Exigo Technologies
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January 17, 2006

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

Re: ENSC 340 Post Mortem for a Bicycle Energy Measurement System

Dear Dr. Rawicz:

The enclosed document, *Post Mortem for a Bicycle Energy Measurement System (BEMS)*, outlines the developmental process of our device for the ENSC 340 project. We have designed and implemented a device which allows the user to measure the energy expended while cycling. The Bicycle Energy Measurement System includes a simple user interface allowing the cyclist to enter personal information similar to the menu system in a basic bicycle computer.

This post mortems provides detailed description of the current state of the device and deviations from the original specifications. Comparisons between the proposed and actual budget and timelines are also included in this document. Each member of Exigo Technologies has included a brief discussion of the experience gained through the duration of the project.

Exigo Technologies consists of two fifth year engineering students: Denis Dmitriev and Mimi Wu. If you have any concerns or questions in regards to our proposal, please do not hesitate to contact me by phone at (778)835-8539, or by e-mail at mwua@sfu.ca. Sincerely,

Mimi Wu

Mimi Wu
Exigo Technologies

Enclosure: Post Mortem for a Bicycle Energy Measurement System

Exigo Technology

Post Mortem for a

Bicycle Energy Measurement System

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Submitted to:	Dr. Andrew Rawicz Brad Oldham Steve Whitmore Mike Sjoerdsma
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1 Introduction

This report outlines the development of our device in the past four months. The current functionality of BEMS, deviations from the original plan, budget and timeline comparisons, team and final product evaluations are also discussed in this report.

2 Overview of the project

BEMS is a product that measures the energy expended by the cyclist during an exercise session. This is done by an indirect measurement of the power based on the speed, acceleration, and inclination of the bicycle at any given moment. BEMS is intended to provide detailed energy expenditure information to the cyclist while doing so on a budget. Figure 1 illustrates the system overview.

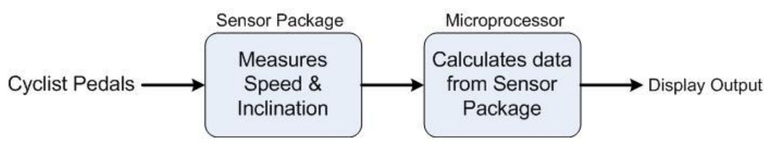

Figure 1: System overview

BEMS consists of two major units: the sensor unit and the display unit. The current state of these two components are discussed in the following sections.

2.1 Sensor unit

The sensor unit is responsible for measuring the speed and inclination used by the microcontroller to calculate energy expended by the cyclist during a bike ride. The speed is measured directly by coupling a small wheel onto the rim of the front wheel of a bicycle. The optical encoder then converts the sensor wheel's revolution into a pulse train, which the microcontroller uses to calculate speed. The inclination is measured using a dual-axis accelerometer.

2.2 Display unit

The display unit is the central processing centre of BEMS. It performs calculations on the data supplied by the sensor unit, monitors user input, and displays the information. The display unit is attached to the handlebars with a simple clamp.

The central component of device is the microprocessor. The microprocessor chosen was Microchip PIC18LF2620 because it had many tools available such as programmers and compilers, sufficient number of input/output pins and abundant memory.

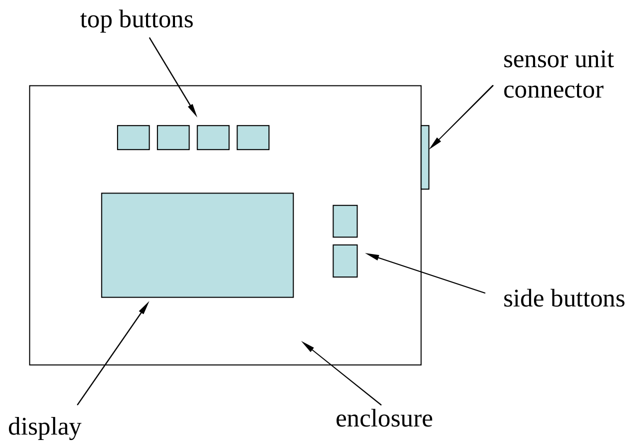

Figure 2: Display unit

The sensor unit outputs data relating to the speed in the form of a pulse train. The pulses are counted by the PIC microcontroller's asynchronous hardware counter, and the number of pulses per unit of time set by the timer is then used to estimate the instantaneous velocity of the bike. The dual-axis accelerometer outputs the information regarding the current incline in the form of two perpendicular components of gravity, as shown in figure 3 for the case of a stationary bike. These components were digitized by the built-in analog to digital converter and then analyzed to extract the angle of incline.

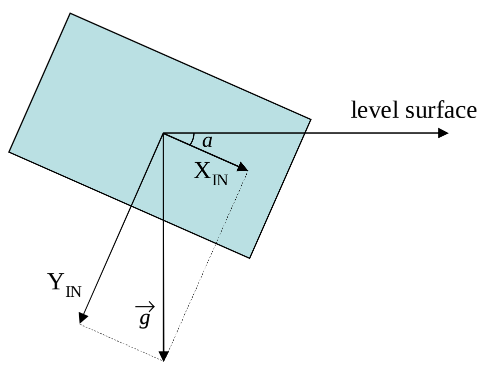

Figure 3: Interpreting the X_{IN} and Y_{IN} signals

The toal energy expended by the cyclist is calculated by integrating the instantaneous power,P over time, where P is

$$P = \max\{Fv, 0\} = \max\{Mv\,(a_m - g\sin\alpha)\,, 0\} \tag{1}$$

with

- $F = M(a_m - a_e)$
- M = combined mass of the cyclist and the bike
- v = current velocity
- a_m = measured acceleration
- a_e = current incline = $g \sin \alpha$.

2.3 User interface

The cyclist interacts with BEMS by using the buttons positioned around the display. Instead of assigning fixed functions to each button, the function is shown on the display beside each button. Photos in figure 4 demonstrate the appearance of the interface in the actual device.

Figure 4: Main display

Each button above the display performs the function stated on the menu line of the display below. When displaying sensor information (as in the picture on the left), pressing the buttons on the right of the display cycles through the available measurements—velocity, total distance, power, energy, trip duration, and average velocity/power. The user may choose to view any two measurements at the same time.

3 Current state of the project

The overall implementation of BEMS matches the proposed functional and design specification documents to a high degree. Both sensor and display units have been implemented and for the most part function as desired. However, some deviations exist. While most of these discrepancies have been caused by time or budgetary constraints, others were simply problems with the original design that would have taken another revision to weed out.

3.1 Overall system

Little of the originally planned power saving features have been implemented. The primary reason for this is that while they are an important part of the final user experience, they are not vital for a proof-of-concept device. It has to be said, however, that the design incorporates all the necessary logic to fully implement selective disabling of the most power-hungry components of the system, such as the display and the optical interrupter. Also, even in the current version of the prototype the sensor unit powers down when disconnected from the display.

A possibly more significant deviation from the original plans is the lack of calibration of BEMS. Two factors played a role in this—not having any reference equipment to calibrate against, and the unending rain that set in when the firmware became ready for the outdoor testing.

3.2 Sensor unit

Sensor unit deviates very little from the original functional and design specifications. The only difference lies in the size of the sensor wheel—if the original design called for a wheel with a circumference of $10cm$, this has been determined to be too small to be reliable. Consequently, the wheel size has been doubled.

The final prototype of the sensor unit is pictured in figure 5 below.

3.3 Display unit

The display unit implementation matches the original functional and design specifications exactly.

3.4 User interface

In its current form, the user interface does not store the cumulative trip information (distance travelled, total energy spent) in the nonvolatile memory. While not difficult to implement in itself, this feature would have required designing an entire trip management interface, which

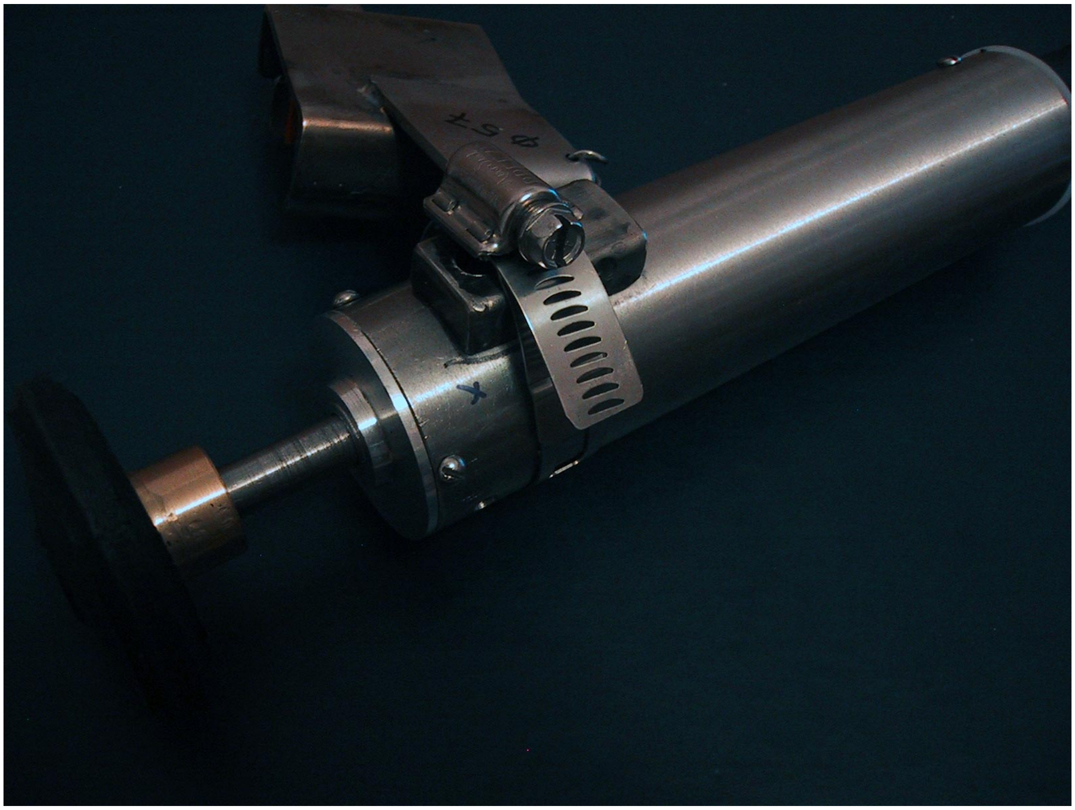

Figure 5: Completed prototype of the sensor unit

was judged to be not important for a proof-of-concept device. Every other proposed feature, except for the power saving functionality described above, has been implemented.

3.5 Possibilities for future development

While it is not in our intentions to bring BEMS to market, if we were planning to, it would be sufficient to resolve the issues described above. At the same time, BEMS might benefit from finding an alternative method of measuring the velocity of the bike, as the current approach of coupling a sensing wheel proved to be error prone due to the wheel skipping at high speeds.

4 Budgetary and time constraints

By making use of samples from Analog Devices and Microchip Inc., we were able to keep our spending to less than half the proposed budget. We also kept our design simple and constructed several components of the device ourselves. The selection of components for the project was dependent on meeting the functional requirements and the price. By keeping these criteria in mind, we were able to keep the cost down.

4.1 Budget

In formation of a budget, we considered ordering all the components needed, as well as shipping costs and contingency. We were able to obtain many components of our project as samples and had our printed circuit board made for free. The proposed budget was $300, but by the end of the semester, our total spending was closer to $140.

We were able to obtain funding from ESSEF of $110, and made use of the the $50 ENSC 340 project fund. Overall, we came under budget and the cost of the entire project was covered by the available funding.

4.2 Time

The table below compares the proposed and actual time of major steps of the project. We were able to finalize the hardware design on time. We were approximately a month behind in receiving all our components. This is attributed both to the extra time it took to acquire the samples and the need to build some of the major components ourselves. Getting the hardware and firmware working also took a bit more time than originally anticipated.

Milestone	**Proposed**	**Actual**
Hardware Design Finalized	Oct 05	Oct 05
All components received	Oct 14	Nov 15
Hardware Ready and Working	Nov 07	Dec 18
Firmware provides desired level of functionality	Nov 20	Jan 11
Demo	Dec 10	Jan 13

5 Personal comments

5.1 Denis Dmitriev

Ever since I started at SFU, I've heard nothing but horror stories about ENSC 340/440. The course's reputation alone made me abandon it twice in the past. However, now that it's all over, I'm pleased to say that most of these reports have been greatly exaggerated.

To me, the high point of the project was seeing every part of my design "just work" the first time around. Aside from that, I have to say that it was nice to work in a small group. Not having to pacify anyone or battle egos allowed me to concentrate on the actual project at hand, even though I have probably deprived Mimi of a lot of the fun in the process. Overall, while BEMS has not been the largest or the most involved thing I ever built, it was large enough in scope to be interesting. It also allowed me to play with a handful of things that I always wanted to mess around with—the OLED display, selected primarily for its coolness factor, the hand-made optical encoder, switching power supplies, and so on. All in all, it has definitely been a positive experience.

5.2 Mimi Wu

When Exigo Technologies was form, I was very excited about the project. It was an area of interest to both Denis and I. When we were not able to recuit more people into our group, we decided we would take on the project ourselves. From the beginning, we knew we had a challenge ahead of us.

This course has taught me endless details regarding developing a product. I have learned that there is much more to developing a product than just the design. There are numerous details involved, including research, component selection, obtaining funding, design and implementation. The documentation for the project, although appearing to be tedious initially, has proved to be very useful. Through the functional specifications, we were able to narrow down the exact requirements of the product, which prevents us from using excessively complex component. Writing the proposal, functional specifications and design specifications had helped the development of our product immensely.

In this course, I was able to apply what was learned in the classroom in a project of our choice. Through the research of the project, I had learned a great deal about the components of our device, including sensors, accelerometers and microcontrollers. I was also able to refresh and improve my programming skills and become more familiar with PIC processors. With the experience I have gained from the project, I am more confident in taking on a complex project, break it down and walk through the necessary steps to achieve a successful end product.

Working as a member of a team in a project of this magnitude has been a valuable learning experience. I have learned that in order to work as a group successfuly, it is necessary to keep channels of communication open. By working as part of a team, I have learned to patiently listen to others while expressing my ideas clearly, taking responsibilities and making compromises. Although we did not have formal meetings, we tried to work closely together and be involved in every part of the project. This resulted in a successful phase of integration and end product.

Overall, I had a learned a lot and had a great experience in the course. It was very exciting and fulfilling to see the the project grow from an idea to a working product.

6 Acknowledgements

We wish to thank Analog Devices Inc. and Microchip Technologies Inc. for providing samples of their products that allowed us to stay within our budget. We also wish to honour Servo-Tek Products Co. for refusing to provide us with a sample of their PM encoder thus forcing us to make our own.

