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neoSpectra
Technologies Incorporated

May 3, 2007

Mr. Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

RE: ENSC 440 ChromaTap Project Post-Mortem

Dear Mr. One:

The attached document, *The ChromaTap Project Post-Mortem*, outlines the process which our company went through to complete our deliverables for ENSC 440. As you are aware, development of the ChromaTap product is on-going, and we are on schedule with the timeline and objectives outlined in *The ChromaTap Project Proposal*.

This post-mortem will describe the current state of the device, and what further work needs to be done in the coming months to deliver a functionally solid and marketable product. As you know, the ChromaTap is a solution for hot water safety which will light the flow of water different intensities of red for hot, and blue for cold, giving the user a visual indicator of water temperature. The ChromaTap will be available in both faucet add-on and showerhead replacement versions, and this post-mortem discusses the state of both prototype models. Additionally, we evaluate the accuracy of our budget and project planning, and describe our individual experiences relating to the project.

NeoSpectra Technologies is made up of four savvy students. Scott Chen, Jacky Cheng, Derek Pang, and Jim Wang will be doing the product development as part of ENSC 440. William Ng, although not currently enrolled in ENSC 440, has been a cofounder of NeoSpectra, and he is valuable source for market and technical consultation.

If you have any questions or concerns, please feel free to contact me personally at 604-306-9511, or the group by e-mail at ensc440-neospectra-tech@sfu.ca.

Sincerely,

Derek Pang

Derek Pang
Project Lead
NeoSpectra Technologies Inc.

Enclosure: The ChromaTap Project Post-Mortem

neoSpectra
Technologies Incorporated

THE CHROMATAP PROJECT POST-MORTEM

So Simply Vibrant, Vibrantly Simple.

[The ChromaTap Project Post Mortem]

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Submitted to
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Issue Date
May 3, 2007

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GLOSSARY

BJT Bipolar Junction Transistor. A three-terminal (base, collector, emitter) device constructed of doped semiconductor material used in amplifying or switching applications.

LED Light Emitting Diode. A low power, high intensity light hailed primarily for its longevity and low cost, and also for the simplicity of its implementation in circuits.

mAh Milliampere-hour. A unit of electric charge. One milliampere-hour is equal to 3.6 coulombs, and is the amount of electric charge transferred by a steady current of one ampere for one hour.

NTC Negative Temperature Coefficient. A NTC thermistor has its resistance inversely proportional to the temperature it is subject to.

Op-Amp Operational amplifier. DC-coupled high-gain voltage amplifier with differential inputs and a single output.

REP Rated Electric Power.

SMD Surface Mount Device. A standard acronym for a surface mount package.

SMT Surface Mount Technology. A manufacturing technique in which components that are designed for mounting on the surface of a substrate or PC board are used.

Solidworks A powerful software package allowing users of CAD (Computer Aided Design) and other tools used to develop products.

Zero-Point From the ChromaTap functional specification, the zero-point of ChromaTap means both red and blue LEDs are OFF at the room temperature of 25°

Executive Summary

Household safety is a growing concern for parents with young children in their care. Thousands of children are injured in the home each year, and the most common injuries among children are burns and scalds. In particular, hot water is a common hazard because it is easily accessible by children, who can suffer serious scalds from as little as one second of contact.

The ChromaTap is an easy to use and affordable solution to the problem of hot water burns in the home. It will address this problem both at the sink and in the shower, by lighting the water stream different intensities of red for hot and blue for cold. This provides a reasonable visual indication of water temperature for the user without compromising the availability of hot water, or requiring costly installation like the other current solutions available.

Over the past four months, we have evaluated different design solutions for the ChromaTap (both faucet and shower versions) for engineering merit and commercial potential, focusing on the categories of size, power, reliability, safety, cost, and ease of use. Through this process, we eliminated solar power as a feasible design solution, focusing instead on water and battery power.

The project is divided into two major phases: Increment 1 and Increment 2. In Increment 1, three different prototypes of the NeoSpectra ChromaTap- powered by battery, solar panel, and water turbine – were planned to be constructed and tested by April 2007. In reality, the solar panel prototype was dropped because of feasibility issues, which we will discuss. The other two prototypes were modularized, and the proof of concept was completed on time. Increment 2 involves mechanical and miscellaneous feature improvements on the prototype, and revisions to the mechanical and electrical design with the ultimate goal of commercializing of the ChromaTap.

This post-mortem document will describe the current state of the device, as well as what further work needs to be done in the coming months as part of Increments 2 and 3. Further, we will examine the accuracy of our budget and project planning, and describe our individual project experiences.

Section 1. Introduction

The NeoSpectra ChromaTap is an innovative faucet add-on which gives users a visual indicator of water temperature, thus reducing the incidence and probability of hot water related injuries, as well as providing novelty value. It achieves this goal by implementing an internal water temperature sensor and providing an instant visual feedback to the user by lighting the water up with continuous red-blue bi-color spectra, where red represents temperature higher than room temperature, and blue represents below room temperature. In addition, the intensity of the light is designed to reflect the magnitude of water temperature deviation from the room temperature. A shower version, which is a showerhead replacement providing similar temperature visual indication to the faucet version, is also planned.

While being a stylish household decoration, the ChromaTap is also an educational device for underage users, and a safe-guard device for seniors. It is a compact, and simple attachment, which works with all water taps, and is intended to be safe, affordable, and easy to use and install.

This document describes the results of our four month project, detailing the current state of the prototypes, the design challenges we encountered (most notably our choice to drop the solar powered variant), the accuracy of our budget and project planning, and our interpersonal experiences. Most importantly, we examine the future work that needs to be done in the coming months to make the ChromaTap a marketable commercial product.

Section 2. Current State of the Device

2.1 System Overview

The ChromaTap prototypes we produced adhere to the system architecture diagram shown in Figure 2.1 below, with the added twist of modularization.

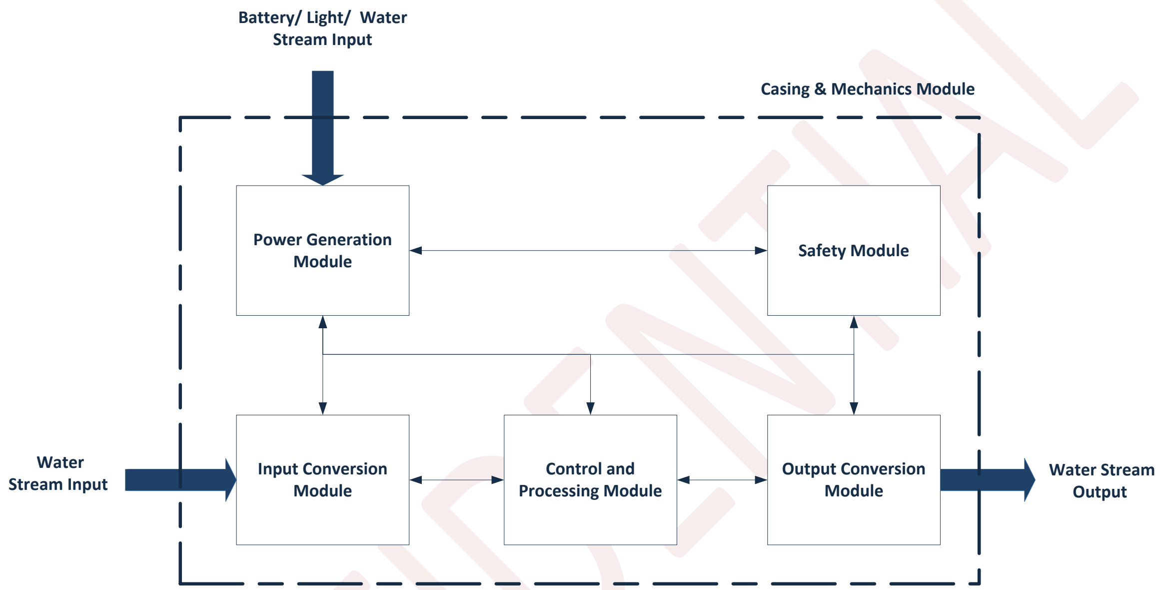

Figure 2.1 : ChromaTap System Architecture Overview

Modularizing our system was very effective because it meant we only needed to produce a single control circuit unit, and could use it with different light output and power input modules. The interface diagram for our selected modularization scheme is shown in Figure 2.2.

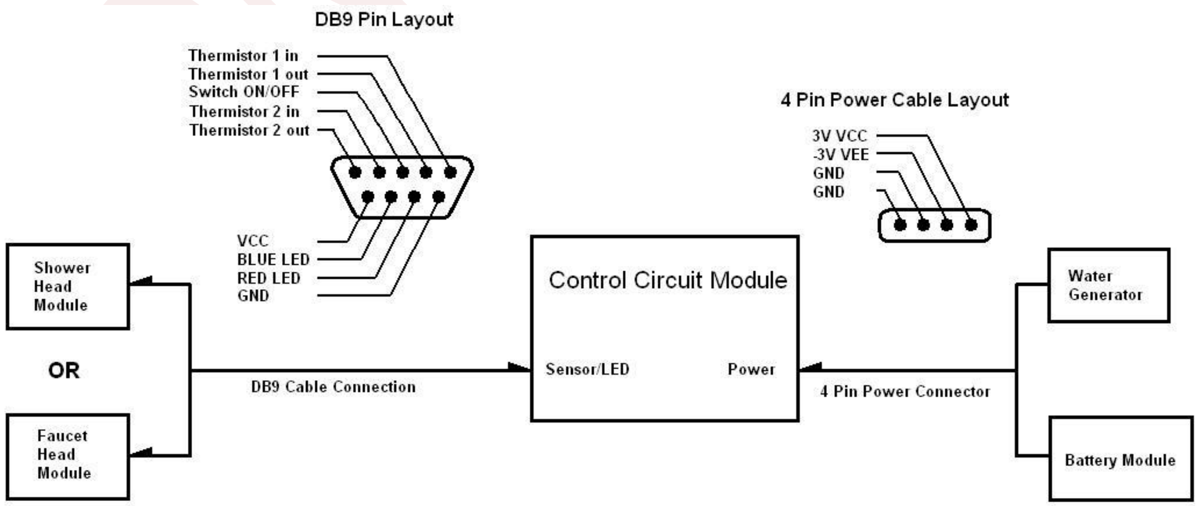

Figure 2.2 : ChromaTap Modularization Diagram

Aside from the benefit of only having a single control module for multiple prototypes, modularization with standardized connections allowed us to develop separate modules concurrently without worrying about whether or not they would work together (similar to software abstraction). This allowed effective individual work and accommodated busy schedules.

2.2 Design Details

As proposed at the beginning of the project, the ChromaTap is designed as an open-loop system with which the water temperature is sampled in real-time, processed, and outputted as LED colour indications into the water stream. The conceptual block diagram of the ChromaTap control system is shown in Figure 2.3.

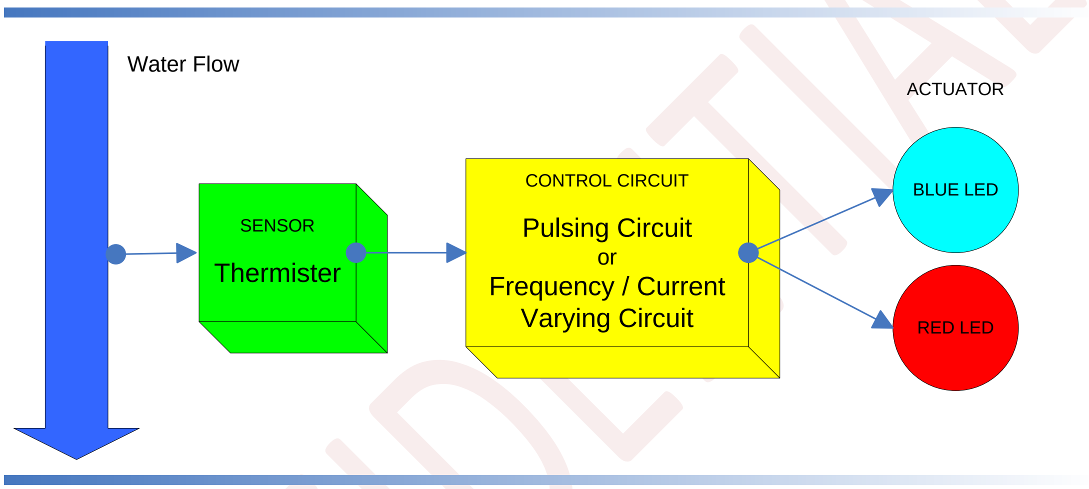

Figure 2.3 : The ChromaTap Control Circuit Block Diagram

The final implementation of the overall control system shown in Figure 2.3 creates a full output color spectrum with respect to water temperature as shown in Figure 2.4.

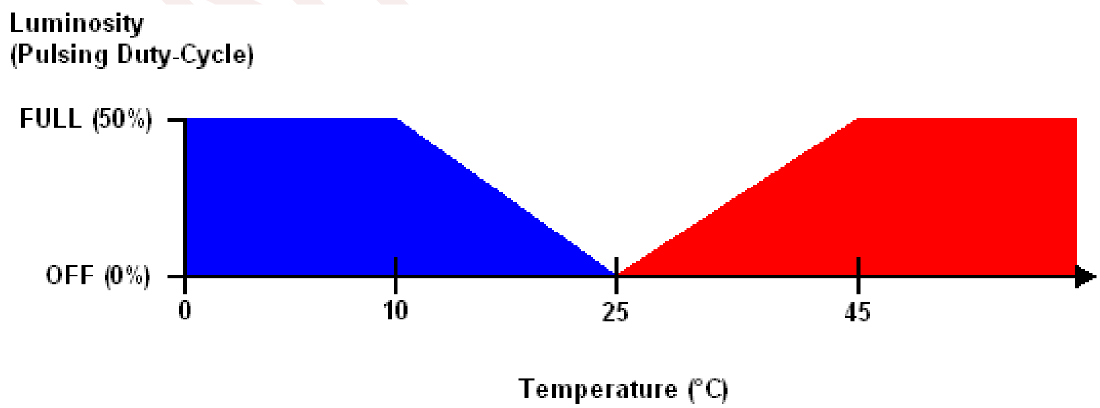

Figure 2.4 : The ChromaTap Output Color Spectrum

The control system is powered by the power supply circuit, of which the conceptual block diagram is presented in Figure 2.5. The voltage regulating circuit guarantees a stable V_{CC} / V_{EE} can be delivered to the control circuit despite the voltage fluctuation at the power source.

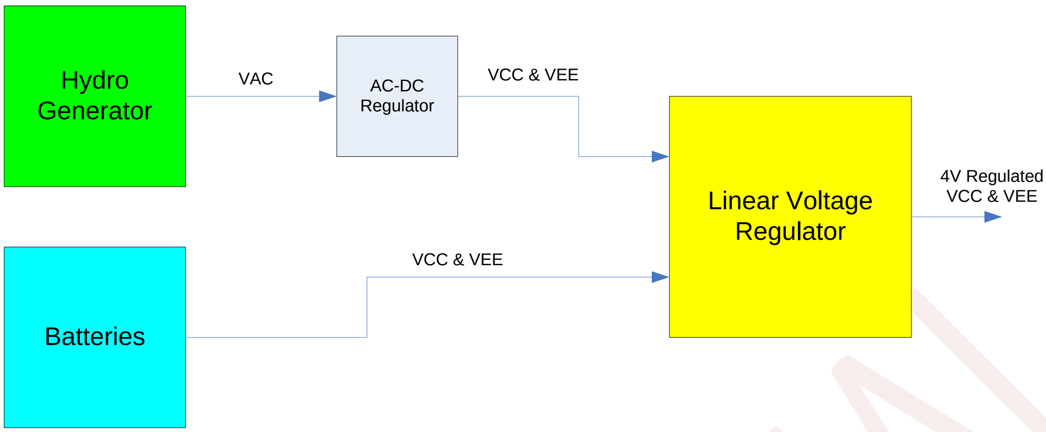

Figure 2.5 : The ChromaTap Power Supply Block Diagram

2.3 Sensor Circuit

The sensor circuit consists of two simple voltage dividing networks as shown in Figure 2.6. Each of the networks is made up of one through-hole resistor and one 0805 SMD 10 kΩ thermistor, and the nodal voltage between the resistor and the thermistor will vary according to the temperature the thermisor is exposed to. The SMD package is smaller in size and is more sensitive to temperature change and is thus preferred over through-hole packages for optimal thermal response time.

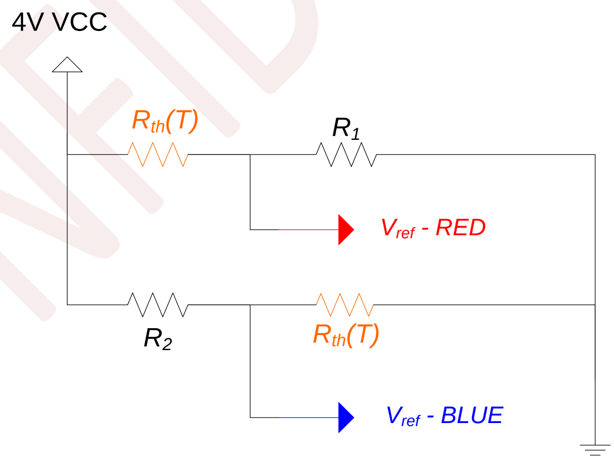

Figure 2.6 : Sensor Circuit Schematic

The mathematical model of the thermistors used in our design is empirically determined to be Eq. 1, with which we obtained the theoretical nodal voltage as a function of temperature, as shown in Figures 2.7 and Figure 2.8.

$$R_{TH} = 378.19x^{-1.1404} \text{ (k}\Omega\text{)} \qquad \text{Eq. 1}$$

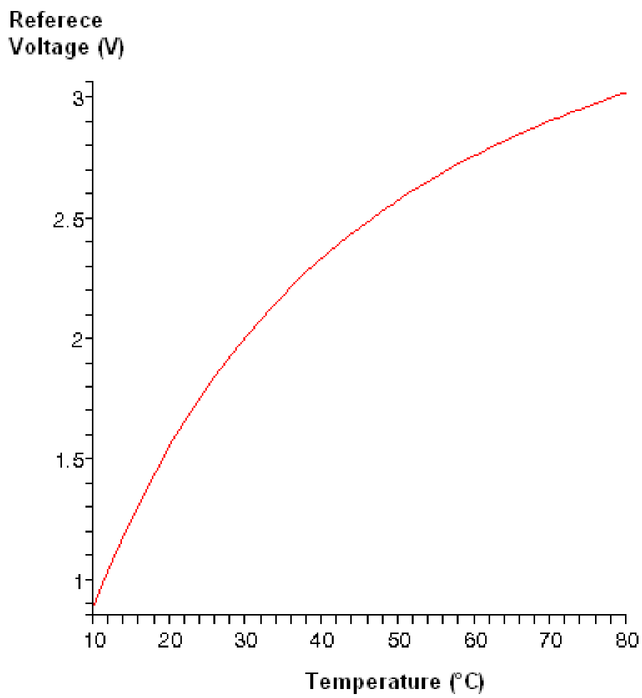

Figure 2.7 : Red LED Reference Voltage Curve

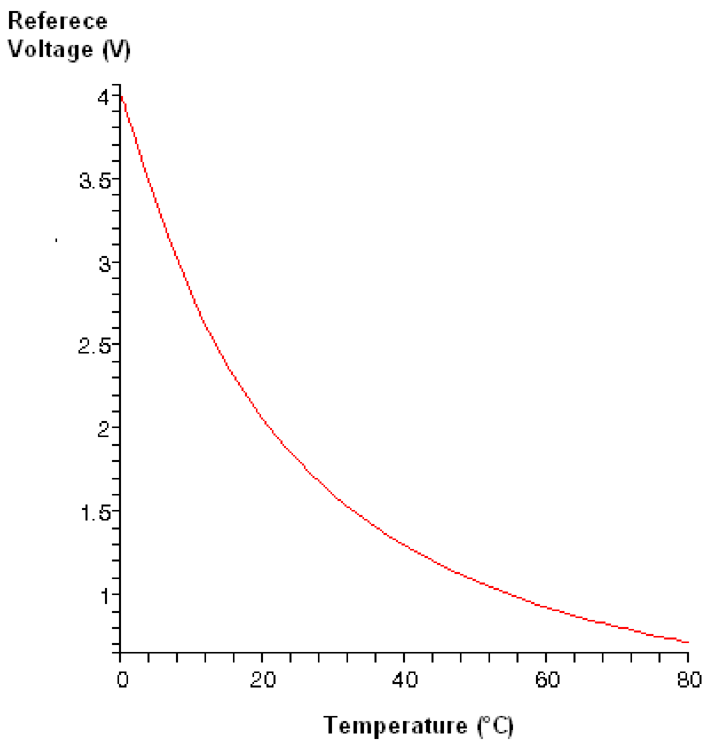

Figure 2.8 : Blue LED Reference Voltage Curve

The two reference voltages are then fed into the control circuit for voltage comparison, and ultimately determine when the LEDs should be turned on. The increasing curve in Figure 3 is used as the control voltage for the red LED, and the decreasing curve for the blue. The two fixed resistors, R1 and R2, in the sensor networks are carefully selected to be 7.9 kΩ and 11.7 kΩ respectively, such that both reference voltages would be "zeroed" at 1.80V when the exposed temperature is at 25°C. This setup, which will be further discussed in the next section, ensures that no LEDs will be turned on when the temperature of the water stream is at room temperature.

2.4 Control Circuit

The control circuit consists of two main parts: the Bi-stable Multi-vibrator and the Comparators, as shown in Figure 2.9.

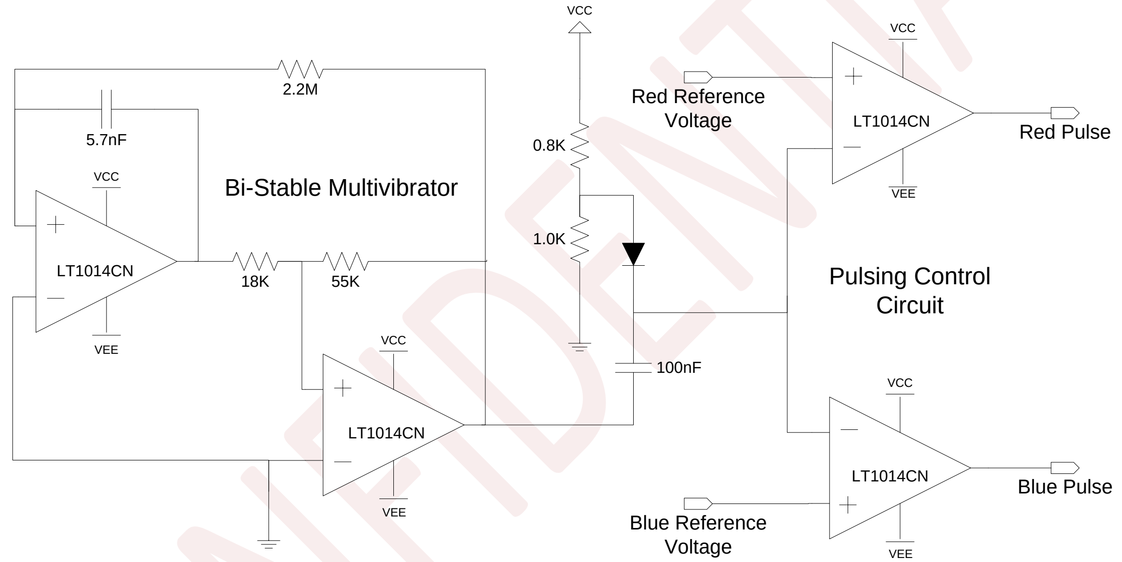

Figure 2.9 : Control Circuit Schematics

The bi-stable multi-vibrator generates a triangular wave at the output terminal with a peak-peak voltage of 1.65V. The wave is clamped up by 1.83V before getting fed into the negative ports of the comparator circuit.

The comparator circuit takes in the two reference voltages from the sensor network, and compares them against the triangular wave. When the reference voltage overlaps the triangular wave, the overlapped region is the *Duty Cycle* of the output waveform. The mechanism of the control circuit is graphically illustrated in Figure 2.10.

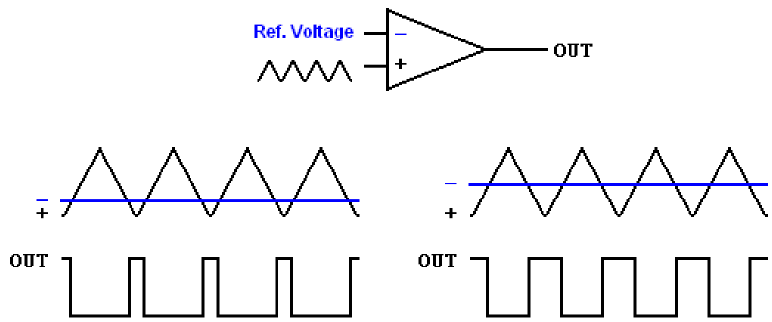

Figure 2.10 : The ChromaTap Control Circuit Mechanism

As a result, when the water temperature is higher than 25° C, the reference voltage for the red LED overlaps the triangular waveform, thereby causing the red LED to be turned on. The higher the temperature, the higher the reference voltage, therefore the higher pulsing duty cycle and the brighter the red LED. The blue LED control network works exactly the opposite way – higher pulsing duty cycle when the temperature is lower. At the approximate range of 24° C to 26° C, neither LEDs would be turned on since both reference voltages are not overlapping the waveform, thus giving the user a clear indication that the water is at room temperature, and is safe to use.

Physically, the control circuit is implemented with the LT1014CN low-power Quad Op Amp chip for improved power conservation. The measured power consumption of the control circuit itself is approximately 810uW at full chip resource utilization. This power consumption rate guarantees that virtually all of the power delivered to the ChromaTap system is consumed by the LEDs for maximum luminosity.

2.5 Actuator Circuit

The actuator circuit consists of two simple LED networks. For the current prototype ChromaTap prototype design, the 10mA high efficiency through-hole packaged LEDs are used for easier installation and optimal luminosity efficiency. The actuator circuit schematics are shown in Figure 2.11, where the two 330Ω resistors are used to limit the current flowing through the LEDs.

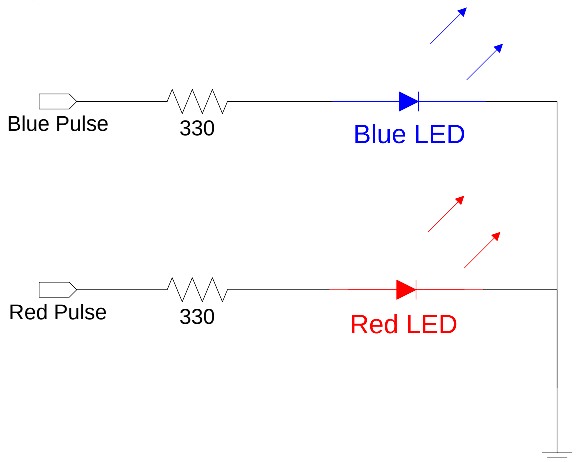

Figure 2.11 : The ChromaTap Control Circuit Mechanism

The ChromaTap prototype offers two different actuator modules: the Faucet Head and the Shower Head. The faucet head module is designed to be attached on to the regular water sink tap, allowing users to enjoy the ChromaTap when using a sink. The shower head module is designed to replace a regular shower head entirely.

2.6 Linear Power Regulation Circuit and Switching Circuit

The ChromaTap control system operates under a voltage of +4V V_{CC} and -4V V_{EE}. The symmetric voltage supply is mandatory since the bi-stable multi-vibrator requires a symmetric voltage for proper operation. To ensure that a stable V_{CC} and V_{EE} are being fed to the control system, the power line from the power source is designed to go through the linear power regulation circuit as shown in Figure 2.12.

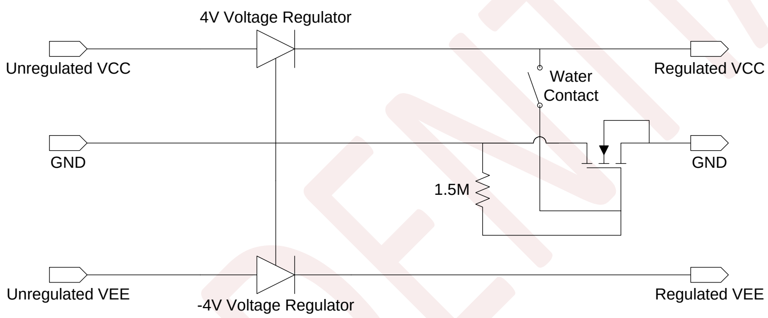

Figure 2.12 : The ChromaTap Control Circuit Mechanism

Both of the voltage regulators have very low drop-out voltage of 0.3V, and can regulate the output voltage at 4V / -4V within 5% tolerance. The output voltage remains highly stable even when the input fluctuates.

In addition to the voltage regulators, a water-flow-triggered MOS switching circuit is also included in Figure 2.12. The gate of the MOSFET is pulled to ground when the water pads are not being shorted by water, and the ground line fed to the ChromaTap control system is open. When the water runs through the ChromaTap, the two water pads are being shorted by an average water resistance of 1MΩ (varies significantly with respect to mineral concentration and water aeration ratio), and the gate voltage is pulled up to V_{CC}, causing a virtual short between the power source ground and the system ground, thereby completing the power supply loop. As soon as the loop is completed, the ChromaTap will start functioning.

2.7 Current Power Solutions

The current power supply solutions for the ChromaTap are the Battery Solution and the hydro generator solution (now referred to as the WaterGen). Each of the solutions has its own advantages and disadvantages, and is suitable for specific applications.

Battery

The battery solution is the simplest power supply solution in terms of circuitry design. As shown in Figure 2.13 , the batteries are directly connected in series to provide +4.5V and -4.5V voltage supplies, both of which are then regulated down to V_{CC} and V_{EE} through the power regulation circuit. The battery interconnections are done easily through a user-friendly battery holder for convenient battery insertion and removal.

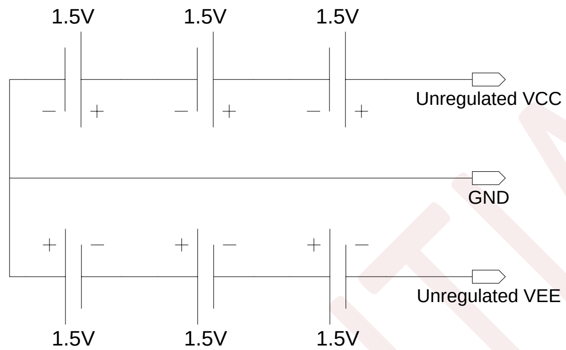

Figure 2.13 : The ChromaTap Control Circuit Mechanism

The battery module has a relatively lower manufacturing cost, and is more space-conserving compared to the WaterGen solution. Nonetheless, users will need to replace the battery every 3 months on average. This minor inconvenience is inevitable when ChromaTap is installed on a bathroom sink tap. As we will discuss in the WaterGen section, in order for the WaterGen module to generate enough power for the ChromaTap control system, users need to increase the water flow rate beyond a certain threshold level; this threshold level is very commonly used in the shower, but is not a realistic flow rate when users are using the sink tap for hand-washing.

As a result, despite the inconvenience of battery replacement, the battery power module is a highly feasible solution that allows us to use a simplified design, reduces the manufacturing cost, and provides stable and usable power regardless of the flow rate under which the ChromaTap is being used. In the prototype design, the faucet head module is powered by batteries.

Water Power Generation

The WaterGen solution consists of a miniature hydro generator and an AC-DC voltage regulation circuit. The hydro generator prototype can utilize approximately 3% of the available mechanical energy in the water stream, and provide a total power of 416mW at a water flow rate of 0.185 L/s. This flow rate is equivalent to that being used in shower. At this flow rate, the hydro generator can produce a satisfyingly stable 5VAC, which is sufficient to power the circuit.

The 5VAC being generated by the hydro generator is then fed into the AC-DC voltage regulator, with the schematic shown in Figure 2.14.

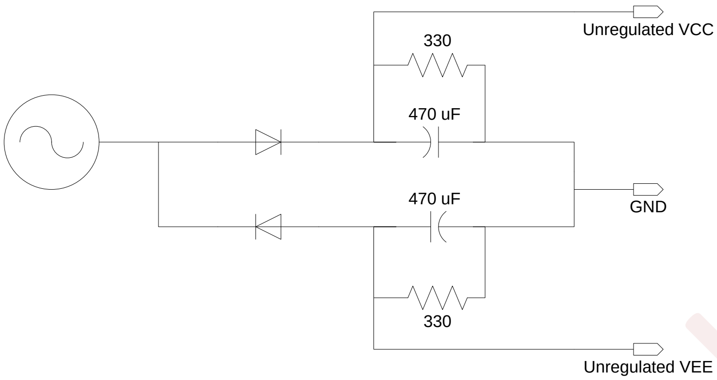

Figure 2.14 : The AC-DC Voltage Regulation Circuit

The upper half-wave rectifier is implemented to convert the positive part of the AC into V_{CC}, and the lower one is to convert the negative part of the AC into V_{EE}. With the help of the two 470uF capacitors, the V_{CC} and V_{EE} being fed into the linear power regulation circuit is relatively stable.

The WaterGen solution provides a clean, sustainable alternative to the battery solution, and eliminates the inconvenience of battery replacement. However, because a relatively high water flow rate is required for effective power generation, the WaterGen is not a suitable solution for the faucet head module. As a result, the WaterGen solution is only used to power the shower head module.

2.8 Mechanical Design

The final mechanical design is essentially unchanged from *The ChromaTap Design Specification*. The only difference is the switching circuit that only has two terminals now. Originally, the switching circuit was designed with 3 terminals to short the circuit since we have 3 different potentials: V_{CC}, V_{EE}, and GND. We later designed a better switching circuit which would save power (since water had significant resistance), and realized that we could short the circuit only using two terminals.

For the material used, we have yet to choose between Polystyrene (PS) and Polycarbonate (PC). This decision will be made in Increment 2.

Section 3. Design Challenges and Results

3.1 Control Circuit

The performance and the power consumption of the control circuit meets the proposed values of 100us throughput-delay and <1mW power dissipation. The size of the prototype control circuit, however, does not meet the one proposed in the design spec due to the fact that only through-hole components were used on the breadboard.

3.2 Actuator Circuit

The performance and the power consumption of the actuator circuit meets the proposed values of 100us throughput-delay and <30mW power dissipation. For better demo effect, however, we have increased the number of LEDs from 2 to 6, which increases the power consumption from 24mW to 72mW. Nonetheless, this temporary design change is not official, and the final implementation of the actuator module still consists of only 2 LEDs. The physical size of the two 3mm LEDs also meets the design spec.

The most important work that we have to do is to research how we can get the maximum visibility of light from the water stream, be that from a lens or by changing flow rates, turbulence, or air/water ratios. This will allow us to use only 2 LEDs and still achieve a greater effect than we currently are seeing with 6 LEDs. Positioning is also important, as the positioning of the 6 LEDs at a diagonal angle in the prototype is not favorable for the maximum effect either (although the positioning is fine in the Solidworks mechanical design).

3.3 Power Regulation Circuit and Switching Circuit

The power regulation circuit was not proposed in the design spec since we did not anticipate fluctuation of supply voltages from the hydro generator and the battery module. However, after we observed the problems, we immediately decided to include linear power regulators to improve the stability of the power supply.

The switching circuit implemented in the prototype meets all the constraints proposed in the design specification.

3.4 Power Solutions

In the functional and design specifications, we proposed three possible power solutions: battery, hydro generator, and solar panel. Each solution is required to provide at least 3V and 50mW of usable power, and is required to meet the proposed size constraints. However, the high efficiency blue LEDs being used in our actuator design required a turn-on voltage higher than 3V. As a result, we had to increase the supply voltage from 3V to 4V.

Battery Module

The final implementation of the battery module provides a VCC of 4.5V and a VEE of -4.5V. However, instead of coin-size batteries, we have used AAA batteries in the battery module simply because we would like to have an easier access to the batteries. Thus, the size of the module does not meet the one proposed in the design spec.

WaterGen Solution

The final implementation of the WaterGen solution is a miniature hydro generator accompanied by an AC-DC rectifier circuit. The performance of the WaterGen prototype meets all the requirements proposed in the design spec; the generator is capable of outputting a voltage of 5VAC and a power of 416mW. The size of the generator, however, is far from meeting the spec, mainly due to the fact that we do not have the materials and accessible manufacturing technology to miniaturize the generator into the form factor we proposed in the design spec.

Solar Panel Solution

The solar panel solution, although proposed in the design spec, was deemed not feasible in the development stage, and discarded. After several power measurements and detailed calculations, we reached the conclusion that, in order to get enough power from the solar panels, we need to construct a solar module as large as 3378 cm^2. This size is far from meeting the one proposed in the design spec, and cannot be optimized due to fundamental technology limitations. Note that our calculation is based on the fact that the environment the ChromaTap will be used in is indoors, and with indoor lighting at best (some washrooms are even darker). So despite our experimentation with different types of solar panels, we chose not to include a solar powered module in the final prototype design because solar power will not be feasible in the final production version.

Section 4. Future Plans

4.1. Design Space Optimization

As we move on to the next stage of development, we will migrate the control system from the breadboard to a multi-layered surface-mount prototype PCB board. All the components will be re-purchased in compact surface-mount package (14-pin SMD for the Op Amp and 0201 SMD for discrete components). The surface-mount design will guarantee that the control circuit can fit into a compact form factor and meet the design requirements.

4.2. Module Integration

After all the designs are re-implemented with surface-mount components, all three modules (ie. Control Module, Power Module, and Actuator Module) can be integrated according to design needs. For the faucet head ChromaTap, the battery module will be integrated with the control module to fit into the faucet head casing. For the showerhead ChromaTap, the miniaturized WaterGen module will be integrated with the control module to fit into the shower head casing.

4.3. Power Conservation

Once moving on to mass-production, we will consider purchasing an IC die that integrates our ChromaTap into a one-chip solution. The silicon IC allows our design to consume a lot less power, thereby extending the battery life of the ChromaTap. In addition, we will re-evaluate the feasibility of solar power depending on how significant the reduction on power consumption will be.

4.4. Sensor Circuit

Once we implement our design on a surface-mount PCB, the waterproof protection for the thermistor can be done through machine manufacturing processes, which provide much higher precision and quality. This achieves a water-tight seal without compromising thermistor sensitivity.

Another alternative solution we will consider is to implement high quality conductor metal strings (such as silver alloy strings) across the water tube in order to acquire instantaneous temperature readings without exposing the thermistor to water. The final solution to optimizing the sensor circuit will be evaluated based on cost, product durability, and safety factors.

4.5. Control Circuit

For now, the LT1014CN low-power op-amp utilized in the control circuit still consumes relatively high power compared to other commercialized low-power op-amps. In the future, we will perform more research on low-power op-amps in order to find an op-amp that is the most suitable for our application, or circumvent this completely with a one-chip solution.

4.6. Actuator Circuit

In the next stage of development, we will attempt to develop a simple water aeration method that increases the light refraction ratio. This way, we can effectively refract the light emitted by the LEDs out of the water stream, thereby making the water more coloured.

We would also do a more exhaustive research on the low-power, high-efficiency 3mm LEDs in order to optimize the power consumption of the actuator circuit, or once again, move to a single chip solution, which has many inherent benefits (except for R&D cost).

4.7. Power Regulation Circuit and Switching Circuit

In order to minimize the power wasted for linear voltage regulation, we will do more thorough research on the available linear voltage regulators in the market, and evaluate the tradeoff between their drop-out voltage and their power consumption rating. In the production model, we aim to find a balanced voltage regulating solution that optimizes the both power consumption rating and performance.

Although the simple switching circuit implemented in our design is highly optimized, the water contact pads need to be optimized in both their shapes and arrangement. In the final production model, we plan to implement the pads along the side of the water tube with a less water-retaining shape in order to ensure reliable switching function.

4.8. Power Supply Solutions

Battery Module

In the final production model, CR2032 or LR44 coin cell batteries will be used instead of AAA batteries in order to meet the proposed size constraints.

WaterGen Module

The WaterGen module requires a significant amount of research in order to determine the feasibility of miniaturization. In the next stage of development, we will mainly focus on developing miniature hydro generator designs that meet our proposed cost and size constraints, and evaluating the power that can be delivered by each design. If we find that WaterGen miniaturization is indeed feasible, the module will be implemented in the final showerhead version of the product.

4.9. Mechanical Design

The mechanical design will be further modified based on changes in the other modules, as well as user input. Of note is the showerhead, and what features might be added to make it a more viable complete showerhead replacement.

Section 5. Time Constraints & Budget

5.1 Budget

Table 5.1 shows the initial budget proposed for the ChromaTap Project.

Table 5.1 : Proposed Budget for the 13-week ChromaTap Capstone Project

Projected Expenses	Estimated Cost ($ CDN)
Temperature Sensors	$20
Generators	$35
Turbine fans	$25
Lighting (LED or otherwise)	$30
Solar Panels	$50
Competitor Product Analysis	$40
Sink and Shower Attachments	$40
Batteries	$10
Electronic Circuit Components/Boards	$50
Casing and Wiring	$50
Subtotal	$350
Contingency (20%)	$70
Total	$420

Our actual expenses totaled ~$385, which well within our initial project budget estimate, using about half of the contingency value set aside. Our actual cost break-down is shown below.

Table 5.2 : Actual Budget for the 13-week ChromaTap Capstone Project (Rounded)

Actual Expenses	Estimated Cost ($ CDN)
Temperature Sensors	$10
Generator	$100
Turbine fans	$5
Lighting (LED or otherwise)	$25
Solar Panels	$35
Competitor Product Analysis	$45
Sink and Shower Attachments	$10
Batteries/Misc	$20
Electronic Circuit Components/Boards	$120
Casing and Wiring	$15
Total	$385

These actual expenses reflect that the water power generation unit cost quite a bit more than we expected because making it durable and smooth running required additional specialty parts such as expensive bearings and magnets. Sampling parts for the electronic circuit design also cost quite a bit more than anticipated. Re-ordering of faulty parts was also required at some points, and these added to the expense. Balancing these cost overruns out was large savings in the sink/shower attachment and casing/wiring sections, and also the turbine fans, where we saved money by using CPU fans, and building our own from spoons. The savings in the casing/wiring and attachment departments can be attributed to cheap parts sourced from the dollar store, which is a great source for parts which can be used creatively.

Our funding came partially from the ESSEF, which assigned us $210 to complete our project. We also received significant outside funding from our participation in the Enterprize 2007 Business Plan Competition, where Jim Wang, William Ng, and Derek Pang won $8000 by placing 2nd at the British Columbia regional level and an additional $20,000 by placing 2nd at the national level.

5.2 Project Planning

Due to Enterprize, our project suffered a two week delay, as preparations were made. The original milestones are shown in Figure 5.1 below.

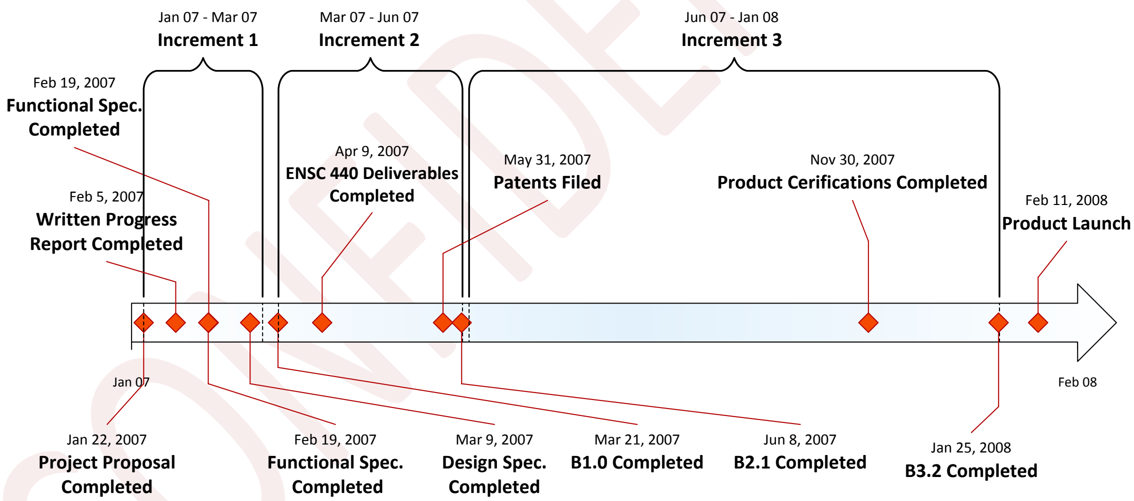

Figure 5.1 : The Major Milestones in the ChromaTap Project

Additional detail regarding our project planning can be found in the proposal, but to keep the length of this document down, the summary is that aside from the two week delay, we adhered to the schedule laid out in *The ChromaTap Project Proposal*, with the usual acceptable discrepancies of 1-2 days (accounting for the two-week delay). The time we invested in project planning was well spent as it gave us direction and objectives for the duration of the project, and it continues to prove invaluable as it guides us past Increment 2 and into Increment 3.

Section 6. Group Dynamics and Individual Reports

6.1 Group Dynamics

Guided by our planning, our group dynamics for the majority of the project were excellent. As mentioned previously, the modularization of the design was also a key factor since it allowed independent work and flexibility of working times. We helped each other out when it was needed on particular tasks, and in the end, we were able to deliver an inspiring proof of concept on time and on budget.

6.2 Derek Pang

These past four months have been stressful and time consuming, but it was all worth it in the end to see our finished prototype working, despite all the challenges we faced.

During the course of the project, we actually did a lot more research than is reflected in our deliverables, looking into different battery charging methods, wireless power generation, and other efficient methods to make the product better for the end user. I learned a lot from this process and I am especially interested in using a product with wireless power generation in the future.

I was also very involved in the water power generation unit, and enjoyed building and optimizing the unit. I felt a great sense of achievement as the results from the final revision of the unit were truly beyond my expectations. To me, that is the embodiment of this course, setting out to do something great, and then beating your own expectations. I experienced a great feeling of accomplishment when we hooked the water generation unit up to the control circuit module, and observed the ChromaTap actually working off of water power alone.

On the leadership side, I was privileged to lead a team of friends and highly skilled workers who worked very effectively as a unit. Our specialties and skills came together to create a product that we are all proud of, with everybody contributing significantly to the portions where they had the most expertise, and picking up new skills as the project went on.

6.3 Jim Wang

ENSC 440 has been a unique experience for me. Not only have I learned technical and group work skills, but also sales and marketing skills. As the presenter at the Enterprize competition for our business plan, I committed to improving my presentation and sales skills, and I feel the results we achieved reflected the effort I put into this aspect. I also came to the full realization that to be an exceptional engineer, one must have critical sales and communications skills, in order to sell ideas effectively to others.

On the technical and group side, I confirmed that nothing ever goes exactly to plan, no matter how you try to anticipate problems. Usually, when failures occur, they’re at the worst possible times. But I feel that an engineer is not defined by the mistakes he or she makes, but how he or she responds to those mistakes or unexpected failures. In this regard, I felt our team did very well, dealing with technical issues effectively and without delay. I also picked up key project management skills, such as being able to see the “big picture” while still working on minute technical details, a skill related to my involvement with the business case.

A really important and enjoyable experience was working with modular design, which although initially difficult to properly define, was extremely beneficial in the later stages of the project as it allowed us to work concurrently and readily isolate issues as they arose. I particularly enjoyed working on many revisions the water generation unit, where I learned mechanical design concepts and applied them to making the unit stronger and more efficient. The circuit design was also rewarding; seeing the final product respond to water temperature was both intriguing and satisfying. I also learned practical skills: many parts from the dollar store can be adapted for creative use, saving time, energy, and money. With the right tools and some creativity, ordinary parts can be applied to novel purposes, such as the casing for our prototype faucet module.

In summary, ENSC 440 has been very enjoyable and educational in many ways for me. I’ve learned leadership, teamwork, and business skills in addition to the expected technical skills, and I sincerely feel that this was a great way to round out my engineering education.

6.4 Scott Chen

A successful team project is fueled by great team dynamics and unquenchable thirst of engineering knowledge; I, as a part of the NeoSpectra project team, have witnessed a well-managed team working relentlessly to put together a stellar project for the past four months. Although under a full work load, every individual in the group has demonstrated his commitment towards the ChromaTap project, and cooperated with other group members to push this project through many major milestones.

Throughout the entire project, we encountered numerous adversities that delayed the project progress and sometimes forced us to adjust our project direction. Nonetheless, we were always able to keep the project going. On top of the unselfish dedication towards the project, everyone was highly motivated to expand their engineering and business knowledge to improve the ChromaTap. As a member of the NeoSpectra development team, I am truly proud of what we have accomplished.

In this project, I have gained valuable experience in engineering design. In the progress of developing the ChromaTap prototype, I had a chance to apply my engineering knowledge from both the *ENSC 225* and the *ENSC 325* courses, as well as the hands-on electric circuit design experience from my internship placement. Moreover, I had numerous opportunities to broaden my engineering knowledge by seeking assistance and suggestions from not only professors, but also my coop supervisors and coworkers. These experiences not only allowed me to contribute to the project, but also to take my engineering skills to a brand new level.

In addition to the engineering experiences, the ChromaTap project has also given me a comprehensive vision over the field of project team management. Throughout the project I was able to participate in project meetings with other group members to make critical decisions on project goals and design changes, and share my management experience from my coop placement with other members. I am certain that, with the success of the ChromaTap project, everyone in the group has gained the required skill sets as well as the confidence to go into the engineering field and participate in, or even manage, a real-life engineering project.

6.5 Jacky Cheng

Working with our team members was an excellent experience; we had different focuses and different concentrations. Without my team members, it would be nearly impossible for me to complete this challenging and time consuming project. I leant a lot of things from the past 4 years; without this project course, I would not be able to understand how everything linked together and what I have truly learnt.

As the only system engineer in the team, my main role in the project was mechanical design. While designing mechanical components, I ran in many different problems that I never thought about. Especially when designing the actual design and layout, it was tough to come up with a satisfying solution even after many revisions and redesigns. Since SFU does not offer any formal mechanical designing courses (only a few courses on mechanical systems), I had to learn it online and looked around to see how things were designed. I started to understand that why some of the designs were bizzare and redundant but necessary to make things work. Aside from that, I realized that there are many different engineering fields that require different knowledge but a lot of things can be accomplished using the same fundamental knowledge.

Solidworks was my best friend during the project period; I spent a lot of time using it and learnt many different functions and features. I was glad that I took ENSC 489 before taking this course since the course material in 489 was really helpful for Solidworks design. It helped me to start with the basic ideas and understand many things can be simulated and designed. We were amazed that Solidworks could do so many things; we looked into size, volume, strain, forces and many different functions. These numerical numbers helped our team to determine what kind of material was best for our project. After many simulations, we came up with Polystyrene(PS) or Polycarbonates(PC) as the material for our casing.

In this project, I also helped in many different parts such as the switching circuit, circuit simulations, water generator, integration and prototype construction. I realized the significant difference between theoretical design and actual practical implementation. Again, I would like to thank my team members: without them, it would be nearly impossible for me to learn all these things and complete the project within the given time frame.

Section 7. Conclusion

We have worked hard over the past four months to complete our ENSC 440 deliverables successfully, but our work is not finished yet, as we still need to research critical areas before we will have a commercially viable product. This work will be done as part of Increments 2 and 3, which are on-going, with Increment 3 slated for completion in early 2008.

The most important work that we have to do is to research how we can get the maximum visibility of light from the water stream, be that from a lens or by changing flow rates, turbulence, or air/water ratios. Another area of research that will be critical to protecting our intellectual property is developing a version of the circuit which is a single piece of silicon. Although this will have a greater R&D cost, the advantages are numerous, and tie into power consumption as well. Also, we were expecting better response times from the thermistor, but better fabrication processes should improve our results and allow us to move to a more representative system. We are also examining changing the device functionality to have a “green” zone where the water is an acceptable temperature. Finally, we need to investigate the feasibility of miniaturization with regards to our water power generation unit.

Overall, modular design was one of our greatest successes, as was water power generation, which went through several revisions before we came to the final, highly effective version. We also realized power savings from using pulsing to achieve different levels of LED brightness. Additionally, we ruled out solar power as a power solution because of the environment that the product was to be used in. Further, down the line, our 3D models and simulations will become useful (after additional tweaking) as the product moves towards commercialization and mass production.

In summary, as part of our ENSC 440 deliverables, we have achieved a solid start in turning ChromaTap into a commercially viable product, and learned a lot about teamwork and project management. We are looking forward to bringing the ChromaTap to the next level as part of on-going development.

Section 8. References

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The ChromaTap Project Post-Mortem

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