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Dr. Andrew Rawicz
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RE: ENSC 340 Design Specification for *AutoWake*™ Sleep Detector

Dear Dr. Rawicz,

Attached, you will find the specifications for the design of *AutoWake* Sleep Detector.

The design of *AutoWake* is meant for alerting drowsy drivers who are at the brink of falling asleep at the wheel. This device is composed of an eyeglass frame and a main control board for user interface purposes [1]. The control board allows the user to activate the device when the frame is properly installed in front of the eyes. For convenience of use, adjustments are made by sales people to ensure appropriate positioning of the frame with respect to the eyes while in use [2].

The attached design specification provides detailed specifications for the design and test of the complete first stage prototype. Our goal is to reach this stage by December 2002.

SecuriTeam members are: Nima Boostani, Azadeh Farzin, Ali Keyvani, and Nasim Morawej. If you have any further inquiries please do not hesitate to contact our Chief Executive Officer, Azadeh Farzin. She can be reached at afarzin@sfu.ca.

Sincerely,

Azadeh Farzin

Azadeh Farzin,
SecuriTeam Co.

Design Specification for

AutoWake Sleep Detector

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Executive Summary

Statistics show a significant correlation between tiredness and car accidents, and thus, sleepy drivers behind the wheel are indirectly a dominant cause of death in North America, second only to heart disease and cancer [3]

SecuriTeam's *AutoWake* is a device aimed at greatly reducing the number of such accidents. The device takes advantage of cutting edge optical technology to monitor the state of the driver's eyes and, using the latest microprocessor components, manages to make a highly accurate assessment of the driver's condition. If *AutoWake* detects that the driver has fallen asleep, it will automatically activate primary and secondary alerts to wake up the sleepy driver. Thus, *AutoWake* saves many lives.

The device consists of a sensor component, in the form of ordinary eyeglasses frame, that the driver will be required to wear. In the case of drivers who wear prescription glasses, the sensor component will be available in the form of and add-on kit, which will very easily attach to the frame of the glasses. *AutoWake* also has the following features:

1. Easy to buy with our reasonable cost.
2. Easy to install.
3. Easy to use.
4. Easy, comfortable and friendly eye-closure detection method.

The design specifications for *AutoWake* including full details of hardware design, firmware design, and test procedures are presented in the following document.

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1 Introduction

AutoWake detects when a driver is on the verge of falling asleep. Since, in this state, the driver is losing control of the car, *AutoWake* responds by alarming the driver. This alarm is *AutoWake*'s primary alarm mechanism. If the primary mechanism is unsuccessful to wake up the driver, *AutoWake* invokes a secondary mechanism to alert the surrounding drivers and pedestrians.

The first stage prototype will be completed by December 2002. Details of mass production of *AutoWake* are left for future investigations.

1.1 Scope

This document provides the hardware and firmware design details as well as test plans for the first stage prototype of *AutoWake*.

1.2 Acronyms

ADC	Analog to Digital Converter
CPU	Central Processing Unit
IR	Infrared
ISR	Interrupt Service Routines
LED	Light Emitting Diode
TTL	Transistor-Transistor Logic

1.3 References

[1] Proposal for *AutoWake, SecuriTeam Co*
[2] Functional Specification for *AutoWake, SecuriTeam Co*
[3] Rothsein Catalog On Disaster Recovery
http://www.disastercenter.com/cdc/

1.4 Intended Audience

Design engineers can use this document to obtain full details of hardware and firmware design of *AutoWake.*
Project manager can use this document for information on project design and objectives.
Test engineers can use this document for testing and debugging the design.

2 System Overview

The information contained in this section describes the overall expected design of *AutoWake*. An eyeglass frame is set up in front of the driver's eye. As shown in Figure 2.1.a, in normal driving conditions, where the eyes of the driver are fully open, one of the two IR emitters casts IR light at the eyelid and the other sensor casts IR light at the eyeball. Two IR receivers detect the light that is reflected from the eyelid and eyeball respectively. The reflection from the eyeball is weaker than that of the eyelid. The signals from the two receivers are compared (more details are provided in Section 3, Hardware Design). The two signals being similar mean that the eyelid has closed over the eyeball. However, if the two signals are significantly different, then circuit interprets this to mean that the eyelid is not obscuring the light reflected from the eyeball as shown in figure 2.1.b. The CPU continually checks the status of the eye. It is not necessary to monitor both eyes, as very few people sleep with exactly one eye open and one eye closed. The CPU is capable of distinguishing between simple eye-blinks and the onset of sleep.

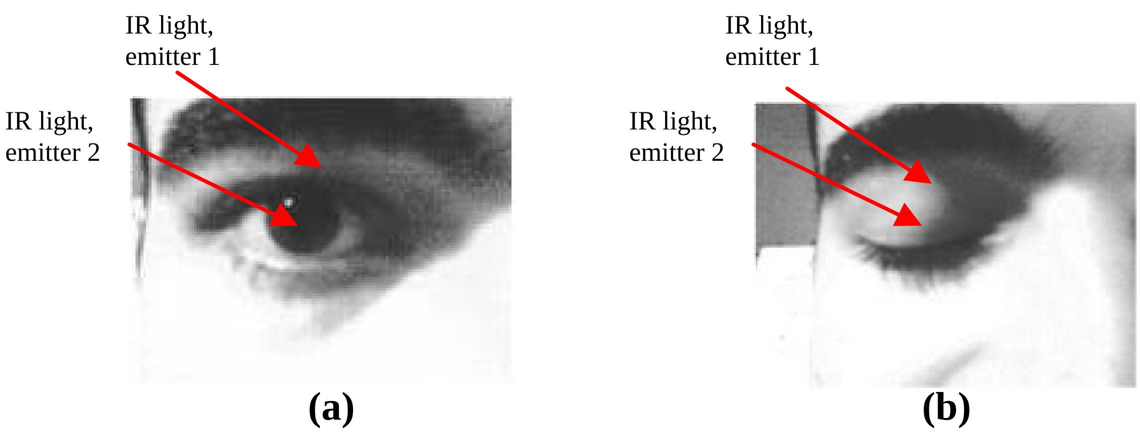


Figure 2.1.1: (a) Different IR light reflections from the eyeball and the eyelid for open eyes
(b) Identical IR light reflections for closed eyes

Upon detecting the onset of sleep, the CPU alarms the driver by activating a buzzer. The alarm ceases, when the driver re-opens her/his eyes. However, the CPU continues the primary alarm and activates a secondary alarm mechanism if the driver fails to wake up. This secondary alarm will be the activation of a flashing lamp in the first stage prototype, and the activation of the horn of the car in the production prototype.

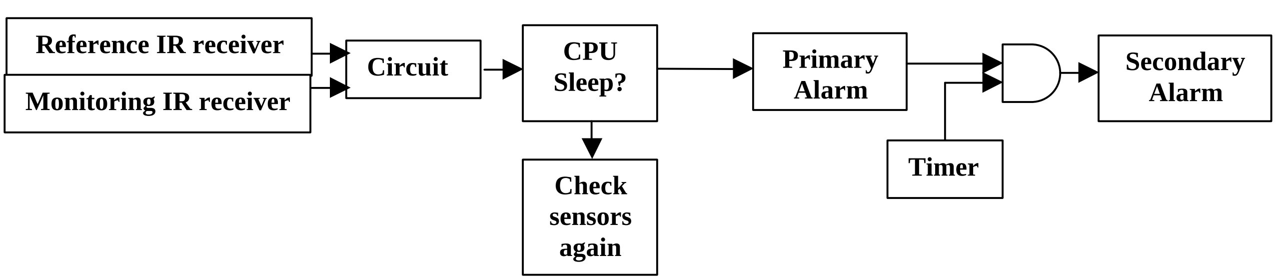


Figure 2.1.2: Block diagram of the general design of *AutoWake* system

If the user wishes to stop/start using the device at any time, a stop/start button is available on the control board in the design of the first stage prototype.

3 Hardware Design

Figure 3.1 shows the major components comprising the system hardware. Each component consists of one or more electrical components. All components are mounted on a single vector board. Please refer to Appendix A, Figure A.1for the detailed schematic of the System Hardware. Component symbols, given in parentheses, in the following description match those of the schematic of figure A.1.

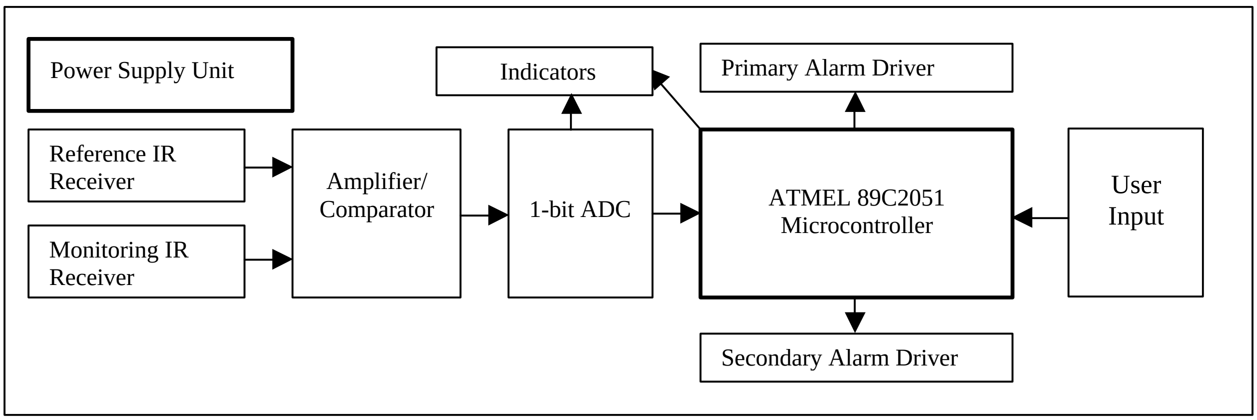


Figure 3.1: Major system hardware components

3.1 Power Supply Unit

This component consists of one LM7805 (U3) and one LM7808 (U4) voltage regulator units designed to provide stable 5V, and 8V power rails from a 12V power input for the circuitry. Regulating the power voltage decreases the amount of fluctuation in the power level that can harm electrical components and decrease detection accuracy.

The 8V power supply merely powers the relays (K1, and K2), while the 5V power supply feeds the rest of the circuit. An 8V power supply was needed because using the 5V power supply, in the configuration used, would not provide the relays with sufficient current to perform switching properly. Refer to figure A.1 of Appendix A for further hardware details.

3.2 IR Emitter/Receivers

The IR emitters provide sufficient IR radiation so that, the IR reflection from the eyeball/eyelid is enough for the IR receivers to respond accordingly. The reference IR emitter points to the top of the eyelid constantly and provides radiation for the reference IR receiver, while the monitoring IR emitter points to the eyeball and provides radiation for the monitoring IR receiver.

The configuration used to drive IR receivers (IRS_1, and IRS_2) consists of two resistor (R1, and R2) and two diodes (D1 and D2). The resistors are chosen to provide sufficient sensitivity as well as limiting the current flow through the IR receivers. The IR emitters (LED4, and LED5) are driven by 2 resistors (R3, and R4) chosen in a way that enough current (but not too much to harm the retina) flows in the IR emitters. The diodes, effectively, add a constant offset to the output of the sensors. This ensures that the input to the Instrumentation Amplifier from the IR receivers is sufficiently above the negative supply rail of the op-amps of the Instrumentation Amplifier (U1A, U2A, and U1B), which is connected to ground. Refer to figure A.1 of Appendix A for further hardware details.

3.3 Instrumentation Amplifier

This component consists of three LF356 op-amps (U1A, U1B, and U2A): two for buffering and reducing the load on the two signals received from the IR receivers, and one for amplifying the voltage difference between the output voltages of the reference IR receiver and monitoring IR receiver. The first two op-amps are connected in the voltage follower configuration, while the third op-amp is configured as a balanced difference amplifier that amplifies the two signals at the output of the first two voltage followers. Refer to figure A.1 of Appendix A for further hardware details.

3.4 1-bit ADC

The function of this component is to convert the voltage received from the Instrumentation Amplifier unit into a 1-bit TTL signal to be used by the microcontroller unit. The conversion is done according to a certain threshold value; an input voltage below the threshold is translated into a TTL Low, while a voltage above the threshold is translated into a TTL High.

This circuit consists of a set of resistors (R7 and R9), a diodes (D3) and a 2N2222 transistor (Q1). The function of the diode, along with the voltage level at the emitter of the transistor, is to provide an appropriate threshold voltage for the switching to occur properly. Resistor R7 is simply a pull-down resistor, while R9 controls the amount of current going into the base of the transistor. Refer to figure A.1 of Appendix A for further hardware details.

3.5 Primary Alert Driver

This component contains an Omron G6E-134P-ST-US Relay (K1) unit in addition to a 2N2222 transistor (Q3) and a resistor (R14.) The microcontroller pin 15 (I/O pin) is connected to the transistor via the resistor. Assigning a logic value '1' to this pin turns the transistor on. The transistor, then, provides sufficient turn on voltage for the relay, which causes the buzzer (primary alert system) to turn on. The relay is connected in parallel with a "*freewheeling*" diode (D5). When the relay is turned off (by placing a logic value '0' on pin 15), this diode dissipates the energy stored in the relay inductor and prevents voltage rise at the collector, and, consequently, prevents the transistor to break down. Refer to figure A.1 of Appendix A for further hardware details.

3.6 Secondary Alert Driver

This component contains an Omron G6E-134P-ST-US relay unit (K2) in addition to a 2N2222 transistor (Q2) and a resistor (R13.) The microcontroller pin 16 (I/O pin) is connected to base of the transistor through the resistor. Assigning a logic value '1' to this pin turns the transistor on. The transistor, then, provides sufficient turn on voltage for the relay, which causes the flasher (secondary alert system) to turn on. The relay is connected in parallel with a "*freewheeling*" diode (D4). When the relay is turned off (by placing a logic value '0' on pin 16), this diode dissipates the energy stored in the relay inductor and prevents voltage rise at the collector, and, consequently, prevents the transistor to break down. Refer to figure A.1 of Appendix A for further hardware details.

3.7 ATMEL 89C2051 Microcontroller

ATMEL 89C2051 is an 8-bit microcontroller with 2K Bytes of FLASH memory, 128 bytes of RAM, two 8-bit I/O ports and two external interrupt pins. The device is compatible with the MCS-51 instruction set

This component is the main control unit of the system. Based on the inputs received from the 1-bit ADC unit, and user inputs[1], the microcontroller makes decisions regarding the state of the system and activates or deactivates the primary and/or secondary alerts accordingly.

Pins 6 and 7, the interrupt pins of the microcontroller (INT0 and INT1), are connected to the output of the 1-bit ADC to detect rising and falling edges of this signal respectively. Furthermore, pin 15 (P1.3) and pin 16 (P1.4) are connected to the input of the primary and secondary alert drivers respectively. These pins are configured as output by the firmware. Placing a logic value '1' on these pins turns the alert systems on while a logic value '0' turns them off.

[1] Reset, Start, and Stop are the possible user inputs to the system. In figure A.1, Appendix A, SW1, and SW2 are the switches provided for Start/Stop, and Reset of the system respectively.

In addition, pins 17 (P1.5) and 18 (P1.6) are connected to indicator LEDs (LED1 and LED2 respectively). More detail regarding these pins is provided under section 3.8: Indicators.

Pin 1, the reset pin of the microcontroller (RST), is connected to VCC via a capacitor and grounded via a resistor (R12 and C3). The time constant of this differentiator configuration is tuned to ensure keeping RST pin at logic value '1' for at least two clock cycles upon powering up the microcontroller. This condition should be met for resetting the microcontroller and starting program execution. In addition, a reset switch (SW1) is connected in parallel with the capacitor to allow the user to reset the system manually. Refer to figure A.1 of Appendix A for further hardware details.

3.8 Indicator

This component consists of three LEDs (LED1, LED2 and LED3) and is intended to reveal the status of the system. LED3 combined with resistors R9 and R10 is connected to the output of the 1-bit ADC. This setup causes the LED to turn on whenever the transistor Q1 is off (i.e. when the 1-bit ADC is outputting a logic value '1' or equivalently when the eye is closed.)

LED1 (combined with resistors R20) and LED2 (combined with R21) are connected to pins 17 (Port 1.5) and 18 (Port 1.6) of the microcontroller respectively. LED1 indicates primary alarm activation, and LED2 indicates secondary alert activation. Each LED turns on when the corresponding alert is activated. Refer to figure A.1 of Appendix A for further hardware details.

3.9 Start/Stop Switch

This SPDT switch (SW2) is used to control the activation or deactivation of the system. The three pins of the switch are connected to ground, 5V power rail, and pin 19 (P1.7, an I/O pin) of the microcontroller. When the switch connects ground to pin 19, A logic '0' is interpreted by the microcontroller and the system stops operation. However, when the switch connects the 5V rail to pin 19, a logic value '1' is interpreted and the system starts operation. Refer to figure A.1 of Appendix A for further hardware details.

4 Firmware Design

The control process of *AutoWake* is mainly done by the design of the firmware. Generating appropriate response corresponding to the states of the eye, as well as user interfacing are handled mainly by the firmware. For further details refer to the following sections.

4.1 High Level Description

In this section general information about the control unit and programming and interfacing have been elaborated.

4.1.1 Control Unit

The control unit employed in the design of the firmware is an ATMEL 89C2051 microcontroller. This microcontroller is equipped with 2K of flash memory, which is a sufficient storage capacity to store the entire control program. The ATMEL 89C2051 has the capability of accepting a 12 MHz oscillator frequency. Code execution is, therefore, fast enough to respond to opening and closure of the eye in an eye blink. This microcontroller also provides support for external and internal interrupts as well as I/O processes.

Upon power up of the system, the microcontroller becomes reset, and the program execution starts.

4.1.2 Programming

An ATMEL programmer device, connected to the PC through the parallel port, is used to program the chip. This programmer device includes a software application that is used for downloading programs into the chip. Programs are written in ATMEL 8051 series assembly language using a text editor, after which they must be assembled and downloaded into the chip by means of the supporting application software for the programmer device.

4.1.3 Interfacing

The interfacing can be broken down into two categories:

- Interfacing user actions to the control unit
- Interfacing hardware signals to the control unit

The signal that is generated by user actions (reset, and stop/start buttons) is interfaced to RST (pin1, reset pin) and P1.7 (pin 19, I/O pin) of the microcontroller respectively. Hardware signals generated by opening and closure of the eye are interfaced to external interrupt pins of the microcontroller (INT0, and INT1). Sensing any changes of the state in these signals invokes the appropriate ISR of the control program to appropriately handle the new state.

4.2 Low Level Details

4.2.1 Subroutines

The main program implements main initializations as well as monitoring user interactions. The following table (Table 4.2.1) lists the interrupt IDs as well as the tasks performed by their corresponding ISRs.

Table 4.2.1: Interrupt IDs and their corresponding tasks

Interrupt ID	Task
Timer 0	Generating delays
Timer 1	Generating a 1Hz square-wave signal to drive the flasher
External Interrupt #0	Eye closure detection
External Interrupt #1	Eye opening detection

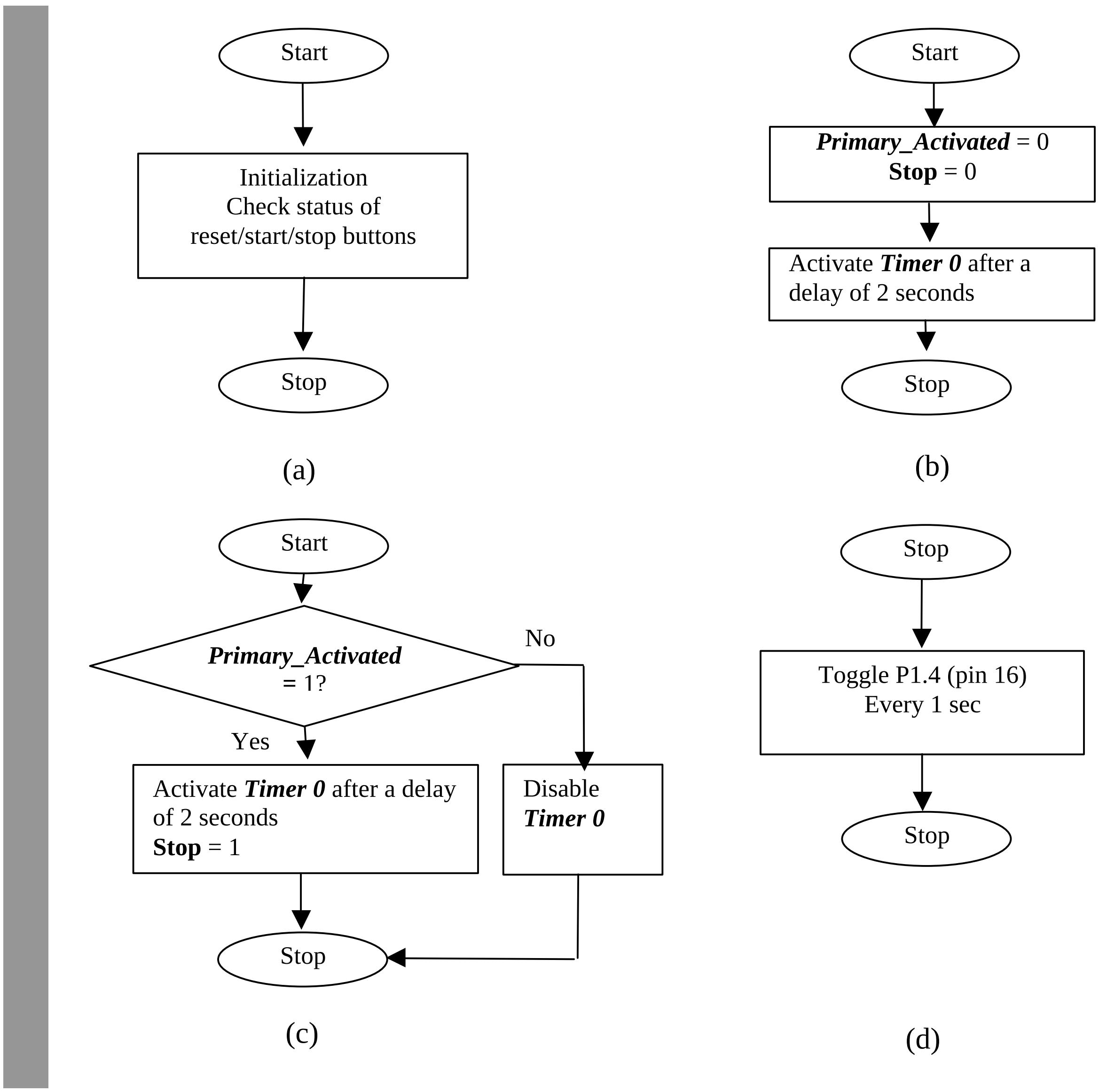
4.2.2 Detailed Description

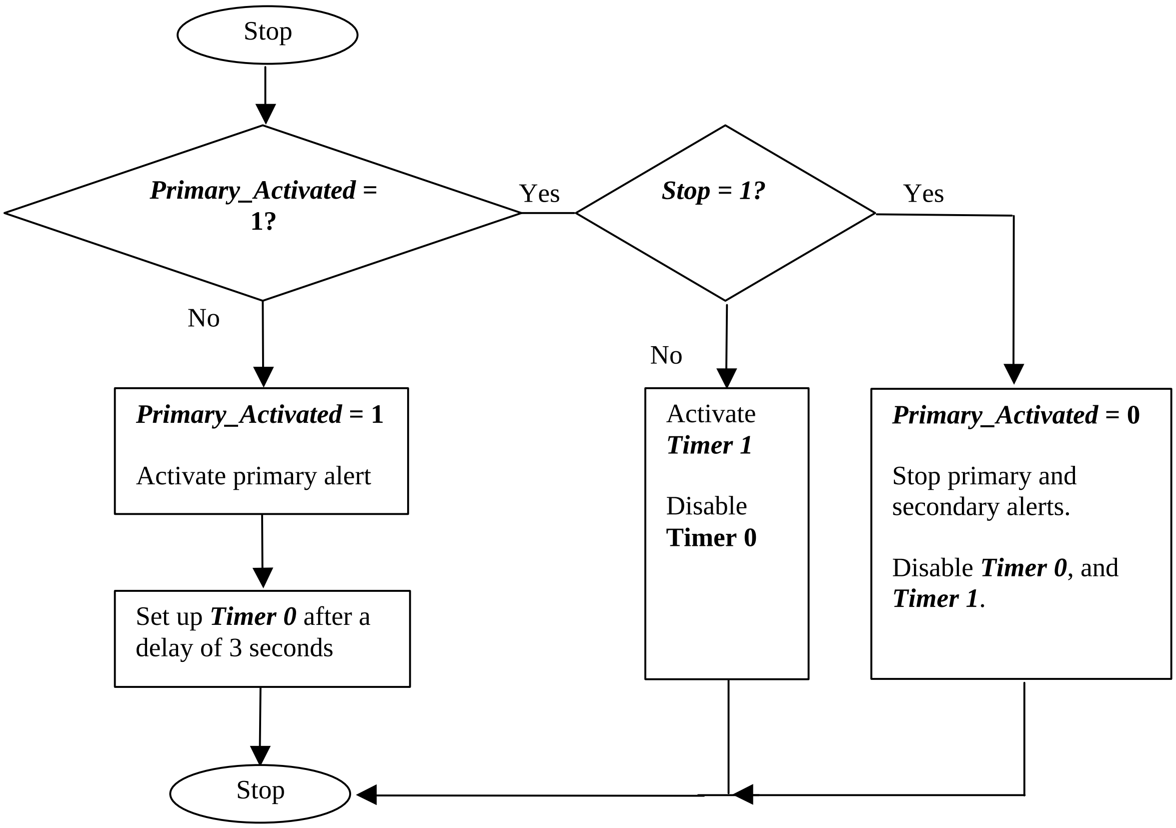
In the system overview section, two alert systems were introduced in the case the driver falls asleep: activating a buzzer (primary alert system), and activating a flasher (secondary alert system). The firmware is designed to investigate the situation and activate an appropriate alert system or a combination of the two.

The reference and monitoring sensors that are mounted on the eyeglass frame generate two voltages. As discussed under hardware design section, amplifying the difference of these voltages and feeding the resultant voltage into a 1 bit ADC (transistor inverter configuration) provides a logic signal of either 5V or 0V. This signal is the only signal that is processed by the 89C2051 ATMEL microcontroller software program. Low to high and high to low transitions of this signal are detected via INT0 (pin 6 which is external ***interrupt #0***), and INT1 (pin 7 which is external ***interrupt #1***) respectively.

The program is consisted of five separate sections. The tasks of the first section, the main program, are initialization and monitoring user actions, as shown in the flowchart of figure. Initialization process includes enabling interrupts globally, enabling external interrupts and setting activation modes (rising edge sensitivity for INT0 and falling edge sensitivity for INT1), and enabling timers and their operating mode (16-bit mode). The remaining four sections, that are solely Interrupt Service Routines (ISRs), constitute the control algorithm of the device. Refer to table 4.2.1 for the task of each individual interrupt.

Interrupt #0 is activated when the eyes become closed (rising edge detected at INT0). As shown in the flowchart of figure 4.1.1(b), when ***interrupt #0*** is activated, ***Primary_Activated*** flag is set to zero, and ***Timer 0*** interrupt is configured to activate after 2 seconds. This delay is necessary in order to distinguish between an eye blink and verge of sleeping. After two seconds has passed (meaning eyes are still closed), ***Primary_Activated*** flag is checked. If the ***Primary_Activated*** flag is zero, it becomes one, and primary alert system is activated. Furthermore, ***Timer 0*** interrupt would be configured to activate after 3 seconds from this time. After 3 seconds (meaning eyes are still closed) the ***Primary_Activated*** flag is checked. Since a value of one would be detected for this flag, ***Timer 1*** interrupt would activate and flasher starts. The system maintains this state until the eyes become open (falling edge detected at INT1) or stop button is pressed. At any instant during execution of the program, if the eyes become open (***Interrupt #1*** activates), ***Primary_Activated*** flag is checked and the system reaches idle state appropriately according to the value of this flag. See the flowchart of the system and ISRs for all the interrupts in figure 4.2.1.





(e)

Figure 4.2.1: (a) Main system (b) ISR for external ***interrupt #0*** (c) ISR for external ***interrupt #1*** (d) ISR for ***Timer 1*** interrupt (e) ISR for ***Timer 0*** interrupt

5 Test-plan

To check the operation of *AutoWake*, we should perform the following test-plans.

5.1 Hardware Test-plan

5.1.1 IR Receivers/Emitters Verification

This verification, requires the following to be performed:

1. Verify the positions of the reference/monitoring IR receivers/emitters to be appropriate.
2. Verify the corresponding voltages of the receivers/emitters to match the desired values.

3. Verify the connection between the receivers/emitters and the board to be reliable.
4. Verify the stability of the IR receivers/emitters on the eyeglass frame.

5.1.2 Circuit Verification

This verification, requires the following to be performed:

1. Check the vector board layout with design schematics for any discrepancies.
2. Check for proper connection for all the pins and wires to the vector board.
3. Check for the usage of proper components.
4. Check for the function of each specific component.

5.1.3 Overall Verification

This verification, requires the following to be performed:

1. Check the input power voltage.
2. Check for the blink indicator LED to properly signal the blinks.

5.2 Firmware Test-plan

For testing the program, a switch is provided that replaces the eye of the driver. Closed switch corresponds to closed eye, and open switch corresponds to open eye. This switch eliminates possible hardware errors when testing the firmware design.

5.2.1 Testing procedure

To assure proper execution of each section of the program, the test procedure is broken down into the following steps as shown in table 5.2.1. The expected output for each step is specified.

Table 5.2.1: Firmware testing steps

Steps	Expected output
Pressing the switch for less than 2 sec	None (remain in idle state)
Releasing the switch within 2 sec	None (remain in idle state)
Pressing the switch more than 2 sec and less than 5 sec.	Primary alert system shall be activated
Pressing the switch for more than 5 sec	Secondary alert system shall be activate as well as the primary alert system
Releasing the switch after 2 sec	Both alert systems shall be deactivated after being activated for 2 sec

Appendix

Appendix A - Schematics

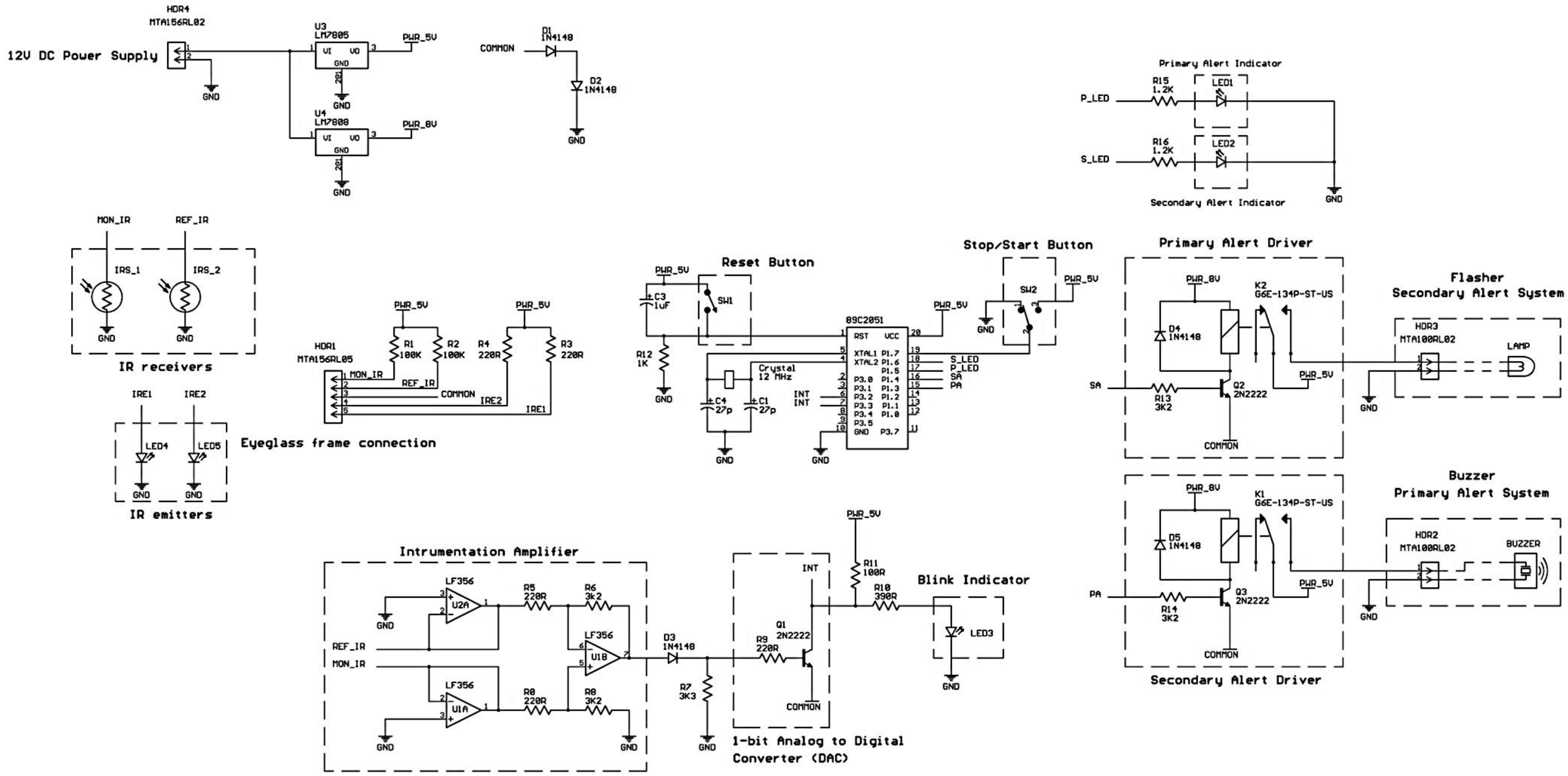


Figure A.1: Hardware design schematic

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