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Dr. Andrew Rawicz
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RE: ENSC 340 process report for AtuoWake™ Sleep Detector

Dear Dr. Rawitcz,

Attached, you will find the process report for *AutoWake Sleep Detector.* Our project was to design a smart eyeglass frame that monitors eye blinks and detects the verge of sleeping.

This document, in detail, outlines the current state of the design. In addition, it elaborates the problems we had to overcome to reach this stage in the design process. Time and budgetary issues and future plans are discussed towards the end.

SecuriTeam® is consisted of four bright and talented individuals: Nima Boostani, Azadeh Farzin, Ali Keyvani, and Nasim Morawej. Their outstanding capabilities were, without any doubt, vital in our team's achievements.

If you have any further inquiries please do not hesitate to contact Azadeh Farzin, the Chief Excecutive Officer, at afarzin@sfu.ca or visit our website at www.sfu.ca/~nmorawej.

Sincerely,

Azadeh Farzin

Azadeh Farzin,
SecuriTeam Co.

Process Report for

AutoWake Sleep Detector

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1. Introduction

Thinking of the main dominant causes of death in North America grouped together the founders of SecuriTeam Co., the above mentioned four individuals, during the past three months. With hard effort and patience, we could successfully invent *AutoWake* with the hope of improving the statistics of accidents caused by sleeping, the main cause of death in North America, second only to heart disease and cancer. This document outlines the current state of the design, the problems we encountered reaching this point in the design process, each individual outstanding capability, and the experiences gained by each team member.

1. Current State of the Design

AutoWake, at its current state, is a pair of glasses that can distinguish between sleepy and normal eyes. The frame is connected to a small portable control board that is easy to mount on the dashboard or underneath the driver seat. When the device detects that the eyes have become closed for more than 2 seconds, it activates primary and secondary alerts in a timing fashion to alert the driver, other drivers, and pedestrians.

What follows in this section, specifies the current state of the hardware, and firmware design and the problems encountered in their implementation. Please refer to Appendix A and Appendix B for the complete circuit schematic and complete firmware code respectively. Where appropriate, the reader is referred to the design specifications document provided for *AutoWake*.

1.1 Hardware

The hardware contains the units depicted in Figure 2.1.1. The following describes each unit at its current state and the problems encountered in the design of the unit. Due to circuit complexity and interconnections between circuit blocks it is not appropriate to divide the schematic into sections. We encourage the reader to refer to the complete circuit schematic in Appendix A for details of each unit. The component symbols referred to in the following match those in the schematic.

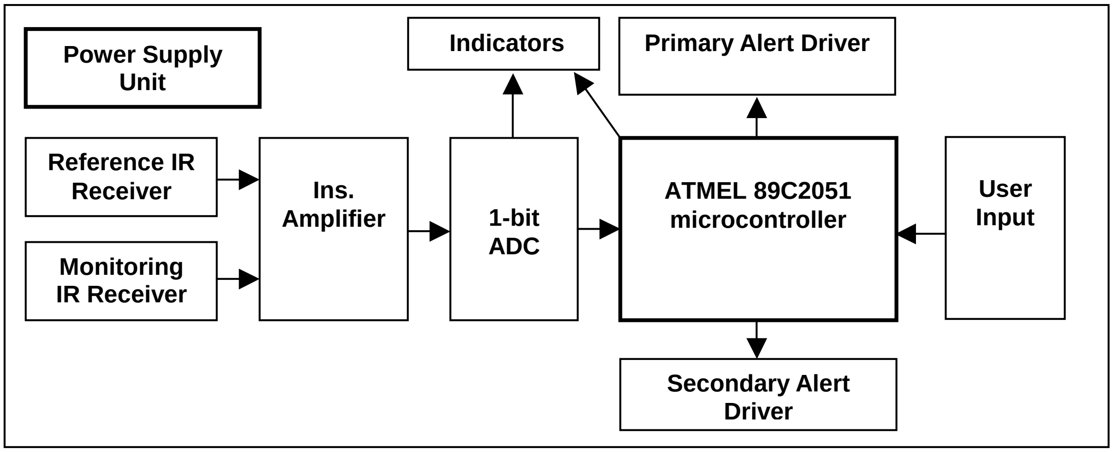


Figure 2.1.1: Hardware block diagram

2.1.1 Power Supply

AutoWake is powered from a 12V DC power supply, the standard voltage of a car battery. A 5V, and an 8V supply are extracted from the 12V supply for logic components and other components that require lower power levels than 12V. For more details refer to the circuit schematic in Appendix A.

We experienced the following problem when designing the power supply unit:

- **Noise**

  We experienced a lot of noise in the power rails due to the presence of high frequency and logic components in our circuit (a 12MHz crystal, the microcontroller unit, and a comparator). Extra-large bypass capacitors are employed (***C2***, ***C5***) in the design of the power supply to eliminate the noise as much as possible.

2.1.2 Blink Detection Unit

This unit is comprised of two pairs of infrared emitter/receiver LEDs (***IRS_1***, ***IRS_2***, ***LED4***, ***LED5***), an instrumentation amplifier (***U1A***, ***U1B***, ***U2A***), and a 1-bit ADC unit (***R9***, ***R17***, ***R18***, ***R19***, ***Q1***, ***U2B***, ***U5***). Refer to sections 3.2, 3.3, and 3.4 of *AutoWake* design specifications document for detailed hardware description. The unit uses two infrared sensors to detect the state of the eye. One infrared LED constantly monitors the infrared reflection from the skin of the eyelid to sense the intensity of light, and the other monitors the eyeball. By feeding the output of the two sensors into the instrumentation amplifier, an analog signal is obtained the magnitude of which corresponds to open and close states of the eye.

However, since the microcontroller unit needs a logic signal to process, a 1-bit ADC unit is used to map the analog voltage magnitude into logic levels corresponding to closure and opening of the eye. Please refer to Appendix A for detailed hardware implementation.

The following problems were encountered and solved in the implementation of the above described blink detection system.

2.1.2.1 Light Intensity

The sensors proved to be very sensitive to variations of light intensity. This light intensity variation was a major problem, specially at the beginning, when we wanted to use only one sensor to detect the blinks. We were never sure in interpreting the signal from the sensor as to whether it was signaling a change in light intensity or a change in the state of the eye. Using a second sensor solved this problem. The task of this second sensor is to constantly monitor the infrared reflection from the eyelid skin and generate a voltage corresponding to the light intensity. By comparing the signals from the monitoring sensor and the reference sensor (using the instrumentation amplifier as explained above) the blinks can easily be detected.

2.1.2.2 Ambient Light

Ambient light had a dramatic effect on the functioning of the sensors. It created a lot of noise in the output signal of the sensors. Shielding the sensors by covering them with black tubes, to high extent, solved this problem.

2.1.2.3 Sensor Calibration

With the equipment at hand (electric tapes and an old frame), mounting the sensors on the frame was a terrible and time-consuming task to accomplish. Considering this fact would, in advance, project the difficulty we went through in calibrating the sensors for optimized blink detection.

We started by monitoring the corner of the eye, however, it turned out that the corner of the eye lead to signal losses and not all blinks were detected. Mounting the sensors on the top edge of the frame proved to produce the most accurate results in detecting the blinks.

2.1.2.4 Logic Signal

When the state of the eyes was changing from open to close, the corresponding transition time in the logic signal was too long to be detected by the microcontroller. We used a comparator (***U5***) with an appropriate threshold voltage (adjustable by ***R17***) in the output stage of the ADC unit to get a sharp transition edge well recognized by the microcontroller.

2.1.2.5 Instability

Due to presence of different noise sources, we experienced an unstable behavior from the logic signal representing the state of the eye. In situations when the eyes were at the verge of closing the logic signal that represents the state of the eye bounced up and down forming an oscillation. We introduced hysterisys in the design of the output stage of the ADC unit to maintain stability of the system and eliminate any instability caused by noise. The hysterisys components are ***R19***, ***R18***, and ***U5*** in the circuit schematic in Appendix A.

2.1.3 Alert Units

A buzzer (primary alert system) and a flasher (secondary alert system) comprise the alert units in the current design. Both alert systems have a separate alert driver circuitry consisting of relays (***K2***, ***K1***), transistors (***Q2***, ***Q3***), feedback diodes (***D7***, ***D8***), and fly-back diodes (***D4***, ***D5***). For principle of operation of these units, refer to sections 3.5, and 3.6 of the design specifications for *AutoWake*.

We encountered the following problem in the design of the alert driver.

2.1.3.1 Insufficient turn-on voltage

In sections 3.5, and 3.6 of the design specifications document for *AutoWake*, the purposed design had two feedback diodes in the emitter circuit of the current amplifier transistors (***Q2***, ***Q3***). Most often, this configuration did not provide the relays with sufficient turn on voltage and consequently the alert systems would not be activated. By only placing one diode in each of the emitter circuits we could obtain an activating voltage high enough for the relays to reliably turn on the alert units when necessary.

1.2 Firmware

We started the main development of the firmware after we were able to acquire a clean logic signal from the detection circuitry. In general, the firmware development phase was followed with few critical problems. However, a number of low-level design decisions had to be made during the course of firmware development. The following is a brief discussion of these decisions (for details on firmware design refer to Appendix B of this document.)

2.1.1 Input Detection

As mentioned in section 3.7 of the design specifications document for *AutoWake*, the microcontroller unit receives only one input from the detection circuitry; a falling edge on this input line corresponds to the eye closing, while a rising edge corresponds to the eye opening. In designing the firmware, we had two options in receiving this signal: through an input port or through an interrupt pin.

Our first approach to use an interrupt pin was not satisfactory since the microcontroller was not able to detect rising edges, meaning that we would not be able to detect eye openings. Therefore, we decided to connect the input to both an interrupt pin *and* an input port. The interrupt pin would detect eye closures (falling edges), while the input port would be continuously sampled in the main body of the program to detect eye openings (logic level '1').

2.1.2 Timers

The behavioral design of the firmware requires at least three timers to generate the following delays:

1. A delay between a detection of eye closure and the activation of the primary alert system.
2. A delay between an activation of the primary alert system and the activation of the secondary alert system.
3. A delay between a detection of the eye opening and the deactivation of both alert systems.
4. A delay needed to generate a square wave signal to drive a 'flashing' secondary alert system.

Nevertheless, as mentioned in the design specifications document for *AutoWake*, the ATMEL 89C2051 microcontroller contains only two timers. To rectify this situation, we devised the following schema:

- Timer 1 was used to generate delays 1 and 2 (of course this would limit us to using the same delay length for both tasks.)
- Timer 2 was used to generate delay 4.
- Delay three was implemented as a simple loop in the main body of the program. This is justified by the fact that, in any case, the main program would have to be in an infinite loop.

1. Future Considerations

The following illustrates future design considerations in order to integrate the performance and reliability of *AutoWake*. In addition, business plans are discussed.

5.1 Hardware

The following are the areas that have drawn our attention and will certainly be considered in our future investigations.

5.1.1 Wireless Data Communication

One of the future research fields in the integration process of *AutoWake* is to use wireless technology to interconnect the frame and the control board. Currently, the eyeglass frame is connected to the main control board via physical wires. We plan to replace the physical wire connection with wireless communication between the control board and the frame. This modification significantly improves the convenience of wearing the frame.

5.1.2 Image Processing

Image processing might be an alternative to the current technology we are using to detect the blinks. However, this technique can only be implemented in vehicles equipped with an advanced computer system. Therefore, it cannot totally replace the cheap and efficient technology currently being used for blink detections.

5.1.3 Design of Special Frames

As previously mentioned, the calibration of the sensors at the current state of the design is a tedious job to do. We are planning to design special frames that accommodate proper space for the sensors as well as hinges to facilitate the calibration process.

5.2 Firmware

For the future design of the firmware we are considering the following areas.

5.2.1 More Flexible Timing

As mentioned in Section 2.2, due to the fact that the microcontroller unit does contain only two timers, we were forced to use the same delay length for two tasks (delays 1 and 2, please refer to section 2.2.2) in addition to using a loop to generate another delay (delay 4.) We are considering developing a more complex algorithm to generate all four delays, with different lengths, using only the two available timers.

5.2.2 Response to More Complex Behavior

We believe that, drivers, while falling asleep, exhibit common behavior. This includes certain patterns in eye blinks and face gestures. As a future consideration, extensive research can be done to find and document these behavioral patterns. The firmware can then be improved to take these patterns into account and to make more intelligent decisions regarding the state of driver.

5.3 Business Plans

The future business plans of *SecuriTeam Co.* include the following.

5.3.1 Patent

We are considering patenting our product. Although similar research from other sources is in progress, we know that a completely different technology is under investigation. Therefore, we still have a chance of getting a patent for *AutoWake*. However, we have to look into the process of patenting more thoroughly to be able to reach the next step, which is marketing.

5.3.2 Marketing

We have investigated the market potential for our product, and we are aware of the great demand for *AutoWake*. We would like to sign business contracts with car companies to either sell our idea to or work with them as a team to integrate *AutoWake* using their facilities. Volvo, and Mercedes are the first two car companies in our list that we might address to discuss our plans with. These companies are greatly concerned about safety issues of their vehicles. Another possible market for our product would be the truck industry where drivers are exposed to long hours of driving and the risk of falling asleep behind the wheel is high.

6. Budget and Funding

Table 6.1 summarizes our projected costs and the amounts we ended up paying.

Table 6.1: Summary of the projected and final costs

Item	Projected Cost	Actual Cost
Development Kit	$160.00	$120.00
Eyeglass frame	$50.00	$10.00
Electronic parts	$50.00	$30.00
Infrared emitting and receiving diodes	$10.00	$4.00
AT89C2051 microcontroller	$10.00	$5.00
Total Cost	**$280.00**	**$169.00**

We received $100.00 funding from ESSEF. This financial assistance failed to fully cover the above expenses. The team members shared the remaining costs equally. Overall, the actual cost was effectively managed to be much lower than the projected cost.

7. Timing

The design and implementation of the first prototype for *AutoWake* commenced on September 16th, 2002 and was concluded on November 15th, 2002, some fifteen days ahead of schedule (please refer to *AutoWake*'s proposal document for a detailed timeline). The demo and presentation were performed on December 2nd, 2002.

The early completion of the project was due to the team's strong commitment to the proposed schedule. In order to prepare for any unforeseen difficulties that we may have encountered, we tried not to stay behind but to be ahead of our schedule at any given time. Fortunately, through allocating sufficient time to research and prototyping, and therefore by making informed decisions, we were able to avoid such obstacles. Table 7.1 summarizes the actual timeline of our major milestones (please refer to Section 5 of *AutoWake*'s Proposal Document for our proposed schedule).

Table 7.1: Timeline of milestones

Order	Major Milestone	Time Reached
1	Design begins.	Sept.16
2	Feasibility testing and calibration ended successfully.	Oct. 1
3	Logic Unit test bed completed.	Oct. 7
4	Primary and Secondary Alarm circuits completed.	Oct. 23
5	Logic Unit interfacing completed.	Nov. 3
6	Firmware design completed.	Nov. 10
7	Final Testing and Debugging completed.	Nov. 15

Indeed, one of the most important lessons we learned throughout this project was the importance of adhering to a well-planned schedule. In the end, we all developed a much-deserved appreciation for discipline and timeliness as a key element to any successful project.

8. Group Dynamics and Personal Profiles

Since our group formation, we scheduled the meetings making sure that every group member can attend those meetings. Having every member in the meetings had the advantage of everyone being aware of details and aspects of the project at every stage, and it had the disadvantage of falling behind once one person could not attend a meeting. We also avoided unnecessary gatherings and tried to communicate through email whenever possible. We had short gatherings for each of the documentations, to split the work and divide up the sections. Having done our shares individually, we then put together, and proof read the final document before submission.

The following describes each member's personal skills as well as responsibility during the development of the first prototype of *AutoWake*.

Azadeh Farzin

I am a fourth year Electronics Engineering student. My engineering education in electronics engineering was mainly focused on the theoretical aspects of designing. Being involved in this project was an exceptional opportunity to apply the theory that I had learned in four years to real world.

In our project I was involved in all aspects of the project, from hardware and firmware design to documentation, along with the other group members. My main responsibility was managing and organizing the team activity to make sure that necessary meetings were held and all the deadlines were met as scheduled.

I believe that accomplishing this project significantly improved my abilities, interest and enthusiasm towards hardware and firmware design, communication skills, and teamwork. Simply stated, it was a magnificent experience.

Nima Boostani

I am a fourth year systems engineering student with a concrete background in mechanical design, electronics design, and software programming. My previous experiences include design of a line-tracing robot, design of a Laparoscopic Joystick and its I/O interface, design of a four channel motor driver, developing a 3D modeling software in C, developing computer games, and other diverse projects.

My main focus throughout the project was on hardware schematics, design, and testing. My background in these areas was a major advantage to the team as considerable amount of time was saved by fast problem solving and familiarity with design methods and electronic components. With the help of other group members, the design and testing process was even faster in such a way that all the deadlines for hardware testing and debugging were met earlier than scheduled. I was also involved, interactively, with other group members in the process of firmware development and documentation.

Overall, from practical point of view, this project helped develop my skills more fully in hardware and firmware design. I found the opportunity to, effectively and efficiently, make use of my latest engineering trainings in practice and towards the invention of a device that can save lives. My highest benefit from doing this project was to become familiar with team handling procedures and to realize the importance and usefulness of team approach towards problem solving techniques, and to appreciate the key role of documentation. Admittedly, accomplishing this project was a real team experience in a real design situation.

Ali Keyvani

I am a fourth year Computer Engineering student. My background ranges from writing Object-Oriented Multithreaded software to designing PCB schematics and FPGA design for various companies.

I was involved in all aspects of the project while my main focus was on firmware design. I took part in resolving general design issues, hardware and software development, and documentation. We were faced with many challenges during the course of this project, all of which provided me with valuable technical experience. Furthermore, I learned many things about group dynamics and improved my interpersonal skills.

Nevertheless, my greatest accomplishment was, I would say, the sense of satisfaction I gained from knowing that all these years of hard work have enabled me to, indeed, make a difference.

Nasim Morawej

I came to engineering to think of ideas that can actually be implemented. After four years of studying in electronic engineering, as I have been involved in the complete design process of *AutoWake* in ENSC 340, I realized that I am going in the right direction towards my goal.

In ENSC 340, I got the opportunity to experience hands-on hardware and firmware design. This was a great learning process for me since I did not have the chance, in my co-op or previous projects, to practice what I have learned during my engineering training. One of my major tasks was to assemble the hardware and cooperate in setting up testing plans. I was also involved in the design of firmware development along with the other group members. Finally, I had a lot of fun constructing the website surprisingly fast to amaze the group members as they did not expect my early accomplishment.

While looking through last year's documentations, I came up with this sentence, which I found very true:

"It is not the course that is important, it is the self-discovery that it brings out that is valuable and insightful." [1]

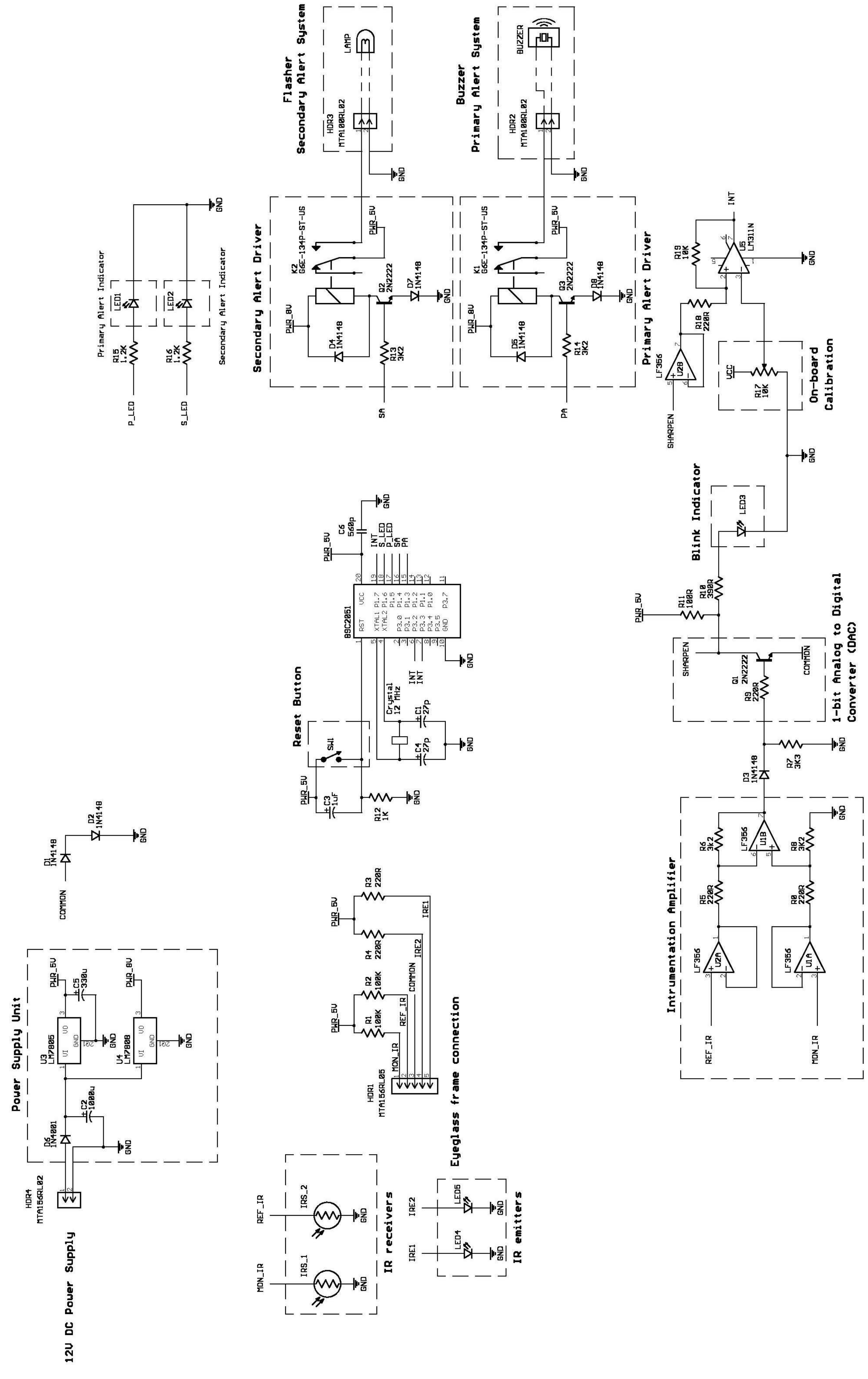
At the end, I want to acknowledge that ENSC 340 was a very valuable course for me and I appreciate those that I have learned from throughout this course and my course of education.

[1] QND Medical Devices, Process Report, December 2000, , Stephen Liu

Appendices

Appendix A

Circuit Schematic



Notes: P3.2 can be configured to be External Interrupt #0 pin
P3.3 can be configured to be External Interrupt #1 pin
IR receivers and IR emitters are mounted on an eyeglass frame
All resistors are 5%

Appendix B

Firmware Code

```
; AutoWake firmware code, Nov 15, 2002.
; Copyright of SecuriTeam Co.

        ORG     000H
        AJMP    MAIN

        ;Interrupt Vector BEGIN

        ORG     003H
        AJMP    EXT0_ISR

        ORG     00BH
        AJMP    TIMER0_ISR

        ORG     01BH
        AJMP    TIMER1_ISR

        ;Interrupt Vector END


        ORG     030H
MAIN:
        ;Set external interrupt mode
        SETB    IT0                         ;Falling edge

        ;Set timer mode to 16-bit
        MOV     TMOD, #11H

        ;Enable interrupts
        MOV     IE, #8BH

        MOV     P1, #0
        SETB    P1.7                        ;This pin is an input
        SETB    P1.6                        ;Red LED Off
        SETB    P1.5                        ;Yellow LED Off
        SETB    P1.4                        ;Flasher Off
        SETB    P1.3                        ;Buzzer Off

        ;Loop indefinitely
LOOP:
        ;Read signal coming from sensor
        JNB     P1.7, LOOP                  ;Do nothing if closed
```

```
LOOP:
        ;Read signal coming from sensor
        JNB     P1.7, LOOP                 ;Do nothing if closed

        ;
        ; 1 second delay before resetting
        ;

        MOV     R6, #20
LOOPAZI1:
        DJNZ    R6, LOOPAZI2
        JNB     P1.7, LOOP                       ;After delay, if the eye is closed
                                           ;don't reset
        ACALL   RESET_ALL
        AJMP    LOOP
LOOPAZI2:
        MOV     R5, #250
STUCK2:
        DJNZ    R5, LOOPAZI3
        AJMP    LOOPAZI1
LOOPAZI3:
        MOV     R4, #200
STUCK3:
        DJNZ    R4, STUCK3
        AJMP    STUCK2

        ;
        ; END: 1 second delay
        ;



        AJMP LOOP

        ;Reset the timers, LEDs...
RESET_ALL:
        ;Disable Alarms
        CLR     EX0                        ;Disabling external interrupt 0
```

```
        CLR     TR0
        CLR     TR1
        SETB    P1.4                    ;Flasher Off
        SETB    P1.3                    ;Buzzer Off
        SETB    P1.6                    ;Red LED Off
        SETB    P1.5                    ;Yellow LED Off

        SETB     EX0                    ;Enabling external interrupt 0

        RET

        ;Falling Edge = Closed
EXT0_ISR:
        ;Set duration (2 seconds)
        MOV     R7, #80
        SETB    TF0                     ;Envoke timer interrupt
        RETI

TIMER0_ISR:
        CLR     TR0                           ;Stop timer
        DJNZ    R7, BIGGER_ZERO

        ;Start Blinking
        MOV     R3, #10
        SETB    TF1

        AJMP    EXIT0

BIGGER_ZERO:
        CJNE    R7, #40, NOT_FOURTY

        CLR     P1.3                    ;Turn Buzzer on
        CLR     P1.5                    ;Turn Yellow LED on

NOT_FOURTY:
        MOV     TH0, #HIGH(-50000)      ;Set duration
        MOV     TL0, #LOW(-50000)
        SETB    TR0                     ;Enable timer
EXIT0:
```

```
        RETI

        ;Secondary Alarm Blink
TIMER1_ISR:
        CLR     TR1                         ;Stop timer
        DJNZ    R3, SKIP1

        CPL     P1.4                    ;Turn Lamp on
        CLR     P1.6                    ;Turn Red LED on

        MOV     R3, #10
SKIP1:

        MOV     TH1, #HIGH(-50000)      ;Set duration
        MOV     TL1, #LOW(-50000)
        SETB    TR1                     ;Enable Timer

        RETI

END
```