March 13, 2011

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

Re: ENSC 305/440 Design specification for intelligent Lifeguard systems for swimming pools

Dear Dr. Rawicz,

Please find the attached document that provides the technical guidelines for designs of iLifeguard from Guess Inc. iLifeguard is an underwater communication system built to prevent the loss of lives due to drowning by alerting the lifeguards when a swimmer is in need of help.

The enclosed document contains detailed information of the conceptual model design in addition to the user input guidelines. Furthermore, solutions are proposed for the required product modifications and for future design improvements.

GESS is comprised of five passionate and industrious engineers namely: Suleiman Mohamed, Mehdi Elahi, Elis Micka, GurmanThind and myself. The product has an immense social benefit which we intend to service by providing a reliable, affordable and appealing life saving device. For any questions or concerns please contact us at ssk15@sfu.ca.

Sincerely,
Shivam Kishore
Shivam Kishore
Executive manager

Guardian Electronics System

22nd January 2011

Functional Specification for

Executives:

Shivam Kishore – Chief Executive Officer
Elis Micka – Chief Design Engineer
Suleiman Mohamed – Chief Software Engineer
Gurman Thind – Chief Hardware Engineer
Mehdi Elahi – Chief Research Engineer

Contact Person:

Shivam Kishore
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Submitted to:

Dr. Andrew Rawicz – ENSC 440
Mike Sjoerdsma – ENSC 305

Executive Summary

Design Specifications of iLifeguard provide the detailed technical guidelines in developing and designing the proof-of-concept model. This document contains rigorous detail analysis of overall system design with various facts and configurations to set up necessary communication links under water. Considering the previous functional analysis in the Functional Specifications of the iLifeguard, our focus would be to further discuss and analyze the designs specification for our proof-of-concept model.

The design report supports the arguments and justifies the requirement for our proposed design choices. The transmitter circuits were designed and then implemented on printed circuit boards, which require further material to make them water resistant. The bracelet design which consists of the transmitter and the pressure sensor will be modified to fit on the user's wrist with comfort and the components will be sealed to prevent any water leakage. The size of the printed circuit board was modified so that it would adjust easily in the bracelet. It has a microcontroller to receive the signal from the sensor and send it to the transceiver, which then relays it to the receiver.

The transceiver, which is comprised of transducer (acoustic receiver) and a RF transmitter, will be placed at the brim of the pool partially underwater and will be sealed so that no water leaks into the circuit. The transducer ought to be in water for effective under water communication and RF transmitter will be above the water surface to transmit the electromagnetic signal to the receiver with the lifeguard. Alerting mechanism for iLifeguard will be done via audible and visible alarm system equipped with speaker and flashing lights.

The testing mechanisms regarding the hardware and software concepts related to iLifeguard during the development have been included. The adapted microcontroller software testing and collaboration of various components in the overall system has been provided at the end of design specification.

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Acronyms

A/D	Analog/Digital
CAD	Computer Aided design
DIP	Dual inline package
EMF	Electromagnetic Field
IC	Integrated Circuit
I/O	Input/output
LED	Light-emitting diode
PCB	Printed circuit Board
RF	Radio Frequency
SMD	Surface mount devices
SPI	Serial peripheral Interface
TQFP	Thin Quad Flat Pack
USART	Universal Synchronous Asynchronous-Receiver-Transmitter

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1.0 Introduction

iLifeguard is an intelligent underwater communication system that through a relay of signal transfers alerts the lifeguard when a swimmer is in a state of drowning. By keeping track of the duration the swimmer stays at a particular depth, iLifeguard system will be able to communicate with the lifeguard outside the pool ensuring the safety of the swimmer. The design specifications describe the technical details for each component of the iLifeguard along with the overall high level design of the system.

1.1 Scope

This document describes the design specifications that must be satisfied by the iLifeguard system. This assemblage of specifications completely describes the design and working of the proof-of-concept. The listed specifications will lay the foundation for the final design of iLifeguard and will be referred to in future documents. As we are focusing on the proof-of-concept system, only design considerations pertaining to the functional requirements marked I or II will be explicitly discussed.

1.2 Intended Audience

The design requirement is intended for use by all members of GESS Inc.
The CEO of the company shall use this document to monitor progress through the development stage. Furthermore, these requirements shall act as guidelines for the design engineers and shall be kept in mind throughout the design and the implementation phase of the system. During the testing phase this document will be used by engineers to assess the similarity in the functionalities of the actual system and the one described in this document.

2.0 System Overview

The iLifeGuard System's mode of operation is based on acoustic and radio wireless communication between three devices. The first is a bracelet worn by the swimmer which is responsible for sending a signal when a swimmer is at risk of drowning. The second device is installed at the top corner of the pool. It is responsible for receiving signals sent by the bracelet while at the same time relaying the received signal to the third device carried by the lifeguard which beeps whenever a swimmer activates their bracelet. Figure 2.1 below shows an overview of the configuration of the iLifeGuard system.

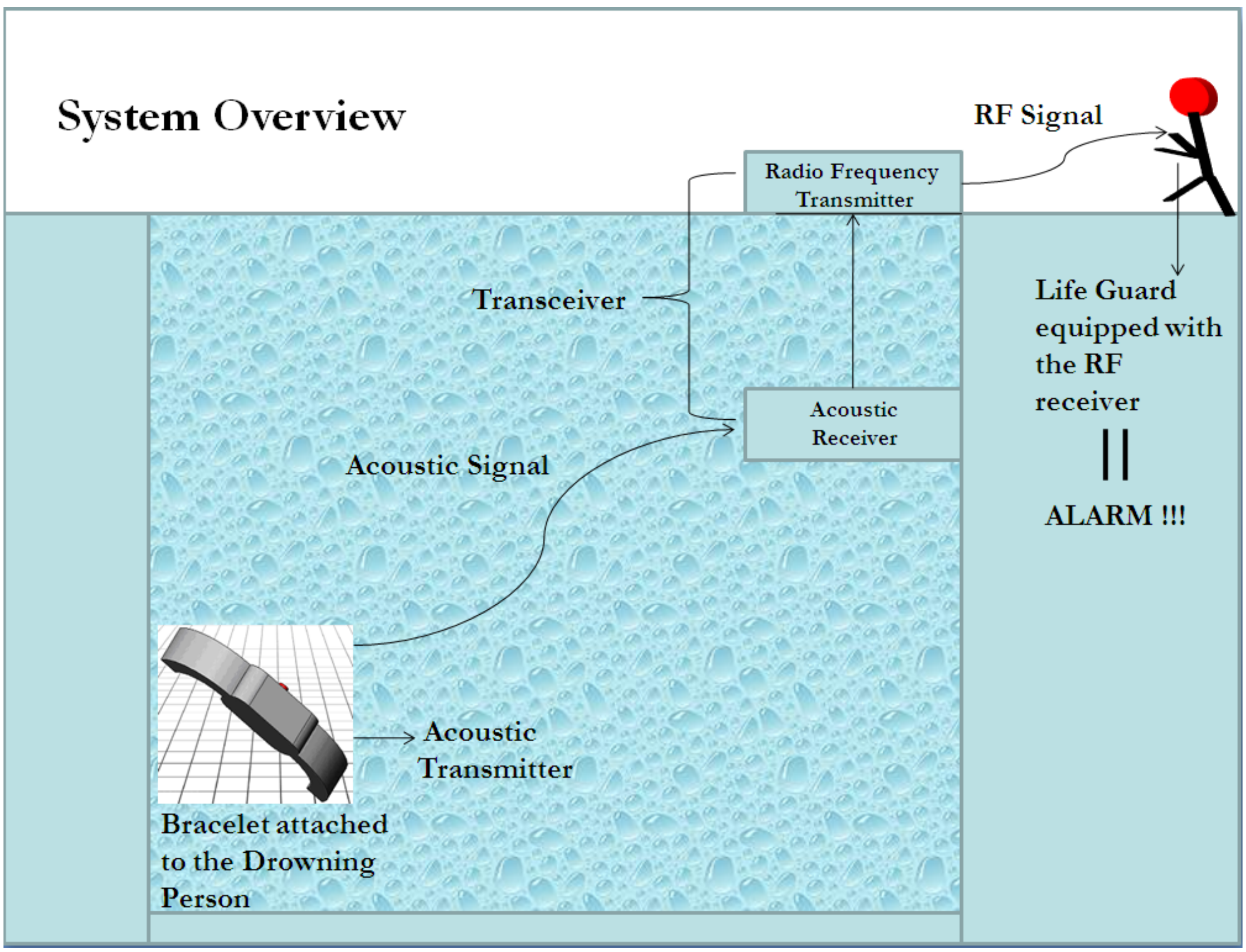

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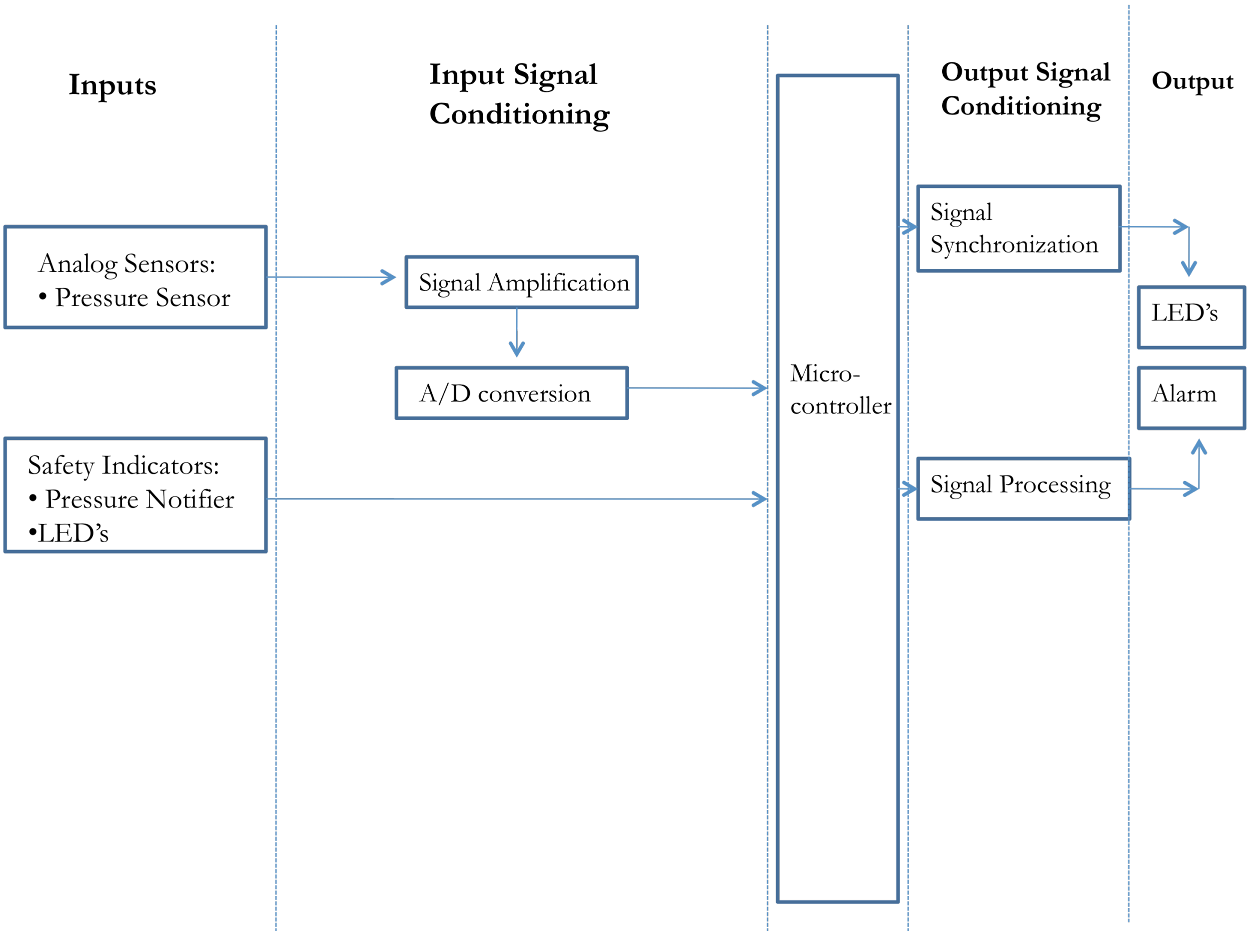
Figure 2.1 – System Overview

2.1 High Level System Design

The system inputs include user input buttons, analog sensors, safety indicators and current measurements. These inputs are made available to the microcontroller by means of signal amplifications, signal filtering and A/D conversions. The outputs of the system are the LEDs and the sound alarms which are a consequence of signal synchronization and processing in the output stage.

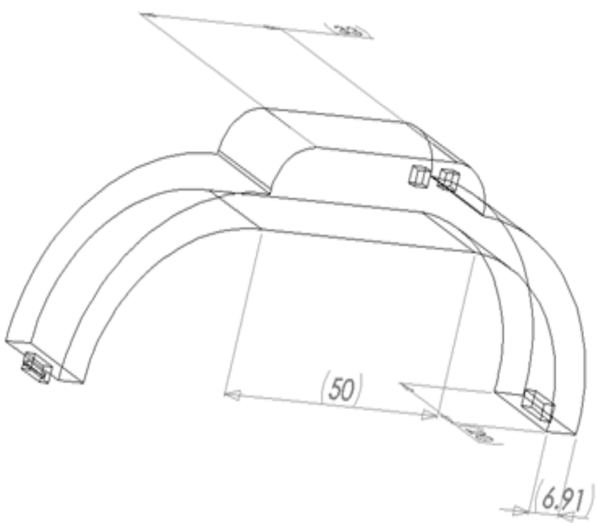


2.1- High Level System Design

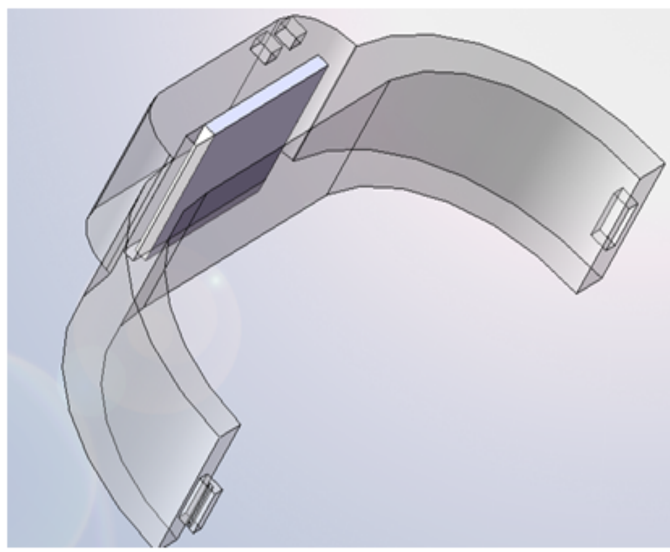
3.0 Bracelet Design

3.1 Physical and Mechanical Design

The bracelet comprises of the transmitter PCB for transmitting acoustic signal along with the acoustic buzzer and a pressure sensor which measures the pressure. The bracelet is designed to appear as a watch with the PCB attached on one end and the pressure sensor and the buzzer on the other. Care has been taken to ensure that it fits comfortably on the wrist of the user. The pressure sensor and the buzzer are manufactured water-resistant and are thus directly attached to the bracelet. The cables which will connect the pressure sensor and the buzzer to the PCB will be water resistant and will be embedded in the strap of the bracelet and thus will be visually hidden. The images 3.1 and 3.2 below show the 3-D representations and the approximate dimensions of the bracelet design respectively.



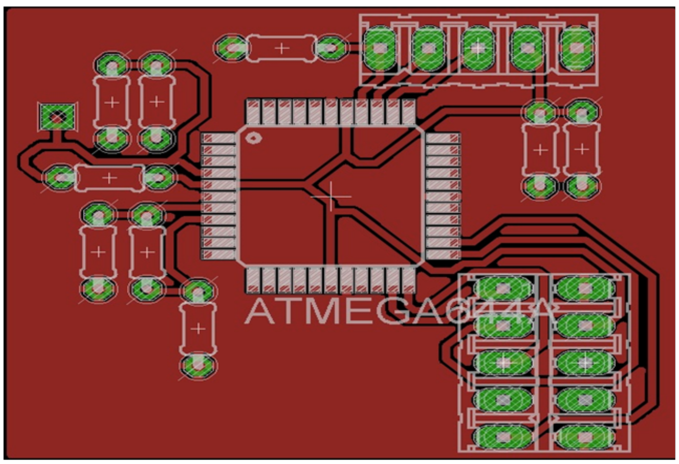
3.1- Dimensions of the Bracelet



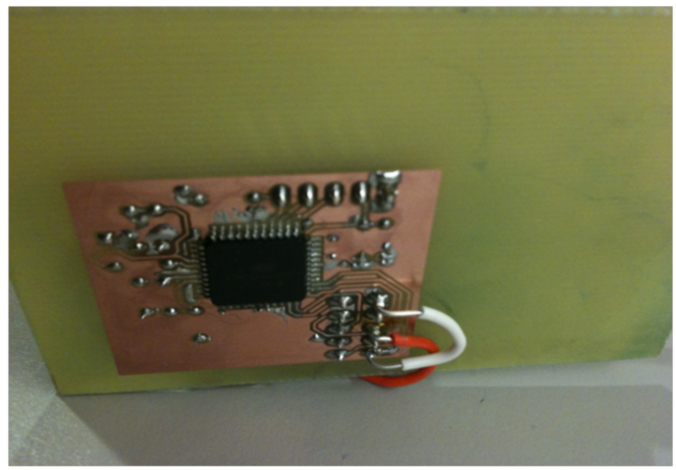
3.2 – 3-D representation of the bracelet with the PCB

3.1.1 Printed Circuit Board Design

The PCB design layout was etched on the PCB board and the components were then soldered on the layout. Care was taken to ensure that the size of the PCB is small enough to appear as a square watch dial. Since it will be operating underwater, the need to waterproof the PCB is essential. The case in which the PCB is enclosed is sealed to ensure that water does not leak into the circuit. In addition, it will be coated with a layer of silicon based coater to further prevent any damage due to unlikely water leakage. The case of the PCB will be transparent to enable clear visibility of the circuit. Figure 3.3 below shows the design layout for the PCB. Figure 3.4 displays the finished PCB without the casing and the coating.



3.3 – Design Layout of the PCB



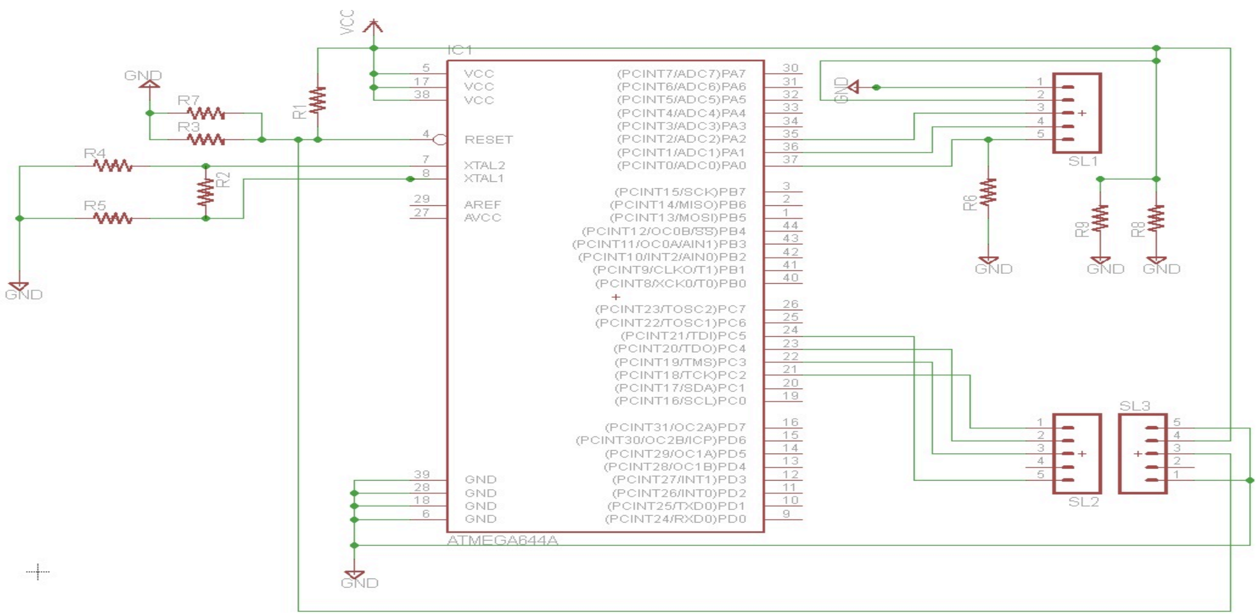
3.4 – Completed PCB with the components

3.2 Electronic Design

In order to measure the depth of the drowning person a pressure sensor has been incorporated in the bracelet design. The sensor that we chose is manufactured waterproof and water resistant and hence there is no need to further water proof it. The sensor communicates real time with the microcontroller embedded in the PCB. It sends the real time pressure values at which the drowning person is at. Using these pressure values the approximate depth of the drowning person is calculated. The appropriate depth values along with the suitable timing form the parameters for the microcontroller to initiate an acoustic signal by activating the buzzer.

3.2.1 Microcontroller Specifications

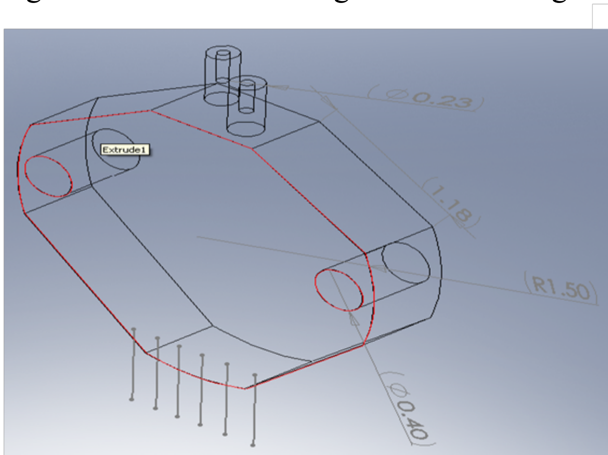
ATMEGA644PV microcontroller was used for the acoustic transmission part of the project. The transmitted acoustic signal is a square wave with a frequency of 25 KHz, and amplitude of 3.5 - 5 volts. The microcontroller was used to create a noise free output with 25 KHz frequency. This is done by switching output pin of the microcontroller on and off, while having a delay of 20µS between each on and off sequence. Microcontroller is attached to the PCB and is the controlling factor for all the other components of the bracelet. Figure 3.5 shows the schematics for the microcontroller and its pin attachments to the other components in the PCB.

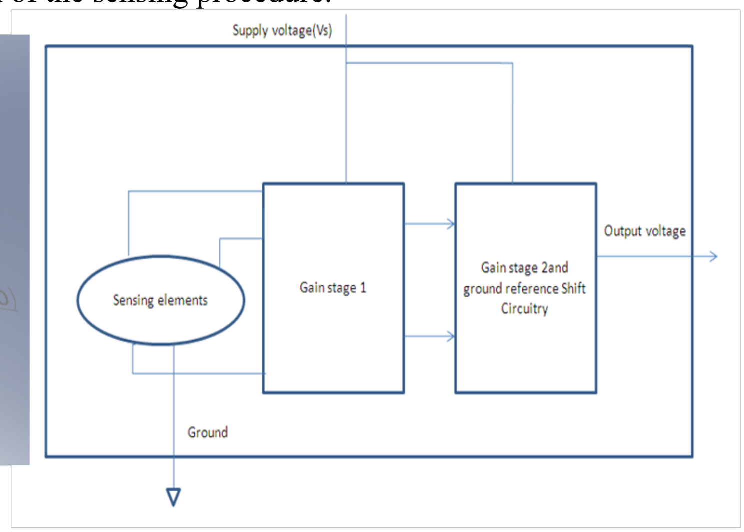


3.5 – Eagle Schematic of bracelet with microcontroller

3.2.2 Sensor Specifications

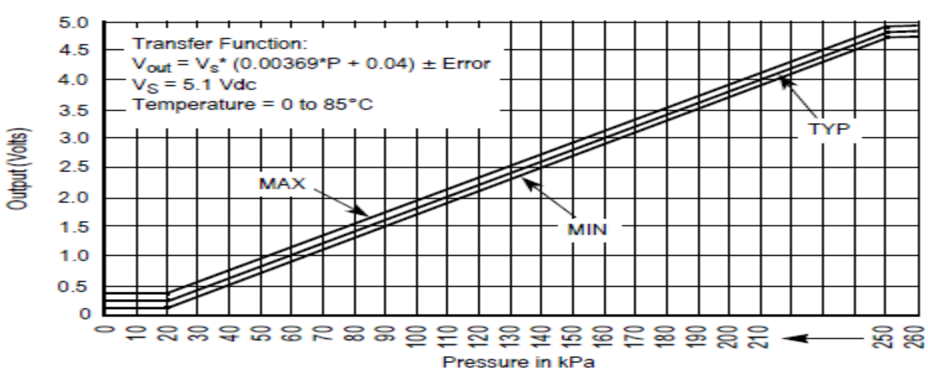
Pressure sensor has been attached with the bracelet to sense the pressure and produce a gain which is further multiplied to the voltage and then fed to the microcontroller. At different depths the output voltages from the pressure sensor, read by microcontroller, will acknowledge the related depth of the swimmer. Figure 3.6 is the 3-D representation of the sensor along with the dimensions. Figure 3.7 is the block diagram for the design of the sensing procedure.





3.6 – Microcontroller Schematics **3.7 – Pressure Sensing Block Diagram**

The sensing elements will be in contact with water to detect the pressure level. The gain stages were added for required amplification and noise reduction. The weight of this pressure sensor is close to 4.0 grams and small size makes it ideal for our bracelet design. The decoupling capacitors were also added in the design to filter noise and power supply decoupling.



3.8 – Graph of Output Voltage Vs Pressure

From the graph above (figure 3.8), the output voltage vary with pressure under the swimming pool. The output voltage starts increasing after 20kPa from less than 0.5 volts to 4.5 volts at 250kPa.

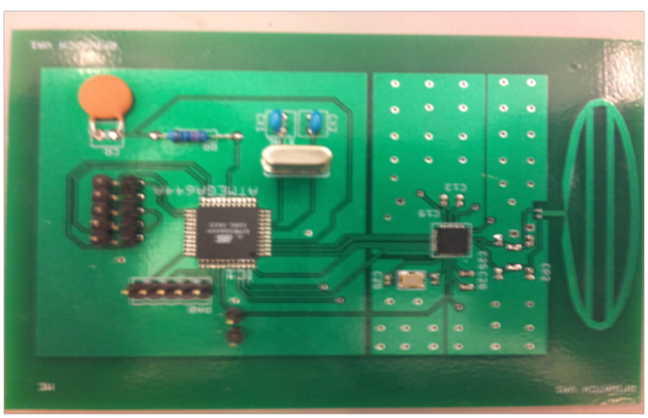
3.3 Power Specifications

Transmitter device uses Atmega644PV microcontroller as its main processing unit. Microcontroller is the only component that needs a constant power supply. Power to all the other components is supplied by the microcontroller. This PV series of the Atmega644 is designed for 1.8 to 5.5 voltage source, which is ideal for our device. At 1MHz this microcontroller draws 0.4mA. This means the power consumption is 720µW. To supply the power a 3V lithium coin battery cell is used.

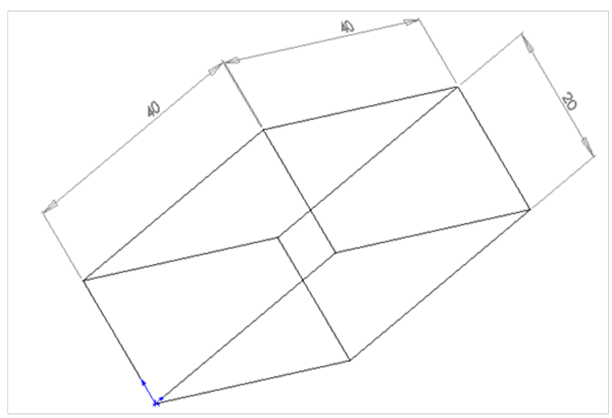
4.0 Transceiver Design

4.1 Physical and Mechanical Design

The transceiver is comprised of an acoustic receiver and a RF transmitter. The RF transmitter is a PCB with a microcontroller which is responsible for communication between itself and the acoustic receiver. The receiver is a manufactured waterproof microphone and receives the acoustic signal transmitted by the transmitter attached to the bracelet. The transceiver will be enclosed in a transparent waterproof casing for clear visibility of the PCB and to prevent any water leakage in to circuit. The diagrams below show the 3-D representation and the approximate dimensions of the acoustic receiver and the image of the RF transmitter. Figure 4.1 below is displays the actual RF board. Figure 4.2 shows 3-D design of waterproof casing of the RF board.



4.1 – RF Board Design



4.2 – 3-D design of the RF board Case

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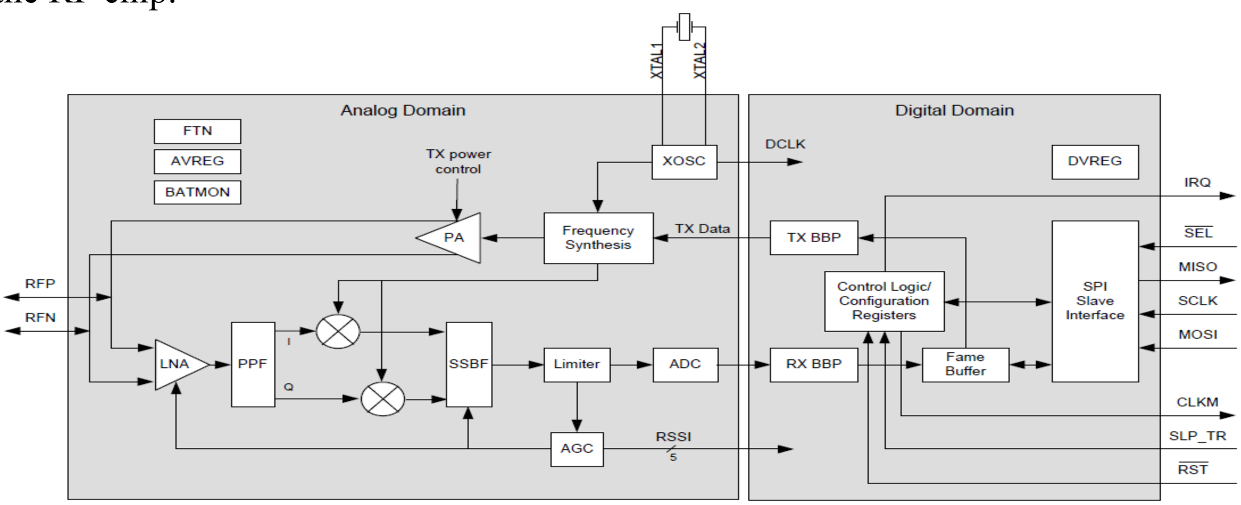
4.2 Electronic Design

The main component of the electronic design is the RF transmitter board. It forms the basis of RF signal transmission and the acoustic signal detection. The second component is the acoustic receiver which receives the signals from the bracelet.

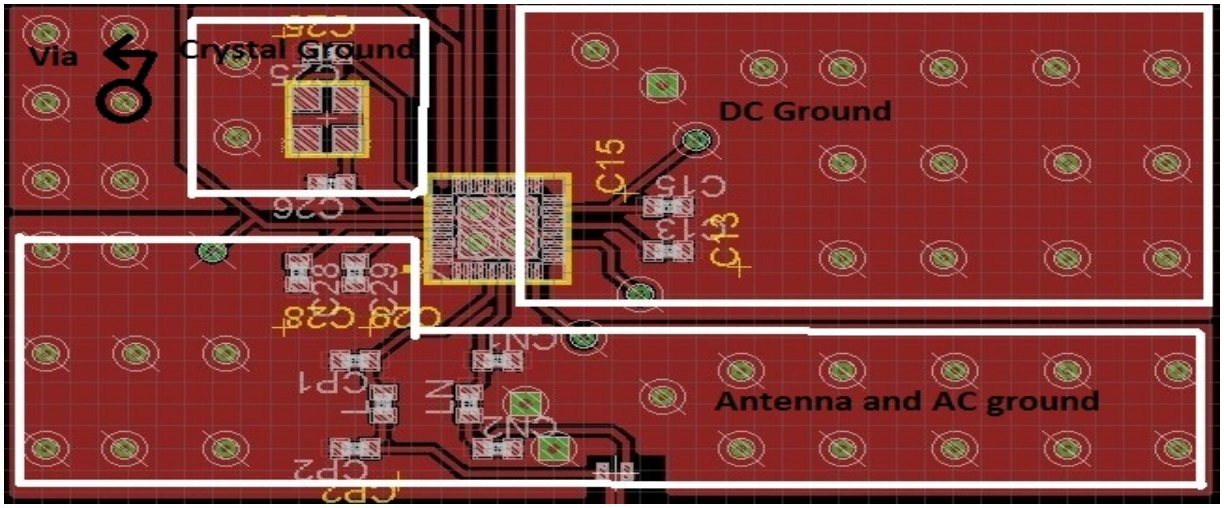
4.2.1 RF Transmitter Specifications

Atmel AT86RF230 wireless chip is used to deal with the RF transmission part of the project. This transmitter works with 2.4GHz centre frequency, and it can have an output power of -17 dBm to 3 dBm. The chip itself contains all the necessary hardware to operate except the antenna part and the decoupling capacitors. This means that the chip would take care of all the modulations and demodulations, and also any amplification that is required. Figure (4.3) illustrates the block diagram of the RF chip.



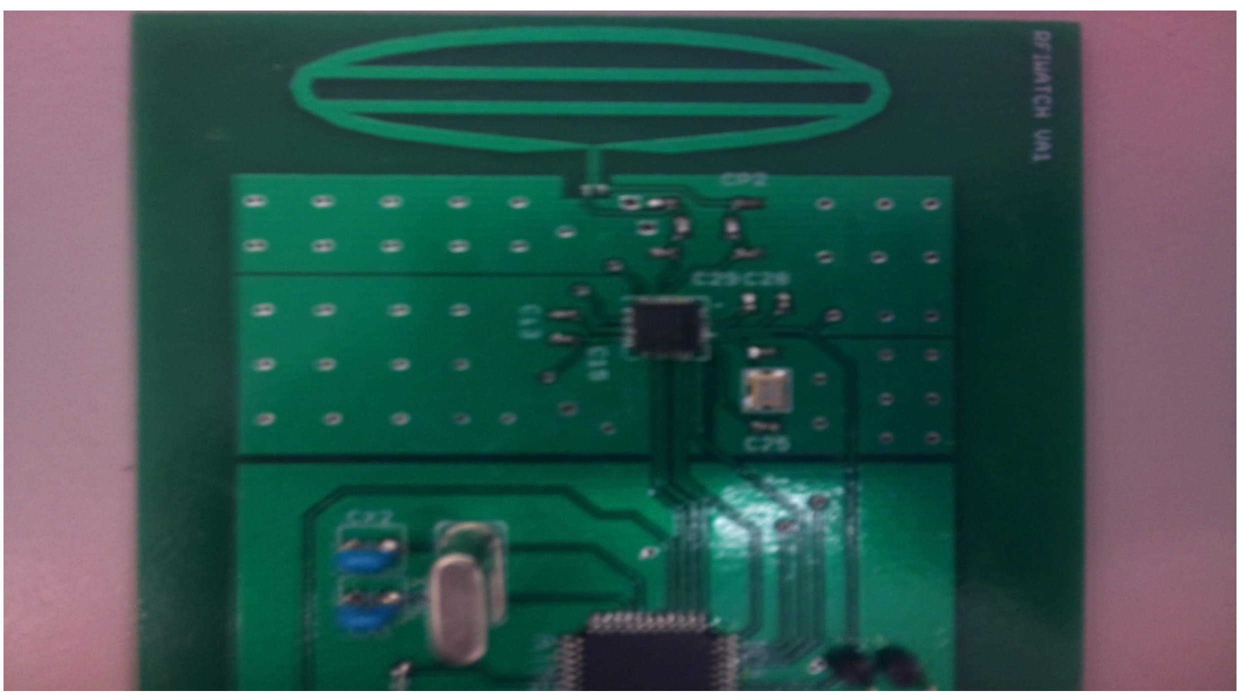
4.3 – RF Chip Design

To insure that the RF chip can operate, designing the PCB for this chip requires following some design specifications. The ground plane of the RF PCB has been divided into 3 different ground planes, AC and antenna ground, DC ground, and crystal ground, which they are all connected at the centre pad of the RF chip based on star typology. This will separate the noise especially in the critical areas such as antenna. To reduce the overall ground impedance and electromagnetic effect of different PCB layers, the PCB ground plane and the soldering pad for the center pad of the RF chip is filled with vias. Figure (4.4) shows the PCB design layout of the RF board with vias.



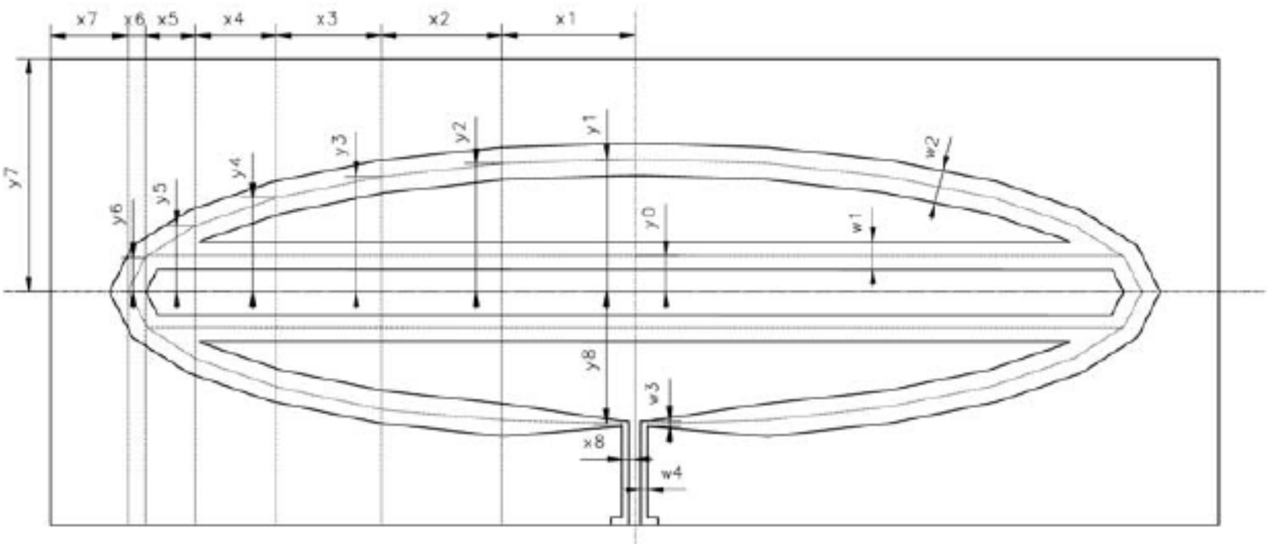
4.4 – PCB design Layout

Since the board works with a high frequency, 2.4 GHz, components like decoupling capacitors and crystals could affect the operation of the RF communication. In this design to reduce the noise and the effect of the electromagnetic field of the small components, all the components are surface mount (SMD) parts, and the capacitors and inductors are ceramic 0402 in size with temperature coefficient of C0G or NP0.



4.5 – Transmitter Antenna Design

One of the important design parameter of the RF transmission is the antenna. In this project we are using folded dipole PCB antenna based on Atmel design. This design was created as a library for Eagle CAD, so it can be used in PCB design. Figure (4.5) above shows the actual antenna on theRF board and figure (4.6) below shows the dimensions of the antenna that was designed.



4.6 – Transmitter Antenna Dimensions

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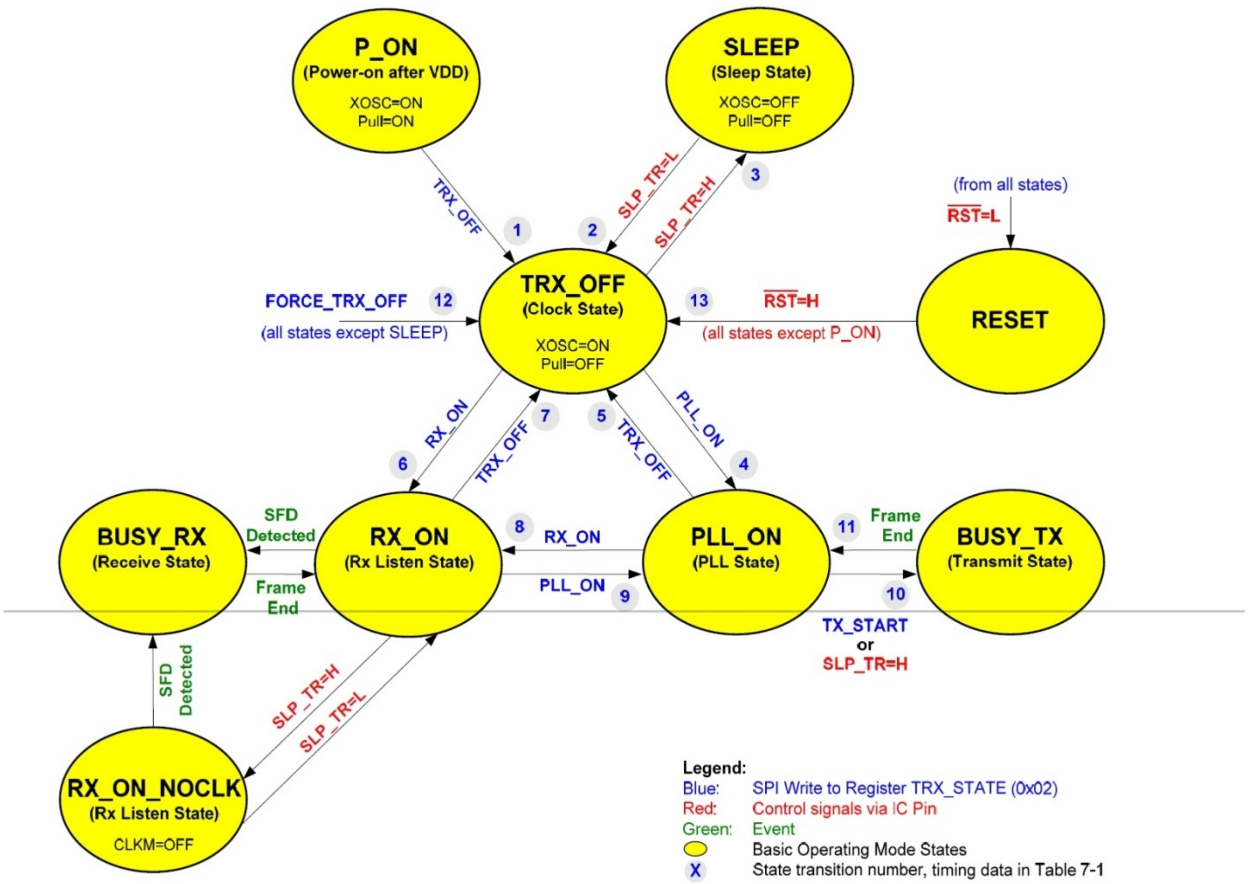
The main processing unit, the microcontroller, controls the RF chip by using Serial Peripheral Interface (SPI) communication. The microcontroller can change the state of the RF chip by writing or reading a specific register, and RF chip will perform a certain task when it is in that state. Therefore, there is no software programming involved on the RF chip directly, and all the commands are already available inside the chip, and they can be triggered by changing registers from the microcontroller. Figure (4.7) shows a simple state diagram of the RF chip.



4.7 – State Diagram of RF Chip

When the microcontroller writes into a send frame register byte of the RF chip in PLL_ON state the RF chip will go to BUSY_TX state, and start transmitting the frame. Similarly, when the RF chip is in RX_ON state and there is an incoming data, the RF chip will go into BUSY_RX until the receive frame register byte finishes receiving the incoming data.
In order to create specific communication protocol for the device, we decided to send a 1-byte message containing and the SOS message.

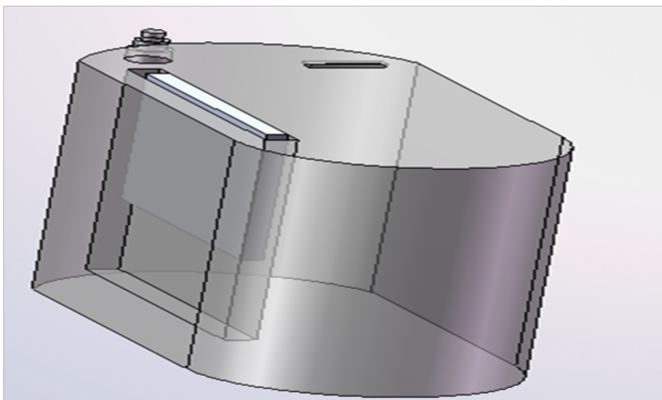
4.3 Power Specifications

Transceiver device uses Atmega644V microcontroller as its processing unit. The V version of Atmega644 is designed for 1.8 to 5.5 voltage source and 240µA in Active mode, which consumes 432µW at 1MHz. Since microcontroller powers the other components in the circuit we need to constantly supply the power to microcontroller. To supply the power a 3V lithium coin battery cell is used.

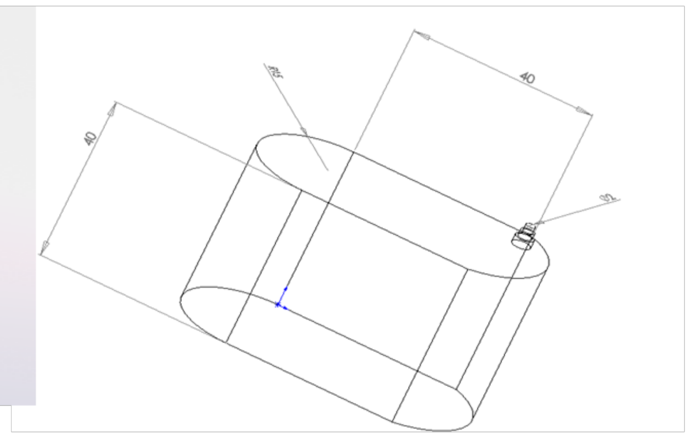
5.0 RF Receiver Design

5.1 Physical and Mechanical Design

RF receiver comprises of the RF receiver board which shall be enclosed in a transparent case. It also consists of a buzzer and a LED which are connected to the board and act as alerting measures for the lifeguard. Figure (5.1) below shows the 3-D representation of RF board in the casing and figure (5.2) shows the 3-D representations and the approximate dimensions of the receiver casing design.



5.1 – Receiver RF board and the casing design



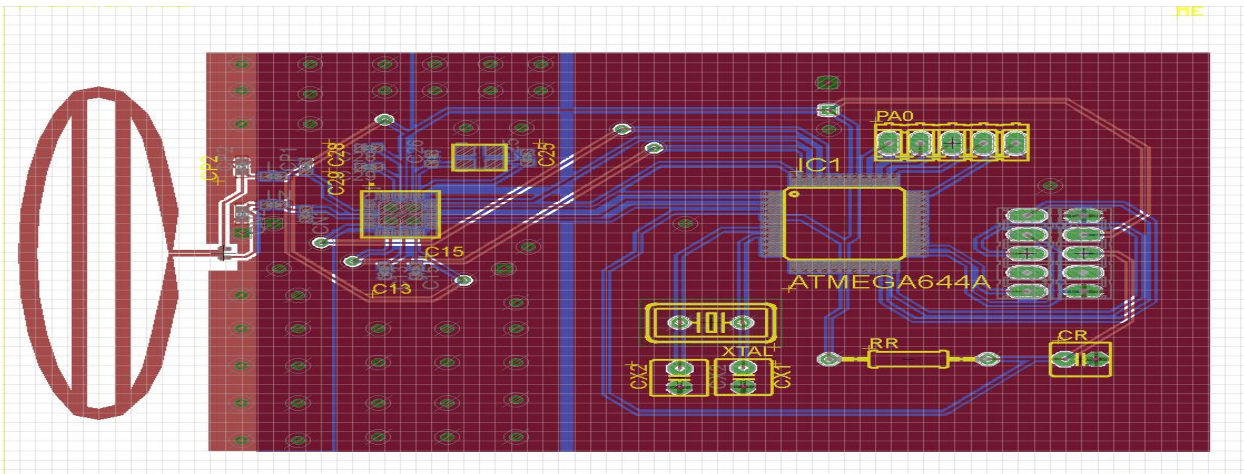
5.2 – Dimension of Receiver RF board casing

5.2 Electronic Design

The main component of the electronic design is the RF receiver board. It forms the basis of RF signal detection and reception. The secondary components are the buzzer and the LED which are the alerting mechanisms

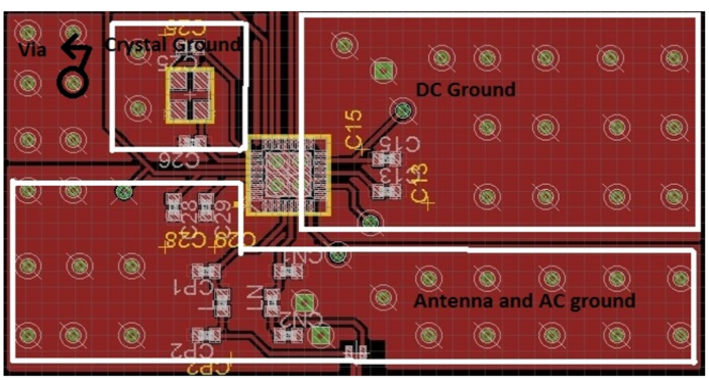
5.2.1 RF Receiver Specification

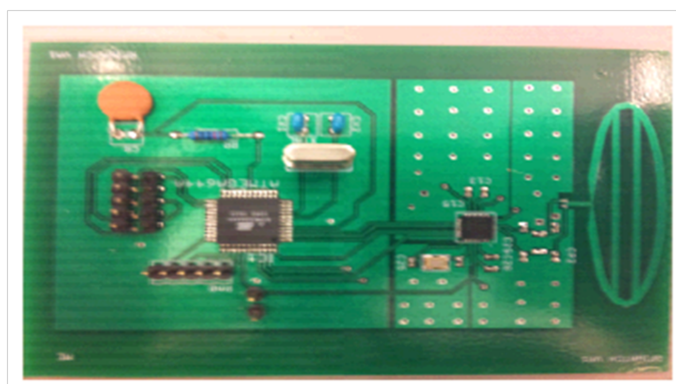
Atmel AT86RF230 wireless chip is used to deal with the RF transmission part of the project. This transmitter works with a 2.4GHz centre frequency, and it can have an output power of -17 dBm to 3 dBm. The chip itself contains all the necessary hardware to operate except the antenna part and the decoupling capacitors. This means that the chip would take care of all the modulations and demodulations, and also any amplification that is required. Figure (5.3) illustrates the schematic of the RF board containing the chip and the microcontroller.



5.3 – Receiver RF board Schematic Design

To ensure that the RF chip can operate, designing the PCB for this chip requires following some design specifications.
The ground plane of the RF PCB has been divided into 3 different ground planes, AC and antenna ground, DC ground, and crystal ground, which they are all connected at the centre pad of the RF chip based on star typology. This will separate the noise especially in the critical areas such as antenna. To reduce the overall ground impedance and electromagnetic effect of different PCB layers, the PCB ground plane and the soldering pad for the center pad of the RF chip is filled with vias. Figures (5.4) and (5.5) below show the PCB layout with the vias and the finished PCB respectively.

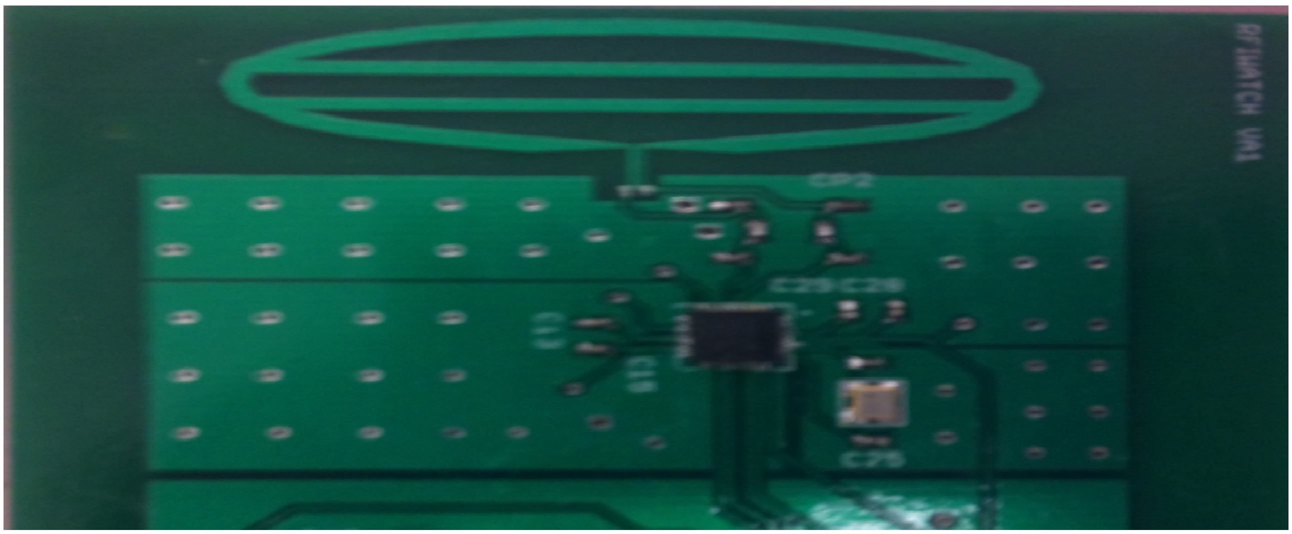




5.4 – Receiver RF board Layout with vias **5.5 – Completed Receiver RF board**

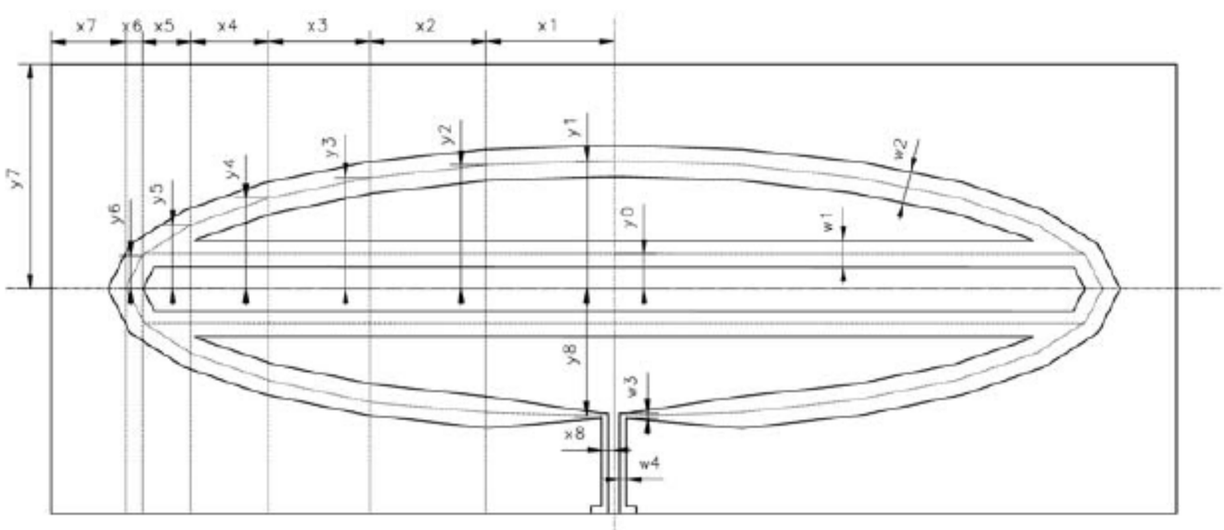
Since the board works with a high frequency, 2.4 GHz, components like decoupling capacitors and crystals could affect the operation of the RF reception. In this design to reduce the noise and the effect of the electromagnetic field of the small components, all the components are surface mount

(SMD) parts, and the capacitors and inductors are ceramic 0402 in size with temperature coefficient of C0G or NP0.



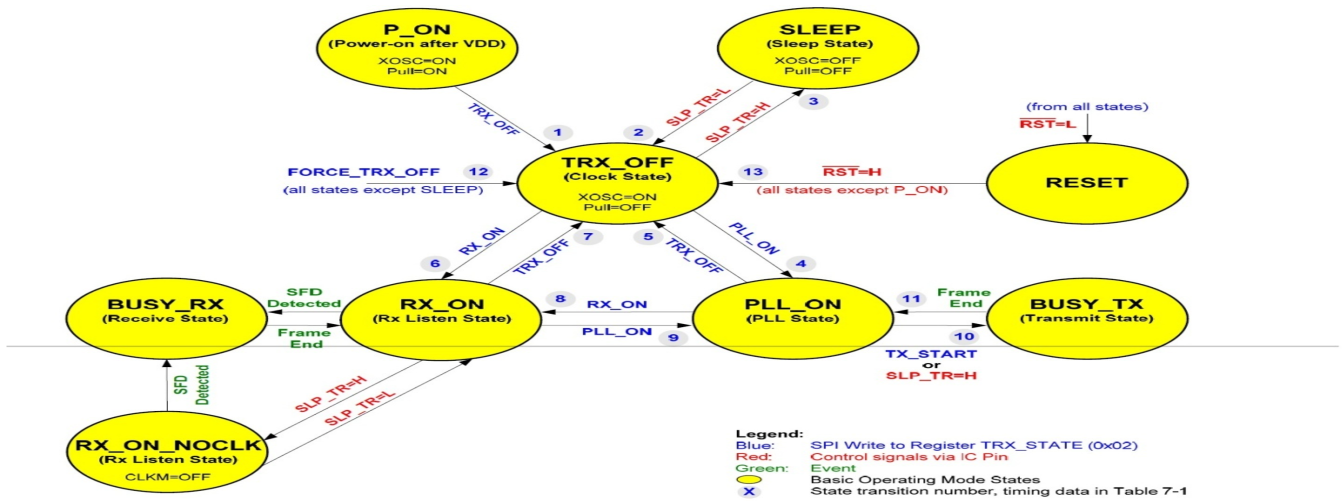
5.6 – Receiver RF Antenna design

One of the important design parameter of the RF reception is the antenna. In this project we are using folded dipole PCB antenna based on Atmel design. This design was created as a library for Eagle CAD, so it can be used in PCB design. Figure (5.6) above show the antenna design in the actual receiver PCB and figure (5.7) below show the dimensions of the receiver antenna.



5.7 – Receiver RF Antenna dimensions

The main processing unit, the microcontroller, controls the RF chip by using Serial Peripheral Interface (SPI) communication. The microcontroller can change the state of the RF chip by writing or reading a specific register, and RF chip will perform a certain task when it is in that state. Therefore, there is no software programming involved on the RF chip directly, and all the commands are already available inside the chip, and they can be triggered by changing registers from the microcontroller. Figure (5.8) shows a simple state diagram of the RF chip.



5.8 – State diagram for the RF receiver chip

When the microcontroller writes into a send frame register byte of the RF chip in PLL_ON state the RF chip will go to BUSY_TX state, and start transmitting the frame. Similarly, when the RF chip is in RX_ON state and there is an incoming data, the RF chip will go into BUSY_RX until the receive frame register byte finishes receiving the incoming data.

It must be noted that our RF board design is capable of both receiving and transmitting RF signals and is hence a transceiver. However, since we need to receiver acoustic signal and then transmit and receive RF signals we use two RF boards in succession, one acting as a transmitter and another acting as a receiver. They differ only in the way their software is written to enable them to perform the specified tasks and have the absolute same physical design.

In order to create specific communication protocol for the device, the receiver receives the 1 byte SOS message sent by the transmitter and then sends the signal to the LED's and the buzzer to react accordingly.

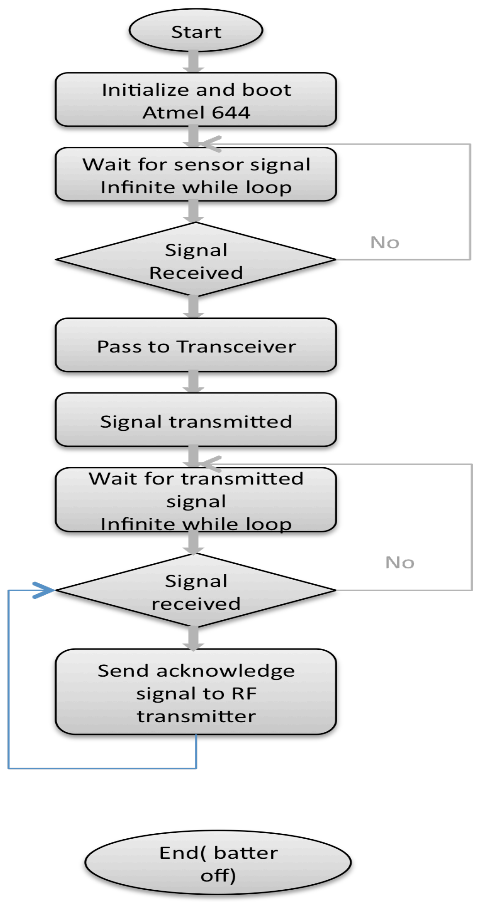
5.3 Power Specifications

The receiver device uses Atmega644PA microcontroller. The PA series of Atmega644 is designed to work with 1.8 to 5.5 volt, and 0.4mA current, which consumes 720µW of power at 1MHz. A 3V lithium coin battery cell will be used to supply the needed power.

6.0 System Test Plan

6.1 Objective

Several areas of the iLifeguard system will be tested to ensure that the system is reliable and safe. Some of the test cases are intended to ensure functionalities of the system while the rest are required for the production design. Figure (6.1) below shows the flow chart for the overall software testing that shall be implemented.



6.1 – Flow Chart for the software testing

6.2 Test Case: 1

System : Sensor
Description : Testing the functionality of the sensor

Table 1: Testing results of sensor

Step	Action	Expected Results	Pass/Fail
1	Turn system on	On button on bracelet turns green	
2	Dip the sensor in water while changing the depth	Pressure readings increases with depth	
3	Move the sensor sideways	Pressure readings remains constant for the same depth	

6.3 Test Case: 2

System: Timer
Description: Testing the functionality of the timer

Table 2: Testing results of Timer

Step	Action	Expected Results	Pass/Fail
1	Turn system on	On button on bracelet turns green	
2	Dip the sensor in water and start timer	The timer will start counting down from 10 seconds	
3	Wait until timer expires	The LED on the bracelet blinks	

6.3 Test Case: 3

System: The integrated system
Description: Testing the functionality of the timer

Table 3 : Testing Case 3

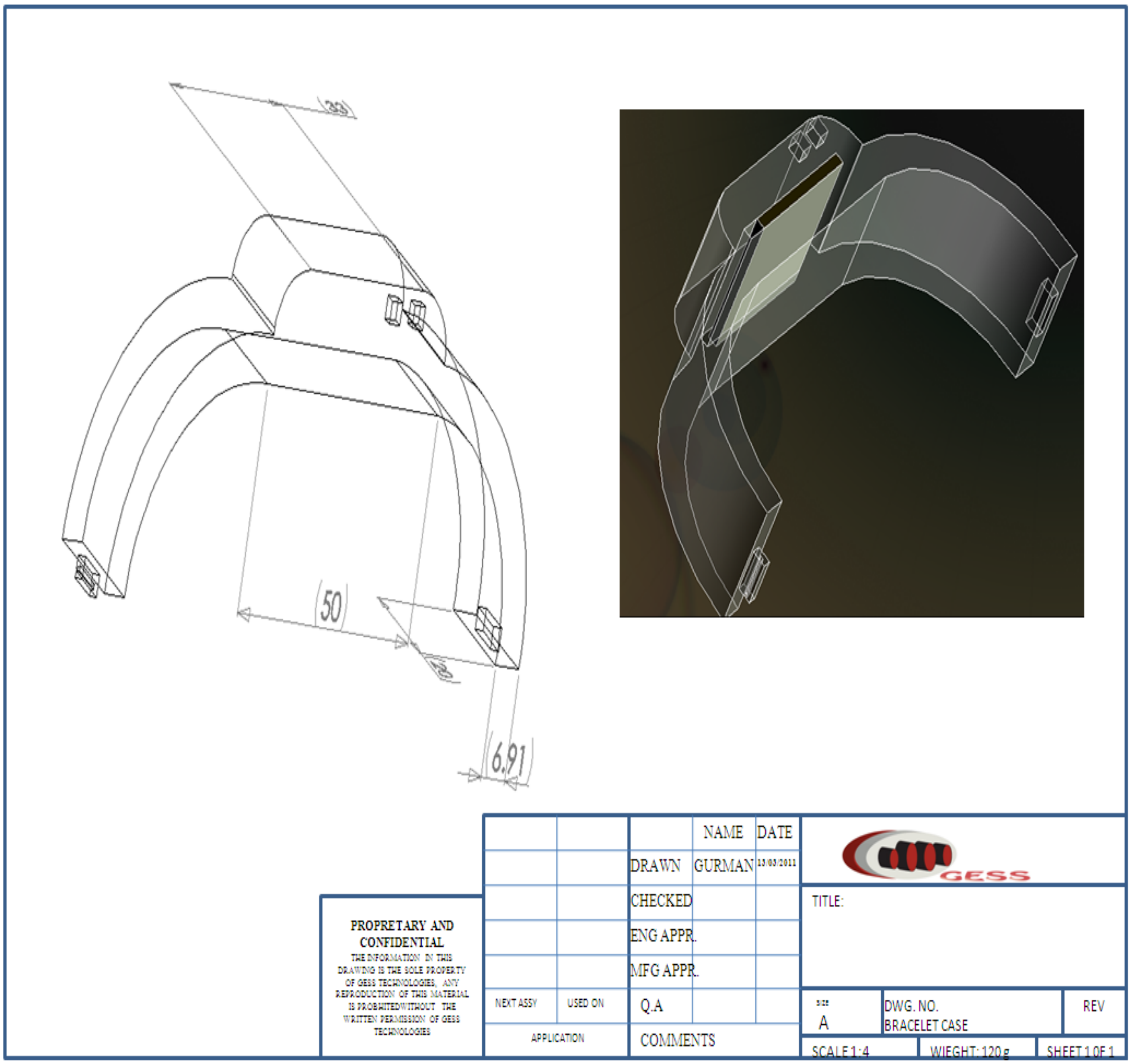
Step	Action	Expected Result	Pass/Fail
1	Turn system on	On button on bracelet turns green	
2	Dip the sensor in water and start timer	Pressure readings increases with depth and timer starts counting down from 10 seconds	
3	Wait until timer expires	The LED on the bracelet blinks, the receiver held by the lifeguard beeps.	

7.0 Conclusion

In this document, design solutions consistent with the functional specifications earlier developed were proposed. As a result, the components were selected to meet the functional specifications while staying within the projected budget. To ensure that all the requirements of the ilifeguard are met, a test plan covering all possible scenarios is included in the document.

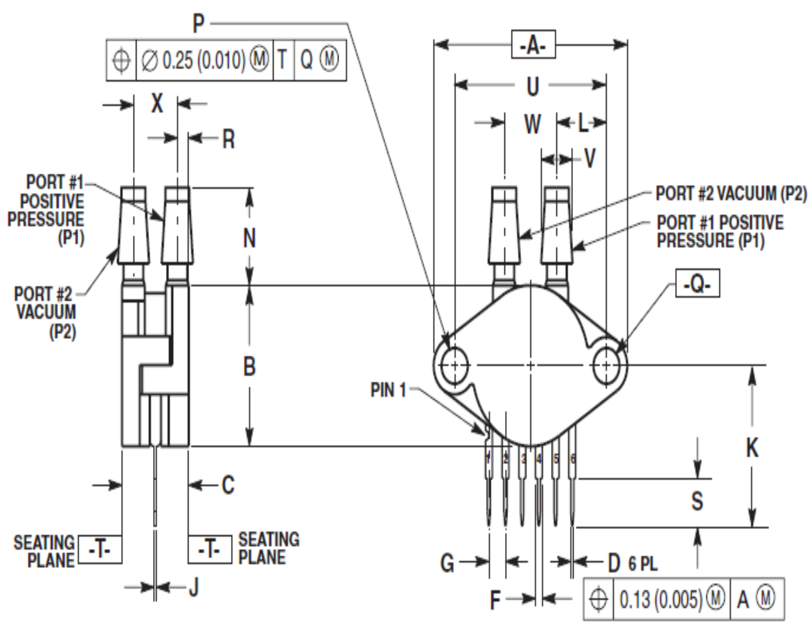
Appendix: Material drawings

Bracelet:



Pressure Sensor:

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCH.



	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	1.145	1.175	29.08	29.85
B	0.685	0.715	17.40	18.16
C	0.405	0.435	10.29	11.05
D	0.027	0.033	0.68	0.84
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.41
K	0.695	0.725	17.65	18.42
L	0.290	0.300	7.37	7.62
N	0.420	0.440	10.67	11.18
P	0.153	0.159	3.89	4.04
Q	0.153	0.159	3.89	4.04
R	0.063	0.083	1.60	2.11
S	0.220	0.240	5.59	6.10
U	0.910 BSC		23.11 BSC	
V	0.182	0.194	4.62	4.93
W	0.310	0.330	7.87	8.38
X	0.248	0.278	6.30	7.06

STYLE 1:
PIN 1. V_{OUT}
2. GROUND
3. V_{CC}
4. V1
5. V2
6. V_{EX}

PRESSURE AND VACUUM SIDE DUAL PORTED (DP)
CASE 867C-05
ISSUE F

MPX4250

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