FINAL YEAR PROJECT REPORT ON

WIRELESS PORTABLE PYROMETER

SUBMITTED TO SAVITRIBAI PHULE PUNE UNIVERSITY

FOR THE FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF ENGINEERING

In

Electronics and Telecommunication

Submitted By

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DEPT. OF ELECTRONICS AND TELECOMMUNICATION

PUNE VIDYARTHI GRIHA'S COLLEGE OF ENGINEERING AND TECHNOLOGY,

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DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION ENGINEERING

PUNE VIDYARTHI GRIHA'S COLLEGE OF ENGINEERING AND TECHNOLOGY, PUNE 9

CERTIFICATE

THIS IS TO CERTIFY THAT THE FINAL YEAR PROJECT ENTITLED

"WIRELESS PORTABLE PYROMETER"

HAS BEEN SUCCESSFULLY COMPLETED BY

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TOWARDS THE PARTIAL FULFILLMENT OF THE DEGREE OF BACHELOR OF ENGINEERING IN ELECTRONICS AND TELECOMMUNICATION AS AWARDED BY THE SAVITRIBAI PHULE PUNE UNIVERSITY, AT PUNE VIDYARTHI GRIHA'S COLLEGE OF ENGINEERING DURING THE ACADEMIC YEAR 2017-18.

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To,
Head of Department,
Electronics and Telecommunications,
PVG's COET,
Pune.

Subject: Technical and Financial Sponsorship for B.E. Project

Respected Sir,

We at **Fluxion Process Solutions** are ready to offer technical guidance and financial support to the B.E. project being undertaken by the following students from **PVG's COET**

Bhushan Borse (B120073022)

Deepesh Sonigra (B120073121)

Samadnya Kalaskar (B120073064)

Their project **'Wireless Portable Pyrometer'** can be shaped as a very good product and we would like to guide that process.

Regards,

Mangesh Purandare
Partner

Fluxion Process Solutions

ACKNOWLEDGEMENTS

I have taken meticulous efforts in the completion of this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them.

I would like to express my humble thanks to our project sponsor, "Fluxion Process Solutions" for providing me an opportunity to work with them. Especially, the Partner/Senior Development Engineer, Mr.Mangesh Purandare for giving me his precious time and relevant knowledge.

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I would like to express my gratitude towards my parents & members of Pune Vidyarthi Griha's College of Engineering & Technology for their kind cooperation in making various facilities available for the completion of this project.

Lastly, my kind token of appreciation to my colleagues and my friends who supported me and helped me whenever I needed them.

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LIST OF ABBREVIATIONS

ABBREVIATION	FULL FORM
ADC	Analog To Digital converter
RTC	Real Time Clock
I2C	Inter Integrated Circuits
EEPROM	Electrically Erasable Programmable Read Only Memory
UART	Universal Asynchronous Receiver Transmitter
LCD	Liquid Crystal Display
SPI	Serial Peripheral Interface
Wi-Fi	Wireless Fidelity

ABSTRACT

A Pyrometer is suited for the measurement of temperature of objects or any surfaces that are being heated. For example, in the foundry industry, reliable measurement of the temperature is essential as when the metal cools down it should attain certain temperature to display tensile properties.

The pyrometer makes it possible for foundries to gain new insight into what temperature levels are at the mould or die during the casting process. The portability of the pyrometer can enable one to navigate throughout the foundry because many casts are processed at a time.

The Wireless Portable Pyrometer works as an aid for the industries where metals are casted at high temperatures. It lessens the burden caused by possible human error in keeping records. It has modern connectivity as it features us with, system data storage, data update through UART and Wi-Fi connectivity.

CONTENTS

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

In the foundry industry, the process of melting the metals is one of the essential and crucial processes. Such a process involves generation of extremely high temperatures (1000^{o}C to 1700^{o}C)[1]. It is of utmost importance that appropriate levels of temperature are attained in order to exhibit tensile properties of the molten metal. Controlling and observing the process may become a tedious job if one has to note down the essential levels intermittently. In addition, it is difficult to detect and correct faults/errors occurring during the process. Furthermore, the human effort required to monitor and note down a large set of readings is nearly unfathomable. The job could be made easier if there is a device, which can facilitate the measurement of the temperature levels and also provide a complete set of readings from time to time. Also, the accuracy rendered by such a device is an additional benefit.

1.2 RELEVANCE

The foundry industries require temperature monitoring for the metal casting processes. We aim to design a device that fulfills this need and provides ease of operation. Our device conforms to the basic requirements of measuring the temperature and storing it through the in-built data logger. It also has an interaction platform made available by keys, display and LEDs. The Wireless Portable Pyrometer can be highly useful to the foundry industries. Its functionality and features keep it far from being obsolete.

1.3 MOTIVATION

The need for such a product is a driving force behind the making of this device. The current market scenario and sparse availability of such a device is an important factor behind this device [4]. Another motivation is, presenting a fully functional device with attractive features, at an affordable cost. The demand for a pocket-friendly price and good serviceability of the product bolster up its need.

CHAPTER 2
LITERATURE SURVEY

2.1 Comparison

Parameters	**Pyrometers available in market**		**Wireless Portable Pyrometer**
Companies	The Pyrometer Instrument Company, Inc [4]	Artech [4]	Our product
Method	Portable	Wall or Floor-mounting MS Panel	Handheld, portable
Data transfer	Digital Readout ±1°F or C	To PC and printer	To PC and to wireless display
Accuracy	±1.0% Reading	± 2°C	Expected - ±1.0%
Resolution	1°C	1°C	Expected- 0.1°C
Display	LED display	Red LED display	Battery saving LCD
Operating temperature range	0°C - 1400°C	1000°C - 1800°C	1000°C - 1700°C
Inputs	K-Thermocouple	R,S, B or K Thermocouple - Selectable	R-Thermocouple [5]
Outputs	a) 4 Digits - Characters 3/16" High b) Low Battery Warning Light	a) Temperature Result on 2" Ht 4 digit LED Display b) Bright, Green, Amber and Red lamps for status indication with Hooter c) 4 digit result in current loop at 220 Hz bit rate until reset. d) parallel port for Printer e) RS-232 for PC	a) Temperature result on 3.5 LCD b) 5 LED indicators for the status of the device and battery conditions c) Wi-Fi connectivity with a wireless display for distant measurement of readings d) Communication to PC using RS-232
Data Memory	Not available	Last 190 readings- battery backed	Last 2048 readings- battery backed
Power Supply	Rechargeable, battery operated	Fixed, no battery charging circuit	Rechargeable, battery operated
Compensation	Automatic Cold End Junction	Cold junction compensation automatic	Cold junction compensation by room temp. sensor.
Clock	Time, battery backed	Time, Internal, clock-battery backed	External Real Time Clock, battery backed
Price	Rs. 40,000/piece	Rs. 79,000/piece	Within Rs.30,000/piece

Table 2.1 Literature Survey

We aim to design a device for foundries which require intermittent temperature monitoring. The device should be able to measure the temperature of molten metal which is at 1000^{o} C to 1700^{o}C. The in-built Data Logger eliminates human errors in keeping the records. The accuracy, resolution and precision provided by our device is an upper hand as compared to the current market availability of similar pyrometers. We achieve this accuracy by using a Sigma Delta ADC instead of the conventional Dual Slope ADC [6]. This switch facilitates better stability in the A to D conversion. Such a modification in the existing ADC technique is a plus point.

Our design uses a microcontroller which belongs to the SMD packaging type. This enables less usage of on circuit space and makes the circuit compact. Also, we are making use of a LCD display instead of an LED display. This saves the power consumption and makes the device battery efficient [3].

We have focused on making the device portable, it is a handheld unit with a rechargeable battery. We are providing wireless connectivity between the device and a display with the help of a Wi-Fi module [10]. The storage of set of measured temperatures is taken care of by the EEPROM. There are LEDs indicating the current activity performed by the device. Due to these features, our device stands out in comparison to other such parallel devices available in the market.

Monitoring of the temperature of the pouring metal in foundries is a challenging task due to the varying measuring conditions and characteristics of the metal. For our product, the temperature of the metal is measured by a thermocouple immersion probe. Some currently available pyrometers in the market detect the infrared radiation in two different wavelengths and then measure the temperature. The complexities involved in this method make such products expensive as compared to our product.

Our product can be easily connected to available data base systems. It provides automatic recording of the temperature, comprehensive documentation of the temperature readings by large data storage. Minimum system maintenance is required due its mobile deployment and ease of charging. It complies with the standard voltage and current specifications. It has a Wi-Fi module for better display and easy connectivity to PC. Such add on features are not available with most of the market competitors under one single product [4].

CHAPTER 3
SYSTEM ARCHITECTURE

3.1 OBJECTIVES

- To design a wireless, portable device which can be used for temperature measurements ranging between 1000°C to 1700°C.
- The device should be battery operated as well as chargeable.
- There should be a storage facility for the set of readings (temperatures) measured by the device.
- The device should display the date and time of the recorded readings.
- There should be Wireless Connectivity to connect to the display (via Wi-Fi).
- Facility for calibration settings through user interaction.

3.2 SYSTEM BLOCK DIAGRAM

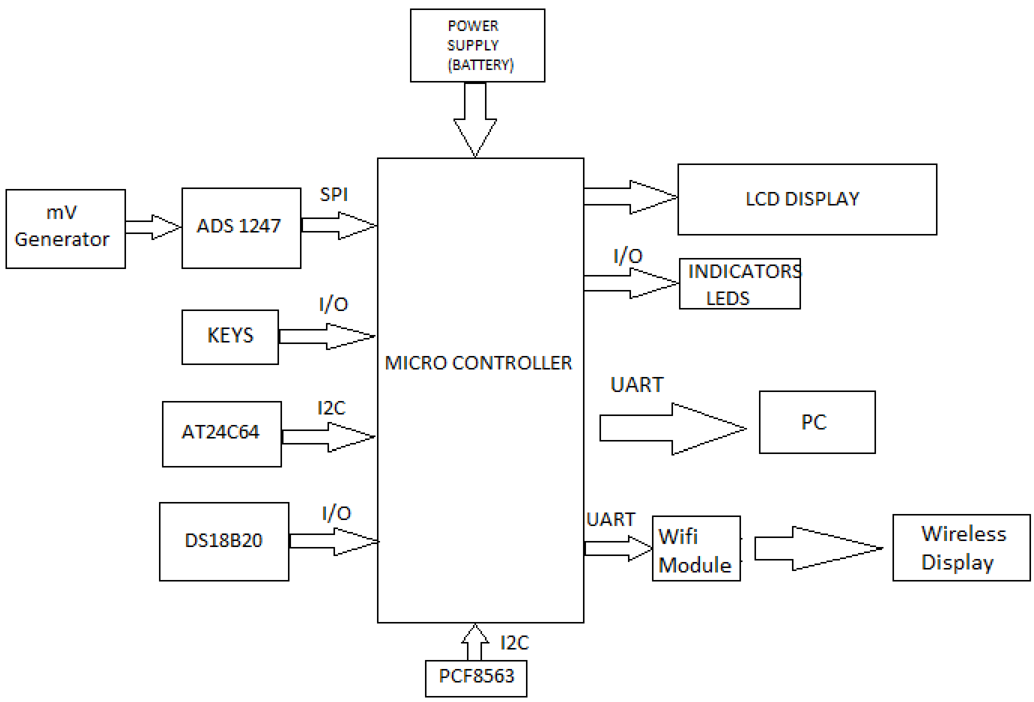

Figure 3.1 System Block Diagram

3.3 DESCRIPTION

1. Temperature Sensor

The temperature sensor is used for sensing the room temperature. This sensor is used for minimizing the Cold Junction Compensation. The sensor output temperature (in digital form) and this temperature is given to the microcontroller [1].

2. Input

The inputs to the system are given using user interface. The inputs required to the system are:

- Thermocouple simulator.

3. Microcontroller

The microcontroller (PIC) is used to do all the logical operations needed and acts as a communication medium between input and output components [15].

4. ADC

The output of thermocouple simulator (in mV) is given as an input to ADC. The ADC is used to convert these values to the corresponding count [6].

5. EEPROM

It is used to store the readings along with the date and time of recording. It can store the data for a couple of months [11].

6. KEYS

They work as an user interface. They will solve the purpose of navigating through the menu.

7. LED

They are used to indicate the current status of the device.

8. RTC

To provide more accurate date and time as compared to the on chip RTC.

9. Wi-Fi module

It transfers the readings to a remote wireless display. This fulfills the wireless aspects of our device.

10. Power Supply

Battery charging facility which makes the device portable and enables recharging whenever required.

3.4 WORKING

- First of all, the thermocouple simulator provides mV readings corresponding to the temperatures ranging between 1000°C to 1700°C [1].
- These readings are given as an input to the ADC. The ADC generates the count which is sent to the microcontroller through SPI [6].
- Further, the temperature value is displayed on a 3.5 LCD display [3].
- The set of readings is saved in the EEPROM through I2C and can be accessed through the PC which is interfaced via UART [9].
- The keys can be used to navigate through the menu.
- The RTC provides with the date and time update to ensure proper ordered set of readings [13].
- The Wi-Fi module is used to send the readings on a distant wireless display. Wi-Fi module is interfaced via UART [10].
- The LED is used to indicate the current status of the device such as battery level, ready status, measure, complete and error.

CHAPTER 4
SYSTEM SPECIFICATIONS

4.1 INTRODUCTION

This chapter covers the specifications of all the components used.

4.2 HARDWARE SPECIFICATIONS

- Inputs – Thermocouple R type simulator, ADC, RTC, room temp. sensor, navigation keys.
- Output – Voltage in mV, 3&1/2 digit LCD, indicator LEDs for POWER ON, MEASURE, HOLD, OPEN, LOW BATT.

4.3 PROGRAMMING

- Data acquisition from user and thermocouple simulator [1].
- Conversion of ADC output to corresponding counts.
- SPI bit banging [9].
- Coding related to different communication protocols (I2C, UART).
- Wi-Fi module LUA script coding.

4.4 COMMUNICATION

- SPI - 3/4-wire SPI (supports all four SPI modes) used for communication between microcontroller and ADC [15].
- I2C- I2C™ Master and Slave mode used for communication between microcontroller and EEPROM, RTC [15].
- UART - Two Enhanced Addressable USART modules used for communication between microcontroller and RS232 and Wi-Fi module [15].
- Wi-Fi - SDIO 2.0

4.5 DEVELOPMENT TOOLS:

- Software –

  MPLAB IDE for PIC programming.

  ORCAD for Schematic and PCB design.

  Hi-Tech Compiler for compilation of the code.

  Logic Analyzer Software for observing waveforms.

4.6 POWER SUPPLY

- 5V Battery.
- Microcontroller power supply, reset, clock- using LM1117 for 5v to 3.3V conversion[7].
- Charging circuit for recharging purpose.
- ADC power supply, reference, clock, etc. - Digital: 3.3V; Analog: Dual supply- +/- 2.5V, Internal Reference, Internal clock, start pin pull up, reset control from microcontroller [6].
- Power ON and OFF control using MOSFET separately for Wi-Fi module.

4.7 CONNECTORS

- ICSP connector
- 2 pin battery
- 2 pin analog
- 3 pin RS232
- 8 pin keyboard

4.7 SIGNAL CONDITIONING

- Analog input signal conditioning using two stage RC filter.

4.8 TEST POINTS

For ease of debugging and testing: CS, MISO, MOSI, SCLK, DRDY, VREFOUT, VREFCOM, RESET, UART1 TTL Tx, Rx, UART2 TTL Tx, Rx.

CHAPTER 5
SYSTEM DESIGN DEVELOPMENT

5.1 INTRODUCTION:

This chapter covers selection of components along with their justification for the selection.

5.2 SELECTION OF COMPONENTS

5.2.1 ADC

- Sigma Delta ADC for better stability as compared to the ADC using Dual Slope technology.
- Minimum requirement is up to 14 bits but due to economical efficiency we prefer 24 bit ADC.
- For a change of 1° C the change in output voltage is 0.01 mV hence internal gain is required for increasing the resolution of ADC.

Manufacturer and Part No.	MICROCHIP MCP3421A0 T-E/CH	MICROCHIP MCP3021A5T-E/OT	TEXAS INSTRUMENTS ADS1247IPW	TEXAS INSTRUMENTS ADS1248IPW
Resolution (Bits)	18bit	10bit	24bit	24bit
Sampling Rate	3.75SPS	22.3kSPS	2kSPS	2kSPS
Supply Voltage Max	5.5V	5.5V	5.5V	5.5V
Supply Voltage Min	2.7V	2.7V	2.7V	2.7V
ADC / DAC Case Style	SOT-23	SOT-23	TSSOP	TSSOP
No. of Pins	6 Pins	5 Pins	20 Pins	28 pins
Data Interface	I2C	I2C	Serial, SPI	Serial, SPI
Range	Single 8-Bit Sigma-Delta ADCs	Single 10-Bit SAR ADCs	Quad 24-Bit Sigma-Delta ADCs	Octal 24-Bit Sigma-Delta ADCs
Price	Rs.112.76	Rs.112.76	Rs.789.64	Rs.805.12

Table 5.1 Comparative study of ADC [2]

Selected ADC => ADS1247

5.2.2 EEPROM

The internal EEPROM (256 bytes) is used to save the settings of the chip.

An external EEPROM is required for saving the recorded data. The memory requirement is of 64 KB.

The Atmel IC AT24C64 provides the required memory and is also available in the market at affordable prices. It has the following features:

- 2-Wire Serial Interface
- Low power consumption ensures optimised use of battery.
- Write Protect Pin for Hardware Data Protection.
- 32-Byte Page Write Mode.
- The device is optimized for use in many industrial and commercial applications where low power and low voltage operation are essential.

5.2.3 RTC

The real time clock is required for keeping the data up to date. It helps in organizing the data chronologically for future reference.

Requirement:

- Fast speed.
- Built-in power-sense circuit that detects power failures and automatically switches to the backup supply.
- Low power consumption.
- Should provideyear, month, day, weekday, hours, minutes, and seconds.

Parameter	PCF8563	DS1307
Interface	Via two-line bidirectional I2C-bus.	I2C Serial Interface
Oscillator	On-chip 32.768kHz oscillator	External 32.768kHz crystal.
Price	Rs. 104.00	Rs. 235.00

Table 5.2 Comparative study of RTC [2]

Selected RTC =>PCF8563

5.2.4 MICROCONTROLLER

Controller Requirement

- LCD driving controller with min 29 LCD segments
- Flash PROM 20 KB
- RAM 512 bytes
- 2 UART
- 1 I2C
- 1 SPI

Manufacturer and Part No.	MICROCHIP PIC18F65K90-I/PT	MICROCHIP PIC16F1938-I/SO	MICROCHIP PIC16F1939-I/P	MICROCHIP PIC16F1939-I/PT
Controller Family/Series	PIC18FxxKxx	PIC16F19xx	PIC16F19xx	PIC16F19xx
Program Memory Size	32KB	28KB	28KB	28KB
RAM Memory Size	2KB	1KB	1KB	1KB
EEPROM size	1024B	256B	256B	256B
No. of Pins	64	28	40	44
MCU Case Style	TQFP	SOIC	DIP	TQFP
No. of I/O's	53	25	36	36
Embedded Interface Type	EUSART, I2C, SPI	EUSART, I2C, SPI	EUSART, I2C, SPI	EUSART, I2C, SPI
Supply Voltage Max	5.5V	5.5V	5.5V	5.5V
Supply Voltage Min	1.8V	1.8V	1.8V	1.8V
LCD segments	132	60	96	96
Price	Rs.295	Rs.163.28	Rs.181.51	Rs.204.10

Table 5.3 Comparative study of Microcontroller [2] [8]

Selected Controller =>PIC18F65K90

5.2.5 ROOM TEMPERATURE SENSOR

Requirement

- Accuracy minimum 0.1°C.
- 1-wire interface via I/O pin.
- For battery optimization purposes it should not require any external power supply.

Parameter	LM92	DS18B20
Interface	I2CSerial Bus interface	1-Wire bus (requires only 1 data line)
Temp. measurement Range	−25°C to 150°C,	-55°C to +125°C
Accuracy	±0.5°C for 10°C to 50°C	±0.5°C for -10°C to +85°C
Price	Rs.656.00	Rs.360

Table 5.4 Comparative study of Room Temperature sensor [2]

Selected Sensor =>DS18B20

5.2.5 Wi-Fi MODULE

Parameters	ESP 8266 - 01	ESP 8266 - 02	ESP 8266 - 05	ESP 8266 - 12
Form Factor	Small	Small	Medium	Large
Pricing	Rs. 250	Rs. 340	Rs. 430	Rs. 255

Table 5.5 Comparative study of Wi-Fi module [4]

Selected Wi-Fi module=>ESP 8266 - 01

CHAPTER 6

SCHEMATIC DESIGN

6.1 INTRODUCTION

The schematic design is made with the ORCAD software. We made use of the built-in available components. Also, we designed some components which weren't available already. While doing so, we used the datasheets of the respective components and made the connections accordingly.

6.2 GUIDELINE DOCUMENT

- We considered a step by step approach towards making the schematic design.
- We enlisted all the components and performed the calculations related to their power requirements.
- We checked the availability of the components on the software.
- If a particular component wasn't available, we designed it by using the software.
- We learnt the concept of 'NET ALIAS'. This method makes it easy to make connections in the schematic diagram.
- Using the same concept, we established separate tracks for digital and analog ground.
- The overall understanding of power consumption, current and voltage requirements of various components helped us in dividing the VCC and Battery supplies accordingly.
- We thoroughly checked the NET LIST generated with the help of the schematic and planned the placement of various components based on their footprint requirements.
- We made a checklist to verify all the connections and to ensure their proper functioning.
- We made use of Excel sheets to allocate and check the various LCD segments, UART, SPI and I2C interfaced modules.
- Finally, we made sure that all the circuits required for matching the various components has been considered.
- We have tried to make an optimal use of available resources which is reflected through our schematic design.

6.3 SCHEMATIC :

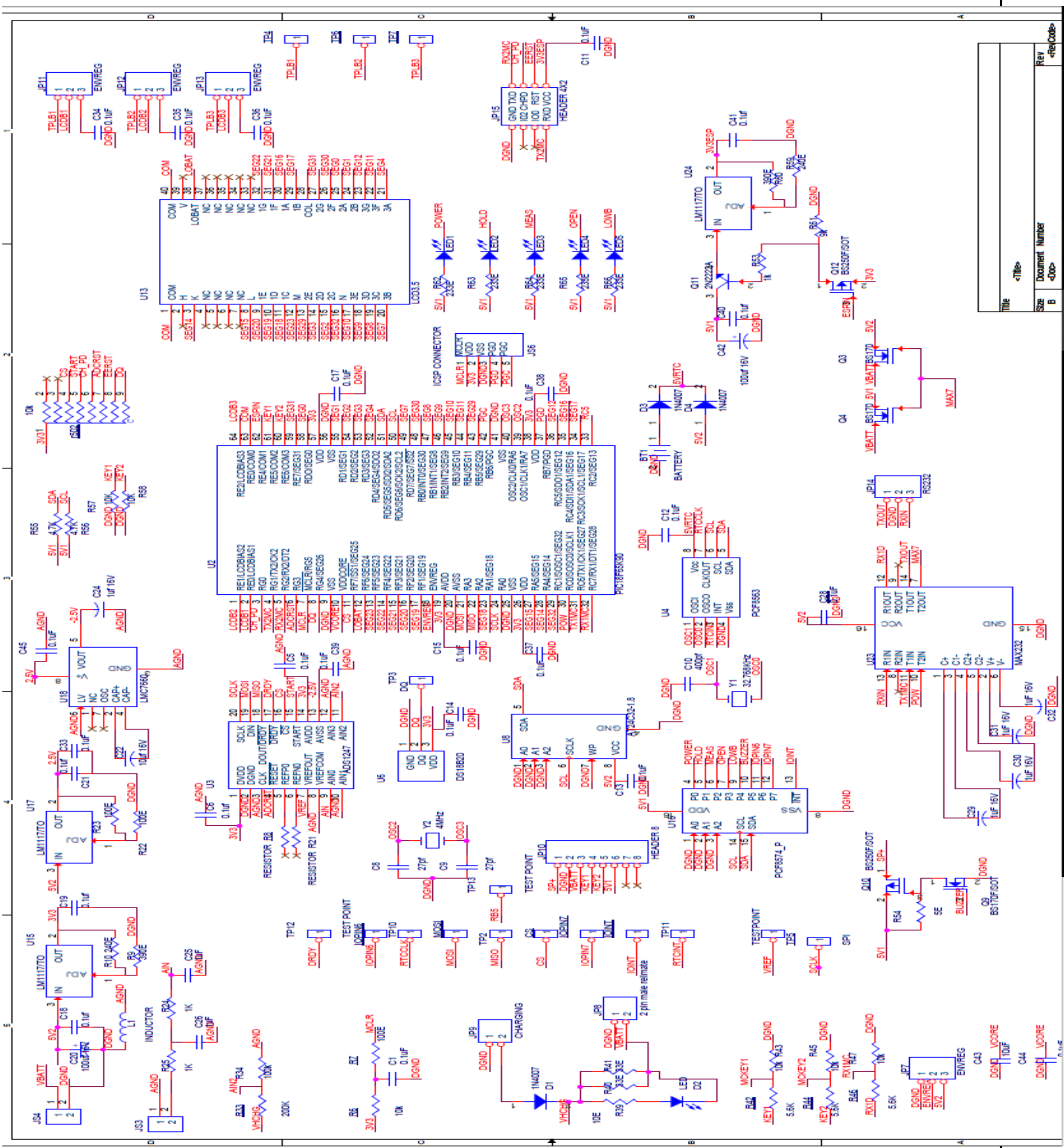

Fig 6.1 Schematic Design

CHAPTER 7
PROJECT PLAN

Working for a project as a group is a test of personal skills and requires cooperation and mutual understanding. Everyone should work sincerely to make the product one of the best in domain. We have made sure that we work out of our comfort zone and make the best use of our skill set. It is important to make a feasible plan at the beginning level of the project and work according to that until the target is achieved. Considering various aspects we have made the following project plan

MONTH	**TASK**
June	Topic Selection
July	Literature Survey
August	Specification document, Block Diagram and Component Selection
September	Schematic Entry (ORCAD)
October	UART coding, I2C coding
November	Wi-Fi module coding, SPI bit banging, Art Work Layout (2 weeks)
December	Software coding and testing
January	PCB layout ready (6 weeks)
February	Component placement, ADC stability check
March	PCB soldering, LCD, Keypad testing and coding
April	Integrating
May	Unit Testing for final product

Table 7.1 Project Plan

MONTH	Bhushan	Deepesh	Samadnya
June	Requirement gathering, Literature survey	Requirement gathering, Literature survey	Requirement gathering, Literature survey
July	Comparative study for component selection	Specification requirements, memory, accuracy calculations	Comparative study for component selection
August	Block Diagram	Block Diagram	Block Diagram
September	Power supply design, battery charging circuit, selection of Wi-Fi module	I2C, SPI,UART interface distribution, compatibility calculations	LCD segment allocation, Project Report and Documentation
October	Timer coding	Schematic design	Schematic design
November	Net list correction, Footprint allocation	Art work layout	I2C coding, UART coding
December	PCB Layout check	Microcontroller start up code, SPI coding	PCB Layout check
January	PCB soldering	UART coding	PCB soldering
February	Unit Testing	ADC coding	Unit testing
March	Interrupt based timer coding	LCD coding	I2C coding
April	Unit Testing	Temperature calculation coding Wi-Fi Coding	Temperature calculation coding
May	Unit Testing	Unit Testing	Unit Testing

Table 7.2 Work Distribution

CHAPTER 8

RESULTS

POWER SUPPLY OUTPUT:

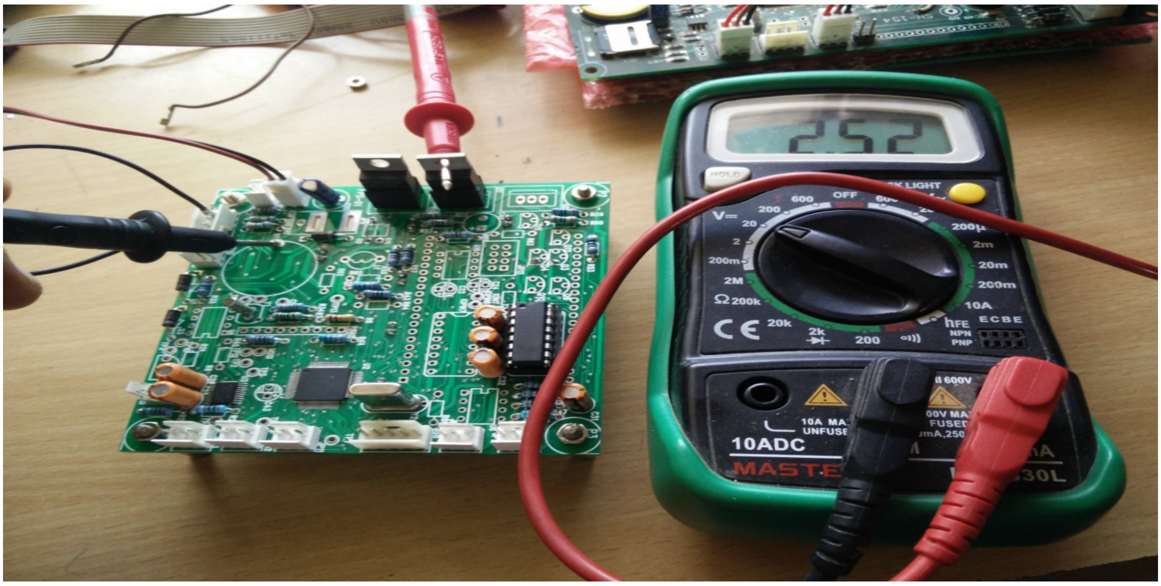

Fig 8.1 Power supply output for 2.5V

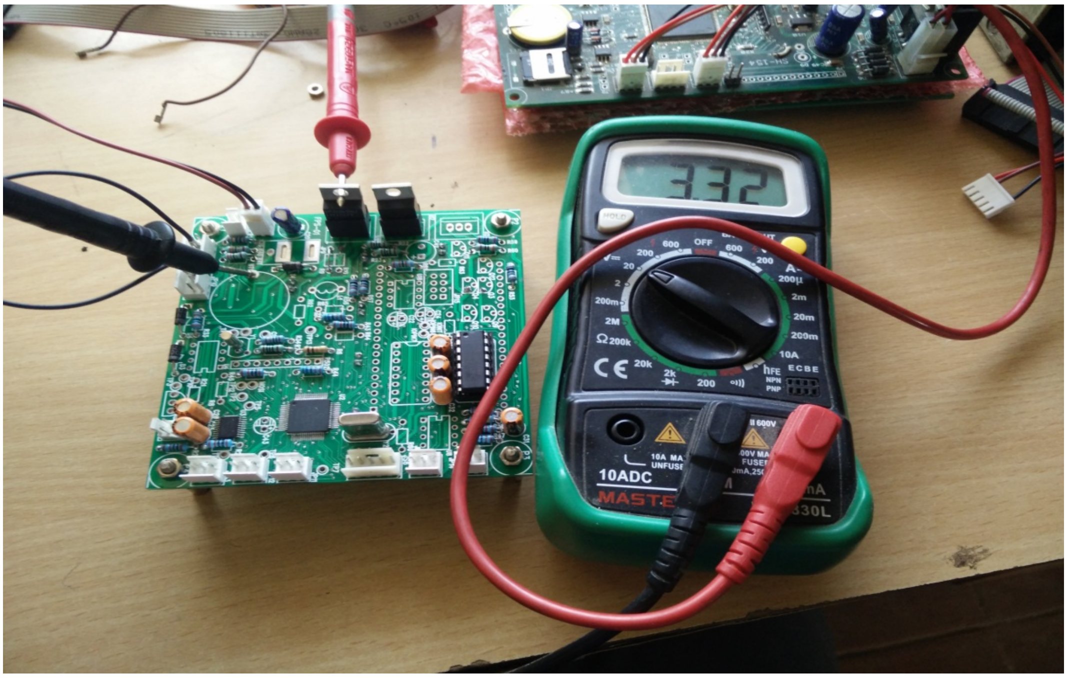

Fig 8.2 Power supply output for 3.3V

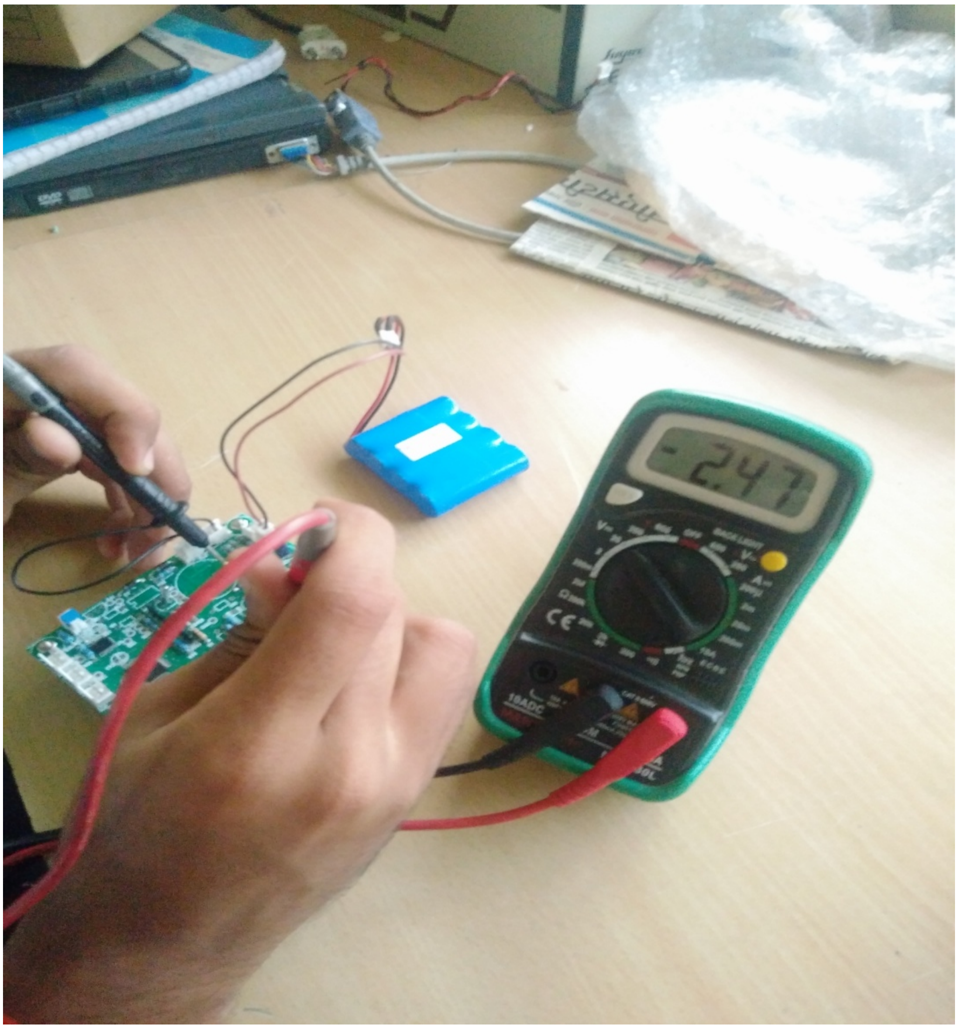

Fig 8.3 Power supply output for -2.47V

UART OUTPUT:

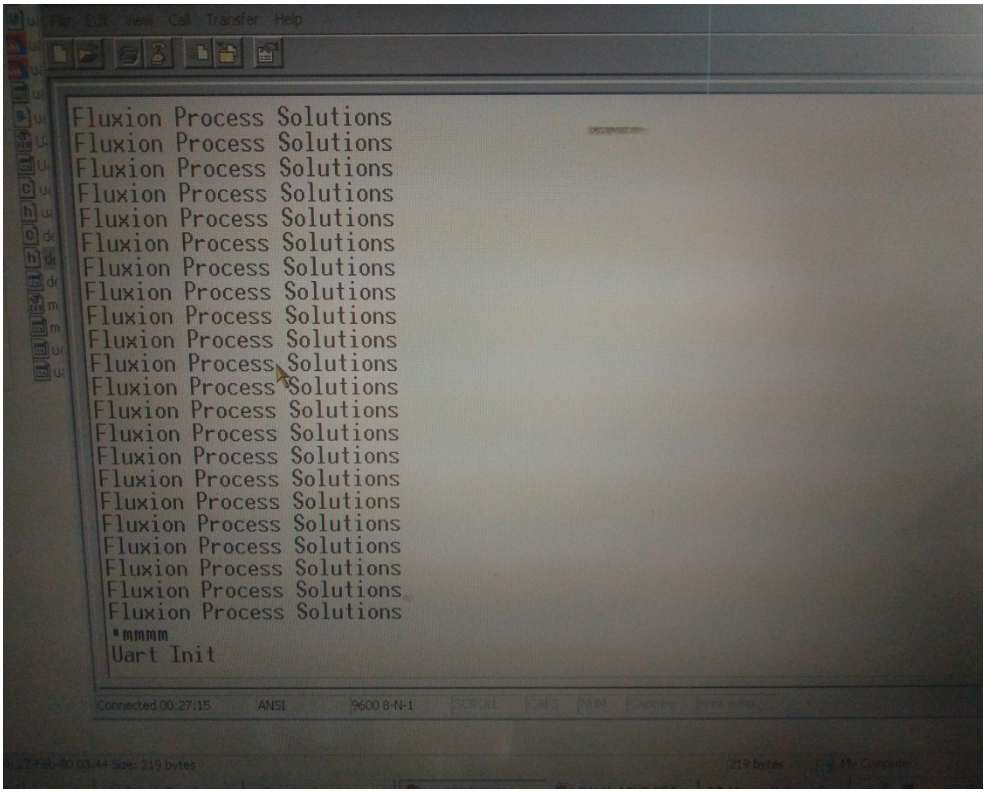

Fig 8.4 UART Output on PC via RS-232

- We were able to display a desired string on the PC with the help of a connection through the RS-232 port.
- We made use of the PC's Hyper Terminal to communicate and send the desired message on screen.

ADC OUTPUT:

Fig 8.5 mV generator set to minimum value for R type Thermocouple

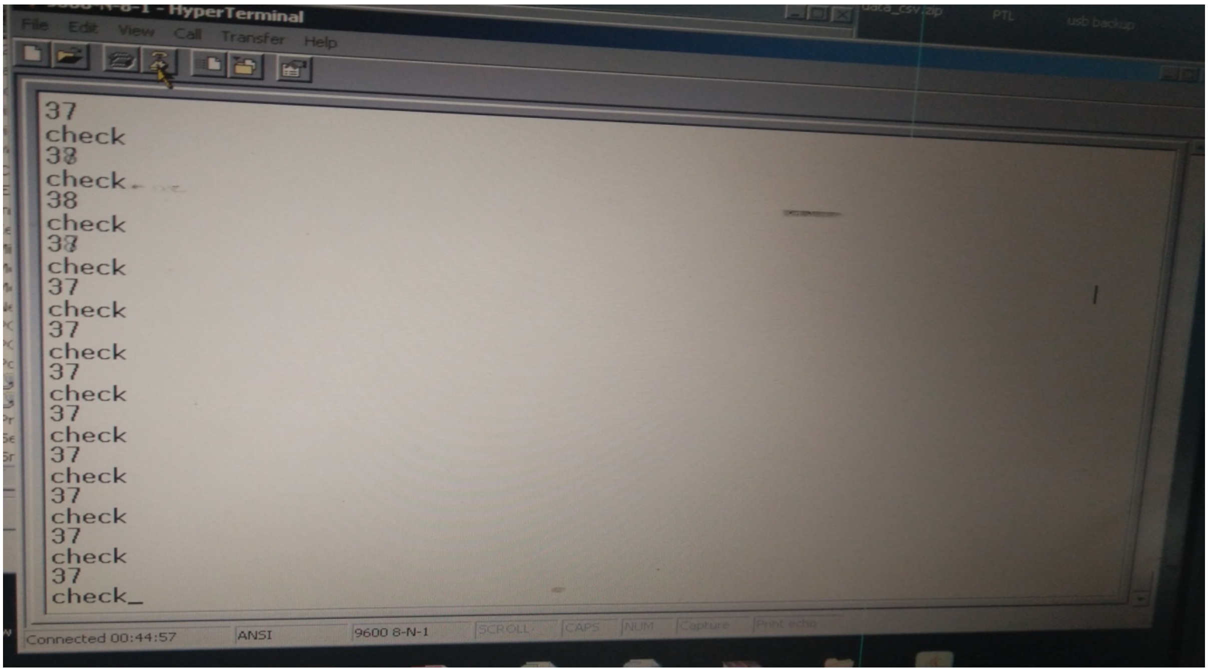

Fig 8.6 Output of ADC for minimum mV input

Fig 8.7 mV generator set to maximum value for R type Thermocouple

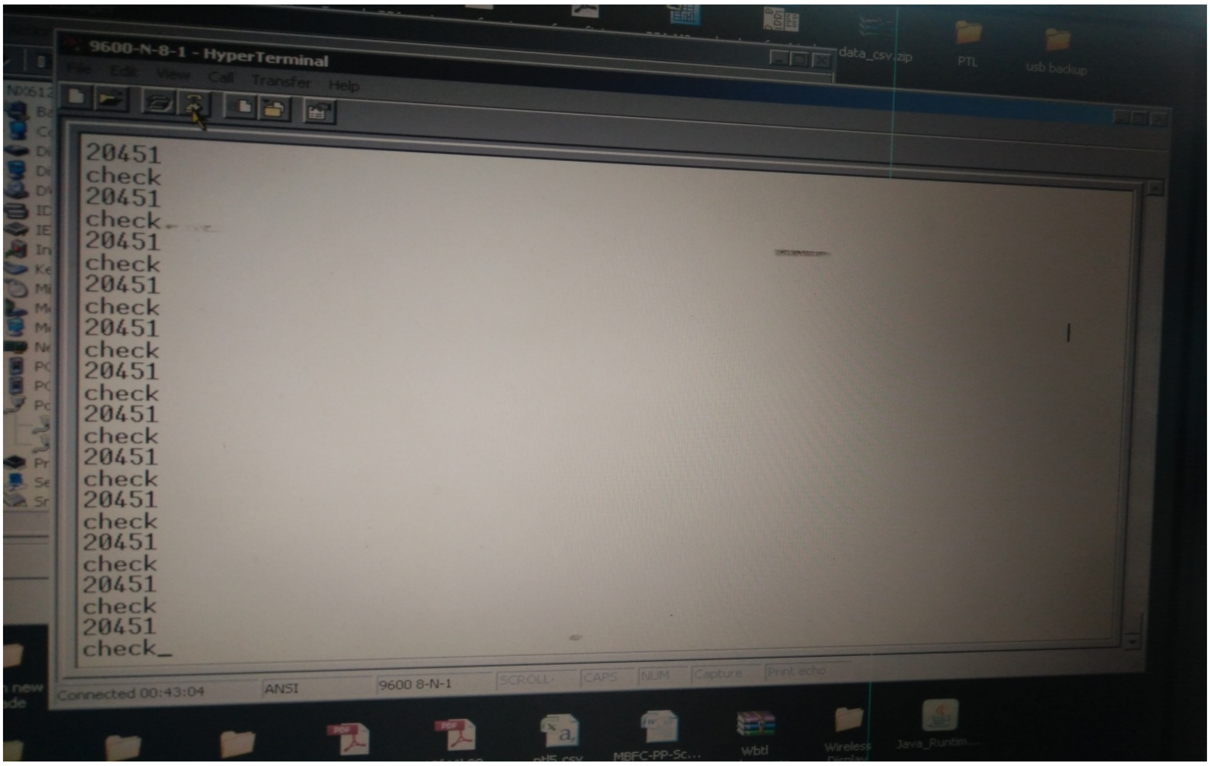

Fig 8.8 Output of ADC for maximum mV input

LCD OUTPUT:

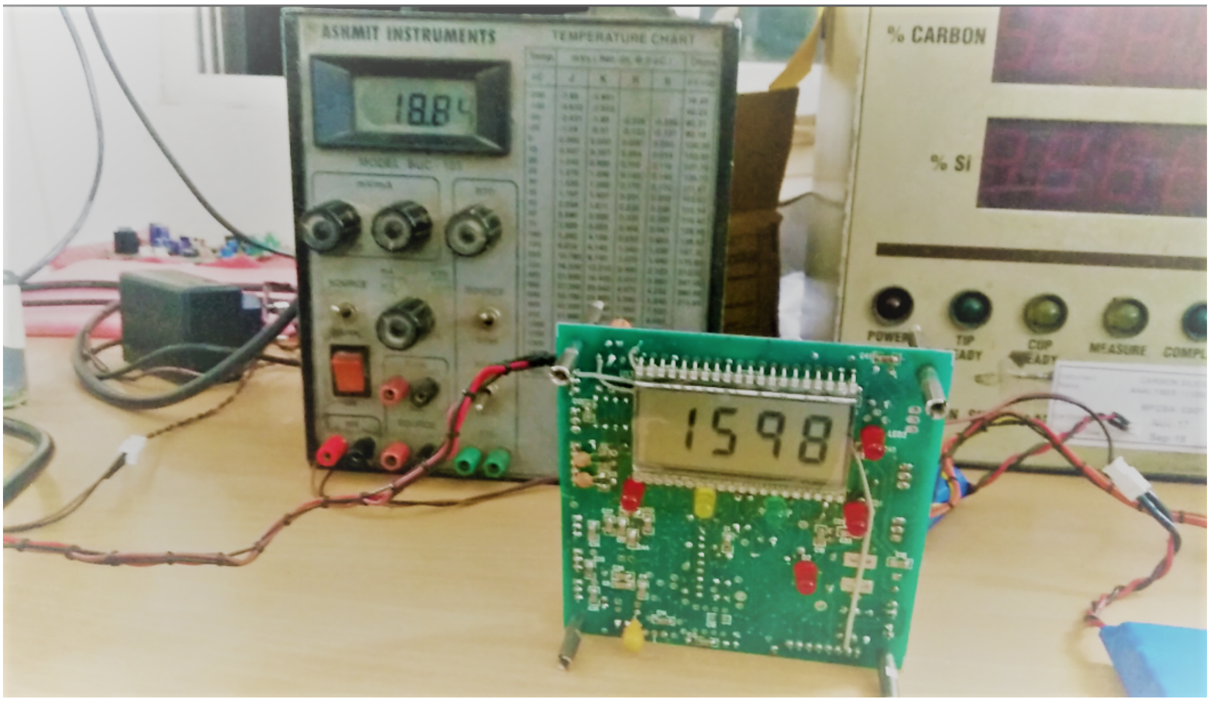

Fig 8.9 Temperature displayed on LCD for a mV value of 18.84mV

- We were able to display the temperature associated to a particular mV value based on the R-type look up table.
- Expected value was 1600° C, we were able to get 1598° C on the LCD display.
- We used linear straight line equations and slope point formula to calibrate the temperature values on varying the mV input.

LED INDICATOR OUTPUT:

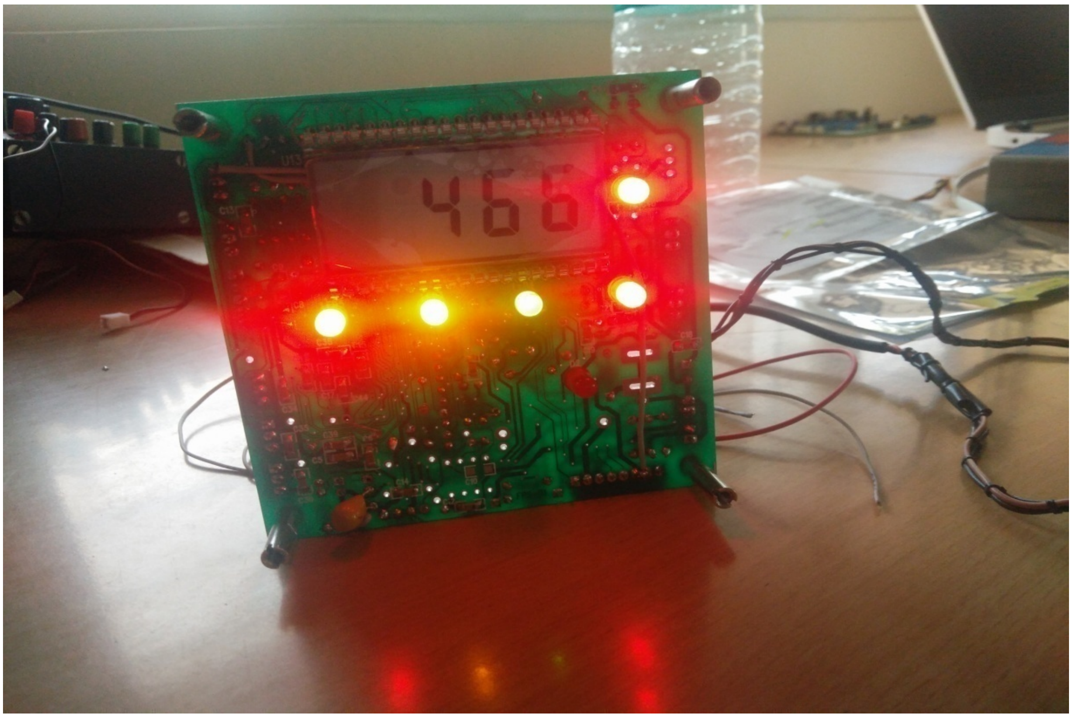

Fig 8.10 LED Indicators

- We were able to interface LEDs via an IO expander (PCF8574A).
- Various states of the device can be indicated with the help of these LED indicators.
- We indicate the following states of our device:

1. POWER is turned ON.
2. HOLD until device is ready for the next measurement.
3. MEASURE indicates that the device is ready for measurement.
4. OPEN mode is on.
5. LOW BATTERY indication.

LED INDICATOR STATE DIAGRAM:

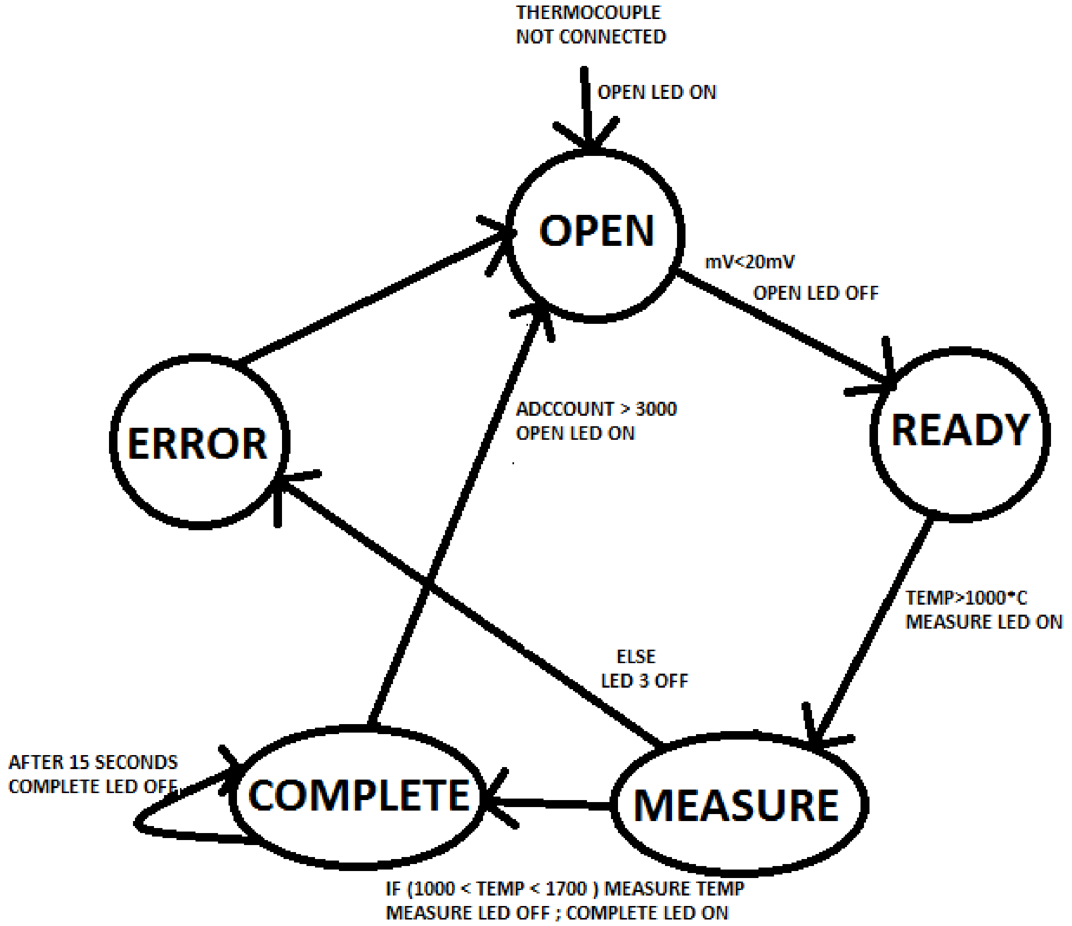

Fig 8.11 LED Indicator State Diagram

LOGIC ANALYZER:

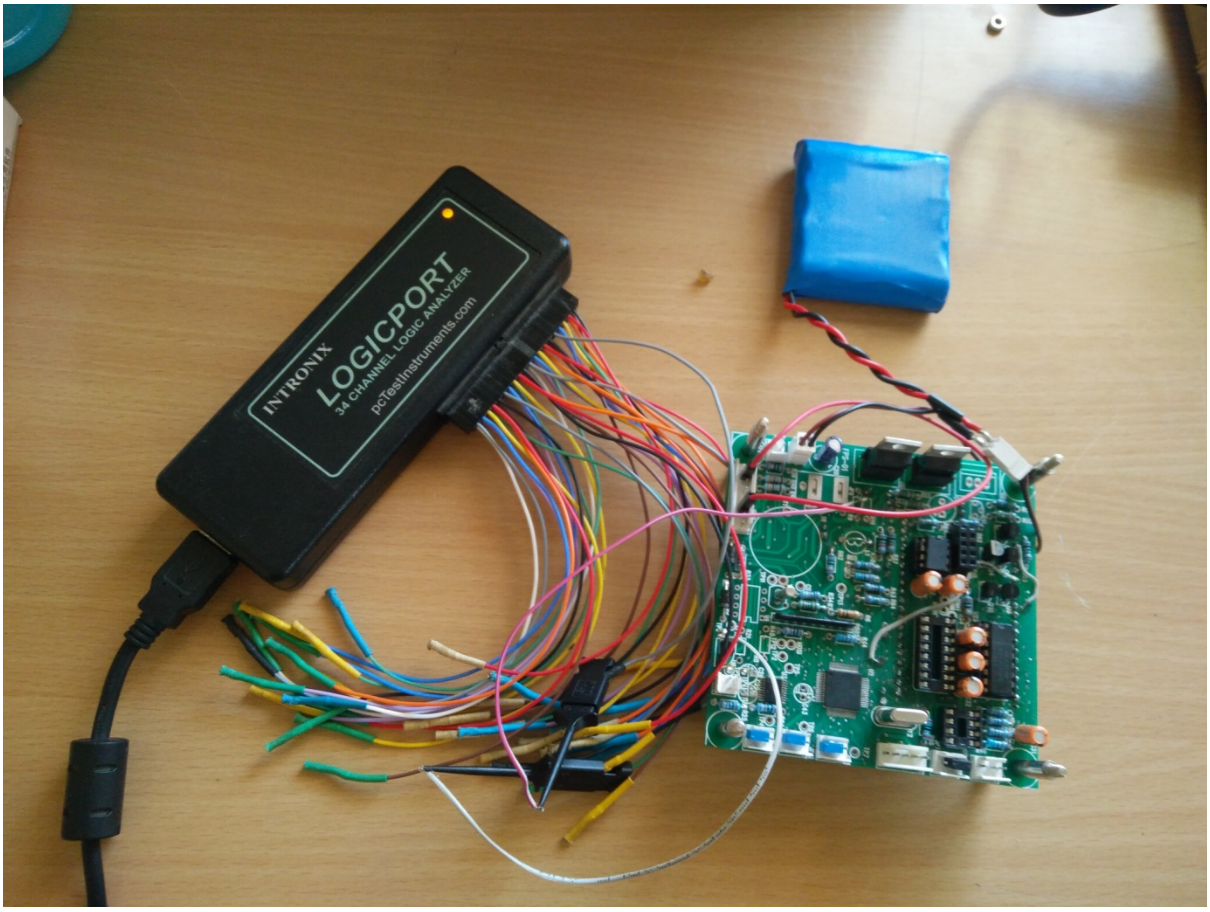

Fig 8.12 Logic Analyzer

- We were able to connect the various Test Points on our Board to a Logic Analyzer.
- We saw the various Timing diagrams required to verify the DS18B20 operating states with the help of this 34 channel Logic Analyzer.
- It also helped us in the debugging process of ADC1247, when the ADC IC was not functioning properly.

FINAL PRODUCT:

Fig 8.13 Final Product

OBSERVATION TABLE:

Sr. No.	Component	Expected result	Practical Result	Remark
1	Power Supply check	3.3V +2.5V -2.5V	3.29V +2.48V -2.48V	Practical result is almost similar to the expected result.
2	UART initialization	UART_Init to be printed on PC.	UART_Init is displayed on the PC.	Verified by printing UART_Init along with other strings on PC through the hyper terminal using RS-232 communication protocol.
3	ADC initialization	Show the ADC count on PC via UART.	ADC count is displayed on the PC through UART.	Verified by varying the output of mV generator as an input to the ADC and displaying the count on PC.
4	LCD	Get a linearly varying value of temperature on LCD.	Displayed the 4 digit temperature value on the LCD.	We checked the temperature on the LCD display by varying the output of mV generator as an input to the ADC.
5	DS18B20	Get a calibrated output after the room temperature compensation	Got the calibrated output after room temperature compensation.	We calculated the offset of room temperature and got better results.

Table 8.1 Expected vs. Practical Results

PROBLEMS FACED:

Sr. No.	Problems Faced	Solutions
1	While initializing UART communication, due to the discrepancy in TX, RX pin connections, the MAX 232 IC was heating up.	We replaced the IC as well as made changes in the connection externally.
2	Due to use of all the LCD segments, the MSSP module for SPI interface wasn't available.	We performed SPI bit banging in our code.
3	UART code wasn't working due to improper for loop and baud rate calculation formula.	We replaced the code with a correct one.
4	Due to an unprecedented short connection in the battery supply, the battery exploded.	We replaced it with a new one.
5	An improper value of the capacitor was creating issues while starting the ADC IC.	We recalculated and replaced it.
6	The use of 3.5 LCD caused problems at the time of soldering due to unavailability of a compatible connector.	We had to directly solder the LCD to the PCB.
7	There were times when the MPLAB programmer won't work due to a loose ICSP connector.	We did the proper connection of ICSP connector.
8	Our software code length wasn't within the limits of C18 compiler due its storage location in the data memory.	We had to switch to HI-TECH compiler for further coding.
9	Due to etching of the track, some connections on the PCB weren't responding to continuity.	We established connections through external wires.
10	We needed to cross check the timing diagrams of the different peripherals.	We used a 34-channel logic analyzer to overcome this problem.

Table 8.2 Problems and Solutions

CHAPTER 9
CONCLUSION

We have gained insight about the various parameters associated with a pyrometer. We learned the importance of meticulous research required to select a particular component. We learned various software tools. We got an opportunity to learn the steps used to design a product at an industrial level.

We also learned methods of coding like 'bit banging' for SPI interface. We got a hands-on experience of soldering and PCB designing. With this project, we conclude that the proposed device would prove to be cost efficient and yet produce the results with high accuracy. Due to its variety of features it will be capable of competing with similar market devices.

CHAPTER 10
FUTURE SCOPE

1. Foundry/Furnace: We can use this system in industries where metals are melted at high temperature.

2. Evolve the current wireless pyrometer to a wireless ADC system. It will be more compact and easier to handle.

3. Explore the project domain from the point of view of Intelligent Systems.

4. We can make a closed loop system which automatically adjusts the temperature of the furnace with the help of an intelligent machine and Internet of Things.

CHAPTER 11

BILL OF MATERIAL

Table 9.1 Bill of material [2] [4]

Sr. No.	Component Name	Product No.	Quantity	Price
1.	ADC	ADS1247	1	789
2.	RTC	PCF8563	1	104
3.	Room Temp.	DS18B20	1	360
4.	EEPROM	AT24C64	1	55
5.	Wi-Fi	ESP-01	1	250
6.	3.5 LCD	T0	1	250
7.	LEDs		5	5
8.	Keys		3	10
9.	Micro-Controller	PIC18F65K90	1	295

Estimated Total- **Rs.2120**

***The cost for PCB art work and layout, PCB printing, housing, some passive components, battery charging circuit as well as other future expenses are tentatively not included.**

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[2]www.element14.com-Component Selection and availability.

[3]http://ww1.microchip.com/downloads/en/devicedoc/39666f.pdf-AN658 LCD Fundamentals and the LCD Driver Module of 8-Bit PIC MCUs.

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