School of Engineering Science
Burnaby BC, V5A 1S6
slik-440@sfu.ca

April 12th, 2004

Lakshman One, Mike Sjoerdsma, Nakul Verma
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

RE: ENSC 440/305 – Design Specification for the Driver Health Monitor

Dear Mr. One, Mr. Sjoerdsma and Mr. Verma,

Attached you will find the post-morterm report for *Driver Health Monitor System*, for our ENSC 440 project. This document includes the current state and problems encountered while creating this prototype model. This document also describes the team dynamics, costs, and the future plans for continuing on better improving this model.

The purpose of this document is to illustrate the specific designs of the prototype hardware and software components. These specifications will be used as a guideline for any future development of the design.

SLiK Devices Ltd. Engineering team consists of four creative and self-motivated engineering students from Simon Fraser University. These team members are Reza Sanaie, Behroz Sabet, Vedran Karamani, and Gary Lu. If you have any questions or comments about our project or the specifications, please contact us by email at slik-440@sfu.ca or by phone at (604) 338-4244.

Sincerely,

Reza Sanaie
President and CEO
SLiK Devices Ltd.

Enclosure: SLiK Design Specification

School of Engineering Science
Burnaby BC, V5A 1S6
slik-440@sfu.ca

Driver Health Monitor
Post-Morterm

Team Members:	Reza Sanaie (20003-5441)
	Behroz Sabet (20003-4618)
	Vedran Karamani (20002-4167)
	Gary Lu (20006-0337)
Team Contact:	slik-440@sfu.ca
Submitted to:	Lakshman One (ENSC 440)
	Mike Sjoerdsma (ENSC 305)
	School of Engineering Science
	Simon Fraser University
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School of Engineering Science
Burnaby BC, V5A 1S6
slik-440@sfu.ca

Executive Summary

Less than a month ago on Highway 99 north of Squamish a southbound sedan carrying five hotel workers crossed the centre line and collided, head-on with a northbound SUV carrying two passengers. All seven people involved died at the scene of the accidents. Coroner Jody Doll said driver fatigue may have been a factor since the young man at the wheel of a sedan that crossed the centre line had just finished working a night shift in a Whistler hotel[1].

Driver fatigue is an area of transportation research that deserves much more attention than the current efforts put into detecting it. Patients with obstructive sleep apnea (OSA), narcolepsy patients, night-shift workers, adolescents, and individuals suffering from acute or chronic sleep deprivation are all at risk for drowsy driving car crashes. Driver drowsiness represents an important risk on the roads, given that it is one of the main factors leading to accidents or near-missed accidents. This fact has been proven by many studies that have established links between driver drowsiness and road accidents. An important drawback of current studies is the fact that they have been performed either on a driving-simulator, or by using non-transparent sensors, which might affect the driving task, and therefore, the behavior of the drivers in a drowsy condition.

The Driver Health Monitor Module makes use of highly accurate and sensitive sensors to detect the drowsiness of the driver. The module will be self-contained, robust and able to calibrate itself to different drivers' characteristics. The parameters that are being monitored are heart rate, reaction time, temperature, and respiratory rate. The past research on the correspondence of these parameters to human drowsiness is well defined and available for comparison.

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School of Engineering Science
Burnaby BC, V5A 1S6
slik-440@sfu.ca

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1 Introduction

Detecting drowsiness of a driver has been attempted by many institutes and research program due to the high risk of car incidents occurrence that have been fatal in most cases.

Drowsiness in combination with alcohol and/or drug usage can put the life of the driver and the passengers in extreme risk. As a result, acknowledging the problem of detecting this risk is on demand and essential. Enforcing law in regards to sleepiness is almost impossible from the legal point of view. In addition, many work patterns of individuals involved in late night or just simply long shifts of duties make sleepiness an inevitable factor to avoid.

This document outlines the functional specification of the driver Health Monitor Module, the parameters that need to be monitored, and the factors that make this module convenient in terms of use and stability. The description begins with defining the interface specifications, the sensor requirement followed by the system defined specifications and wireless transmission requirements and flowchart.

2 Current state of the device

The Driver Health Monitor is currently at prototype level. Individual sensors are operating at satisfactory level. However, the micro-controller is not yet capable to simulate the sensor signals simultaneously. Furthermore more data of fatigue driver are required to calibrate the sensors. The details for each sensor are given below.

2.1 Reaction Sensor

Reaction sensor simulator is currently consisted of two main units. Namely the implantation is done via PC with code written in C++. Please refer to the figure below.

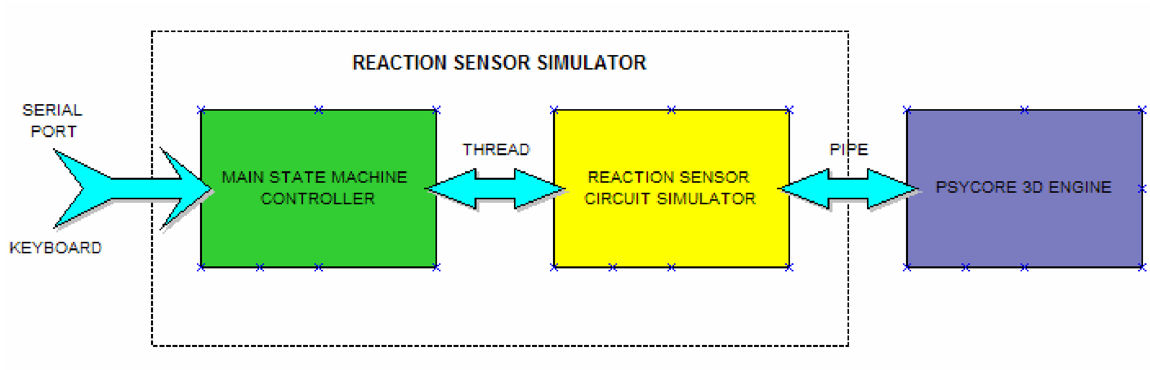

Figure 1 Reaction Sensor Simulator Block Diagram

Blocked off is first component the simulator itself. Second integral part is the Psycore 3D Engine that interfaces to the simulator steering wheel. Simulator further consists of the main state machine controller and code-simulated digital reaction sensor circuitry.

One of the first problems encountered was the proper code construction to truly represent and in that sense appropriately simulate actual digital hardware circuitry. For that purposes the simulator was designed to be multithreaded to most closely correspond to parallel operation of the digital circuit. State machine was also designed as a loop decoder MUX with appropriate sleep clauses that could be easily translated to clocked digital operation.

Further problems encountered were based on design of the most appropriate reaction test vectors as well as ensuring for safe operation. In that regard user reaction data logging was implemented were some preliminary statistical analysis could be preformed. Please refer to the following figure 2.

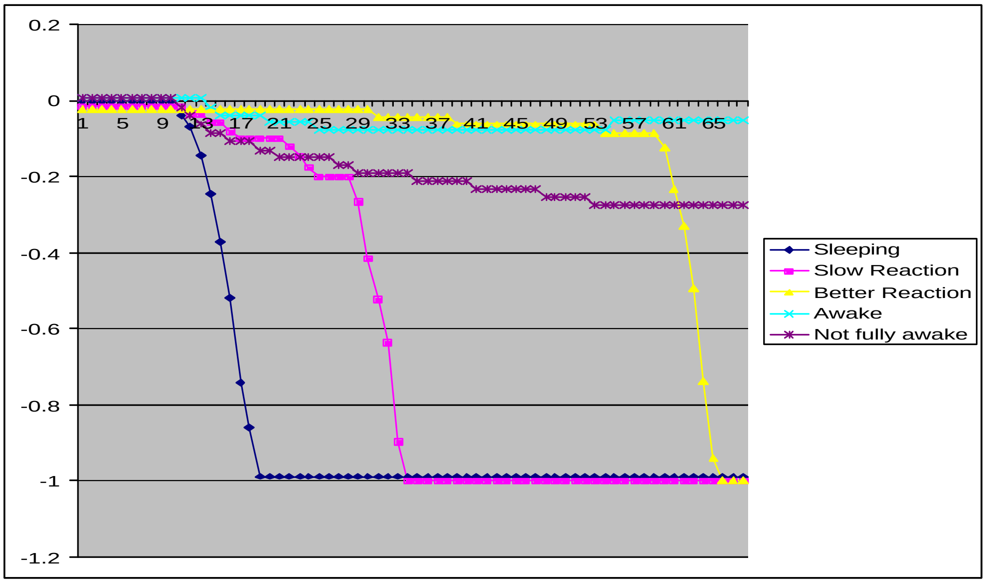

Figure 2 – Graph of different states of driver in response to a test force

After analysis and testing of several possible test vectors and their responses, prototype test vector was developed to most accurately determine driver's reaction ability while providing for a sufficiently safe operation.

Additional safety measures were implemented after analysis of the systems operating conditions. Namely condition for application of the reaction test was defined where if not satisfied the sensor circuitry would block on performing the test and report failure of meeting the appropriate operational conditions. These improvements provided for more safe and sound complete engineering solution.

2.2 Breathing Sensor

Our breathing rate sensor is capable to detect a driver's breathing rate with an uncertainty of ± 2 breathes per minutes. Not only it has this high accuracy, but also it can detect both deep and shallow breathes that the driver has taken. The following figure has shown the result of a user has taken constant breaths.

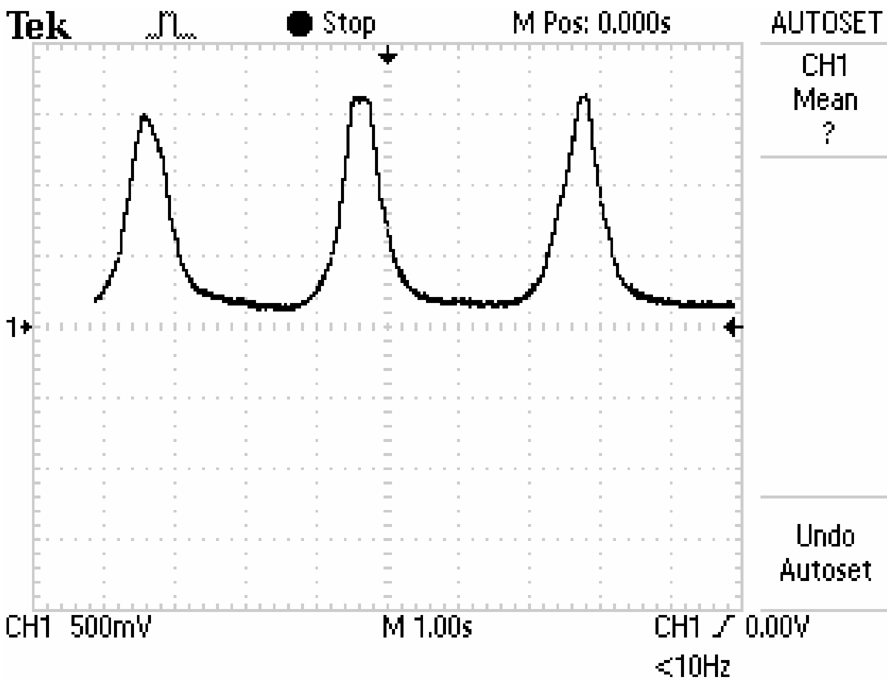

Figure 3: Result from Breathing Rate Sensor

According to Figure 3, the user's breathing rate is said to be roughly 20 breathes per minutes, and the output signal is within a 1.5 V range. This clean signal is processed in the same way as the one from heart rate sensor.

The functional requirement of this sensor has met what we have proposed in the functional specification, which it will be integrated as part of a seatbelt. In Figure 4, it has illustrated the physical representation of the sensor.

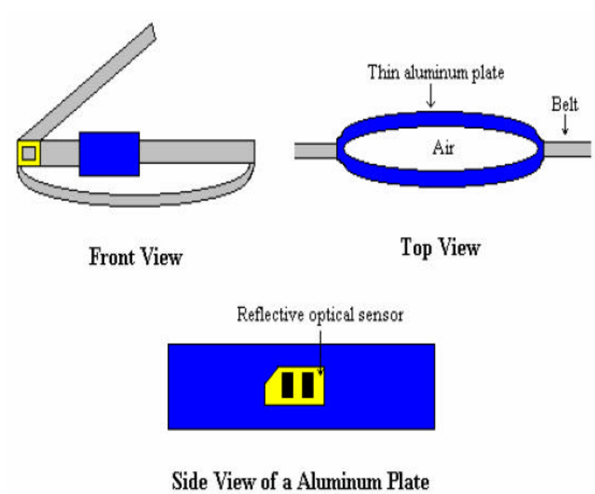

Figure 4: Physical view of Breathing Rate Sensor

2.3 Heart Rate Sensor

The heart rate sensor is capable to detect a driver's heartbeats with an uncertainty of ± 3 pulses. In Figure 5, it shows a user's heart rate that is roughly about 80 beats per minute. This result is quite satisfactory because the signal has very little attenuation.

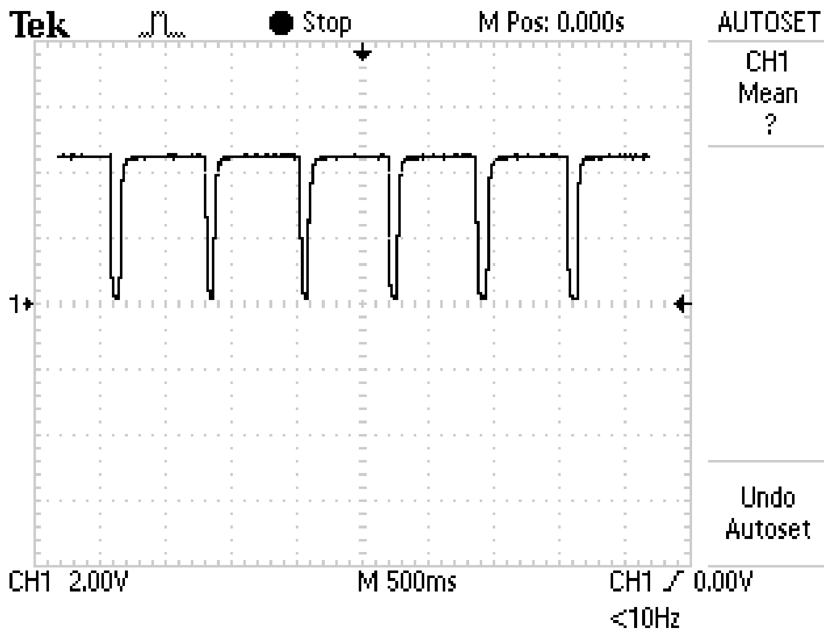

Figure 5: Result from Heart Rate Sensor

In order for this sensor to function properly, it is required a 5 V power supply and a steady attachment of the sensor on a driver's finger. A heart rate counter can be easily set up for the data processing at the micro-controller by just passing this signal through a simple comparator.

The physical design of the current heart rate sensor is a little different from what has been proposed, instead of making it as a ring we have it as a finger clip, which has to be stabilized firmly on a driver's finger.

2.4 Temperature Sensor

Our temperature sensor is able to detect body temperature with an uncertainty of ± 1°C. The range of the temperature it can measure is from -10°C to 45°C. At room temperature, the output signal of the sensor is at about 6.0 V. Every 1 V increase at the output indicates an increase of 7.49°C.

This particular temperature sensor requires ± 9 V power supply, and has an output voltage range from 0 V to 8.46 V. Moreover, the output signal stabilizes after 3 to 4 seconds after the user put it on his/her palm, so this sensor behavior needs to be considered for measuring driver's fatigue.

Currently, this sensor is just a prototype that it has the thermal transducer sensor connecting to the circuit through two long wires. The future development of this sensor will make it built around the steering wheel for the driver's convenience.

3 Problems Encountered

3.1 Heart Rate Sensor

The biggest the problem we had at the beginning of designing this sensor was extracting a very small phototransistor signal, which comes from the inferred diode. But at the end, we could still solve this problem by using the past knowledge learned in the engineering courses such as, low-pass filtering, circuit clipping and non-inverting amplifying.

Another major problem encountered was the fact that the signal fed into the micro controller was meant to have low SNR and very reliable. To do that we decided to use a comparator designed with op-amps. We observed a very large SNR and therefore a very unclean signal using the op-amp for the comparator design. At the second attempt, we used the logic gates (invertors and NAND gates) to implement a simple comparator at the hardware level, which yield the desired signal, but to make the system more robust we decided to make this implementation at the software level instead.

3.2 Breathing Sensor

The original design of the breathing sensor was using strain gauge to detect the driver's abdominal movement and to output corresponding output voltage based on the amount of movement caused by the driver. After several tests, the connecting pins that were soldered earlier on the strain gauge started to fall off and even the strain gauges themselves started peeling off from the aluminum plate. Also, the change of strain gauge resistance caused by the driver's abdominal movement is very insignificant, which is about 2Ω out of 480Ω, a 0.5% resistance change.

Due to these two major problems, we have started looking for alternative solution to approach the task. Since we have used inferred diode and phototransistor for heart rate sensor, we researched furthermore of this type of active components and finally found ON2180 photo reflective sensor to replace the strain gauge. Because strain gauge and reflective sensor are measuring different parameters, the original design of our breathing rate sensor has been modified as mentioned in our design specification.

The finished prototype of the breathing rate sensor has a minor problem, which is it does not measure the user's breathing rate if he/she straps it on at the right amount of tightness and position.

3.3 *Temperature Sensor*

The problem encountered at the beginning of the design was that the supply voltages for the op amps used was decided to be 5v. In testing the circuit we observed that the buffers and the difference amps used were not functioning properly, therefore we used a higher supply voltage of 9v. The problem of feeding a circuit to a high impedance one was solved by using buffers.

4 Summary of Budget

The summary of the costs of making a simple prototype model of the DHM has been listed in Table 1. The biggest part of this sum is the cost of Force Feedback wheel which is just an emulator for a steering wheel. When manufacturing the DHM of course a force feedback wheel will not be required as the wheel itself already comes built on the car.

Table 1 – Costs for the prototype in Canadian dollars

Costs for making the prototype model		
Part	**Measurement**	**Cost($)**
Reflective Sensor ON2180-ND	Breathing Rate	5.00
Thermo-transducerAD590	Temperature Sensor	0.00
KIE7304 Inferred Emitter	ECG Heart Rate	1.50
KID7407 Photo Transistor	ECG Heart Rate	1.50
OOpic Micro	Micro-Controller	50.00
LCD	LCD Display	30.00
Wheel Force Feedback	Reaction Time	80.00
	Total:	168.00

Other sensors and amplifier can be purchased in large quantities to get more discounts on parts and the circuit can be mass produced on a PCB board. This will cause both the cost and the size of the final model to be very small.

5 Future Plans

Future development of the reaction sensor would involve the actual mechanical prototyping. This would involve defining specifications and mapping the simulator functionality to the equivalent functional mechanical components. Finally the packaging minimization and ease of integration into legacy vehicles would be one of the future development directions.

Major portion of the future work would be statistical analysis of the user reaction data. This would involve development and testing of various reaction test vectors as well as application of such to a variety of statistically sound users where a clear distinction could be drawn for the most appropriate vectors and methods for testing the driver's ability to react. Again, through further statistical analysis of such reaction ability profile a clear distinction would be made on the defining trigger data that most clearly corresponds to user's level of drowsiness or lack of reaction focus.

6 Personal Contributions

6.1 *Reza Sanaie*

My primary contribution has been to work on the software component of the project in the microcontroller section as well as partial contribution to the reaction sensor software. I was responsible to gather data from different sensors in our prototype design and analyze them in the microcontroller. I also worked on communication lines between the micro and PC through RS232 serial port.

As the project manager my other responsibilities included leading the project, organizing and revising the documents before final submission and solving problems within the group.

6.2 *Vedran Karamani*

My primary responsibility with the project was the design and the implementation of the reaction sensor simulator. The design stage consisted of system analysis and developme nt of the best possible method for simulating the required testing mechanism for the driver's reaction ability. Please refer to the figure below.

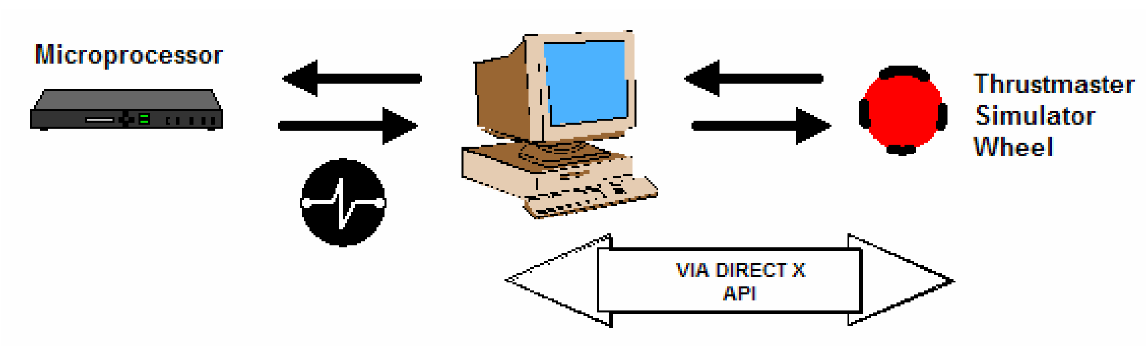

Figure 3 Reaction Sensor Simulator Design Overview

Major experience gained was through defining and developing such a system. A lot of engineering ideas were formed while the decision has been made to implement such a system through force-feedback type of a device as if it was to be implemented in the actual vehicle's steering mechanism. Further specification of such a system involved best possible method of developing a communication channel between the system's micro controller and the actual physical steering wheel simulator. It has been decided to do so through a series of DirectX based applications remotely communicating through a RS232 port of a PC.

My further contribution and experience consisted of implementation and testing of such a system as well as support in successful integration of the reaction sensor simulator with the rest of the project. I feel that I have gained much knowledge in system design and implementation through this project as well as I have learned to value the importance and essence of successful overall project integration. Also, working in my team I have gained experience in project documentation and had a chance to contribute in overall project presentation.

6.3 Gary Liu

My role in this project is to do the hardware design and hardware implementation to meet our requirements of the project. My main contribution is on the heart rate sensor, temperature sensor, and breathing sensor. Initially I thought that I would be able to design and build all the sensors within a month or two, but as time goes by, I realized that I was falling behind the schedule and hence I have invited Behroz to join me building the temperature sensor, heart rate sensor and breathing sensor.

At the beginning stage of hardware design, we spent most of our time in researching the suitable components for the sensors, and that is probably the reason we fell behind the schedule initially. In our schedule, we expected the project design and implementation would take up most of the time, but it turns out that debugging was the most frustrating part. During the debugging process, I found it is the most valuable experience in this course because I learned how to trouble-shoot a problem from scratch.

Also, I found teamwork plays a crucial role in determining a project's success. It doesn't matter how well one part of the project has been done, if other parts fail, the whole project would fail. I discovered that working independently with lack of group communication is a bad idea because it makes one thinks "I am the only one is working" and this doesn't get the group going any further if a team member is stuck at a problem. Therefore, having a good team communication and solving the problems together as a group can lead us from a frustrating situation to a more optimistic one.

From the previous courses, I have never gotten a chance to design a circuit and implement it to make it work. This course gave me an opportunity to apply and review the knowledge from what I have learned to solve the design problems, and so I think it would prepare me well to deal with real world problems after I graduate.

6.4 Behroz Sabet

My main responsibility of the project was to design, implement, and test the temperature, heart rate, and breathing rate sensor. In addition, I was responsible for making appropriate decision into making sure that these parameters are significant enough for the implementation of DHM. I gained experience in designing, and calibrating these circuits for our own specific requirements.

There were many engineering design ideas used previously in my courses that applied to building these sensors. In addition, to make our module is more robust, a great deal of work was done by me, and Gary Lu into making sure that our design would be stable enough in terms of connection to the micro controller during integration of the whole system.

7 Conclusion

SLiK Devices Ltd. Successfully designed a prototype version of Driver Health Monitoring system which was able to fully detect the driver's drowsiness based on its algorithms and statistical values. Of course there needs to be much more research done in this area and many different test cases be applied based on the four parameters of interest to detect if a driver is falling sleep or no. These statistical values vary by age, sex, race and many other different factors that we will need to take into account.