SUN SMART School of Engineering Science, Burnaby, BC, V5A 1S6

March 05, 2009
Dr. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Design Specifications for a Portable UVB Monitoring System

Dear Dr. Leung:

Attached is the design specifications of a Portable UVB Monitoring System designed and developed by Sun Smart Inc. This product senses UVB rays constantly, updates and displays the UVB index and required amount of SPF to be applied on the user interface. It can also remind the user to re-apply their sunscreen using a buzzer. The user interface also displays a clock for optimized usage of this device.

This document applies to the final product as well as proof of concept since it is the optimized version of our prototype. The prototype used AVR butterfly board but the final product is a PCB that contains all components and is stationed in a wrist watch.

Sun Smart consists of three fourth and fifth-year engineering students: Nima Edelkhani, Kimia Nassehi and Daryoush Sahebjavaher. If you have any questions or concerns about our proposal, please feel free to contact me by phone at (604) 992-1364 or by e-mail at nedelkha@sfu.ca.

Sincerely,

Nima Edelkhani

Nima Edelkhani
Sun Smart Inc.

Enclosure: *Design Specification for a Portable UVB Monitoring System*

SUN SMART

Design Specification for the

Portable UVB Monitoring Device

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EXECUTIVE SUMMERY

Sun Smart Inc. has provided detailed documentation of functional specifications of Portable UV Monitoring System [1]. This document helps engineers and prospect developers get familiar with the general idea of devices used in this product. In design specification document, Sun Smart will explain the reason behind choosing each component, selection criteria, limitations and components behaviour.

This document will provide detailed explanation of design, implementation and development of the final component which is an optimized version of the prototype (proof of concept). This product has a unique quality to it and that is the small size of the final product. PUMS is small enough to fit in wrist watch and works with a 3V battery which makes it portable and easy to use at every location. Due to the small size we had to overcome the challenge of optimizing and fitting every component on a very small PCB. The PCB that has been ordered contains a microcontroller that works as the brain of the device. This device senses amount of UVB constantly since it never sleeps and reports the amount of UVB at any time. The user interface consists of a LCD that shows the clock, UVB index and amount of required SPF. We used an external flash memory, not the internal memory on microprocessor due to the size of our program. The watch case was carefully measured by cullies in order to provide exact measurements of available space to fit all components properly. We refer to the components specified in functional specifications and explain the detail of each device and why they were chosen.

The software used in our design is in C language due to our microprocessor specification. The LCD interface used I2C protocol which was implemented in our C program so that master (microcontroller) would be able to write to the slave (LCD). We also used EAGLE program to build our circuit schematic and PCB. We used EAGLE to build our Gerber files and order the PCB to the manufacturer.

We are following the time schedule as expected and we are not behind in our schedule therefore the PUMS demo is set to be carried on April 7th of 2009. This demo will include both prototype (on AVR butterfly) and the final product in a wrist watch.

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GLOSSARY

FR-4	Flame Retardant 4
I2C	Inter-Integrated Circuit
JTAG	Joint Test Action Group
LPI	Liquid Photo-imageable
PCB	Printed Circuit Board
PUMS	Portable UVB Monitoring System
PWM	Pulse Width Modulation
UI	User Interface

1. INTRODUCTION

The Portable UVB Monitoring System is a small, portable and handy device which can be used daily to show UVB index level, amount of SPF required to be applied and reminds users to re apply their sunscreen in predefined intervals. This device can be used in any age group and is believed to help lower the risk of getting sun burnt therefore lower skin cancer risks. This device is most useful for people who go camping, mountain climbing, and hiking and also for outside workers. We cannot avoid being exposed to sun but we can avoid the harmful UV rays of sun by knowing the danger and applying sun screen or in extreme cases, seeking shade.

This device works by constantly monitoring the UVB rays and collecting the amount of current caused by this level of UVB, converting the current to voltage, comparing the voltage level with the table of values for UVB index stored on the memory and then displaying this UVB index using I2C protocol on the UI. The SPF level is then derived by comparing the UVB index with SPF table stored on memory and displaying the SPF level on LCD using the same interface method. The clock is also displayed on user interface and can be set as well (by using the side push buttons on the PCB). Going from one menu to other is made possible by using the other push button.

The design specification of Portable UVB Monitoring System gives great details on each of the devices used in our design and talks about limitations.

1.1 SCOPE

The design specification of PUMS meets the functional specifications as explained in the document. In addition, it gives the details on the decision criteria and the aspects required by our design and development by referring to all devices named in the functional specification of a Portable UVB Monitoring System [1]. This design specification gives the proof of concept by explaining how very component works, why it has to work like that and how we approached this decision.

1.2 INTENDED AUDIENCE

The design specification of Portable UVB Monitoring System is prepared for use of Sun Smart group members for further reference and the purpose of documentation. The design specification can be used by design engineers as a guideline and reference for future analysis or building and development or to improve the current state of design. Test engineers can use this document to know the proper behaviour of device and observe any defect or un-predicted outcome. They can also come up with different test plans for this product using this document.

2. SYSTEM SPECIFICATION

The Portable UVB monitoring system is implemented inside a wrist watch with a four character LCD and two input buttons. The system is capable of displaying the time, the UV index and a recommended SPF level. A buzzer may go off when the UV index is dangerously high.

2.1 MECHANICAL DESIGN

The PUMS is a small PCB board with electrical components on both sides including UV sensing unit, processing unit, switches and the LCD. Later, this assembly is fit inside a watch to be presented as a final product. For a more efficient use of space and a simpler PCB design PUMS is designed to fit inside a square watch. Figure 2.1 shows the inner and outer dimensions of the watch:

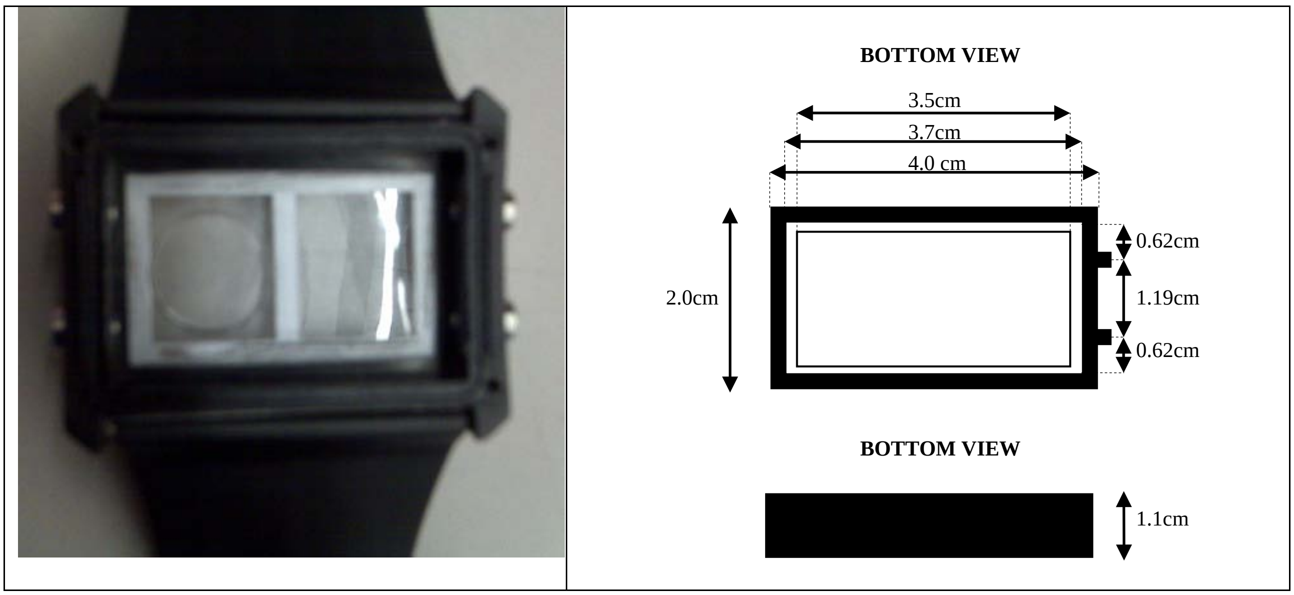

Figure 2.1: Mechanical dimensions

These dimensions define some of the constraints on the PCB design. The PCB width and length should be 2.0 cm and 3.7cm respectively. Knowing that a PCB is usually between 1.5 to 2 mm thick, the height of components mounted on both sides of the PCB should be considered so that the overall height doesn’t exceed the 1.1 cm limit.

Table 2.1 lists of large electrical components:

Component	Width	Length	Height
ATMEGA169	16mm	16mm	1.2mm
LCD	13.5mm	12mm	6mm
Battery	16mm	16mm	1.5mm
UV sensor	2.5mm	1.8mm	2.43mm
Switch	5mm	8.1mm	2mm

Table 2.1: Large electrical component dimensions

Some other mechanical constrains are given by electrical components that have to be fixed in a certain position. It is important that the UV sensor is mounted on the top side of the PCB so that it is able to detect UV light. The display LCD has to be on the top side and the battery. The battery and the Microprocessor have to be on opposite top and bottom side of the boards because of their mutually exclusive size (each occupy more than half of the space on one side, so they have to be on separate sides). As shown on Figure 2.7 the LCD and the ATMEGA 169 are assembled on top of each other, creating the object with maximum height on the top side of the PCB. The battery is the object with the maximum height in at the bottom side of the PCB and this makes the overall height of the Assembled PCB 6+1.2+1.5+2 = 10.7mm, complying with the maximum height specifications.

As shown on Figure 2.7, the two switches are also on the top side of the PCB and fixed on the right edge in a way that they are aligned with the push buttons on the watch case. Moreover, they have the appropriate distance from the edge of the PCB to be triggered when the push button is pressed.

2.2 ELECTRONIC DESIGN

In this section we will concentrate on the most important aspect of our design, the electronics design. We will first explain why we chose the components that we chose to go with and then we will have a section that goes through the details of our electronics design in different stages of the project.

2.2.1 COMPONENT SELECTION

In this section I elaborate on the selection of components for the first and second phase of our project. We should note that the component selection for the second phase of the project is highly related to the components of the AVR Butterfly board that was used in our first phase.

AVR BUTTERFLY BOARD

The AVR Butterfly board from Atmel was chosen as the main component of the first stage of our project (the proof of concept phase). This board comes equipped with many features. The most important features of this board that made us choose it for the first stage were:

- Ease of programmability (program in C language and upload through the RS232 port with no external hardware)
- A relatively high-speed microprocessor (Atmel Atmega169)
- Having an analog-to-digital converter (A/D channel)
- Having an on board LCD with controller
- Having a 4 Mbit Dataflash for data storage
- Having many output pins for testing
- Power up with 3V
- Having a joystick (used for moving through the menus)

The following figure shows this evaluation board (Figure 2.2) [2].

Figure 2.2 Atmel AVR Butterfly board

ATMEL ATMEGA169 MICROCONTROLLER

The ATmega169 microcontroller is the main processing unit of the second phase of our project. This is the same microcontroller that is used in the AVR Butterfly board. This is an 8-bit microcontroller with 16K bytes of in-system-programmable flash. It comes in 64-pin surface mount package with is suitable for our PCB design. It is compliant with our LCD utilizing an i^2c bus. It has both external and internal interrupt resources that enable us to develop a watch function as well as a menu architecture that is browsed using the push buttons. The fact that this microcontroller is powered up with 2.7V combined with its ultra low power consumption (~350µA in active mode), makes this microcontroller perfect for our design since it can be easily powered up by a small watch battery.

EXTERNAL DATAFLASH

We have used a serial flash memory from Atmel (AT45DB041D-SU). This flash gets directly connected to the microcontroller and it allows us to store 4-megabit of data in an external memory.

UV SENSOR

Our main sensing component is a very small UV sensor from the API Advanced Photonix, Inc (PDU-G106B-SM). This UVB sensor has a 320nm UVB response and it comes in a 2.8*3.5mm surface mount package. It is intended application are UVB power meter and sun dosimeter which makes it just suitable for our UVB monitoring device. The following figure shows our UVB sensor [3]:

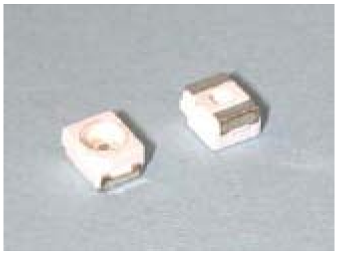

Figure 2.3 UVB Sensor

OPERATIONAL AMPLIFIER

We use an OPA2347 dual op-amp from Texas Instruments for amplification purposes. This amplifier has special characteristics that we crucial to our design. Those specifications are:

- Single supply 2.3V-5.5V
- Rail-to-rail input and output
- Very low power consumption
- Extremely low bias current (maximum 10pA)
- Come in surface mount package

LCD

Due to the very limited amount of space that we have available for the second phase of our project, we needed an extremely small LCD character module that has at least four digits and can be powered up with 3V. After extensive research we finally found a 4-digit LCD that is smaller than a thumbnail (12mm*13.5mm together with the controller). The LCD is from Pacific Display Devices company (model number: 04101). As mentioned, this LCD comes with a Philips PCF8576 controller which makes it much easier for us to program it. It communicates with our microcontroller through a serial i^2c bus. Figure 2.4 shows the size of the LCD.

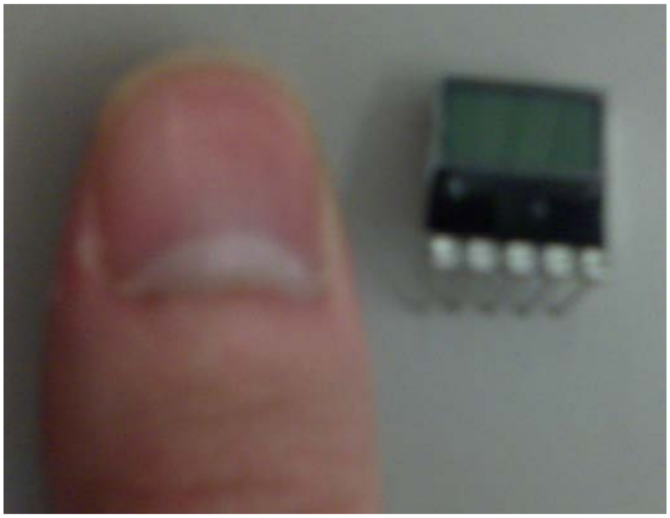

Figure 2.4 Size of the LCD

PUSH BUTTONS

Since the finished product is supposed to be placed in a wrist watch case, we have placed two push buttons on our PCB that are aligned with the push buttons of our wrist watch. Therefore using the original push buttons of the watch, the user can go through the menus of this device and work with it just like a watch. The push buttons that we chose are from C&K Components (SDS004). They are connected to a 3V line and they produce an interrupt for the microcontroller every time they are pressed.

2.2.2 DESIGN DETAILS

In this section we will first introduce the detailed electronic design of our device and then we will elaborate on the PCB design. The following figure shows the detailed electronics schematic of our device.

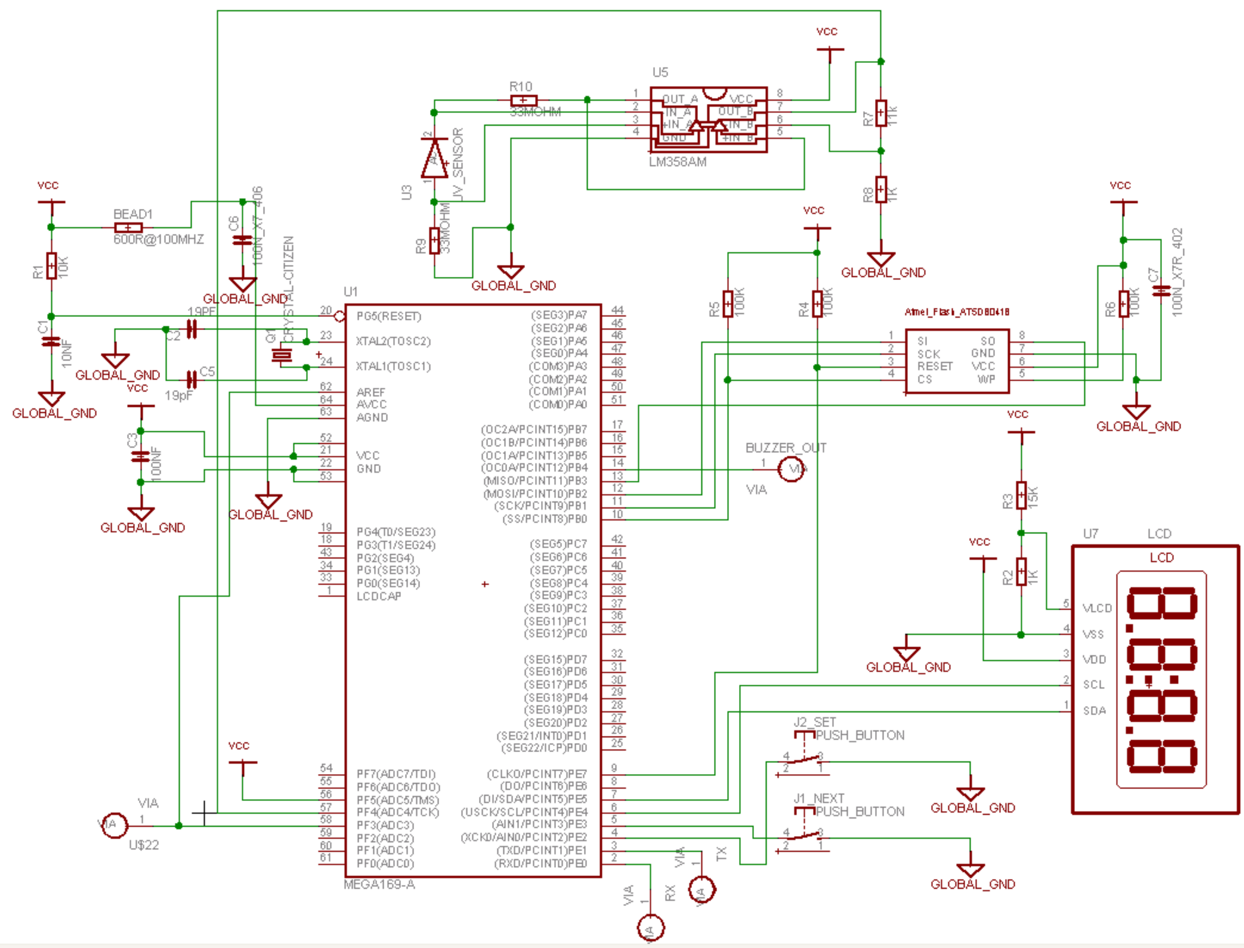

Figure 2.5 Detailed Electronic Schematic

The main building blocks of the above design are: Microcontroller, Flash memory, Sensor and amplification unit, LCD and push buttons.

One of the parts that we decided to focus on is the topology of our sensing unit. In this design we have used the topology in figure 2.2.3 to convert the current of our sensor to a voltage reading. We specifically need an extremely low bias current amplifier for this purpose, so that all the current would pass through the resistor instead of going into the amplifier [4].

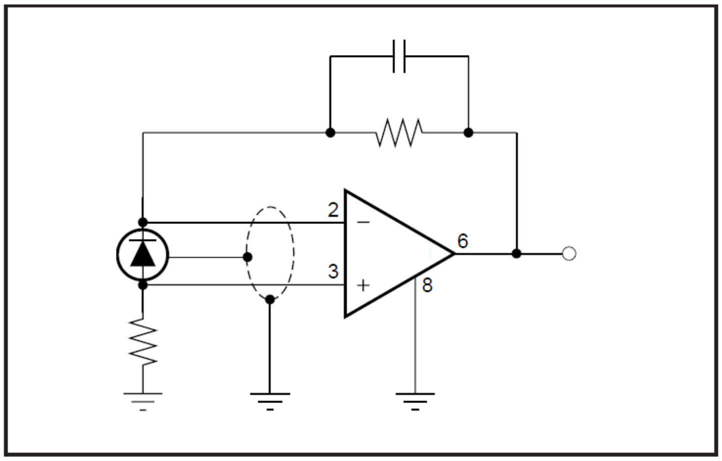

Figure 2.6 Sensor Unit

From the output of the above stage we have used another amplifier in a non-inverting configuration to adjust the output limits of our sensor. In calibration we fine-tune this gain so that the output range of our sensor unit will be adjusted to the input limits of the A/D channel of our microcontroller.

Next I will explain the PCB design. We have managed to do a 2-layer PCB design using Eagle Professional software and fit all of our components in a very small space. The PCB's electrical specifications are: 2-layers, FR-4 62mil, minimum line width of 6mils and LPI mask. The following figures show the top layer and bottom layer of our PCB:

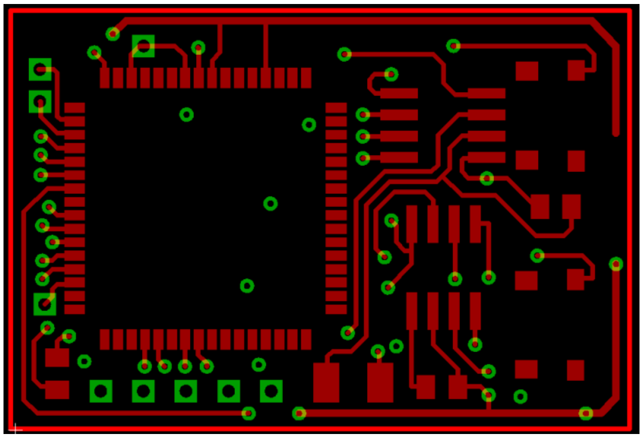

Figure 2.7 PCB – Top Layer plus Vias and Pads

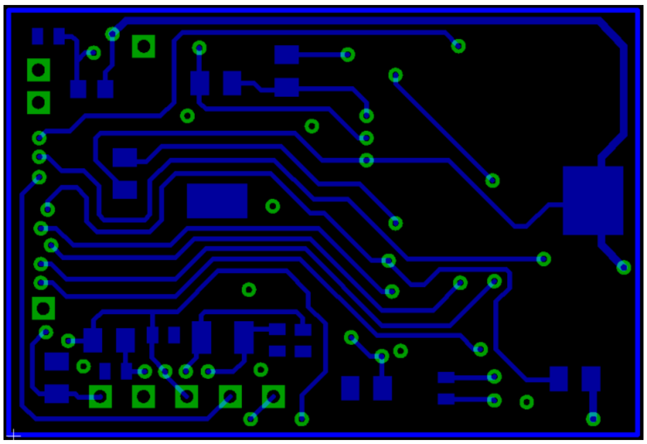

Figure 2.8 PCB – Bottom Layer plus Vias and Pads

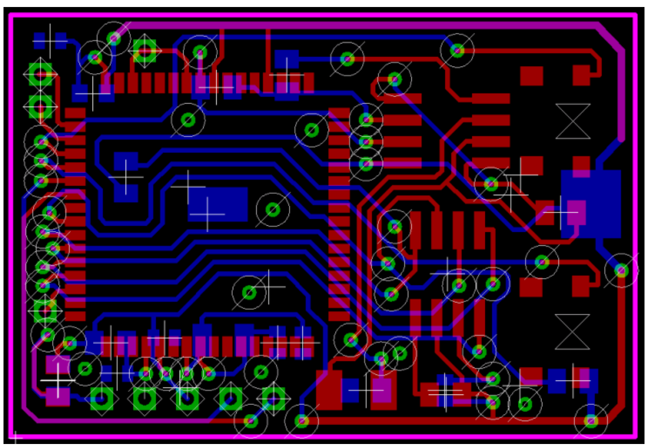

Figure 2.9 PCB – Top/Bottom Layer plus Vias and Pads and Holes

2.3 SOFTWARE

The ATMEGA 169, which is the processing unit of the PUMS, performs functions such as acquiring signals from the UV sensor, calibrating, sensing user interface push buttons, communicating to the LCD and generating a PWM signal for the buzzer. The ATMEGA 169 microprocessor was programmed in C language to perform the functions mentioned above.

2.3.1 UVB READING

The ATMEGA 169 has an internal Analog to Digital convertor (ADC) which is connected to port E via a multiplexer. The software initializes the ADC such that one of the pins on port E can be connected to the UVB sensor, acquiring voltage readings in digital format.

2.3.2 UVB CALIBRATING

The voltage generated by the UVB sensor needs to be calibrated in order to show the correct UV index. A calibration mapping table was developed in the software so that each voltage reading from the UVB sensor corresponds to a certain UV index. A recommended SPF level table was also developed to output a recommendation based on the UVB readings.

2.3.3 BUTTONS

ATMEGA 169 is programmed to generate an interrupt once a button is presses. Pressing a button results one of the pins on port B to experience a level shift from a logic 1 to a logic 0, triggering an external interrupt. The program checks which switch was pressed and depending on its state perform the expected action. Figure 2.7 shows how the buttons interact with the user.

2.3.4 LCD

Communication with the custom LCD is performed via the I^2C bus. The ATMEGA 169's USI hardware module can be configured to TWI (Two Wire mode) mode. With correct initialization and software, the TWI hardware can essentially be used to follow the I^2C protocol. Once the SCL and SDA pins of the LCD is connected in to corresponding pins on the ATMEGA 169, the processor will act as a master and the LCD will be in slave mode. A set of control messages are sent to initialize the LCD and then the data is sent over to be displayed on the LCD.

2.3.5 BUZZER

The Piezoelectric buzzer requires a digital square signal as an input in order to generate a buzzing sound. The frequency of the signal determines the pitch of the sound generated. The ATMEGA 169 has an easy to use internal PWM generator which can be initialized and programmed to generate the desired output signal on port B.

2.3.6 ClOCK

The ATMEGA 169 has two 8 bit counters and one 16 bit counter. The software initializes the two 8 bit counters A and B, sets them to zero and calibrate them using the 32.768 kHz external crystal oscillator. One of the counters starts running and interrupt is generated once the difference between counter A and B is greater than the incremental value. This is the most accurate way of generating a clock since each interrupt will represent a fraction of a second and an external crystal has been used for accurate calibration.

Figure 2.10 shows how the clock can be set via the two buttons available:

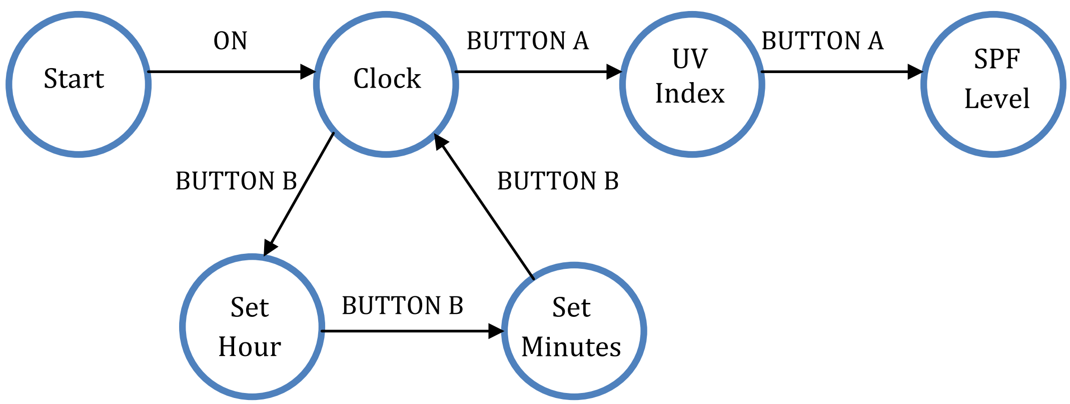

Figure 2.10: State diagram

3. ENVIRONMENTAL CONSIDERATION

We have made sure that every component used in our design has been selected so that they are lead-free, both for the purpose of environmental consideration and the safety issues concerning the usage of lead. Using lead in electrical components has been an issue since the improper disposal of devices containing lead leach into environment and pollutes the soil and water [5]. This lead then intoxicates adults and children and causes health issues. We are building this device to decrease health issues not to increase them. Therefore except for the PCB every other device lacks lead. We have also designed our device so that it uses little power and doesn't use electricity or fuel to charge up. A small 3V battery will be good enough for a long time.

4. CONCLUSION

In the Design Specification for Portable UVB Monitoring System we have explained why our design specification meets our functional specification. Sun Smart group has then implemented these explained requirements in actual design and development to implement the desired final product. At the end of this project we have a final product that meets all the design criteria. By testing the product we can solve any software/hardware defects to get the functional working product that can be presented and used.

5. REFERENCES

[1] Sun Smart Inc, "Functional Specification for a Portable UVB Monitoring System", Simon Fraser University, Burnaby, BC, Canada, February 2009

[2]Atmel Corporation, AVR Butterfly, Atmel, 2009, Available: http://www.atmel.com/dyn/Products/tools_card.asp?tool_id=3146, [Accessed: March 02, 2009]

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[4]Advanced Photonix Inc, The API Advantage, API, 2009, Available: http://www.advancedphotonix.com/, [Accessed: March 02, 2009]

[5]Texas Instrument Incorporated, Burr Brown Application Bulletin, TI, 2000, Available: http://focus.ti.com/lit/an/sboa061/sboa061.pdf, [Accessed: March 03, 2009]