyuk

Every project is one of a kind experience and this one was no different. I am person that is always positive looking on things and trying to get most of good things and learn and move on when encountering problems. So when working in a group on this project I have tried to learn and to get valuable experience.

As a student who has being in the engineering for almost 5 years I have hear and seen others talking and working on the scary ensc project and often a thought crossed my mind that it will be different for me but I was not realistic. It didn't help that I was on my international coop semester before and didn't get back till first week of classes. But nevertheless I was able to find a group to join. Surprisingly we had a very promising start with healthy group discussions and work planning but unfortunately the schoolwork and personal responsibilities always were getting in the way and putting project quite often into lower priority.

Overall I am happy about the group work in terms of choice of the project, planning and documentation preparation. The group had weekly meetings (sometimes twice a week) to discus the state of the project, and to update everyone else of what is going on.

One of the things that I have learned from this project is - write everything down on paper and don't think that you will figure it out later because when the time will come you will not have time and there are always other things to do (final exams) or you simply forget. Also start implementation earlier. I tend to forget that I am still learning and the first design does not work exactly as desired it always needs to be tweaked or changed. That is when you need extra time and maybe by having second semester would be a good idea. Than you don't need to worry about the paper work but concentrate on the implementation.

Jeff Chen

Technically, while tangling with amplifiers to achieve gain of 3 at 30 MHz, there are two things that I learnt. First, it was the chose of amplifier. Initially, because I didn't read the data sheet carefully enough, so I picked an amplifier with insufficient gain-bandwidth product. Therefore, I have to pick another amplifier, which is waste time and funds. Secondly, I learned that the breadboard is only good for frequency below 10MHz after struggling for 1 week.

Other than the technical lessons, I understand the importance of teamwork. Doing a project course is definitely different than doing a lab for a course. Each person must play major role in the team to achieve success. Secondly, the importance of time management, we should schedule everything a head a little for any unpredicted incident. For example, the mis-ordering of parts delayed my schedule, along with team schedule, for approximately 4 days. Most important thing that I learned is that ALWAYS consult with expert when problems occurs and not to be too stubborn for a particular problem. Before knowing the breadboard is only good till 10MHz, I struggled with it for a week, tried various circuits, various set of resistors.

Finally, it's my pleasure to work with my team members. I have learned a lot from them so I must thank them all.

Connor Gillan

Over the course of this semester I have continued the juggling act of school and reality. The demands for this course are quite intense, and not to be taken lightly. I have a habit of registering rather late, and this semester was no different, and so I did not get into a group until the last minute. As Steve always sends out in an e-mail just before the start of classes, "…You are already behind." he speaks the truth. I would have liked to have gotten an earlier start on the project as a whole, I think this would have helped reduce the number of last minute editing changes to each assignment, and given us the opportunity to produce a much nicer and more polished product.

I am very happy about our choice of project, and our research into the possibilities available for the monitoring of diabetes. In creating a successful venture, you need to identify what the market is, and what your possible design directions are. I think we did really well in these initial planning stages and if we were participating in a project management/proposal course we would have done amazingly well. The only problem was that we still needed to actually come up with something to demo.

We did not order our required parts or even start building anything until the last 2 weeks of the semester. As I said in our Q&A session, no matter what you try and do, there will always be problems with building your product. I rebuilt each section that I was working on at least 3 times to ensure that everything is connected properly.

We had a lot of things that we wanted to do, but again ran out of time. We wanted to do a large amount of characterization with respect to the various solutions of glucose that we were using, also we had looked into trying to miniaturize *gSense*, have boards built and ideally power the system by battery. I think that if this course were longer, 2 semesters for example we would have been able to complete many of these secondary goals.

I ended up editing almost all the documents at some stage of their development. Why is it so hard for people to put 2 spaces after a sentence..

Graham Laverty

I learned a number of things during the course of this project. One of them was that the "extra work" required by "good organisation" paid off quite rapidly when applied to a multi-person project. By this we mean not just in terms of documentation, but also in terms of communications and delegating specific responsibilities to specific group members. That in particular was an issue we had earlier on – it wasn't always easy to sub-delegate specific tasks to specific members, especially when not all of them were able to attend all meetings. In terms of documentation, we could delegate subsections of the documentation to team members, then have the sections merged cohesively, then edited by the group as a whole until the final draft was ready (the website aided considerably in the preparation and dissemination of drafts). However breaking apart responsibilities of circuit design, for example, is a great deal harder especially when not all group members are completely versed in the operation of the circuit design as a whole. Generally "in person" meetings were more efficient since not all group members tended to read emails with the same level of care and generally it was much easier to discuss and assign responsibilities in person.

It was interesting being able to apply my chemistry knowledge towards the project – since I usually apply more coding and design skills; it was interesting literally mixing chemicals for the project. I found sourcing some of the components very stressful initially – locating suitable sources of glucose (not exactly something a grocery store or even a health food store would stock). Even locating suitable receptacles was a nontrivial task that involved visiting as many stores as possible looking for suitable supplies. Eventually I was able to locate all of them, but it was very different from the usually more academic exercises I perform on a daily basis at SFU.

Overall the project has been a great learning experience, a more practical "hands-on" experience even than most labs since a great deal more flexibility, which meant generally a lot more "figuring out new things as a group", then applying it than is typically with more structure academic courses. It was also an interesting learning experience in terms of group dynamics.

Tony Tsai

I found the project to be really interesting except for the part of communication. We did have lots of problems in communication in the beginning. Such as conflicts in ideas and schedules, however, everything seems to work out in the end. It is just that we need to spend more time working with each others. What I learn from this project the most is the general idea of how a project is build up from an initial idea to the actual circuits. My task is to set up an oscillator that generates a 30MHz square wave. After measuring the part, serious overshoot was observed, and we did not get a good looking square wave. During this process of solving this problem, I have communicated with the group members, ECS technician and TAs. The technician Dan Kelly from ECS tried to solve the problem through email. We sent each other more than 20 e-mails. I was a little bit frustrated since it took so long to find out that the problem was caused by the capacitance of the long cable of the oscilloscope probe we use in Lab 1. The loading capacitance is so big so that we are unable to observe a perfect square wave. However, meanwhile, the group members, ECS technician, TAs are all willing to discuss the problems with me. I am glad to have the opportunity to work with those talented people who are specialized in hardware design and technical writings.

