November 6, 2009

Dr. John S. Bird
School of Engineering Science,
Simon Fraser University,
Burnaby, BC, V5A 1S6

Re: ENSC 440 Design Specifications for Auto-Splice Conductivity Analyzer

Dear Dr. Bird:

The attached document from Prospect1 Inc. outlines design specifications for the Auto-Splice Conductivity Analyzer (ASCA). ASCA is a device that can be used to analyze the imbalance of current flow in splices of an ACSR (Aluminum Conductor Steel Reinforced) overhead wire joint. By investigating current flow patterns, the user can identify the extent of damage present in the splice connecting the wires.

The 'Design Specifications' outlines necessary design considerations that need to be taken care of in order for the ASCA device to perform its desired tasks. This document also lists test plans to ensure proper operation of our product. Design improvements for future iterations of the device are also discussed here, but, will not be implemented at this stage of development.

Prospect1 Inc. consists of four enthusiastic and hard working fourth year Engineering Science students: Sam Hoque, Amir Najafzadeh, Milad Moezzie and Zhouhao Cui. We are very excited about the opportunity this project may hold in lessening the failure rates of automatic splices in overhead distribution systems. Please feel welcome to contact us if you have any questions or concerns by phone at (778) 229-9190 or by e-mail at prospect-1@sfu.ca

Sincerely yours,

Amir NajafZadeh
CEO Prospect1 Inc.

Enclosure: *Design Specifications for Auto-Splice Conductivity Analyzer*

Design Specifications for

Auto-Splice Conductivity Analyzer

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Executive Summary

This list of design specifications mentioned here is suited for the proof-of-concept model and will detail our proposed implementation of phases I and II of the *Functional Specifications for Auto-Splice Conductivity Analyzer (ASCA)* [1]. This document outlines the design of the ASCA device as well as theoretical and practical justifications for these design choices.

This document contains an overview of system specifications for the ASCA Device. It includes high level system design, graphics, comparison and evaluation for chosen components, as well as low level descriptions of major functional units as the user interface unit and control unit. This document also details the choice of hardware components as the MCU, Hall Effect Sensors utilized herein and the choice of software environment and the reasoning behind it. General software program process flow is also included here. Moreover, the functional, performance, and user acceptance test plans have been detailed here as well.

Development of the ASCA device is divided in to two phases. Upon completion of the first phase, the device will be able to obtain data regarding magnetic field intensity around live wire utilizing the Hall Effect Sensors and store them in a microcontroller. The microcontroller will read inputs from the Hall Effect Sensors, apply a differentiating algorithm, and save the data on the built-in memory.

In the second phase, this data will be sent to the output and displayed on the user interface unit. The user interface unit consists of a few LEDs and an LCD. During this phase, the casing of the device will also be prepared and the product will reach completion. The first prototype is expected to conform to these design specifications by the scheduled completion date of December 15, 2009.

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Glossary

ASCA	Auto-Splice Conductivity Analyzer
ACSR	Aluminum Conductor Steel Reinforced (overhead wire)
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MCU	Arduino Duemilanove Micro Controller
Splice	An electrical splice is the joining of two or more electrical conductors by mechanically twisting them together or by using a special splicing device [2]
Hot Stick	An insulated rod usually made of fiber glass. It can be of extendable length [3]
User	Certified Technicians/Electricians who are authorized to perform maintenance and testing on overhead transmission lines
PIC	Programmable Intelligent Computer
CPU	Central Processing Unit
PVC	Polyvinyl Cholride (A durable, easy to use polymer)
RoHS	Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations

1. Introduction

Auto-Splice Conductivity Analyzer (ASCA) is designed to determine current imbalance in overhead transmission line cable splices [2]. As splices age, Aluminum components oxidize to form an insulating barrier, thereby increasing their resistance and causing a current imbalance in cables' strands [4]. From the resulting magnetic field around the cables' strands, this imbalance can be found, and used to verify if the splice is faulty. The device has an LCD on it, which shows the intensity of the magnetic field around the splice. There are also a couple of LEDs on the device, which lets the user know if the intensity of the magnetic field is within range or out of range. ASCA can be attached to the overhead wire as a slide-on device to obtain data using a hot stick [3]. The design requirements for the ASCA device, as well as the reasoning behind it are described in this document.

1.1 Scope

The design specification shall meet all requirements for a proof-of-concept system and a partial set of requirements for a production model mentioned in the document: *Functional Specifications for Auto-Splice Conductivity Analyzer* [1]. As we are focusing on the proof-of-concept system for now, design considerations pertaining to the functional requirements marked Type I will be primarily discussed here. Simplified algorithms and design schematics will be used to explain various concepts. More detailed diagrams will be included as appendices for referencing purposes.

1.2 Intended Audience

- **Project managers** shall use it to evaluate progress throughout different development phases. It will also assist them in complying with necessary manufacturing and usability standards.

- **Design engineers** shall follow this document to meet overall design requirements from production to implementation of device.

- **Test engineers** shall use this document to assess the match in functionality between the actual device and the guidelines outlined here.

- **Marketing department** may also use this document to develop marketing materials and identify similarities in features (if any) with competitor's products.

2 System Specifications

The ASCA device will assist in locating faulty splices on overhead transmission lines. Once the user uses a hot stick to mount and slide the ASCA device along the length of a splice on overhead transmission lines,

- The device will measure the intensity of magnetic field along the length of a splice which connects two live wires.
- The device then compares this measurement with an 'ideal scenario' measurement (which has been taken earlier) where all the strands in a splice were intact.
- The MCU built in the device then sends this measurement as output to the user interface unit. The user interface unit consists of a LCD and a few LEDs.

3 Overall System Design

This section provides a general, high-level explanation of the ASCA device, as well as a short summary of the design characteristics of each component. More detail information about individual components will be furnished in a well fashioned manner later.

3.1 High Level System Design

The ASCA system can be modeled at a high-level as shown in Figure 3.1.

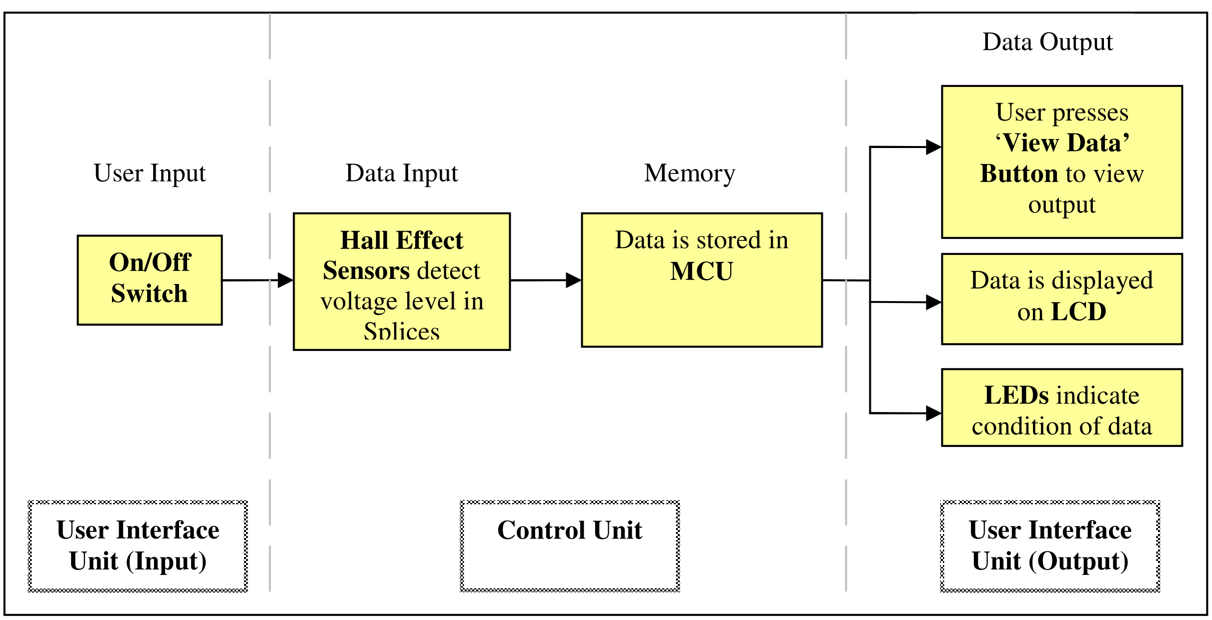

Figure 3.1: High-Level Functional Block Diagram

3.2 Control Unit

It is made up of an Arduino Duemilanove Micro Controller (MCU) and a couple of DN6847 Hall Effect Sensors. This is the heart of the device and takes care of most of the functionality of the device. Primary functions of the control unit include:

- To obtain data through the Hall Effect Sensors.
- To store data in MCU.
- To convert the information received from analog to digital.
- To send the output display to the LCD.
- To send output information to appropriate LEDs.

3.3 User Interface Unit

The user interface unit can be subdivided in to two components, the input and the output. The input is an ‘On/Off’ switch while the output consists of a push button, LCD and three LEDs. The device is turned on by pushing the ‘On/Off’ switch by the user. After obtaining data, the user presses the ‘View Data’ button to observe captured data. This is when stored data is displayed on the LCD along with an LED indicator. There are three LEDs on the device and they represent the following:

- Green LED: Data is within optimal range.
- Red LED: Data is out of range.
- Blue LED: Data is irrelevant or there is insufficient data.

4 Control Unit

The control unit consists of two primary components: two DN6847 Hall Effect Sensors and an Arduino Duemilanove Micro Controller (MCU). The software and the environment used to integrate the control unit with the user interface unit are also discussed here.

4.1 DN6847 Hall Effect Sensors

DN6847 Hall Effect Sensors are chosen to measure the magnetic field intensity around live wire splices. An alternating current carrying conductor produces a magnetic field around it. The functionality of these chips is very simple in nature as they are able to measure this magnetic field intensity directly, once placed near (within mechanical tolerance) a current conducting splice. Two sensors are used instead of one for precision of measurement. Attached is a pin diagram and positioning instructions for a DN6847 Hall Effect Sensor [5].

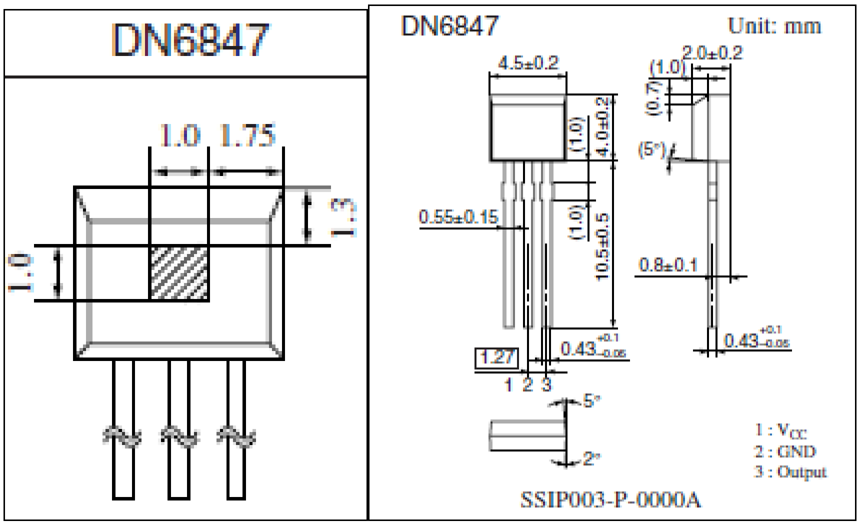

Figure 4.1.1: Pin diagram and Positioning Instructions for DN6847 Hall Effect Sensors

Advantages of the DN6847 Hall Effect Sensor:

- High sensitivity.
- Low drift.
- Stabilized temperature characteristics.
- Wide operating supply voltage range (VCC = 4.5 V to 16 V).
- Compatibility with the Atmel ATmega328 chip.
- Low cost.

Some useful properties of the DN6847 Hall Effect Sensor are mentioned below [5]:

Table 4.1.1: Properties of DN6847 Hall Effect Sensors

Property	Value
Supply voltage (V_{CC})	4.5 to 16 V
Supply current (I_{CC})	6 to 5.5 mA
Operating ambient temperature	-40 to 100 °C
Power dissipation	150 mW
Storage temperature	-55 to 125 °C

4.2 Arduino Duemilanove Micro Controller

For the core of our control unit, we chose the Arduino board. The current basic board from Arduino Duemilanove uses the Atmel ATmega328 chip. Once the Hall Effect Sensors obtain data, it is sent to this chip. Analog data is converted to Digital data and then stored here. Later, when the user presses the 'View Data' button, this data is sent as output to the LCD and appropriate LEDs are lit.

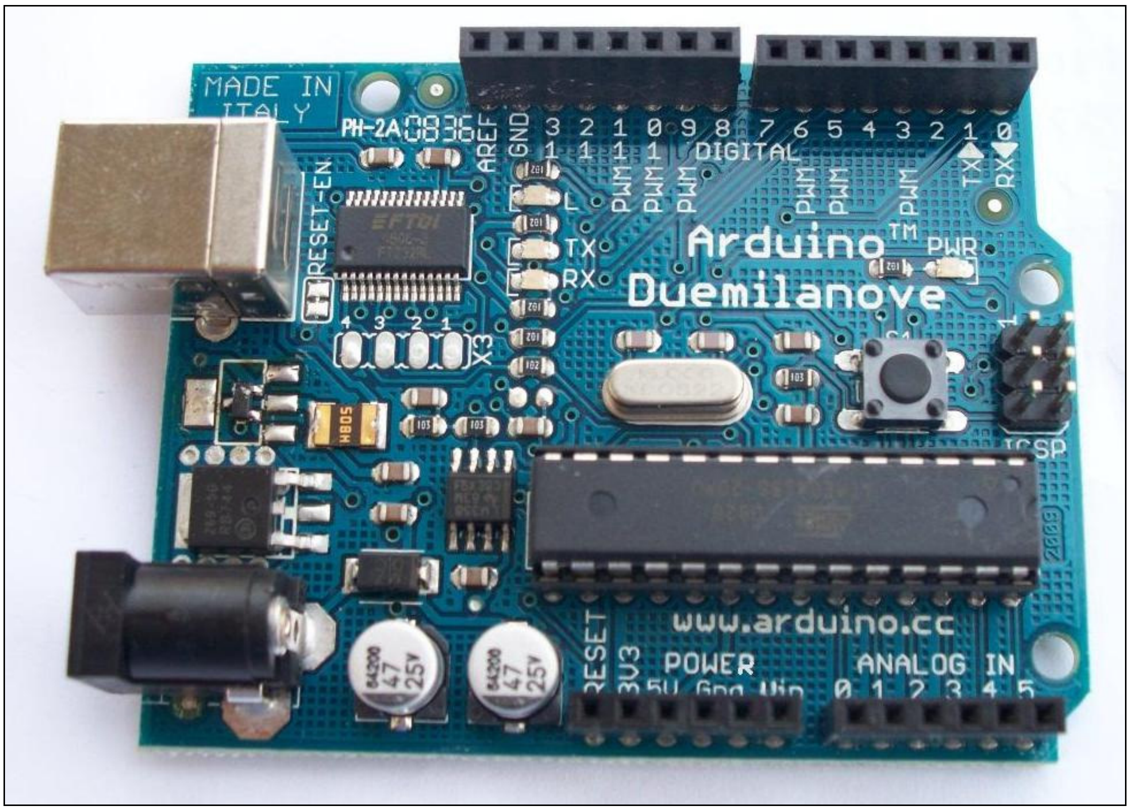

Figure 4.2.1: The Arduino Duemilanove PIC board which uses the Atmel ATmega328 chip

Advantages of this PIC:

- High pin count.
- Compatibility with many programming kits.
- 32kb built in flash memory.
- On-chip 2-cycle Multiplier.
- Built in Bootloader.
- Built in Analog to Digital converter.
- Multiple Power Supply options.
- Dedicated software provided by manufacturer.
- Can be made portable.
- Built in LEDs. Can be utilized in future models.
- Low cost.

Some useful properties of the Atmel ATmega328 chip are mentioned below [6]:

Table 4.2.1: Properties of the Atmel ATmega328 chip

Property	Value
Operating Temp	–40°C to 85°C
Power Consumption	At 1 MHz, 1.8V, 25°C – Active Mode: 0.2 mA – Power-down Mode: 0.1 µA – Power-save Mode: 0.75 µA
Operating Voltage	1.8 - 5.5V
Memory	32KB
Registers	32 x 8
Speed Grade:	0 - 20 MHz @ 1.8 - 5.5V
Timer/Counters	Two 8-bit or One 16-bit
I/O and Packages	23 Programmable I/O Lines
Write/Erase Cycles	10,000 Flash/100,000 EEPROM
Single Clock Cycle Execution	131
PWM Channels	6
Data retention	20 years at 85°C/100 years at 25°C

The pin diagram and CPU architecture of the chip is shown here for reference (Figure 4.2.2) [6].

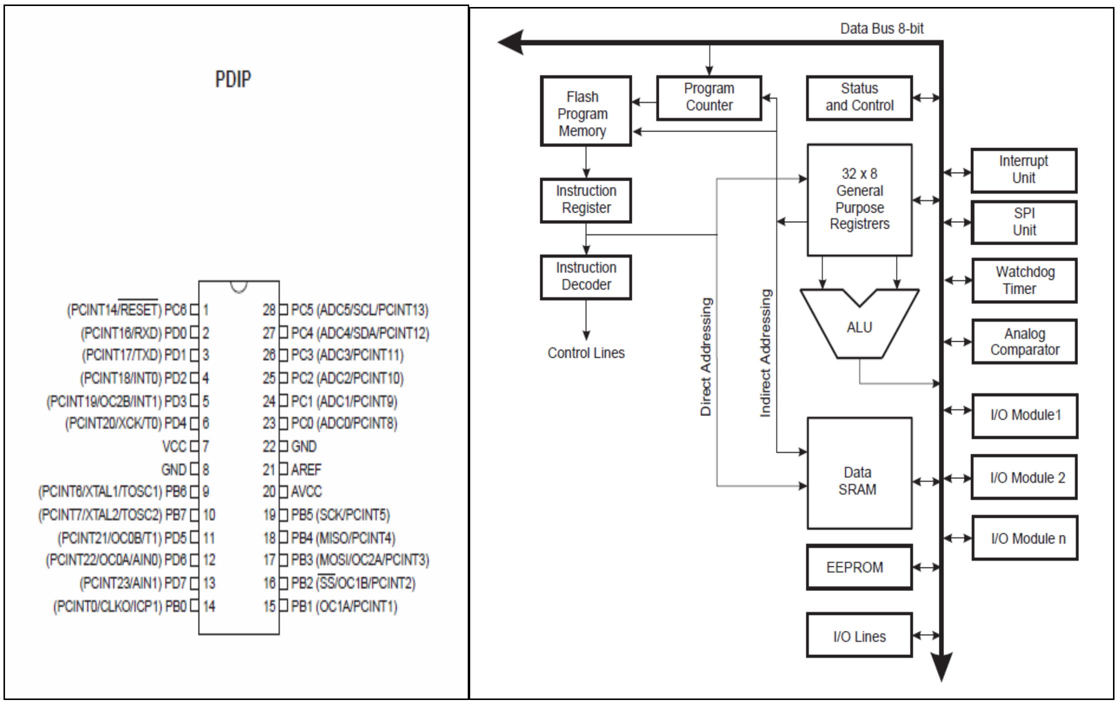

Figure 4.2.2: Pin diagram and CPU Architecture of the Atmel ATmega328 chip

4.3 Software Environment

There is no additional need to utilize a certain software/coding language as the manufacturer has prepared a pre-developed software environment to program the Arduino board. The software is very easy to use and tailor made for the simplicity of users. The communication interface makes uploading and compiling data very straightforward. Once a piece of code has finished running, it is uploaded on the board and compiled. Also, there are additional tutorials offered by the manufacturer on their website. These tutorials provide helpful pointers in accomplishing different tasks through this PIC.

Some key features [7] of this software and the software environment are:

- The environment is written in Java and based on Processing, avr-gcc, and other open source software.
- Both the simulator and the PIC are produced by the same manufacturer. Thus it is easier to obtain help and support.

5 User Interface Unit

The user interface unit is divided in to two parts, the input and the output. The input consists of an 'On/Off' switch. And the output comprises of a push button, a LCD and three LEDs.

5.1 Input

A momentary-on pushbutton is used as the 'On/Off' switch for this device. The user presses this switch to turn on the device. Once turned on, it is mounted on a hot stick to slide along a splice's length.

5.1.1 On/Off Switch

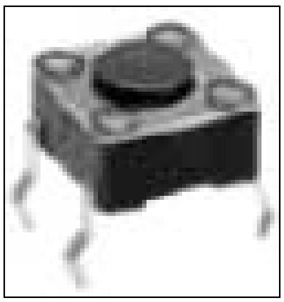

Figure 5.1.1: Push Button

We will be using momentary-on Tyco FSM Series tact pushbuttons. Once the switch is turned on, a blinking LED on the device will indicate that the device is turned on. An image of the switch is attached for clarification. Key features of the button are listed in the following table [8].

Table 5.1.1: Properties of Tyco FSM Series tact pushbutton

Property	Value
Contact Rating	50 mA @ 12 VDC
Initial Contact Resistance	100 milliohms max
Insulation Resistance	100 megohms min@ 500 VDC
Dielectric Strength	500 VAC for 1 minute
Actuation Force	130±50 gms
Actuator Travel	0.254mm [.010 in.]
Life Expectancy	Up to 20,000 cycles

Advantages of the Tyco FSM Series tact pushbutton:

- Low cost.
- Durability.
- Long Lasting.
- Easy to use.

5.2 Output

The output has three components: a TS1620-1 LCD, three 3mm Type 01 553-xxxx-300 LEDs and a Tyco FSM Series tact pushbutton.

5.2.1 LCD Display

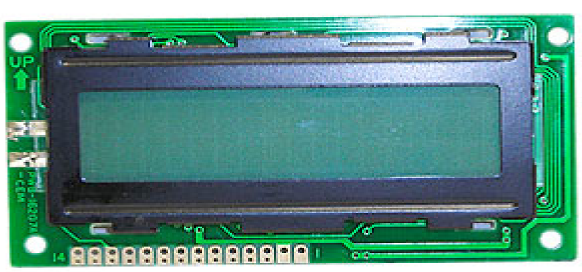

Figure 5.2.1: TS1620-1 LCD

The TS1620-1 LCD is used in the ASCA device. Once the MCU has captured data it is displayed on this LCD as output. This shows users the reading obtained through the Hall Effect Sensors. The properties of the LCD are mentioned in the following table [9].

Table 5.2.1: Properties of the TS1620-1 LCD

Property	Value
Operating Temp	Min.0C ~ Max. 50C
Storage Temp	Min. -20 C ~ Max. 70 C
Viewing Area	61.0 (W) × 16.0 (H) mm
Outline Dimensions	84.0 (W) × 44.0 (H) × 11.0 max. (D) mm
Weight	50g max
LCD Type	STN / Neutral-mode / Reflective
Display Format	16 characters × 2 lines

Display Fonts	5 × 8 dots (1 character)
Viewing Angle	6:00
Backlight	None

Advantages of the TS1620-1 LCD:
- Can display two lines of characters and numbers. This feature can be utilized for future upgrades on the model.
- Low cost and durable.
- Light weight.
- Long Lasting and easy to use.

5.2.2 3mm Type 01 553-xxxx-300 LEDs

The LEDs are designed to show the state of conductivity on the overhead wire splice. Since we have predetermined a reference voltage value as the minimum accepted value, once the data is acquired from the Hall Effect Sensors, it can be easily found if this is below or above the 'ideal scenario' value. It provides an alternative way of showing the result to the user. Three 3mm Type 01 553-xxxx-300 LEDs are used in this device. The green 553-0122-300 LED is used to show that data is within optimal range. The red 553-0110-300 LED is used to indicate data is out of range. While the blue 553-0188-300 LED lights up when data is irrelevant or there is insufficient data. Along with the LCD, these three LEDs complete the visual display aspect of the output. The properties of the LEDs are mentioned in table 5.2.2 [10]. An image and specification of the LED are also attached here.

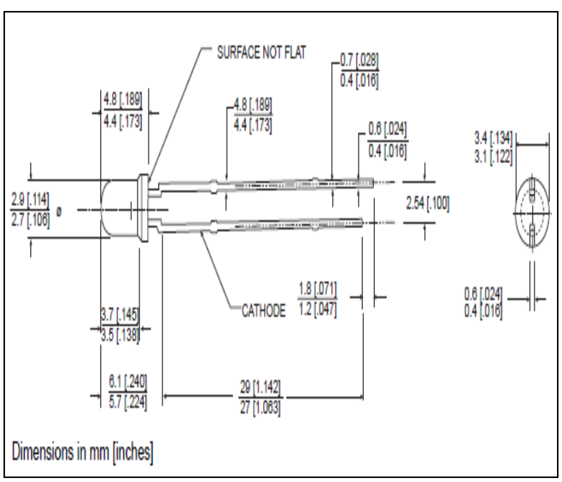

Figure 5.2.2: 3mm Type 01 553-xxxx-300 LEDs

Table 5.2.2: Properties of 3mm Type 01 553-xxxx-300 LEDs

Property	Red	Green	Blue	Unit
Peak Wavelength	635	565	428	Nm
LV	10	16	12	mCd
VF	2	2.1	3.5	V
Test Current	10	10	10	mA
Viewing Angle	45	45	70	°
Operating Temperature Range	-40~85			°C
Storage Temperature Range	-25~85			°C

Advantages of 3mm Type 01 553-xxxx-300 LEDs:
- Low cost and performance.
- Optimal operating range of temperature.
- Durability.
- Long Lasting and easy to use.

5.2.3 Tyco FSM Series tact pushbutton

Another Tyco FSM Series tact pushbutton is used to View Data. This is the same pushbutton switch used to turn on the device. Due to its similarity, lightweight and ease of functionality this switch is used. Specifications and advantages of this switch can be found in section 5.1.1.

6 Mechanical Design

Casing for the ASCA device and its dimensions are shown in figure 6.1. The device is mostly made of PVC material. The LCD, switches and LEDs are mounted on the user interface unit, which is made of PVC cuboids. Underneath the user interface unit lays the Arduino Duemilanove PIC. All the wire connections and soldering are hidden by this case. There is also a PVC hook in the middle of its top surface. This is used to mount the device on a splice using a hot stick.

The cylindrical shaped component, also made of PVC material, holds the Hall Effect Sensors. Wire connections are etched along its walls and connect to the PIC.

PVC is used for its low cost, durability, ease of use and non-conducting nature of electricity and heat [11]. This also reduces the risks of arcing and static current damaging the device.

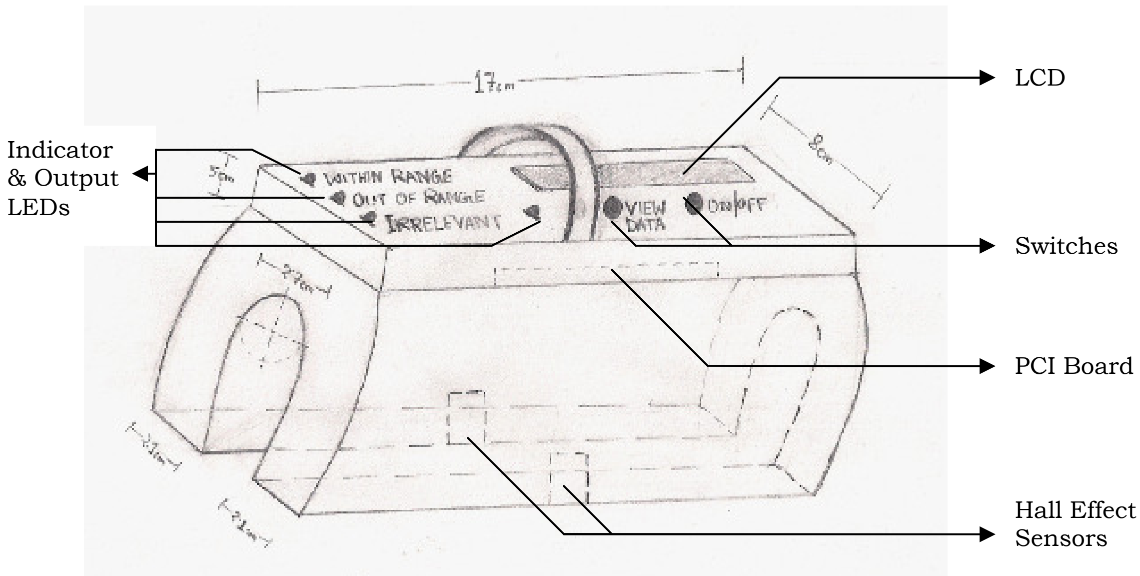

Figure 6.1: Mechanical Design of the ASCA device

A flowchart of how the device performs from the beginning to the end is attached in figure 6.2. This explains step by step how this device functions.

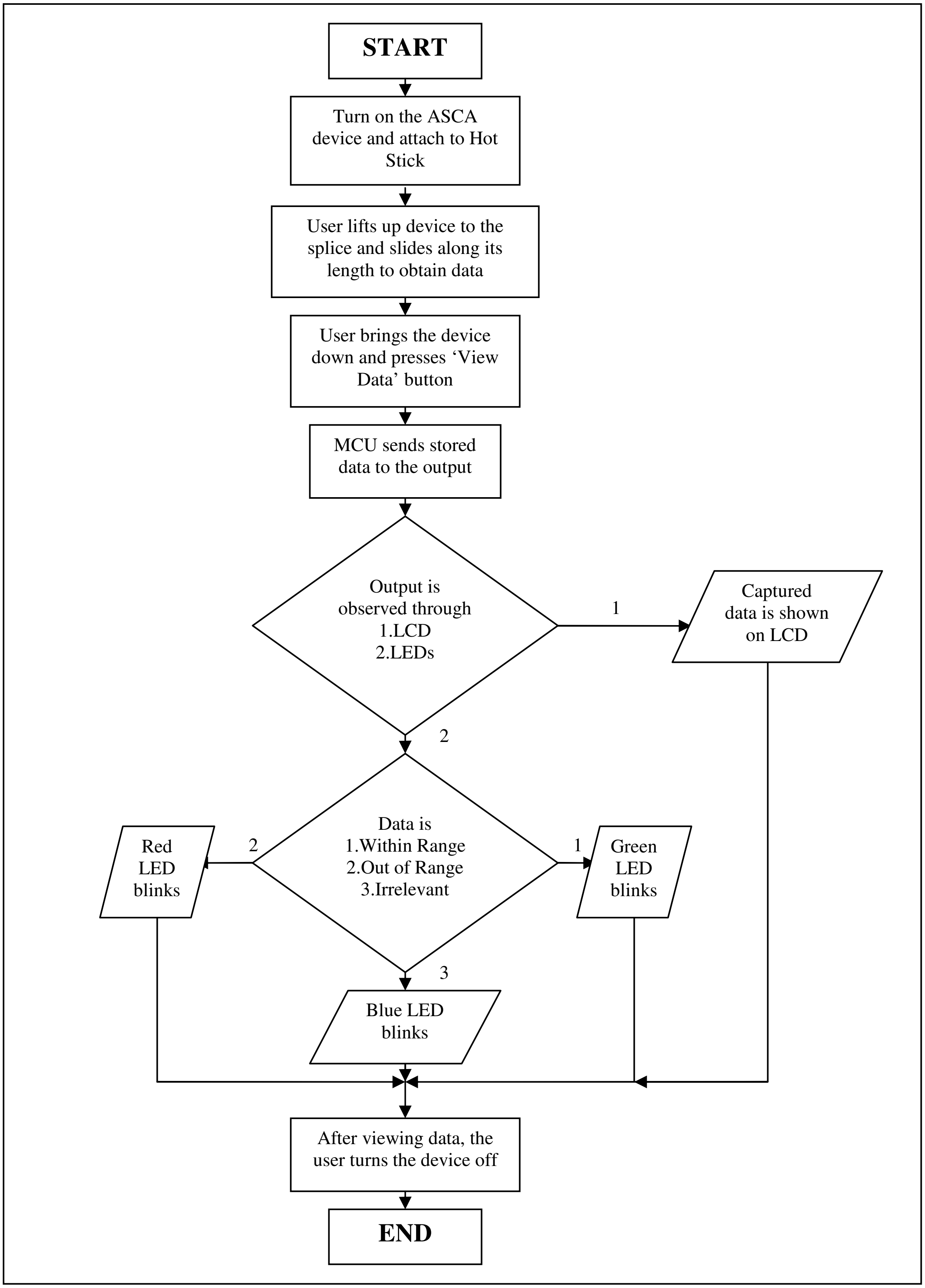

Figure 6.2: Flowchart of functionality for the ASCA device

7 Environmental Considerations

- Prospect1 Inc. has paid utmost attention and degree of care to the environmental aspect of the design during the device's production and distribution. The components chosen for the device adhere to RoHS directives [12]. It limits the release of dangerous chemicals such as lead, cadmium and mercury into the environment. It also protects the user from emissions of these dangerous components. The device is 'lead' free; both in its components and during soldering.

- The device is able to run and operate with minimal power consumption. The ASCA device does not need a lot of power to function.

- In case the device reaches the end of its useful life, the user is provided with complete information on proper disposal and recycling of the electronic device and battery.

8 System Test Plan

In order for the system to function in a reliable manner, it is necessary to test it during different stages of design and implementation, prototype building and manufacturing. To avoid errors, the general test plan is to test each module as it is built, and to retest the modules upon integration into a complete unit. Device specifications mentioned in functional specifications [1] emphasize on boundary conditions that should be taken care of throughout the design. From designing this device to building a prototype, the tests associated with various stages can be divided in to three main categories. For this project, they will be named as unit testing, constituent testing and prototype testing.

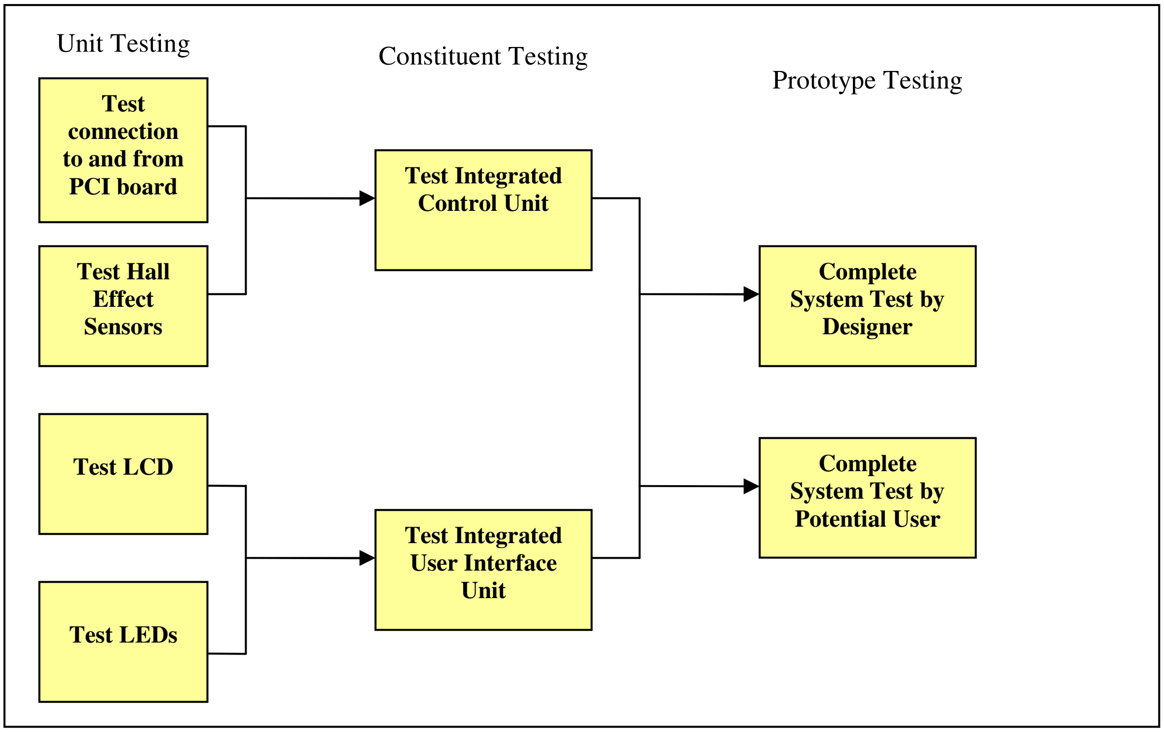

Figure 8.1: High-Level Block Diagram for System Test Plan

There will be five primary unit tests; one each for the switches, MCU, Hall Effect Sensors, LCD and LEDs. These tests ensure that the design and each individual internal component are functioning in a desired manner. Different steps associated with these tests and expected results are mentioned below.

Table 8.1: Unit test description

Test No.	Functions of Test	Description/Results
1.1.1	'On/Off' Power Switch	By pressing it once, the device turns on. Pressing it again turns the device off. A blinking LED indicates power is turned on.
1.1.2	'View Data' Switch	LCD display starts and an appropriate LED lights up as the switch is turned on.
1.2	Hall Effect Sensors	Measurement is taken by the sensor in presence and absence of a magnetic field to ensure accurate data measurement.
1.3.1	MCU Power	A blinking LED indicates power is turned on.

1.3.2	MCU Data Storage	A stack register can be used to note if the MCU memory is getting filled as the sensors keep on capturing data.
1.3.3	MCU Output	LCD display shows measurement and an LED lights up accordingly.
1.4.1	LCD Display (idle state)	No data is displayed before the 'View Data' Switch is pressed.
1.4.2	LCD Display (active state)	Measured data is displayed after the 'View Data' Switch is pressed.
1.5.1	LED (idle state)	None of the LEDs are lit before the 'View Data' Switch is pressed.
1.5.2	LED (active state)	According to range of data, suitable LED lights up after the 'View Data' Switch is pressed.

Once satisfactory results are obtained through unit tests, next step is to perform constituent testing. At this stage, the design gets divided into smaller building blocks. For example, the user interface unit and the control unit.

Table 8.2: Constituent test description

Test No.	Description of Tests
2.1	Hall Effect Sensors and MCU - When the sensors are placed close to an alternating current conductor, they measure the magnetic field intensity and this data is then sent to the MCU to convert from analog to digital and store in its memory. Once again a stack register can be used to notice if the memory is getting filled. As the sensors are connected to the MCU here, if the memory starts getting full, this test will confirm that the connection between the sensors and the MCU are as desired. - This would also ensure that the sensors are placed within threshold distance form the conducting wire/splice to measure magnetic field intensity.
2.2	LED, LCD and the MCU - The following three tests determine if the connection from the MCU

	to the output (LED, LCD) is intact and if the device is providing its output as desired.
2.2.1	LED and the MCU - The MCU sends output to the LEDs when ‘View Data’ button is pressed. According to the range of data the corresponding LED lights up. The LED display should also be in sync with the LCD.
2.2.2	LCD and the MCU - The MCU sends output data to the LCD when ‘View Data’ button is pressed. Measured magnetic field intensity is displayed on the LCD. The LCD display should also be in sync with the LEDs.
2.2.3	LCD and LEDs - According to the measured reading on the LCD a corresponding LED should light up. For example, if the data is out of range, the red LED lights up. Thus the display on the LCD should match the LED light to confirm the device’s accurate functionality.

The last step in the system test plan is prototype testing. After the smaller blocks pass constituent testing, they are ready for integration. Once integrated, prototype testing can make sure that the smaller blocks put together are functioning well and are in cohesion. At this stage, boundary conditions shall be tested in greater details again. This may give the designers an idea on how well the functionality of the device in different conditions matches its functional specifications. It may also be a good idea to have potential users try the prototype before commercialization or mass production of this device is done. Their feedback may point to any negativity in the device or lead to possible upgrades and improvements for future.

At this stage of testing, the ASCA device is tested by the user as a complete unit. Detail functionalities described in functional specifications [1] are tested and made sure the device is working as it is supposed to.

If at any point of the building process, a change in either design or raw material was found necessary, the system shall be tested again from the stage where changes were needed.

9 Future upgrades

9.1 Hall Effect Sensor Noise Reducing Circuit

This is a very simple circuitry that might be used to reduce introduced noise. Although the effect of this circuit can be minimal, this can be particularly useful where the data is irrelevant. In such cases, some data signals exceed the maximum or minimum allowable range. This circuit can then be useful in distinguishing between useful and distorted data.

9.2 Integrating Hot Stick and separating the user interface unit

The ASCA device has multiple power sources. This of course gives the device added portability as well as a chance to power/operate the device from a laptop or an alternating power source. In future models, for instantaneous observations, the user interface unit can be separated and held in hand while the rest of the device is mounted on overhead wire. For this model to be produced, wiring needs to be incorporated with the hot stick.

10 Conclusion

The 'Design Specifications for an Auto Splice Conductivity Analyzer' provides a clear and concise overview of our projected design. This is very much in correlation with the functional specification [1]. There is a comparative analysis outlined here for each component, which explains why they were chosen for the ASCA device. Extensive test plans ensure the device meets its goals during the manufacturing and production phases. This is not a rigid design as there is room for future improvement.

11 References

[1] Functional Specifications for the Auto-Splice Conductivity Analyzer, http://www.ensc.sfu.ca/~whitmore/courses/ensc305/projects/current/efunc.pdf

[2] Splices, Integrated Publishing, http://www.tpub.com/content/construction/14027/css/14027_121.htm

[3] TEL-O-POLE II Parts List, Hastings, http://www.westernsafety.com/Hastings/hastingspg1.html

[4] Transmission & Distribution World, "Forensic Analysis of Automatic Splices Leads to Change", http://tdworld.com/mag/power_forensic_analysis_automatic

[5] Hall Effect Sensors, http://www.datasheetcatalog.org/datasheet/panasonic/SPC00002CEB.pdf

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[8] Properties of Tyco FSM Series tact pushbutton, http://www.e-sonic.com/aboutus/cat/S/switches%2029.pdf

[9] Properties of the TS1620-1 LCD, http://displaybras.com.br/pdf/DAN%201602B-2.pdf

[10] Properties of 3mm Type 01 553-xxxx-300 LEDs, http://www.digchip.com/datasheets/download_datasheet.php?id=67832&part-number=553-0188-310

[11] PVC in Use, http://www.asf.com.au/PDFS/PVC.pdf

[12] RoHS, http://www.rohs.gov.uk/

[13] Engineering Science 305/440, http://www.ensc.sfu.ca/~whitmore/courses/ensc305

