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March 3, 2004

Lakshman One and Mike Sjoerdsma
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RE: ENSC 440/305 – Design Specification for the Driver Health Monitor

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

Attached you will find out design specification for the *Driver Health Monitor System* for ENSC 440. This document includes the specific designs of each component of DHM system that are in accordance to the functional requirements mentioned in our functional specification document. In addition, described in this document, is our plan for testing the components and the integrated version.

The purpose of this document is to illustrate the specific design implementation of all the hardware and software components at the prototype level. 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 Functional Specification

Design Specification for Driver Health Monitor

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1 Introduction

The Driver Health Monitor Module makes use of highly accurate and sensitive sensors to detect the drowsiness of the driver. 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.

In this document you will find out design specification for the Driver Health Monitor System. This document includes the specific designs of each component of DHM system that are in accordance to the functional requirements mentioned in out functional specification document. In addition, described in this document, is our plan for testing the components and the integrated version.

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

1.1 Intended Audiences

This Design Specifications is intended for those who have engineering background. However, the layout of our design is presenting in such a way that even someone without any technical background can also interpret it easily. Our group will be using this Design Specifications as guidance to build the Driver Health Monitor. Detail designs of this document are expected to be revised and modified for the future reference.

2 System Hardware

2.1 Hardware Overview

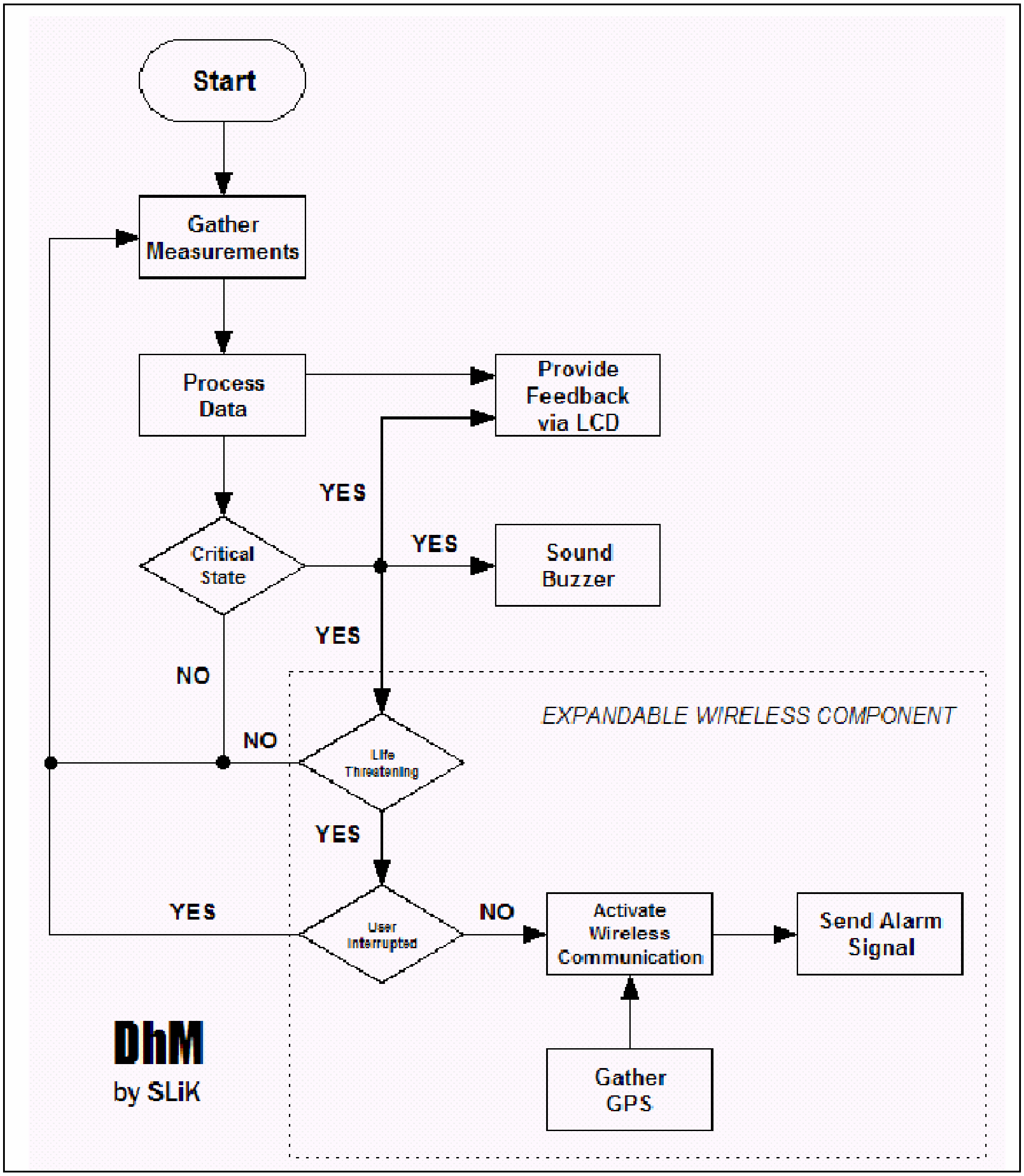


Figure 1 - Design overview of DHM

Figure 1 shows the design overview of DHM. The gathered data that are collected from heart rate sensor (HRS), breathing sensor (BS), temperature sensor (TS), and reaction sensor (RS), would be processed and then display to the driver. If these data indicate the driver is in critical state, safety measures, such as buzzer warning would be activated.

As shown in Figure 2, the layout of the hardware for the DHM is mainly consisted of BS, HRS, TS, RS, microprocessor, and buzzer. Some of these sensors will be built in with existing car components. For instance, the breathing sensor shall be woven with the seatbelt without interrupting driver's concentration.\

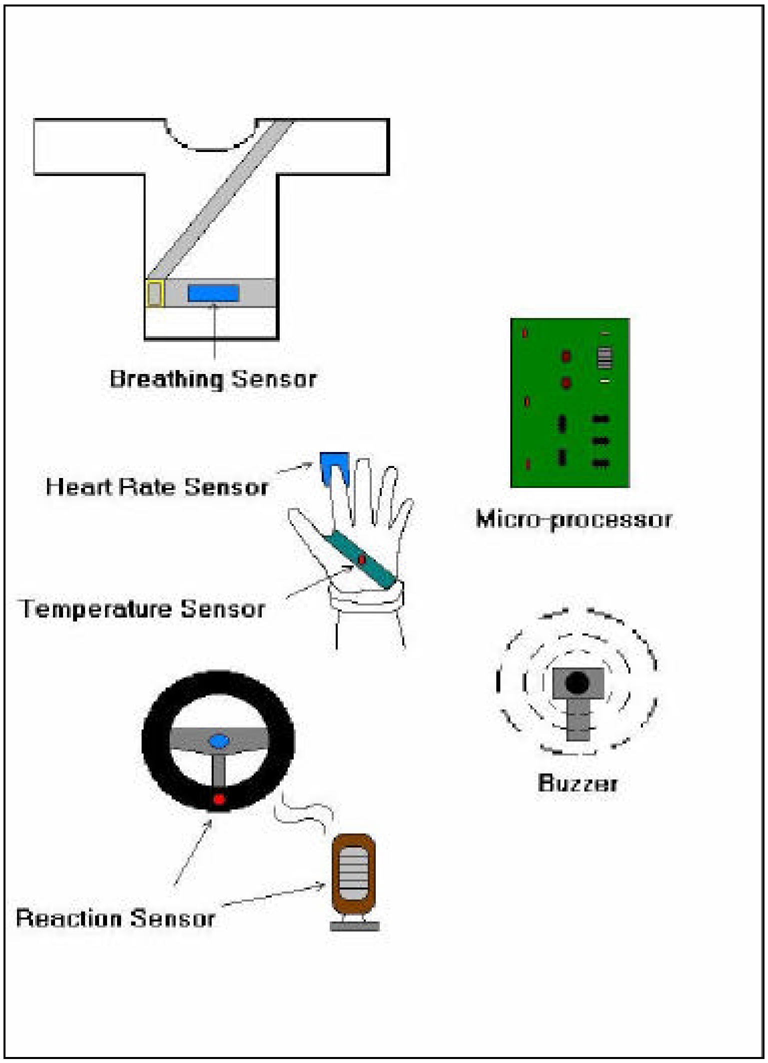


Figure 2 - Hardware overview of DHM

Since each part of the hardware will be implemented as a module, further modification or extension on one part would not affect the others. This also allows each component to be tested before integrating them together, therefore results higher reliability for the prototype.

2.2 Respiratory Rate Module

As mentioned previously, our BS will be integrated into the seatbelt. The reason for this is we are aiming to minimize any movement constrains and inconvenience to the driver. As the result, this modified seatbelt is no different from ordinary seatbelt except its lower strap is extended to wrap around the driver's back and has the sensor built into it as shown in Figure 2.

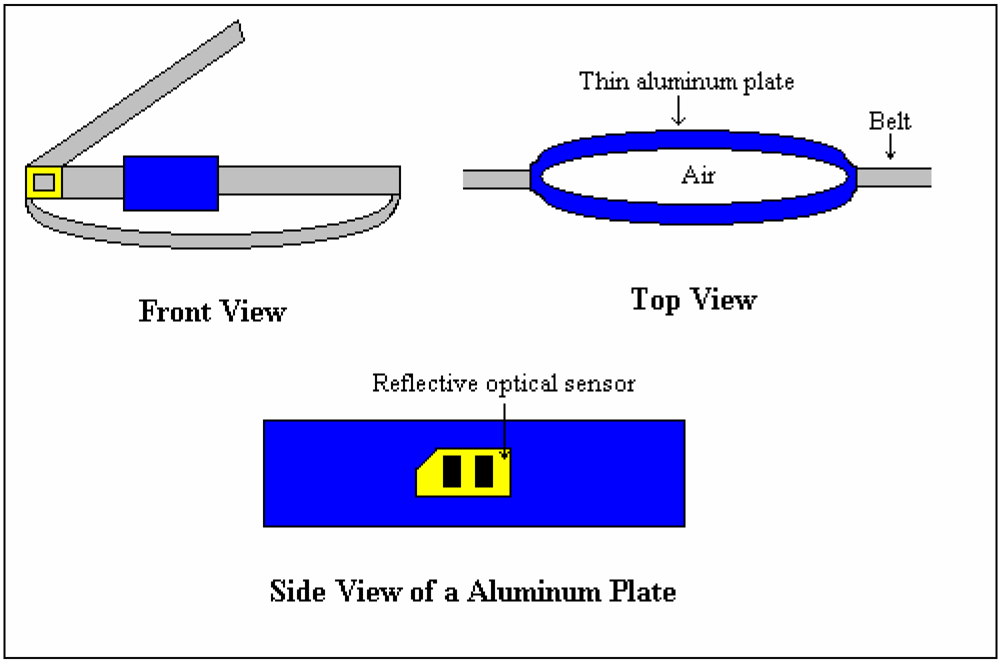
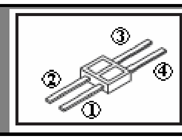


Figure 3 - Layout of Breathing Sensor

As shown in Figure 3, our BS is mainly consisted of two pieces of aluminum plates and a reflective photo sensor (RPS). Firstly, when the driver breathes in, the abdominal expansion would force the two thin aluminum plates squeezed against each other. At this point, the RPS would output the maximum output-voltage, since it has picked up the most light-reflection from the adjacent aluminum plate. Secondly, when the driver breathes out, adnominal compression would leave more space for the two aluminum plates to deform back to their original shapes. Since there is a greater distance between the two plates, amount of light-reflection goes to the ROS is expected to be less. Hence, by monitoring the output-voltage level, we can obtain the driver's breathing rate.

As for the RPS, we typically choose ON2180-ND. This photo sensor consists of a high efficiency GaAs infrared light emitting diode, which is integrated with a high sensitivity phototransistor. ON2180-ND's specification is shown in Table 1.

Table 1 - Specification of Reflective Photo Sensor

	
Part No.	ON2180-ND
Typ. T on/ t off (µsec.)	20/20
Input V_R I_F	3V 50mA
Output I_C V_{CEO}	20mA 30V

Referring to Table 1, pin 2 and pin 3 are the voltage input of the sensor. By powering up these 2 pins with 3 volts, both inferred transmitter and receiver will be activated. Pin 1 is the output of the sensor, whose voltage changes is proportional to the amount of light that has received on the receiver. The circuit implementation for RPS is described in Figure 4.

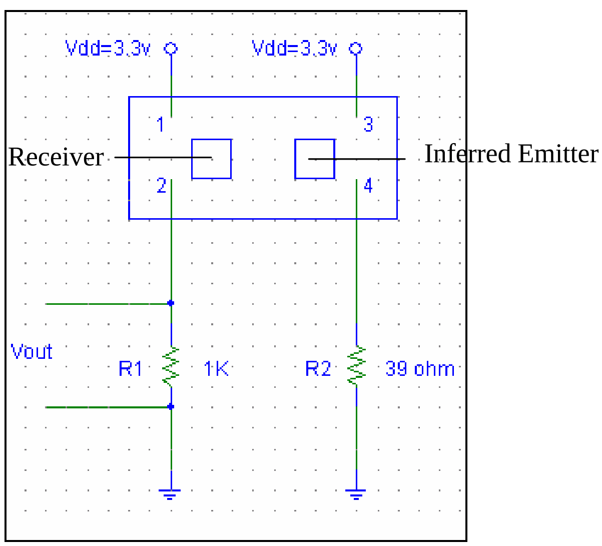


Figure 4 - Schematic of Respiratory Rate Sensor

According to the above figure, our whole RRS circuit is consisted of only two resistors and the reflected photo sensor. The maximum current across R2 can not exceed 50mA, therefore we must pick the value of 39 O or higher for R2. As for R1, any resistor that does not load the circuit is suitable.

2.3 Temperature Sensor Module

The temperature sensor is strapped on the palm of the driver as already shown in Figure 2, and in contact with the hand during driving. The temperature data is constantly read by the micro-controller in order that the temperature abnormality be analyzed. There would be two references for comparing the temperature data for the micro-controller. First, is the typical temperature change of human body sourced from data sheet of past test cases. Secondly, the reference could be individually set to the data gathered at the beginning of the use of the device. In other words, the device would be calibrated for the individual characteristics of the driver. Then, these values would be compared against the gathered data by the micro-controller and appropriate indices for the temperature would be set internally.

The temperature sensor circuit shown below makes use of AD590 chip. In AD590 the voltage is converted to a current by low temperature coefficient thin-film resistors. The total current of the device is then forced to be a multiple of this current. The circuit schematic is shown in Figure 6. The following specifications illustrated different requirements and our effort to meet them.

Table 2 - AD590 Specification

Parameter	Min	Max	Units
Power Supply	4	30	Volts
Current O/P	298.2		uA
Break Down Voltage	+/- 200		Volts
Calibration Error @25 C	1		C
Absolute Error	3		C

From Figure 5, we notice the voltage supply of the sensor has to be at least 4 V in order to achieve an accurate output current. Base on the measured output current level, we can determine the driver's body temperature.

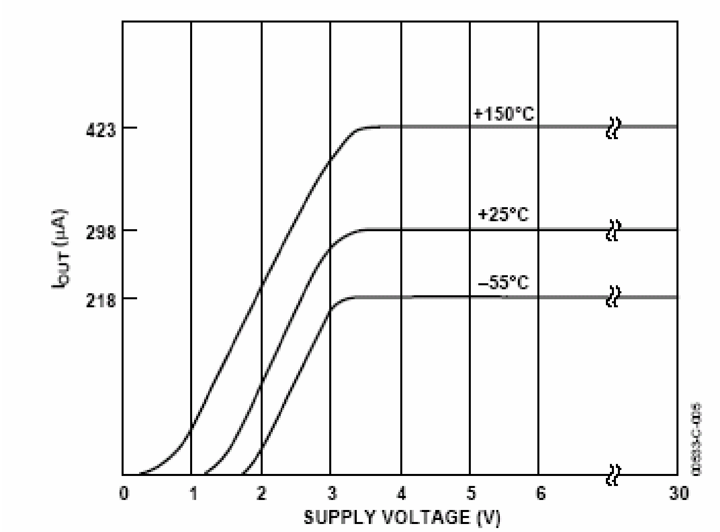


Figure 5 - AD590 I vs V (Range of Operation)

Because the change of the output voltage is very small, we must eliminate the DC offset and then amplify the small signal. To do so, we have employed a difference amplifier and an inverting amplifier as shown in Figure 6.

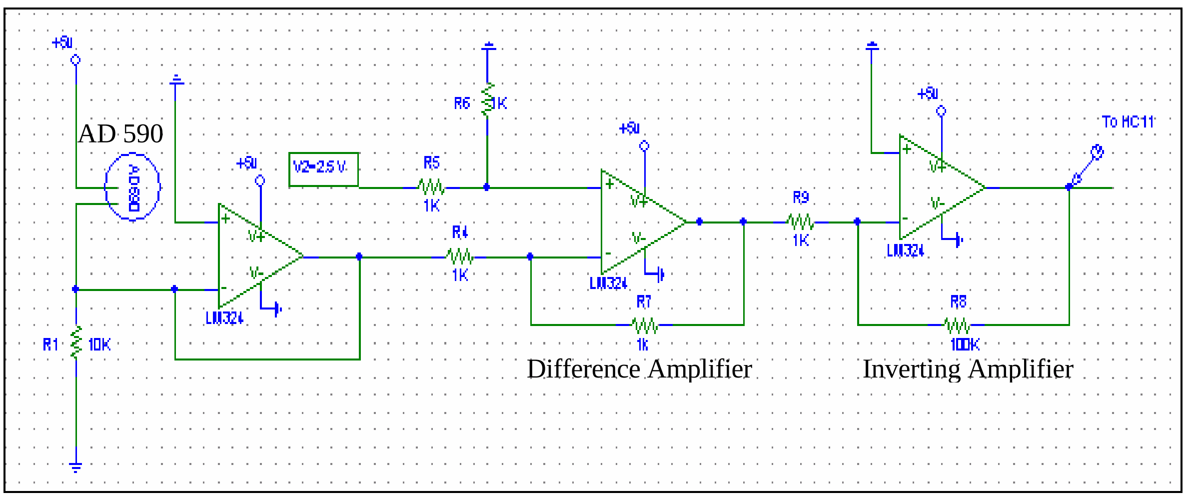


Figure 6 - Schematic of Temperature Sensor

From the above schematic of TS, the minimum operating voltage for the temperature sensor is approximately 3 V. In addition, it is observed for every µA increase in the output current there would be 1 degree increase in the measured temperature. This fact is consistent with the plot shown in Figure 5.

2.4 Heart Rate Module

In order to measure an accurate heart rate of the driver, we will be using a photo transistor and an inferred emitter. The output signal from the photo transistor is a very small signal therefore a set of filter implementations and signal amplification is required. The specifications of both the photo transistor and the inferred emitter are in accordance to our design specifications. The following Table shows these specifications.

Table 3 - Specifications of IR LED and IR Phototransistor

Symbol	Parameter	Min	Typ	Max	Unit	Test Condition
V_F	Forward Voltage		1.3	1.7	V	V_R =5.0V
I_F	Forward Current				µA	I_F =100mA
V_R	Reverse Voltage		1.3	1.7	V	V_R =5.0V
I_R	Reverse Current			10	µA	I_F =100mA
P_O	Radiant Power	21	35		mW	I_F =100mA
l_P	Peak Spectral Wavelength		880		nm	I_F =100mA
Δl	Spectral Bandwidth Between Half Power		80		nm	I_F =100mA
θ	Viewing Angle to Half Intensity		25		Deg	

a) KIE7304 Inferred Emitter

Symbol	Parameter	Min	Typ	Max	Unit	Test Condition
I_C	Collector Current			100	nA	V_{CE} =15V E=0
V_{CEO}	Collector-Emitter Breakdown Voltage	30			V	I_C =100µA E=0
BV_{ECO}	Emitter-Collector Breakdown Voltage	5			V	I_C =100µA E=0
$V_{CE}(SAT)$	Collector-Emitter Saturation Voltage		0.4		V	I_C =0.5mA E=20mW/cm^2
I_D	Dark Current			100	nA	V_{CE} =15V E=0
I_L	Photo Current Tungsten Source at Colour Temperature of 2854 °K	1.0	20		mA	V_{CE} =5V E=20mW/cm^2
t_r	Rise Time (10% to 90%)		5		µs	V_{CE} =30V
t_f	Rise Time (90% to 10%)		5		µs	I_L =800µA

b) KID7407 Photo Transistor

Hence, we have built our circuit for the HRS as shown in Figure 8. The inferred emitter has the most satisfactory performance when its forward current is set to be around 100 mA, so we used a value of 68 O for R1 under the 5 V voltage supply.

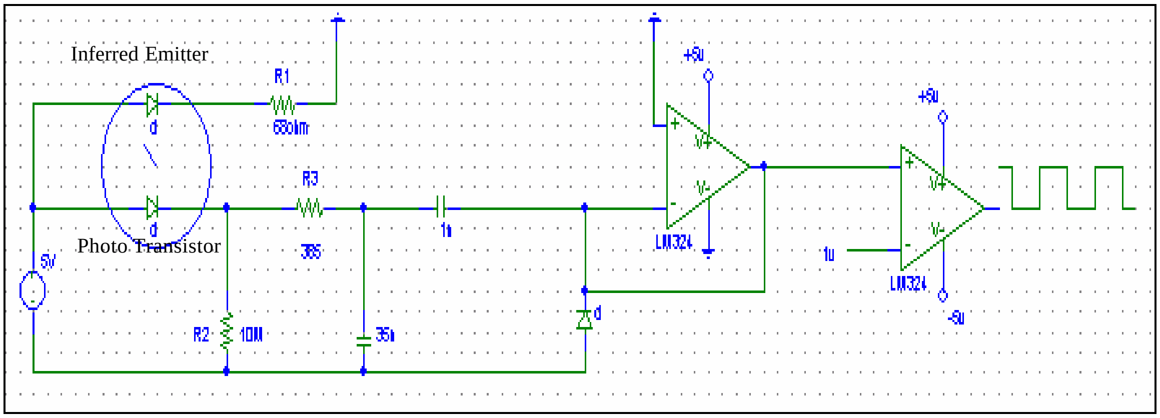


Figure 7 - Schematic of HRS Implementation

Due to all kinds of interferences from the outside world such as incandescent light, the most challenging part of this design is to extract a clean and stable signal from the photo transistor. We approach this problem by first using a low pass filter with a cutoff frequency of 30Hz to filter out any noise above that frequency. Afterward, we use a high pass filter to eliminate any unwanted DC offset, and then amplify this small signal with a non-inverting amplifier to obtain the optimal signal. Finally, we can obtain the pulse chain by feeding this amplified signal to a comparator.

2.5 Reaction Time Module

Reaction sensor mechanism consists of force feedback motor attached to the vehicle's steering control. Microcontroller will interface with the force feedback mechanism in order to periodically induce test driving vectors to the user. The test vector specification is fairly simple:

Obviously the test vector will be applied solely to the steering control not the actual vehicle's steering mechanism. This will allow for testing the users reaction time as if the imposed test driving condition was real.

For the functional project demo we will simulate the above described system through a PC steering wheel simulator with force feedback capability.

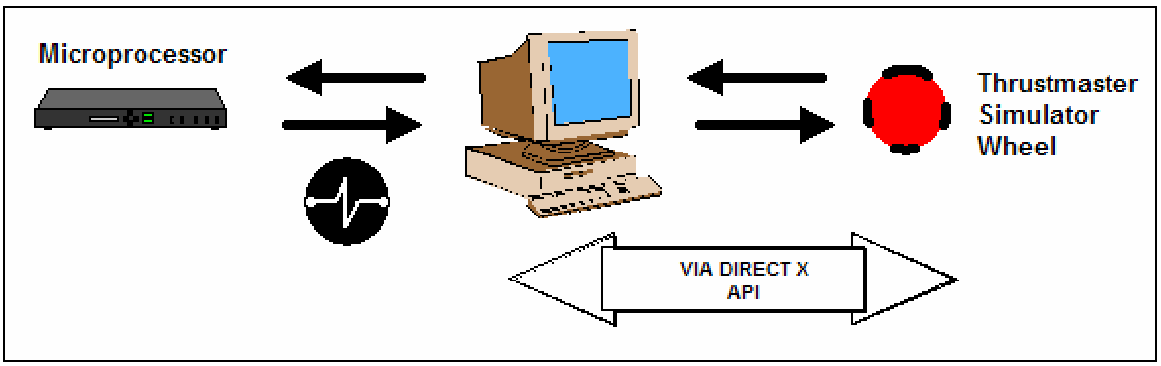


Figure 8 - Simulation of the Reaction Sensor Mechanism

3 System Software

3.1 OOPIC Microcontroller

The brain of DHM is consisted of an OOPic microcontroller which allows programming the device in high level object oriented languages such as C++ and Java. A major advantage of this chip is that it is really cost efficient, light and it works with a 9V which makes our design module portable.

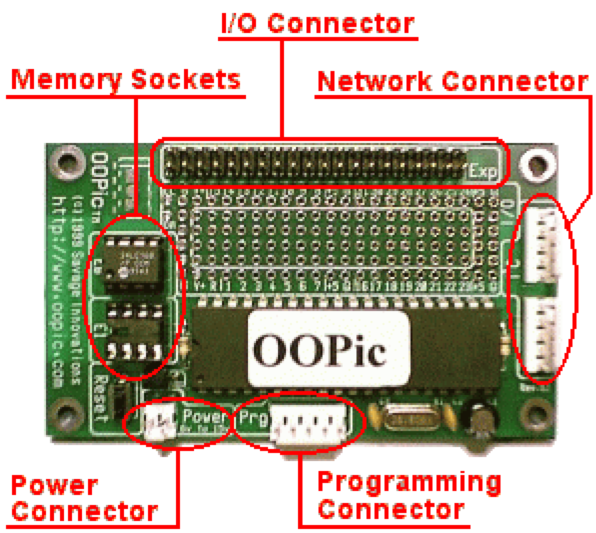
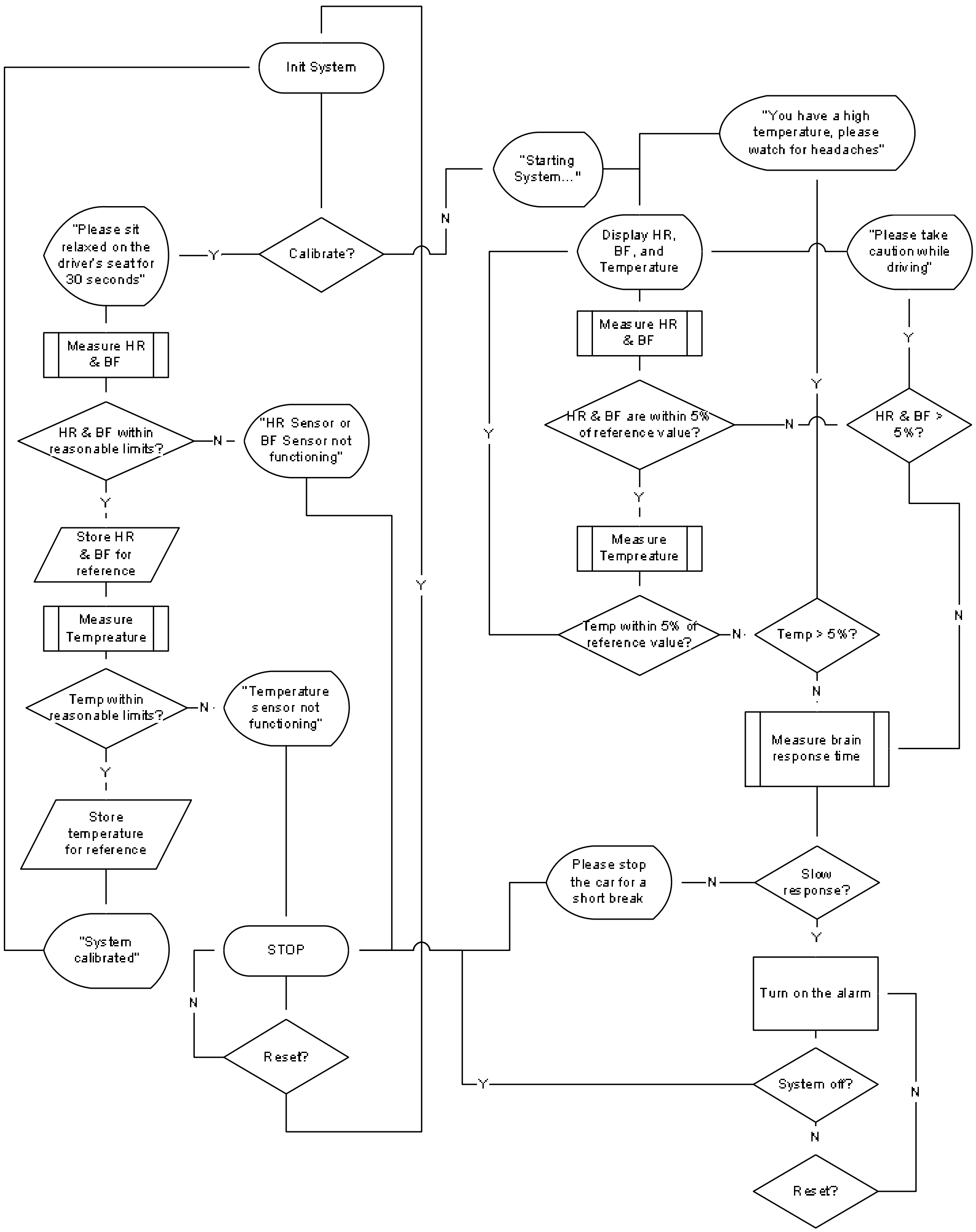


Figure 9 - OOPic Microcontroller

OOPic can be programmed through its own graphical IDE, which downloads the program on the EEPROM of the microcontroller through parallel port. This parallel port connection will also be used during the operation to transmit responses from force feedback wheel to the microcontroller via PC. OOPic communicates with the outside world through 31 I/O lines, 4 analog-to-digital (A/D) converters and 2 pulse width modulators (PWM). OOPic also comes with many modules available for our product such as counter, timers and virtual logic circuits composed of basic logic gates.

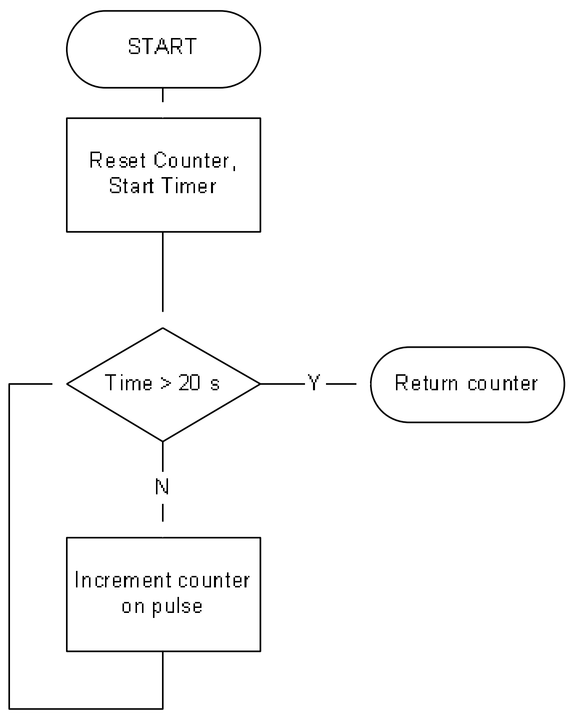
3.2 Logic Flow

The flow chart of the system has been show in Figure 10. There are two main components to the program. First component is the calibration algorithm, and the second component is the normal operation of the device.


Init System
Calibrate?
Y
N
"Please sit relaxed on the driver's seat for 30 seconds"
Measure HR & BF
HR & BF within reasonable limits?
N
"HR Sensor or BF Sensor not functioning"
Y
Store HR & BF for reference
Measure Tempreature
Temp within reasonable limits?
N
"Temperature sensor not functioning"
Y
Store temperature for reference
"System calibrated"
STOP
N
Reset?
Y
"Starting System..."
"You have a high temperature, please watch for headaches"
Display HR, BF, and Temperature
"Please take caution while driving"
Measure HR & BF
HR & BF are within 5% of reference value?
N
HR & BF > 5%?
Y
Measure Tempreature
Temp within 5% of reference value?
Temp > 5%?
Measure brain response time
Please stop the car for a short break
Slow response?
Turn on the alarm
System off?
Reset?

customizes the device to operate based on the data gathered from the driver instead of statistical data obtained from group studies for variables such as breathing frequency. At any given moment, the system can hold data for only one person, but in next phases of the project we can add an optional component to create a profile for different drivers of a vehicle.

The calibration phase will take approximately 30 seconds and the driver has to be awake and relaxed while doing the calibration. It is recommended that calibration be done early in the morning so that the gathered data resemble their true values for the driver. Incase that the sensors are not properly connected to the driver or they are malfunctioning the calibration will fail and display on the LCD what component has failed. This mode will be detected by invalid or out of boundary values for desired parameters (For example a body temperature of 20 degrees.) If the inputs are reasonable values, DHM will store them and during the normal device operation the inputs will be compared against these calibrated values. The algorithm for measuring the heart rate or breathing frequency is shown in Figure 11.



The second component of the system is **normal operation component** of the DHM. The device will go into an infinite loop to gather inputs from the driver and compares them with reference values that are previously stored. If the inputs are within 5% of the reference values, this discrepancy will be accounted as reasonable variation of input and noise. Incase the breathing frequency or heart rate of the driver are greater than 5% of reference value, this means that the driver is hyperactive and a warning will be displayed to notify the driver about his condition and take caution while driving. If the temperature is above 5% of the reference value, this means that the driver is suffering from a fever or other sort of disorders which has caused these high body temperatures. Again, if the driver has high body temperatures he will be awake enough to operate his vehicle and therefore a warning message will only be displayed.

The problem occurs if any of these three parameters fall below their acceptable values. In this case DHM will try to measure the brain response time of the driver. Brain response time measurement is done using our own BrainTracker™ technology. First step of the process is disengaging the steering wheel from the wheels, in order to take control of the steering wheel without affecting the movement and direction of the car. This should be a very short period of time since the driver will not be able to control the car during the execution of this process. Approximately a five seconds time period would be long enough for the driver to try to stabilize the steering wheel. Next a random signal for rotation of the steering wheel is sent to the force feedback steering wheel. If the driver is awake or half sleeping he will immediately try to stabilize the wheel. The brain response time is measured from the time the signal is sent until the time that the driver has stabilized the wheel. If this value is larger than the statistical brain response time of a normal average driver, the alarm will be turned on until it is turned off specifically by the driver. The statistical data of normality is well researched and results are available to us for comparison. The 5% limit to decide if any of the temperatures should be considered as high or low has to be researched through statistical figures.

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4 User Interface

The user interface of the device consists of the OOPIC's LCD and LED's. Upon monitoring the driver's health, OOPIC is able to draw the driver's attention by beeping and displaying warning lights. Then, optionally, the driver would have the choice to make contact with other numbers through SMS messaging. These numbers would either be predefined by the user at the beginning of the process, or could be entered by the driver on OOPIC upon being warned of the situation.

5 Test Plan

This section illustrates the method by which the testing of the individual modules and the system as a whole is performed.

The preliminary testing would be performed on each hardware module. Parameters like calibration error, SNR, sensors' maximum current flow, etc would be done in a setting very much like a driving environment. Subjects of the preliminary testing would be of different age, and sleep pattern, so the gathered data can be used as a reference of comparison for OOPIC.

By the end of the preliminary testing, the expected result of the software analysis would be known. During the secondary testing, each hardware module is analyzed by the software component of the OOPIC and the analysis is compared with the expected results. This set-up would be done, again, individually for each hardware component. During the secondary testing, in preparation for the final testing, parallel effort would be put into integrating the hardware, software and user interface components together.
Final testing of DHM would involve testing the integrated product under different test cases. These test cases include combination of different sensor inputs, as well as, the validity and sensitivity of the actual warning mechanism of OOPIC.

6 Conclusion

In this document, all of the design decisions for the Driver Health Monitor were outlined. All hardware components have been chosen and circuits are currently being produced. Firmware flowcharts have been designed which allow for structured and reliable programming. SLiK team feels confident that a fully functional prototype of the Driver Health Monitor will be completed by the scheduled April milestone.

7 Glossary of Terms

BS	Breathing Sensor
DHM	Driver Health Monitor
HRS	Heart Rate Sensor
OOPic	Object Oriented Programmable Integrated Circuit
RS	Reaction Sensor
RS	Reflective Photo Sensor
TS	Temperature Sensor