AN INTERNSHIP REPORT ON

REMOTE DIAGNOSTICS AND PREDICTIVE MAINTENANCE

Submitted In the partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology in

Electronics and Communication Engineering

By

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[Reg. No. 201FA05103]

Under the guidance of

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Reporting Test Lead

Under the guidance of

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Asst Professor

(ACCREDITED BY NAAC WITH **'A+' GRADE)**

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

(ACCREDITED BY **NBA)**

VIGNAN'S FOUNDATION FOR SCIENCE, TECHNOLOGY AND RESEARCH

(Deemed to be University**)**

VADLAMUDI, GUNTUR – 522 213, INDIA.

June – 2024

CERTIFICATE

This is to certify that the internship report entitled **"INTERNSHIP IN EMBEDDED"** that is being submitted by **K. Trinath** bearing **Regd. No. 201FA05103** in partial fulfilment for the award of BTech degree in Electronics and Communication Engineering to Vignan's Foundation for Science Technology and Research University, is a record of bonafide work carried out by them at **Efftronics Systems Pvt, Ltd** under the supervision of Manoj Mande and the internal guidance of Dr. G. S. R. Satyanarayana of ECE Department.

G.S.R. Satyanarayana

Signature of the faculty guide
Dr. G.S.R Satyanarayana
Asst Professor

Signature of the Head of the Department
Dr. T. Pitchaiah ME, Ph.D.,
Professor

01/06/24

Signature of the External Examiner

DECLARATION

I hereby declare that the internship work entitled "**INTERNSHIP IN EMBEDDED DOMAIN**" is being submitted to Vignan's Foundation for Science, Technology and Research, University, in partial fulfillment for the award of BTech degree in Electronics and Communication Engineering. The work was originally designed and executed by me under the guidance of my supervisor Manoj Mande with Dr. G.S.R Satyanarayana as faculty guide at Department of Electronics and Communication Engineering, Vignan's Foundation for Science Technology and Research University and was not a duplication of work done by someone else. I hold the responsibility of the originality of the work incorporated into this thesis.

K.Trinath

Signature of the candidate

K. Trinath – 201FA05103

ACKNOWLEDGEMENT

I am deeply grateful to **Mr. Manoj Mande**, whose inspiration and timely guidance were invaluable in the successful completion of my project. I extend my heartfelt thanks to my internal guide, **Dr. G.S.R Satyanarayana** of VFSTR for his expert guidance and insightful suggestions that significantly contributed to the timely completion of my project.

I would like to express my special thanks to **Dr. T. Pitchaiah**, Head of the Department, ECE, and **Dr. K. Vamsi Krishna**, the Internship Coordinator, Department of ECE, VFSTR, for their unwavering support and assistance during the program.

Words fall short in conveying my sincere appreciation to **Mr. Manoj Mande** and all the team members for their encouragement, guidance, and cooperation throughout my stay in the company.

I wish to express my gratitude to **Dr. P. Nagabushan**, Vice-Chancellor of VFSTR, for providing me with this incredible opportunity for industrial exposure and to participate in Live Projects.

I am also thankful to all my faculty members and the technical staff for their support, which was crucial in completing my work successfully. Finally, I wish to express my deepest thanks to my parents for their unwavering support and encouragement throughout my life.

Major Design (Internship Project Work) Experience Information

Student Name	K. Trinath (201FA05103)
Project Title	Remote Diagnostics for Predictive Maintenance System
Program Concentration Area	To enhance the maintenance process by leveraging real-time data and advanced analytics to predict and prevent equipment failures before they occur.
Constraints - Examples	
Economic	Fixed budget
Environmental	Friendly
Sustainability	Assessing through several key dimensions including environmental, economic, social sustainability.
Manufacturability	Yes
Ethical	Followed the standard professional ethics
Health and Safety	Guidelines are followed
Social	Enhanced safety, service reliability and employment stability
Political	None
Other	Can be updated and scaled to accommodate new technologies and expanded operations, and ensuring long-term viability.
Standards	
1.	Qcom, RS485, J-Flash
2.	Power BI, NMDL, Reports Tool
Previous Course Required for the Major Design Experience	1. IoT 2. MPMC 3. DCCN 4. Networking

Supervisor Project Co-Ordinator Head of the department ECE

INTERNSHIP SUMMARY

Location: Mangalagiri

Center: Efftronics Systems Pvt. Ltd.

Duration: 5 months

Date of start: 7th February 2024

Date of submission: 7th July 2024

Training details: Internship in Embedded Domain(R&D)

Project Details: RDPM, BHMU

Name of Faculty guide: Dr. G.S.R Satyanarayana, Asst Professor, VFSTR University

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2. SEL- Sensor Event Logger
3. DC – Data Concentrator
4. SPAU – Safety Protection Alarm Unit
5. ASSIU – Auto Section Station Indication Unit
6. FEP – Front End Processor
7. RTU – Remote Terminal Unit
8. BHMS – Battery Health Monitoring System
9. PVDU – Point Voltage Detection Unit
10. NMDL – Network Management Data Logger
11. RUI – Railway User Interface
12. LEM – Life Energy Motion
13. RS485 – Recommended Standard 485
14. IoT – Internet of Things
15. I2C – Inter Integrated Circuit
16. CAN – Controller Area Network
17. SPI – Serial Peripheral Interface
18. SAR – Successive Approximation Register
19. UART – Universal Asynchronous Receiver Transmitter
20. USART - Universal Synchronous Asynchronous Receiver Transmitter
21. USB – Universal Serial Bus
22. CTSR – Current Transducer
23. SDA – Serial Data
24. SPD – Surge Protection Devices
25. RAM – Random Access Memory
26. UDP – User Datagram Protocol
27. TCP – Transmission Control Protocol
28. SCL – System Clock
29. IC – Integrated Circuit
30. Vref – Voltage Reference
31. EMI – Electro Magnetic Induction

32. MISO – Multiple Input Single Output
33. MISO – Multiple Input Single Output
34. AC – Alternating Current
35. DC – Direct Current
36. DAC – Digital to Analog Converter
37. ADC – Analog to Digital Converter
38. CAT 6 – Category 6 cable
39. CRC – Cyclic Redundancy Check
40. LED – Light Emitting Diode
41. PPS – Programmable Power Supply
42. RPS – Regulated Power Supply
43. UPS – Uninterrupted Power Supply
44. SMPS – Switching Mode Power Supply

COMPANY PROFILE

Efftronics Systems Private Limited, headquartered in Mangalagiri, India, is a leading end-to-end IoT solutions provider. Established over 35 years ago, the company has built one of India's largest IoT networks, connecting over 6 million signaling assets across 9,000 locations for the Indian Railways. This extensive network enhances system availability through predictive maintenance, increases safety by reducing accidents, and optimizes train operations.

Efftronics specializes in a wide range of smart solutions and services, including smart signaling, smart buildings, smart city solutions, and various IoT services. Their innovative products include data loggers, adaptive traffic control systems, smart water management systems, and smart LED lighting and building automation solutions designed specifically for Indian conditions.

The company prides itself on its significant R&D efforts, with over 100 engineers dedicated to developing more than 50 innovative solutions. These solutions aim to create and deliver continuous value across multiple domains such as railways, urban infrastructure, and industrial segments.

Key figures in the company include Rama Krishna Dasari, the CEO and founder, who has over 35 years of experience in the railway signaling sector. The leadership team also includes experts with decades of experience in hardware, software, and system development, contributing to the company's robust portfolio of smart solutions.

WORK AS A TESTING INTERN

PROJECTS TAKEN BY THE RAILWAYS TEAM FOR TESTING

1. RDPM
2. DATA LOGGER (99/06)
3. ARM DATA LOGGER
4. FEP, DC, RTU
5. BHMS
6. SPAU
7. ASSIU
8. PVDU
9. ANTENNA TESTINGS

PROJECTS INVOLVED

1. RDPM
2. DC
3. BHMS
4. PVDU

RESPONSIBILTIES

1. SETTING UP PROJECT
2. LOAD IMPLEMENTATIONS
3. DATA ANALYZATION SETTING UP IN PC
4. FUNCTIONALITY TESTING
5. DATA AVAILABILITY ANALYSIS
6. STANDARDS RECORDS VERIFICATION
7. CALIBRATIONS
8. CHAMBER TESTINGS FOR ACCURACY
9. BACKUP TESTINGS
10. REPORTS MAKING, DATA ENTRY- EXCEL.

CHAPTER-1

ABSTRACT

The RDPM system developed by RDSO for Railways is a pioneering solution aimed at modernizing railway infrastructure planning and management processes. Leveraging digital technologies, RDPM optimizes track layout design, signaling systems, and infrastructure development, ensuring enhanced safety, efficiency, and cost-effectiveness across railway networks. This abstract explores the key features and benefits of RDPM, highlighting its role in revolutionizing railway planning, maintenance, and expansion initiatives.
RDPM represents a paradigm shift in railway planning and management, enabling Indian Railways to leverage digital technologies for enhanced operational efficiency, safety, and customer satisfaction. Through continuous innovation and collaboration with industry stakeholders, RDPM is poised to drive the transformation of India's railway network into a world-class, technologically advanced transportation system.

The Battery Health Monitoring System (BHMS) is a critical component in modern energy storage management, offering real-time monitoring and analysis of battery health parameters. This abstract presents an overview of BHMS functionalities, including continuous monitoring of battery voltage, current, temperature, and state of charge (SoC). By leveraging advanced sensor technologies and data analytics, BHMS enables proactive maintenance, early fault detection, and optimized performance of battery systems across various applications such as electric vehicles, renewable energy storage, and uninterruptible power supplies (UPS). This abstract highlight the importance of BHMS in ensuring the reliability, longevity, and safety of battery assets, ultimately enhancing the efficiency and sustainability of energy storage systems.

I collaborated closely with development teams to identify, document, and resolve defects, ensuring alignment with functional and performance requirements. Through this internship, I gained hands-on experience with testing tools and methodologies, contributing to the delivery of robust products. This experience honed my analytical skills and provided a deep understanding of quality assurance practices.

CHAPTER-2
INTRODUCTION

Indian Railways (IR), one of the largest and busiest railway networks globally, has been on a continual journey of modernization to improve safety, efficiency, and reliability. A significant milestone in this journey is the implementation of Remote Diagnostics and Predictive Maintenance (RDPM) systems. These advanced technologies represent a paradigm shift from traditional, time-based maintenance approaches to more sophisticated, data-driven strategies.

1.1 What is Remote Diagnostics?

Remote Diagnostics refers to the use of advanced technologies such as Internet of Things (IoT) sensors, data analytics, and cloud computing to monitor the condition of railway assets in real-time. This system enables continuous monitoring and analysis of various parameters such as temperature, vibration, pressure, and other critical indicators of the health of locomotives, tracks, signaling systems, and other infrastructure.

2.2 Key Components of Remote Diagnostics:

2.2.1 IoT Sensors: Devices installed on railway assets to collect real-time data.

These sensors capture various types of data, which can then be analyzed and used for a multitude of applications, including remote diagnostics and predictive maintenance in railways.

Types of IoT Sensors

IoT sensors come in various types, each designed to measure specific parameters. In the context of Indian Railways, the following types of sensors are commonly used: Temperature Sensors, Vibration Sensors, Proximity Sensors, Acoustic Sensors, Humidity Sensors, Optical Sensors.

IoT sensors function by detecting changes in the physical environment and converting these changes into electrical signals. These signals are then processed and transmitted over a network to a central system where the data is analyzed.

Here's a step-by-step overview of how they work:

1. Detection: The sensor detects a specific physical parameter (e.g., temperature, vibration).
2. Conversion: The detected physical change is converted into an electrical signal.
3. Transmission: The electrical signal is transmitted to a central data processing system, usually over a wireless network.

4. Data Processing: The central system processes and analyzes the data to extract meaningful insights.
5. Action: Based on the analysis, actions can be taken, such as triggering alarms, scheduling maintenance, or adjusting operational parameters.

2.2.2 Data Analytics Platforms: Tools and software to process and analyze the collected data. Following are the software tools used by the company. NMDL, Reports are the two tools designed by the company to analyze how the system is working.

1. NMDL
2. QCOMM
3. Power BI
4. Reports Tool

2.2.3 Cloud Computing: Infrastructure for storing and managing data, accessible remotely.

Key Characteristics of Cloud Computing

1. On-Demand Self-Service: Users can access computing resources as needed, without requiring human intervention from the service provider.
2. Broad Network Access: Resources are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops).
3. Resource Pooling: The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to demand.
4. Rapid Elasticity: Resources can be elastically provisioned and released to scale rapidly outward and inward commensurate with demand. For consumers, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.
5. Measured Service: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth).

2.2.4 Communication Networks: Systems to transmit data from sensors to analytics platforms. Types of Communication Networks used:

2.2.4.1 Wired Networks

1. RS232 Communication
2. RS485 Communication
3. Opto Communication

2.2.4.2 Wireless Networks

1. Zigbee

2.3 What is Predictive Maintenance?

Predictive Maintenance involves using data-driven approaches to predict when maintenance should be performed on railway assets. Unlike traditional maintenance, which is scheduled at fixed intervals, predictive maintenance is based on the actual condition and performance of the assets, thereby optimizing maintenance activities.

2.4 Key Components of Predictive Maintenance:

1. Machine Learning Algorithms: Techniques to analyze historical and real-time data to predict potential failures and estimate the remaining useful life (RUL) of components.
2. Condition Monitoring Systems: Tools that continuously assess the health and performance of assets.
3. Predictive Analytics: Analytical processes that provide actionable insights for proactive maintenance decisions.

2.5 Objectives of Implementing RDPM in Indian Railways

1. Enhancing Safety: By detecting potential issues early and addressing them proactively, RDPM systems significantly improve the safety of railway operations.
2. Improving Reliability: Ensuring the reliable performance of railway assets through continuous monitoring and timely maintenance.
3. Reducing Maintenance Costs: Optimizing maintenance schedules based on actual asset conditions, thereby reducing unnecessary maintenance activities and associated costs.
4. Increasing Operational Efficiency: Minimizing unexpected failures and downtimes, leading to smoother and more efficient railway operations.

CHAPTER-3
LITERATURE REVIEW

Tragedy of the Malwa Express Derailment (2012): One significant incident that played a crucial role in highlighting the need for advanced maintenance strategies was the derailment of the Malwa Express in 2012. This accident, attributed to a track failure, resulted in multiple fatalities and injuries. The subsequent investigation revealed that the failure could have been prevented with timely maintenance and better monitoring systems. This incident underscored the critical need for Indian Railways to adopt more proactive and technologically advanced maintenance practices to ensure the safety and reliability of its vast network.

3.1 Ongoing Challenges in Maintenance Practices

3.1.1 Aging Infrastructure:

Track and Rolling Stock: Much of the railway infrastructure, including tracks and rolling stock, was aging, leading to increased wear and tear and a higher frequency of failures.

3.1.2 Manual Inspections: Traditional maintenance practices relied heavily on manual inspections, which were not only time-consuming but also prone to human error.

3.2 High Operational Demands

3.2.1 Increased Traffic: Indian Railways has been experiencing a steady increase in both passenger and freight traffic, putting additional strain on its infrastructure.

3.2.2 Limited Downtime: The high demand for train services meant that there was limited downtime available for maintenance activities, necessitating more efficient maintenance approaches.

3.3 Technological Advancements and Global Trends

Global Adoption of Predictive Maintenance

3.3.1 Benchmarking with Global Railways: Observing the success of remote diagnostics and predictive maintenance in other leading railway networks globally, such as those in Europe and Japan, provided a strong impetus for Indian Railways to modernize its own maintenance strategies.

3.4 Advancements in Technology

3.4.1 IoT and Data Analytics: The rapid advancement in IoT sensors, big data analytics, and machine learning technologies made it feasible to implement sophisticated remote monitoring and predictive maintenance systems.

3.4.2 Cloud Computing: Improvements in cloud computing provided scalable solutions for data storage and processing, making remote diagnostics more accessible and manageable.

3.5 Government Initiatives and Policy Support

Government Focus on Modernization

3.5.1 Budget Allocations: Increased budget allocations for technology adoption and infrastructure modernization in successive railway budgets.

3.5.2 Policy Initiatives: Introduction of policies aimed at improving railway safety and operational efficiency, encouraging the adoption of advanced technologies.

Case Study: Malwa Express Derailment and Subsequent Actions

Incident Overview:

Date: November 22, 2012

Location: Near Kanpur, Uttar Pradesh

Casualties: 37 fatalities, over 150 injuries

3.6 Investigation Findings

3.6.1 Track Failure: The primary cause identified was a track failure that could have been detected and mitigated with better monitoring systems.

3.6.2 Maintenance Gaps: There were significant gaps in the existing maintenance processes, with a reliance on periodic manual inspections that were inadequate for the high traffic volumes.

3.7 Post-Incident Actions

3.7.1 Formation of Expert Committees: Committees comprising railway safety experts and technologists were formed to study the incident and recommend improvements.

3.7.2 Pilot Projects: Initiation of pilot projects to test remote diagnostics and predictive maintenance technologies on select high-traffic routes.

3.7.3 Technology Trials: Trials of IoT sensors and data analytics platforms to monitor the condition of tracks, rolling stock, and other critical components.

3.7.4 Training Programs: Comprehensive training programs for railway staff to familiarize them with new technologies and maintenance practices.

3.7.5 Policy Changes: Introduction of policy changes to facilitate the broader adoption of these technologies across the railway network.

3.8 Outcomes

3.8.1 Enhanced Safety: A noticeable improvement in safety records with a reduction in derailments and other failures.

3.8.2 Operational Efficiency: Increased operational efficiency with fewer disruptions and optimized maintenance schedules.

3.8.3 Scalability: Successful scaling of the pilot projects to other parts of the network, with continuous monitoring and iterative improvements.

The Malwa Express derailment served as a pivotal moment for Indian Railways, highlighting the urgent need for modernization of maintenance practices. The adoption of remote diagnostics and predictive maintenance has since become a critical strategy for enhancing the safety, reliability, and efficiency of the Indian railway network. The integration of advanced technologies, supported by government initiatives and global best practices, marks a significant step forward in transforming Indian Railways into a more resilient and future-ready transportation system.

CHAPTER-4

RDPM SYSTEM

4.1 BLOCK DIAGRAM OF SYSTEM

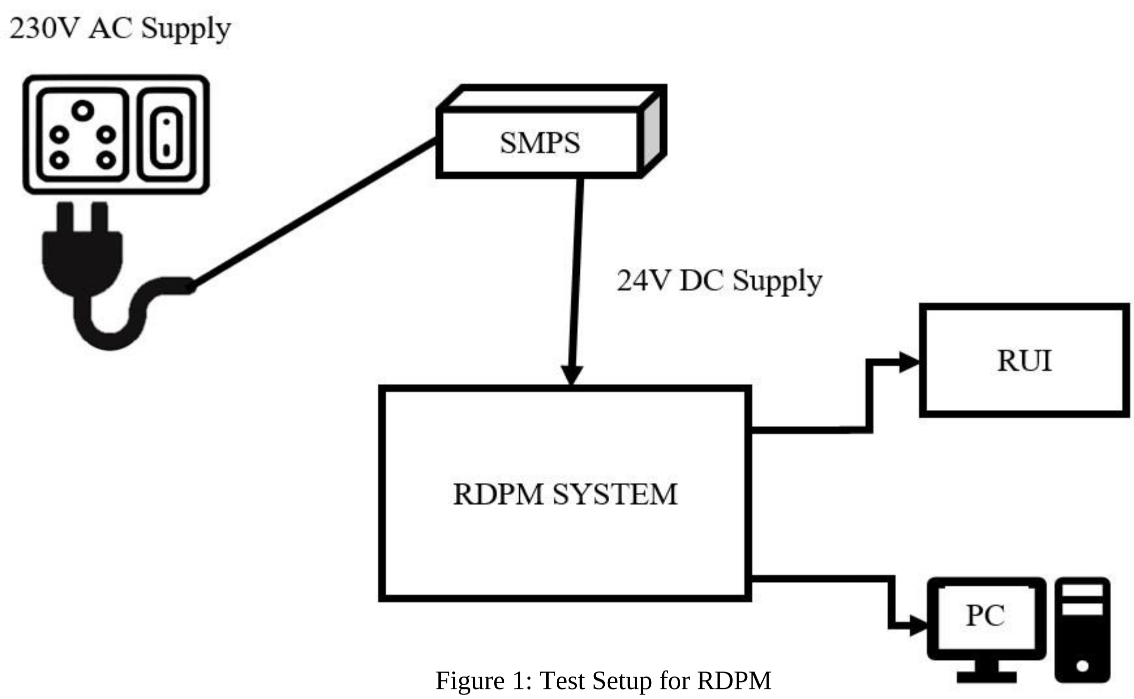

Figure 1: Test Setup for RDPM

4.2 SLAVE CONFIGURATION IN A RDPM SYSTEM

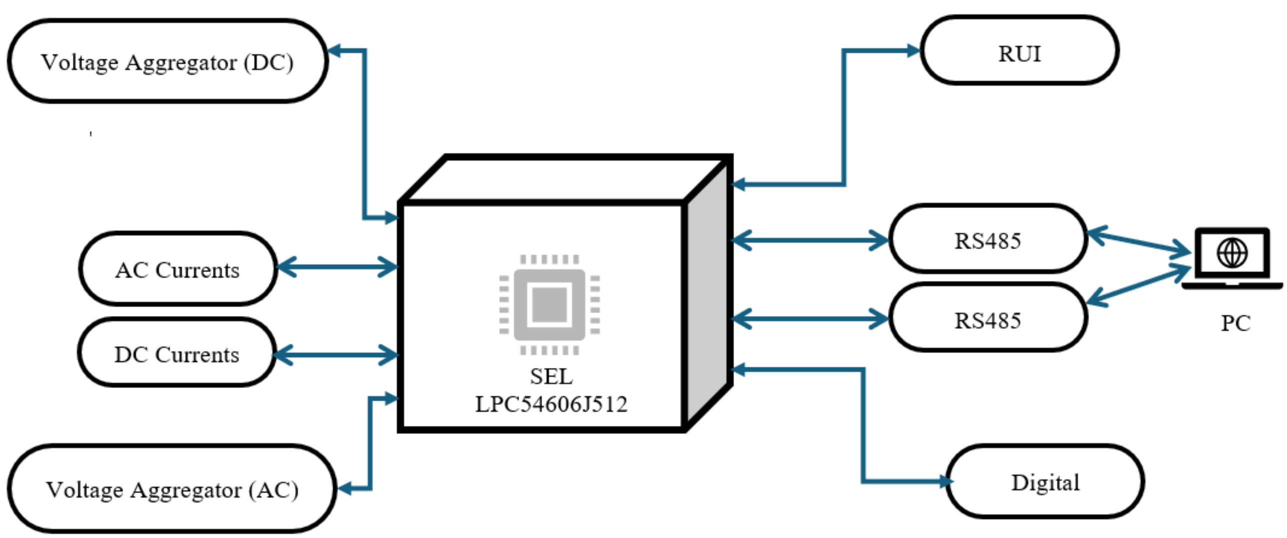

Figure 2: RDPM Module Connection

4.3 MASTER SLAVE CONFIGURATION

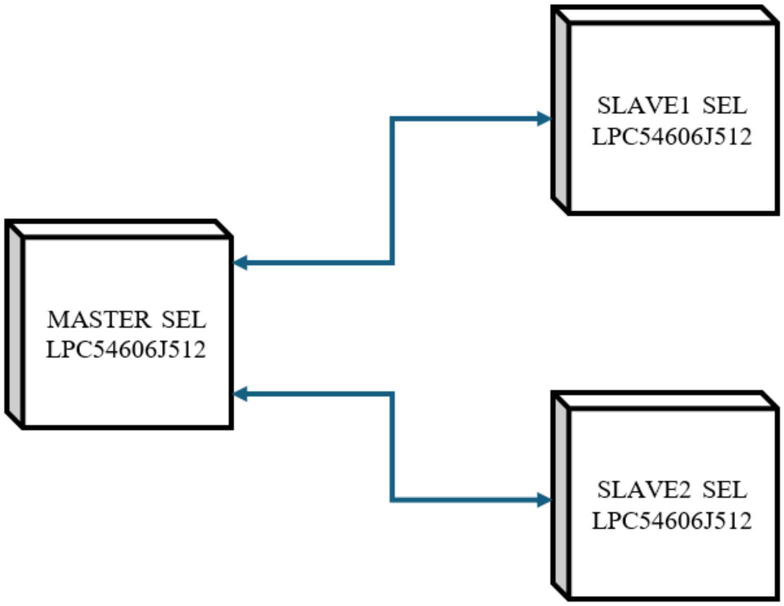

Figure 3: Master-Slave Configuration

4.4 Major Parameters Measuring

1. AC Currents
2. DC Currents
3. AC Voltages
4. DC Voltages
5. Digital (16 Input)

4.5 OUTDOOR GEARS AND THEIR TENTATIVE PARAMETERS TO BE MONITORED:

4.5.1 Signals

1. AC Current
2. AC Voltage
3. Status of local signal control/detection relays at Location boxes.

4.5.2 Points

1. DC operating Current

2. DC operating Voltage
3. Vibration
4. Movement of point machine slides (Drive, lock & Detector)

4.5.3 DC Track Circuits

1. DC feed end and relay end voltage
2. DC feed end and relay end current
3. Track relay position
4. Input Voltage & output current of Track feed battery charger
5. Voltage & charging /discharging current of battery
6. Incoming & outgoing TPR voltage.

4.5.4 Level Crossing Gates

1. AC/DC operating Current of Electrical Lifting Barrier
2. AC/DC operating Voltage of Electrical Lifting Barrier
3. Status of open close position for each boom
4. Locking status of gate

4.5.5 Surge Protection Devices

1. The potential free contacts of SPD devices where available shall be monitored.
2. Care should be taken to keep sensor wiring from SPD such that (electrically) dirty cable in SPD box is not in parallel to sensor wires.

CHAPTER-5

THEORY AND PRACTICAL IMPLEMENTATIONS

5.1 DATA IN A PACKET OF BYTES

5.1.1 STRUCTURE OF A DATA PACKET: A typical data packet consists of three main components

1. Header
2. Payload
3. Trailer

5.1.2 DETAILED BREAKDOWN OF A DATA PACKET

Header:

1. Source Address: The unique address of the sender.
2. Destination Address: The unique address of the receiver.
3. Packet Number/Sequence Number: Identifies the position of the packet in the sequence of transmitted packets, which is useful for reassembling the data correctly at the destination.
4. Protocol Information: Indicates the protocol used for communication (e.g., TCP, UDP).
5. Error Detection Code: Methods like checksums or cyclic redundancy checks (CRC) to detect errors in the header.
6. TTL (Time to Live): Specifies the maximum time the packet is allowed to remain in the network before being discarded.

Payload:

1. Data: The actual user data or message being transmitted. This is the content the sender wants to communicate to the receiver.

Trailer:

1. Error Detection Code: Additional error-checking code used to ensure the integrity of the payload and the trailer. If an error is detected, the packet can be retransmitted.
2. End of Frame: Indicates the end of the packet, helping the receiver know where the packet concludes.

Example of a Data Packet in Byte Form, assume we have a simple packet structure as follows:

Header: 20 bytes

Payload: Variable length, say 100 bytes for this example

Trailer: 4 bytes

The total size of this packet would be 124 bytes.

Example in Hexadecimal Representation:

Header: 45 00 00 7C 1C 46 40 00 40 11 B8 61 C0 A8 00 68 C0 A8 00 01

Payload: 48 65 6C 6C 6F 2C 20 74 68 69 73 20 69 73 20 61 20 64 61 74 61 20 70 61 63 6B 65 74 2E 20 49 74 20 63 6F 6E 74 61 69 6E 73 20 73 6F 6D 65 20 73 61 6D 70 6C 65 20 74 65 78 74 2E 20 41 6E 64 20 6D 6F 72 65 20 64 61 74 61 2E

Trailer: B4 34 12 AF

Header (20 bytes): Contains control and routing information.

Payload (100 bytes): The message data “Hello, this is a data packet. It contains some sample text. And more data.”

Trailer (4 bytes): Error-checking code.

5.1.3 HOW DATA PACKETS ARE USED IN NETWORKS

1. Fragmentation and Reassembly:

   Data that is too large to be sent in a single packet is broken down into smaller packets. Each packet is numbered so that they can be reassembled correctly at the destination.

2. Routing:

   Each packet may take a different path to the destination. Routers use the header information to direct the packets to the correct destination.

3. Error Checking and Correction:

   Error-checking codes in the header and trailer help detect and correct errors that may occur during transmission.

4. Flow Control and Congestion Management:

   Protocols like TCP use sequence numbers and acknowledgments to manage data flow and control congestion, ensuring reliable communication.

5.2 SP06 PROTOCOL

The SP06 protocol includes specifications for the electronic interlocking systems, ensuring they can communicate effectively with other signaling and control systems used across the Indian

Railways network. By adopting these standards, Indian Railways aims to streamline operations, reduce maintenance complexities, and enhance safety measures across its extensive rail network.

5.2.1 EVENT PACKET FORMAT

Data is represented in 16 bytes, where each byte signifies or indicates the specific type of packet created. Reports software is the software application used to acknowledge how data is interpreted in the form of bytes. When packets are created for every 34min all no of packets will be getting generated. Packet data is in hexadecimal format.

<u>16 Bytes- 0 to 15</u>

0 1 → Start Bytes – 0XAA, 0x55

2 → Sys ID – (RDPM, DC, DL, RTU and FEP etc.)

3 4 → Seq No – 0 to 65535 (Bit Resolution)

5 → CRC (Cyclic Redundancy Check)

6 7 8 9 → Soft Time

10 → Generated Packet Type ID (AC Voltage/ AC Current/ DC Voltage/ DC Current/ Digital/ Hour Packet/ Time Difference/ Time write Low/ Time write High/ FL Status/ DL Year record/ FL Status/ Analog etc.)

11 12 13 → Data Bytes – B1 B2 B3 (Generated packet's information)

14 → Checksum

15 → End Byte

Some of the packet's information have enlisted in the below table. In Reports software 14 bytes of data is shown because start ID-2bytes, End Byte-1 and checksum-1 Byte will not be shown.

Table 1: PACKET FORMAT

Packet Type	**Type ID**	**Byte1**	**Byte2**	**Byte3**
Analog	0x01	Value (Voltage)	Value (Voltage)	Channel no
Time Difference	0x02	Status	MSB	LSB
Time Write Low	0x03	Year MSB	Year LSB	Soft Time
Time Write High	0x0A	Soft time	Soft time	Soft time
DL Year Record	0x28	0x00	Year in MSB	Year in LSB

Hour Packets	0x06	0x00	0x00	0x00
All I/P reset	0x07	0x00	0x00	0x00
Communication Status	0x04	Packet Count Lower (2 Bytes)	LSB	Port Number (High nibble) Packet type (Lower Nibble)
Communication Status	0x4C	Packet Count Higher MSB (2 Bytes)	LSB	Port Number (High nibble) Packet type (Lower Nibble)
Health Record	0x05	0x00	0x00	0x00
Port Link Change	0x35	Port Link Status	Port link number	Port link type
System Configuration	0x07	Version Number (Master)	Slave 812/845 (Firmware Version)	Slave 54608 (Controller firmware version)
System Reset	0x23	Main Oscillator Status	Reset	0x00
System Reset (Unknown Reset)	0x23	0XF1	0XFF	0XFF
Backup Health Record	0x14	Backup Health Status	0x00	0x00

5.3 RS485 COMMUNICATION

RS-485 is an electrical-only standard. In contrast to complete interface standards, which define the functional, mechanical, and electrical specifications, RS-485 only defines the electrical characteristics of drivers and receivers that could be used to implement a balanced multipoint transmission line.

5.3.1 KEY FEATURES OF RS-485 ARE

1. Balanced interface
2. Multipoint operation from a single 5-V supply
3. –7-V to +12-V bus common-mode range
4. Up to 32-unit loads
5. 10-Mbps maximum data rate (at 40 feet)
6. 4000-foot maximum cable length (at 100 kbps)

Network Topology used is Daisy Chain Technology. In this topology, the participating drivers, receivers, and transceivers connect to a main cable trunk via short network stubs. The interface bus can be designed for full-duplex or half-duplex transmission

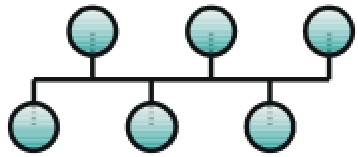

Figure 4: Daisy Chain Topology

5.3.2 DATA RATE VERSUS CABLE LENGTH

The maximum bus length is limited by the transmission line losses and the signal jitter at a given data rate. Because data reliability sharply decreases for a jitter of 10% or more of the baud period, Figure 9-1 shows the cable length versus data rate characteristic of a conventional RS-485 cable for a 10% signal jitter.

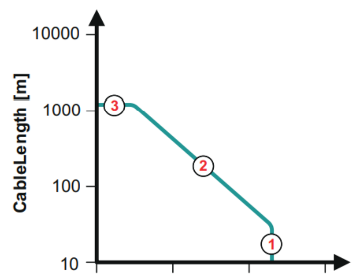

Figure 5: Data rate vs Cable Length graph

ISL8491E1BZ is the driver IC used in the main controller and at the peripheral side too. Full duplex type is the type of communication mainly used for transmitting and receiving.

5.3.3 ISL8941E1BZ

ISL8491E device is ESD protected, BiCMOS, 5V powered, single transceivers that meet both the RS-485 and RS-422 standards for balanced communication. Each driver output and receiver input are protected against ±15Kv ESD strikes, without latch-up. Unlike competitive versions, these devices are specified for 10% tolerance supplies (4.5V to 5.5V).

These devices are configured for full duplex (separate Rx input and Tx output pins) applications, so they are ideal for RS-422 networks requiring high ESD tolerance on the bus pins. Data rates up to 10Mbps are achievable by using the ISL8491E, which feature higher slew rates.

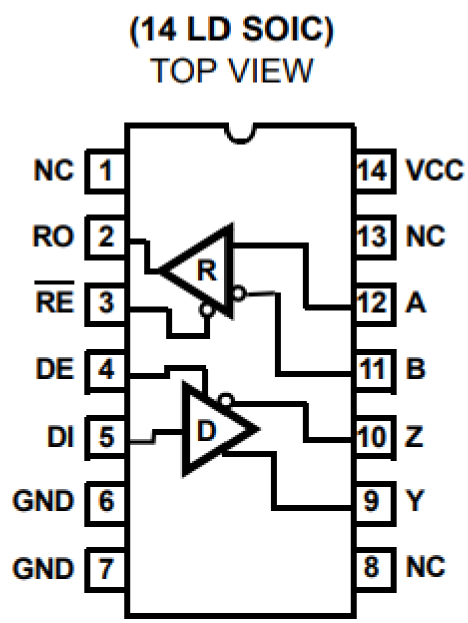

Figure 6: ISL8491EBZ

The devices present a “single unit load” to the RS-485 bus, which allows a total of 32 transmitters and receivers on the network. For “1/8-unit load” versions (256 devices on the bus. Additionally, on-chip thermal shutdown circuitry disables the Tx outputs to prevent damage if power dissipation becomes excessive.

5.3.4 RECEIVER FEATURES

These devices utilize a differential input receiver for maximum noise immunity and common mode rejection. Input sensitivity is ±200Mv, as required by the RS-422 and RS-485 specifications. Receiver input resistance meets the RS-485 “Unit Load” requirement of 12kΩ minimum. Receiver inputs function with common mode voltages as great as ±7V outside the power supplies (i.e., +12V and -7V), making them ideal for long networks where induced voltages are a realistic concern. All the receivers include a “fail-safe if open” function that guarantees a high-level receiver output if the receiver inputs are unconnected (floating). Receivers easily meet the data rate supported by the
corresponding driver. ISL8491E receiver outputs are three-statable via the active low RE input.

5.3.5 DRIVER FEATURES

The RS-485 driver is a differential output device that delivers at least 1.5V across a 54Ω load (RS-485), and at least 2V across a 100Ω load (RS-422). The drivers feature low propagation delay skew to maximize bit width, and to minimize EMI. ISL8491E driver outputs are three statable via the active high DE input. Outputs of ISL8491E drivers are not limited, so faster output transition times allow data rates of at least 10Mbps.

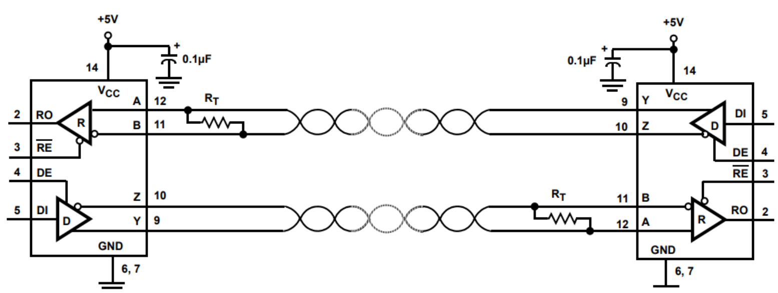

Figure 7: Driver- Receiver connection for Communication

5.3.6 APPLICATIONS

1. Factory Automation
2. Security Networks
3. Building Environmental
4. Control Systems
5. Industrial/Process Control Networks
6. Level Translators (e.g., RS-232 to RS-422)

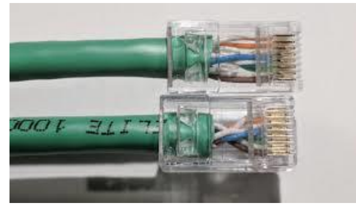

Figure 8: CAT6 Cable (Cross Connection)

Figure 9 : CAT 6 Cable

5.3.7 CONNECTION IMPLEMENTATIONS OF RS485

1. Module to Module connection
2. Module to USB to Isolated RS485 connection

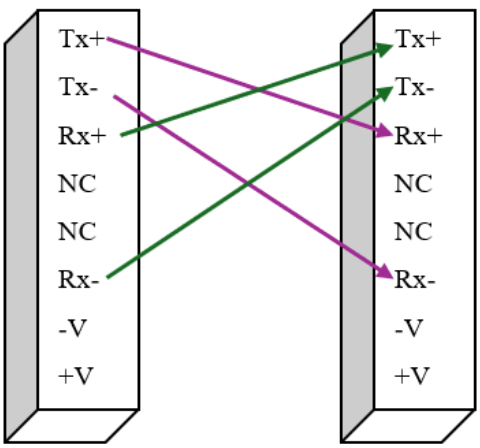

Figure 10: Module-Module Connection

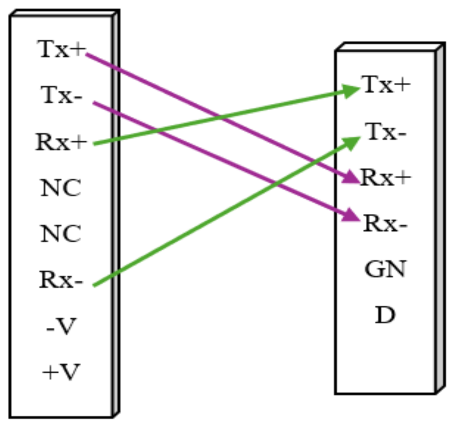

Figure 11: Module-USB to Isolated 485

RS485 uses a master-slave architecture, where one device acts as the master and controls the communication on the bus, while the other devices act as slaves. The master initiates the communication by sending a request, and the slaves respond accordingly. When transmitting data, the master device sends a stream of bits over the A and B lines. A logical “1” is represented by a positive voltage on the A line and a negative voltage on the B line, while a logical “0” is represented by a negative voltage on the A line and a positive voltage on the B line.

This differential signalling allows for noise rejection and ensures reliable data transmission. On the receiving end, the slaves monitor the A and B lines and compare the voltages to determine the transmitted bits. The difference in voltage between the A and B lines is called the “differential voltage” or “common-mode voltage.” If the differential voltage is above a certain threshold, the receiver interprets it as a logical “1,” and if it is below the threshold, it interprets it as a logical “0.”

5.3.8 IMPLEMENTING RS485

1. RS485 transceiver: This is a specialized integrated circuit that converts the UART (Universal Asynchronous Receiver/Transmitter) signals from your microcontroller or computer into RS485-compatible signals.

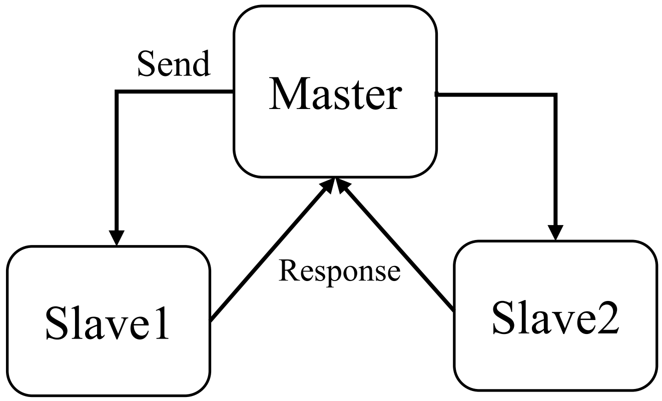

Figure 12: Full Duplex Communication

2. Twisted pair cable: RS485 requires a twisted pair cable to transmit the differential signals. The twisted pair helps to reduce electromagnetic interference (EMI) and crosstalk.
3. Termination resistors: At both ends of the RS485 bus, termination resistors are required to minimize reflections and ensure proper signal integrity.

5.4 CLOSED LOOP CURRENT SENSORS (CTSR)

Compared to the open loop sensors, **Hall effect closed loop sensors** (also called Hall effect “compensated” or “zero flux” sensors) have a compensation circuit that dramatically improves performance.

5.4.1 OPERATION PRINCIPLE

The magnetic flux created by the primary current I_P is balanced by a complementary flux produced by driving a current through the secondary windings.

Figure 13: CTSR Sensor

A hall device and associated electronic circuit are used to generate the secondary (compensating) current that is an exact representation of the primary current.

Electric Current and Magnetic Field Interaction**:**

When a current-carrying conductor or semiconductor is placed in a magnetic field, the magnetic field exerts a force on the moving charge carriers (electrons or holes). This force is known as the Lorentz force. For a conductor with a current III flowing along the x-axis, and a magnetic field BBB applied along the z-axis, the Lorentz force acts along the y-axis.

Charge Carrier Deflection**:**

The Lorentz force causes the charge carriers to deflect towards one side of the conductor. In the case of a negative charge carrier (electron), they will be pushed to one side of the material. For positive charge carriers (holes), they will be pushed to the opposite side.

Formation of Hall Voltage**:**

The accumulation of charge carriers on one side of the material creates a potential difference across the conductor, known as the Hall voltage (VHV_HVH). This potential difference continues to increase until the electric force due to the separation of charges balances the magnetic force (Lorentz force).

5.4.2 TECHNICAL SPECIFICATIONS

Current Range: 0 to ±100A

Supply Voltage: Typically, 5V DC

Output Voltage: Proportional to the input current, usually centered around 2.5V for ‘0’current.

Accuracy: Within 1% of the measured value

Operating Temperature: Ranges from -40°C to +85°C, suitable for various environmental conditions.

Fast Response: Capable of measuring rapidly changing currents accurately.

5.4.3 ADVANTAGES AND LIMITATIONS

Closed loop current sensors ensure DC, AC and complex current waveforms measurement while ensuring galvanic isolation. The main benefits of this technology include very good accuracy and linearity, low gain drift, wide bandwidth, and fast response time. Another advantage is the output current signal that is easily scalable and well suited to high noise environments. On the other hand, **closed loop technology** is showing limits with its high current consumption from the secondary supply (which must provide the compensation as well as bias current),

5.4.4 APPLICATIONS OF CTSR

1. Frequency inverters and 3-phase drives
2. Power factor correction converters
3. Electric welding equipment
4. Power supplies and Uninterruptible Power Supply (UPS)
5. EV motor control
6. Automotive battery management system (BMS)
7. Electric traction systems

5.5 ANALOG TO DIGITAL CONVERTER (ADC)

ADC stands for Analog to digital conversion and it is used to convert analog values from real world into digital values like 1's and 0's. Analog signals the ones that we see in our day-to-day life like temperature, speed, brightness etc. But Can an ADC convert temperature and speed directly into digital values like 0's and 1's?

An ADC can only **convert analog voltage values into digital values**. So, whichever parameter we wish to measure, it should be converted into voltage first, this conversion can be done with the help of **sensors**. For example, to convert temperature values into voltage we can use a Thermistor similarly to convert brightness to voltage we can use a LDR. Once it is converted to voltage we can read it with the help of ADC's.

5.5.1 RESOLUTION (BITS) AND CHANNELS IN ADC

When you read the specification of any Microcontroller or ADC IC, the details of the ADC will be given using the terms channels and Resolution (bits).

Let us assume that our ADC range is from 0V to 5V and we have a 10-bit ADC this means our input voltage 0-5 Volts will be split into 1024 levels of discrete analog values ($2^{10} = 1024$). Meaning 1024 is the resolution for a 10-bit ADC, similarly for a 8-bit ADC resolution will be 512 (2^8) and for a 16-bit ADC resolution will be 65,536 (2^{16}).

With this if the actual input voltage is 0V then the MCU's ADC will read it as 0 and if it is 5V the MCU will read 1024 and if it somewhere in between like 2.5V then the MCU will read 512. We can use the below formulae to calculate the digital value that will be read by the MCU based on the Resolution of the ADC and Operating voltage.

5.5.2 REFERENCE VOLTAGE FOR AN ADC

Another important term that you should be familiar with is the reference voltage. During an ADC conversion the **value of unknown voltage is found by comparing it with a known voltage, this known voltage is called as Reference voltage**. Normally all MCU has an option to set **internal reference voltage,** meaning you can set this voltage internally to some available value using software (program). In an Arduino UNO board, the reference voltage is set to 5V by default internally, if required user can set this reference voltage externally through the Vref pin also after making the required changes in the software.

Always remember that the measured analog voltage value should always be less than the reference voltage value and the reference voltage value should always be less than the operating voltage value of the microcontroller.

Example

Here we are taking example of ADC which has 3-bit resolution and 2V reference voltage. So, it can map the 0-2v analog voltage with 8 (2^3) different levels. So, if analog voltage is 0.25 then the digital value will be 1 in decimal and 001 in binary. Likewise, if analog voltage is 0.5 then the digital value will be 2 in decimal and 010 in binary.

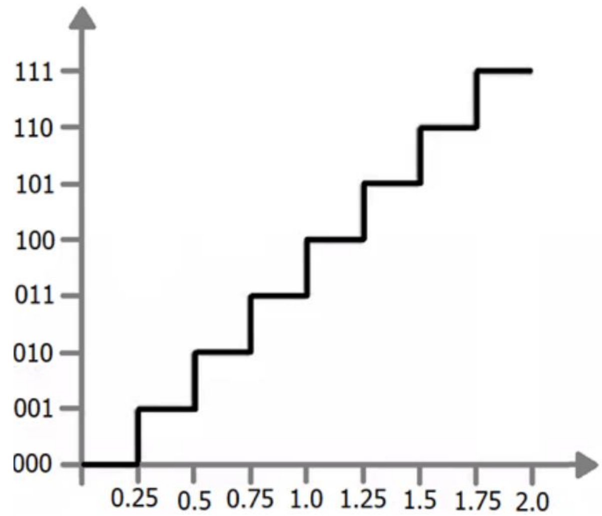

Figure 14: Mapping the Analog values with Digital Levels

Above figure shows that the 2V analog voltage signal is converted into Digital by the samples using Sample and hold circuit. Voltage is equally divided for 3-bit resolution of an ADC.

1. A sample and hold circuit to acquire the input voltage (V_{in}).
2. An analog voltage comparator that compares V_{in} to the output of the internal DAC and outputs the result of the comparison to the successive approximation register (SAR).
3. A successive approximation registers subcircuit designed to supply an approximate digital code of V_{in} to the internal DAC.

4. An internal reference DAC that, for comparison with V_{REF}, supplies the comparator with an analog voltage equal to the digital code output of the SAR_{in}.

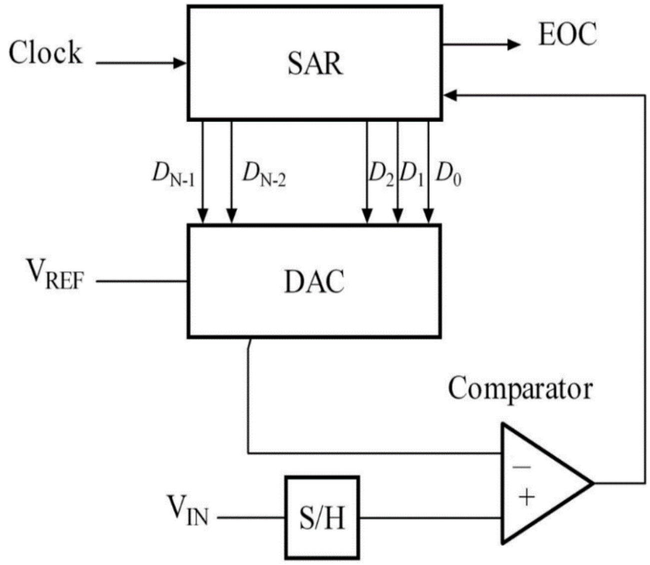

Figure 15: SAR Work Flow

Let's consider an example with a 3-bit SAR ADC to illustrate the process. Assume the input voltage Vin is 3.2V, and the reference voltage Vref is 5V.

Reference Voltage, Vref=5V

3-bit resolution, so possible digital codes are 000 to 111 (0 to 7 in decimal)

Step-by-Step Conversion:

Set MSB (bit 2):

Set the initial guess to 100 (binary) which is 4 in decimal.

DAC output = 4/7×Vref =4/7×5V≈2.86V

Comparator compares Vin→ 3.2V with DAC Output 2.86V:

Vin>2.86, so keep bit 2 as 1.

Set next bit (bit 1):

Now guess 110 (binary) which is 6 in decimal.

DAC output = 6/7×Vref=6/7×5V≈4.29

Comparator compares Vin→ 3.2V

Vin<4.29V, so set bit 1 to 0, keeping the value at 100.

Set next bit (bit 0):

Now guess 101 (binary) which is 5 in decimal.

DAC output = 5/7×Vref=5/7×5V≈3.57

Comparator compares Vin→ 3.2V with DAC Output

so set bit 0 to 0, keeping the value at 100.

At the end of these steps, the final digital output is 100 (binary) which is 4 in decimal. This means the SAR ADC approximated Vin as 4/7×5V≈2.86V. In a higher resolution ADC, this process would continue for more bits to get a more accurate approximation.

5.6 LPC54606J512

LPC54606J512 is a microcontroller from NXP Semiconductors, part of the LPC546xx family. It is designed for embedded applications requiring high performance and low power consumption.

5.6.1 Overview of LPC54606J512

1. Core and Architecture**:** ARM Cortex-M4 Core, Operates at speeds up to 180MHz.
2. Memory: Flash Memory 512 KB of on-chip, RAM 200 KB of SRAM.

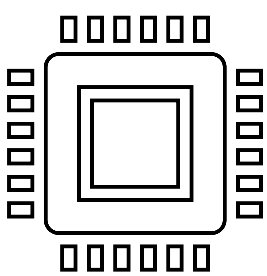

Figure 16: Chip sketch

3. Peripherals and Interfaces**:** Includes a 12-bit ADC, Multiple timers, including general-purpose timers, a state configurable timer, and a real-time clock.
4. Communication Interfaces: Multiple UARTs, SPIs, I2Cs, USB (full-speed host/device/OTG), CAN (Controller Area Network), and an Ethernet MAC.
5. GPIO: A large number of general-purpose I/O pins, allowing for versatile interfacing with other hardware components.
6. Security Features: Includes features like a hardware cryptographic engine, secure boot, and secure debug to enhance the security of applications.

5.6.2 Applications

The LPC54606J512 is well-suited for a variety of embedded applications such as:

1. Industrial Automation: Control systems, data acquisition, and automation tasks.
2. Consumer Electronics: Smart appliances, wearables, and other consumer gadgets.
3. IoT Devices: Internet of Things applications requiring efficient connectivity and low power consumption.
4. Medical Devices: Portable medical equipment and health monitoring systems.
5. Automotive**:** In-vehicle infotainment systems, diagnostic tools, and body electronics.

The above-mentioned controller is mainly used for Sensor Event Logging, this acts like a Master card for any project.

LPC804 and LPC845 are the two other controllers used in Efftronics with different functionalities like 845 is used as a main controller in aggregator, this routes the data towards the SEL. 804 is the other controller used in measuring cards like AC, DC currents and voltages.

5.7 COMMUNICATION PROTOCOLS

5.7.1 Communication Protocol: A set of rules and regulations that allow two electronic devices to connect to exchange the data with one and another.

5.7.2 Why is Communication Protocol Important?

Communication protocols assist varied network devices to converse with each other by transmitting the analog signals, digital signals, different files & process the data from one device to other devices. These types of protocols are applicable in telecommunication & computer networks where suitable rules are executed to transmit information from source to destination.

The most vital protocols within networking are TCP (Transmission Control Protocol) & User datagram protocol (UDP).

5.7.3 Types of Communication Protocols

There are two types of communication protocols which are classified below

1. Inter System Protocol
2. Intra System Protocol

5.7.4 Inter System Protocol

The inter-system protocol using to communicate the two different devices. Like communication between computer to microcontroller kit. The communication is done through an inter bus system.

The different categories of intersystem protocol

1. UART Protocol
2. USART Protocol
3. USB Protocol

1. UART Protocol

UART stands for a universal asynchronous transmitter and receiver. UART Protocols is a serial communication with two wired protocols. The data cable signal lines are labelled as Rx and Tx. Serial communication is commonly used for transmitting and receiving the signal. It is transferred and receives the data serially bit by bit without class pulses. The UART takes bytes of data and sends the individual bits in a sequential manner. UART is a half-duplex protocol. Most of the controllers have hardware UART on board. It uses a single data line for transmitting and receiving the data. It has one start bit, 8-bit data and a one-stop bit mean the 8-bit data transfer one's signal is high to low.

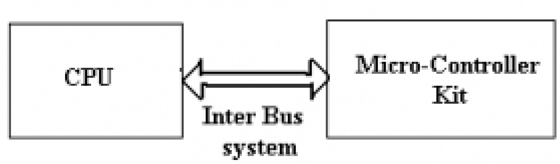

Figure 17: UART Protocol

Ex: Emails, SMS, Walkie-talkie.

2. USART Protocol

USART stands for a universal synchronous and asynchronous transmitter and receiver. It is a serial communication of a two-wire protocol. The data cable signal lines are labelled as Rx and TX. This protocol is used to transmitting and receiving the data byte by byte along with the clock pulses. It is a full-duplex protocol that means transmitting and receiving data simultaneously to different board rates. Different devices communicate with microcontroller to this protocol.

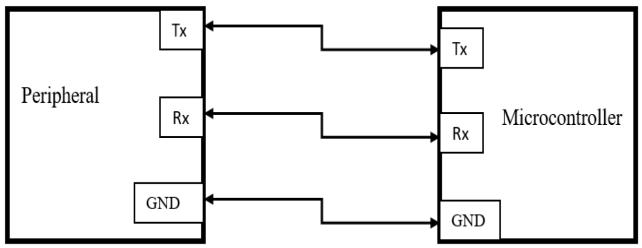

Figure 18: USART Protocol

Ex: Telecommunications.

3. USB Protocol

USB stands for universal serial bus. Again, it is a serial communication of two-wire protocol. The data cable signal lines are labelled D+ and D-. This protocol is used to communicate with the system peripherals. USB protocol is used to send and receive the data serially to the host and

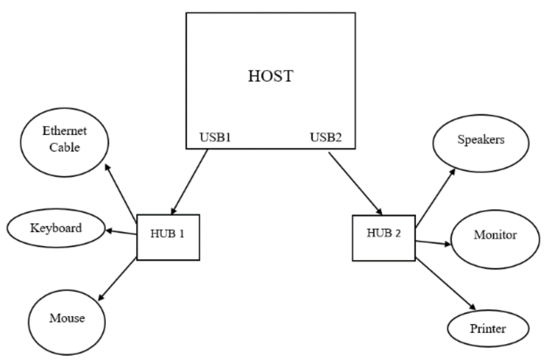

Figure 19: USB Protocol

peripheral devices. USB communication requires driver software that is based on the functionality of the system. USB devices can transfer data on the bus without any request on the host computer. Nowadays most devices are using this technique for communicating with USB protocol. Like a computer to communicate with an ARM controller using USB. USB transfer the data to different modes. first one is slow speed mode 10kbps to 100 kbps; the second one is full speed mode 500kbps to 10mbps, high-speed mode 25mbps to 400 Mbps. USB maximum cable length of 4 meters.

5.7.5 Intra System Protocol

The Intra system protocol is used to communicate the two devices within the circuit board. While using these intra system protocols, without going to intrasystem protocols we will expand the peripherals of the microcontroller. The circuit complexity and power consumption will be

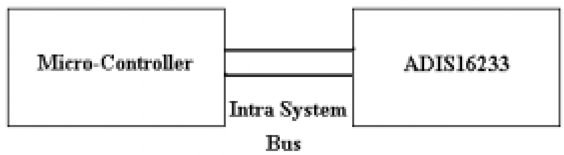

Figure 20: Intrasystem Protocol

increased by using the intrasystem protocol. Using intra system protocols circuit complexity and power consumption, the cost is decreased and it is very secure to accessing the data.
The different categories of intrasystem protocol mainly include the following.

1. I2C Protocol
2. SPI Protocol
3. CAN Protocol

1. I2C Protocol

I2C stands for the inter-integrated circuit and it requires only two wires connecting all peripherals to the microcontroller. I2C requires two wires SDA (serial data line) and SCL (serial clock line)

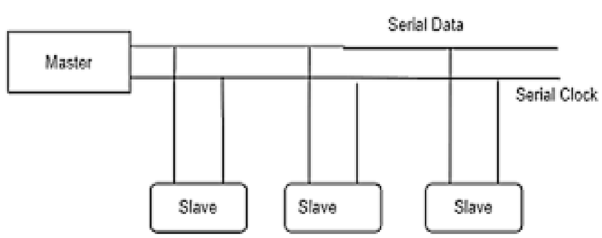

Figure 21: I2C Protocol

to carry information between devices. It is a master to a slave communication protocol. Each slave has a unique address. The master device sends the address of the target slave device and reads/writes the flag. The address matches any slave device that the device is ON, the remaining slave devices are disabled mode.

2. SPI Protocol

SPI stands for the serial peripheral interface. It is one of the serial communication protocols developed by Motorola. Sometimes SPI protocol is also called a 4-wire protocol. It requires four wires MOSI, MISO, SS, and SCLK.SPI protocol used to communicate the master and slave devices.

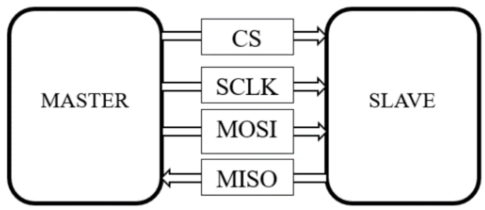

Figure 22: SPI Protocol

3. CAN Protocol

CAN stands for the controller area network. It is a serial communication protocol. It requires two wires CAN High (H+) and CAN low (H-). It was developed by the Robert bosh company in 1985 for in-vehicle networks. It is based on a message-oriented transmission protocol.

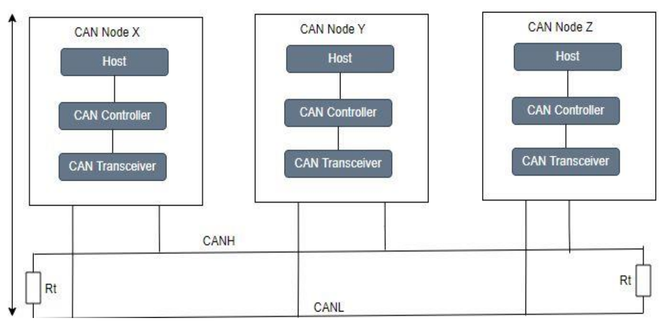

Figure 23: CAN Protocol

CHAPTER- 6
TESTING PROCESS OF RDPM

6.1 CARDS TESTING HARDWARE LEVEL

In a RDPM System, cards to be measured:

Table2 : Hardware Level Testing of cards

S. No	Card Description
1	SEL Cards
2	Digital
3	Aggregator
4	Dual channel Voltage Measuring PCBs
5	Current Measuring PCBs AC and DC

6.1.1 Testing Procedure

1. Test points are given for each card in certain places to check for supply of voltage given to the card. Mainly are TP1- 24V, TP2- 5V and TP3- 3.3V supply. Short circuits also checked if present any through multimeter.
2. Wires, specifically CAT 6 cables are measured for the wire continuity.
3. L- coats are to be seen if applied or not→ these were made to avoid water spillages, surge voltages etc.

6.2 SOFTWARE LEVEL TESTING

1. Codes to be installed or dumped into the microcontroller for different functionalities and different operations.
2. Firstly, Selecting the type of the controller, applying frequency and erasing the chip.
3. Next, Dump the given code.
4. After Downloading the code or installing it to the controller, power reset the device

6.2.1 Types of codes

1. Main Code
2. Port Configuration Code
3. CRC (for DC)

6.3 HARDWARE SETUP

Depending on the version and different types of configurations, hardware setup is made based on the requirement. Mainly worked on Master Slave Configuration of RDPM, for reference see Figure 3.

6.4 TEST CASE EXPLORATION

Test cases are given, with respect to the given cases, one should check for the key insights to be learned, how to do, what to do and analyzing the problem and debugging it is the main work.
In RDPM, different test cases were given to see the working and final level verification.

6.4.2 Module Testing's

1. Dual Channel DC Voltages: 2V, 4V, 6V, 12V, 24V, 48V, 60V and 110V
2. AC Voltages: 110V and 230V
3. DC Currents: 6 channels
4. AC Currents: 6 channels
5. Digitals: 16 inputs

6.4.3 SEL Functionality Testing's

1. Ports Verification
2. Commands Verification through NMDL
3. Data Availability
4. Memory Card Test
5. Packets Information- receiving and processing
6. State checking
7. Power BI reports

6.4.4 RUI Testing's

1. Mnemonics verification
2. Data Verification
3. Version and Baud rate
4. SD card presence

6.4.5 STANDARD RECORDS THROUGH REPORTS SOFTWARE

1. Generated Packets Verification- Type ID, Packet type ID (Analog, digital), time, year and checksum etc.
2. Lag time verification
3. Data Availability
4. Sequence misses and packet losses
5. Time Synchronization

6.4.6 BACKUP TESTING'S

Creation of packets is done to achieve more no of packets in minimum time, for every 34 min data will be updated if there is no changes in the supply or inputs. By using multivibrator for every second, we can create N number of packets with less time.

Main goal is to achieve the retrieve the lost data when it is not live with the NMDL

6.4.7 LED INDICATIONS

1. Checking if the connected ports are blinking or not
2. Health LED blinking
3. Status LED

6.4.8 DOCUMENTING TESTING OUTCOMES

After every test case is done, logging the test results will be seen in the excel given for test cases, there are actual result, remarks, exceptions and failed test case columns are present, Finalizing is done after verification of every test case.

Finally, the above product or project is been tested from Hardware level→ Software level→ Communications→ Individual Functionality level→ Standard Records→ Module level→ total functionality level

CHAPTER- 7

ACCURACY TEST FOR SENSOR IN CHAMBER

7.1 SIGHT REQUIREMNT

60A current sensor is needed in the station room, to measure the above rating LEM 100A sensor (CTSR) is used. Accuracy is tested at different temperatures.

To measure the given rating current source is needed, having the 3A producing source is quite not useful for measuring ratings,

The advantage of LEM sensor is it work on the Hall effect, which also applications like transformers, same goes for the CTSR.

Due to Mutual inductance, and using the transformer ratio we can add more turns around the coil. If 1A given and turns were 20 then, we can get up to 20A current.

7.2 COMPONENTS REQUIRED

1. PPS- Programmable Power Supply
2. SEL
3. Aggregator- DC currents
4. Sensor
5. RUI
6. NMDL running PC
7. 100MM thickness wire
8. RS485 Cables

7.3 BLOCK DIAGRAM

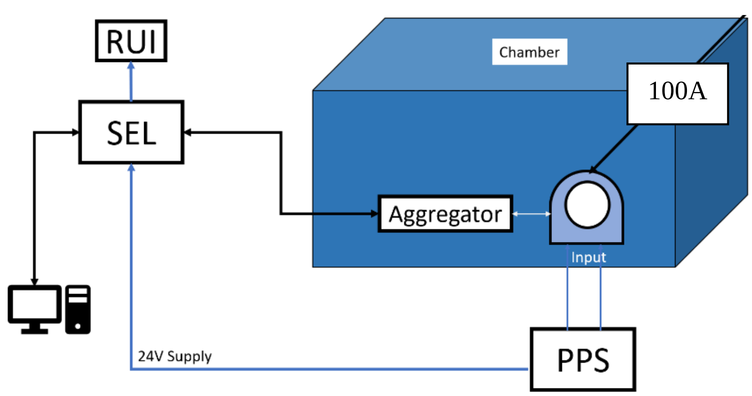

Figure 24: Chamber Setup

7.4 RESULTS

Table 3: Accuracy Results

S.no	CHAMBER VALUE	INPUT VALUE (A)	SCANNEDVALUE(A)	ERROR%
5	10°C	5	5.0568	-1.136
		10	10.006	-0.06
		15	14.93	0.46666667
		20	19.799	1.005
		30	29.791	0.69666667
		40	39.723	0.6925
		50	49.617	0.766
1	30°C	5	5.1	-2
		10	10.065	-0.65
		15	15.03	-0.2
		20	19.917	0.415
		30	29.905	0.31666667
		40	39.876	0.31
		50	49.888	0.224
2	45°C	5	5.1928	-3.856
		10	10.165	-1.65
		15	15.179	-1.1933333
		20	20.034	-0.17
		30	30.064	-0.2133333
		40	40.086	-0.215
		50	50.139	-0.278
6	60°C	5	5.0745	-1.49
		10	10.118	-1.18
		15	15.154	-1.0266667
		20	20.048	-0.24
		30	30.202	-0.6733333
		40	40.249	-0.6225
		50	50.303	-0.606

CHAPTER- 8
CALIBRATION

Calibration is the process of configuring an instrument or device to provide accurate measurements by comparing it to a known standard or reference. This ensures that the instrument's output is both precise and accurate over a specified range of values. Calibration is essential in various fields such as engineering, manufacturing, healthcare, and scientific research to maintain the integrity of measurements and ensure quality control.

8.1 Key Concepts

1. Accuracy and Precision**:**
    1. Accuracy refers to how close a measured value is to the true value or standard.
    2. Precision refers to the consistency of repeated measurements under the same conditions.
2. Calibration Standards**:**
    1. Calibration requires a standard with known and highly accurate properties. These standards are often provided by national or international organizations such as the National Institute of Standards and Technology (NIST) in the United States.
3. Calibration Procedure**:**
    1. The procedure involves adjusting the instrument to match the known standard as closely as possible. This may include zeroing the instrument, adjusting its range, and fine-tuning its response.

8.2 Calibration Process

1. Initial Check**:**
    1. Before calibration, the instrument is checked to ensure it is functioning properly and within its operational specifications.
2. Comparison with Standard**:**
    1. The instrument is compared to a known standard under controlled conditions. This involves measuring the output of the instrument and comparing it to the standard.
3. Adjustment**:**
    1. If discrepancies are found, adjustments are made to the instrument to align its output with the standard. This can involve mechanical adjustments, software updates, or recalibration of sensors.

8.3 Importance

1. Ensuring Quality and Compliance**:**
    1. Calibration is crucial for quality assurance and compliance with industry standards and regulations. It ensures that instruments provide accurate and reliable measurements, which are essential for quality control in manufacturing and other industries.
2. Safety**:**
    1. In fields like healthcare, aviation, and automotive, accurate measurements are critical for safety. Calibration ensures that instruments used in these fields provide correct readings, thus preventing accidents and ensuring safety.
3. Cost Savings**:**
    1. Regular calibration can prevent costly errors and rework by ensuring that instruments perform correctly. It also extends the lifespan of instruments by maintaining their accuracy and reliability.
4. Legal and Regulatory Requirements:
    1. Many industries are subject to strict regulatory requirements that mandate regular calibration of instruments. Compliance with these regulations is essential to avoid legal issues and penalties.

8.4 Challenges

1. Environmental Conditions**:**
    1. Temperature, humidity, and other environmental factors can affect the accuracy of calibration. It is important to perform calibration under controlled conditions to minimize these effects.
2. Instrument Drift**:**
    1. Over time, instruments can drift away from their calibrated state due to wear and tear, environmental factors, or aging components. Regular calibration is necessary to correct for this drift.
3. Complexity of Instruments**:**
    1. Modern instruments can be complex, with multiple parameters that need calibration. This requires specialized knowledge and equipment.
4. Availability of Standards**:**

1. High-precision standards required for calibration may not always be readily available, especially for specialized or new types of measurements.

8.5 Calibration of Cards

Every card present in the RDPM system should be calibrated with respect to the hardware or supply. Basically, firmware is adjusted with respect to the electrical supply.

Different type of cards needs different source of supply

1. DC Voltages- Programmable Power Supply (PPS)
2. DC Currents- PPS with Load
3. AC Voltages- Variac
4. AC Currents- Variac + Resistive Load

External power supply of +24V is given to the System using the Switching Mode Power Supply (SMPS).

Calibration is done with respect to the Multiplication Factor and Offset.

Steps will be distributed as per the high voltage given.

Validation of the steps is important after downloading the hex file generated from the calibration.

Merging of the data is mandatory

Hex files should be dumped in the cards because we are setting a reference voltage at different inputs.

CHAPTER- 9

OVERVIEW OF BHMS

9.1 INTRODUCTION

BHMS is a data logging device which logs battery's characteristics which are essentially needed for monitoring the status like its life expectancy, voltage, current, internal resistance and temperature etc.

Mainly logged data:

1. Charging and Discharge currents of bank
2. Bank and Individual Battery's voltage
3. Temperature of battery room and individual battery temperature
4. Internal Resistance Calculation based on bank discharge

Based on the above logged data it will identify the failure of cell/battery by analyzing the voltage and current characteristics and it can also be used to generate various reports like total charged AH, total discharged AH and data is uploaded to the Personal Computer (PC) or any device from BHMS and Provide the Fault Alarms with message. BHMS online Software application plots the online graphs to understand the behavior of cell/battery during both charging and discharging.

9.2 OBJECTIVE

One of the major applications of batteries with high AH is Uninterruptible Power Supply (UPS).

UPS:

An uninterruptible power supply (UPS) or uninterruptible power source is a type of continual power system that provides automated backup electric power to a load when the input power source or mains power fails. A UPS will provide near-instantaneous protection from input power interruptions by switching to energy stored in battery packs.

Common Power Problems:

The primary role of any UPS is to provide short-term power when the input power source fails. UPS units can stabilize the power supply to connected devices, providing a consistent and reliable source of electricity, even when the utility power is not stable.

However, most UPS units are also capable in varying degrees of correcting common utility power problems:

1. Voltage spike or sustained overvoltage
2. Momentary or sustained reduction in input voltage
3. Voltage sag
4. Noise, defined as a high frequency transient or oscillation, usually injected into the line by nearby equipment
5. Instability of the mains frequency
6. Harmonic distortion, defined as a departure from the ideal sinusoidal waveform expected on the line

9.3 BATTERY BANK

N number of cells/batteries are connected in series and output voltage driven from the bank is N*Vcell.

Example: 55 cells are present in battery bank and each cell generates

2V output voltage

Total voltage driven from the bank is Vtotal = N*Vcell

i.e., Vtotal = 55*2

Vtotal = 110V DC is generated

Battery bank is an example UPS, precisely it is the part of UPS

Figure 25: Battery Bank

9.4 BLOCK DIAGRAMS OF BHMS

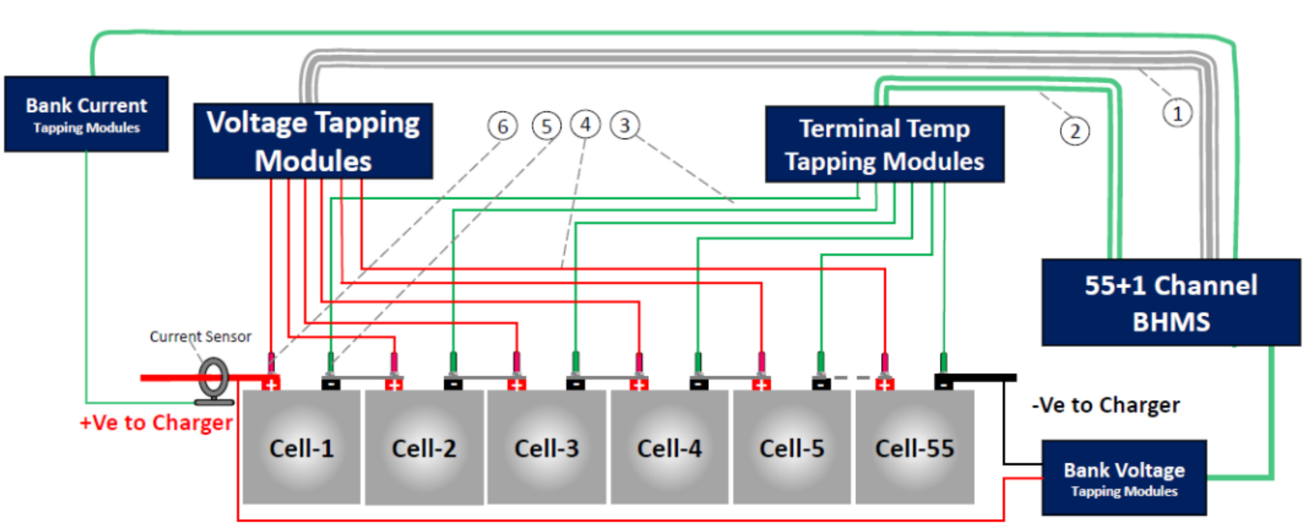

Figure 26: Individual Cell Connectivity to BHMS

CHAPTER- 10

SOFTWARE APPLICATIONS USED

10.1 QCOMM

Quectel is a leading global supplier of Internet of Things (IoT) modules and solutions. They specialize in providing a wide range of communication modules for wireless applications, including cellular, Wi-Fi, and GNSS (Global Navigation Satellite System) technologies.

Through QCOMM one can see and analyze how data is receiving from the module, 16 bytes of data is seen in the main window.

10.2 POWER BI

Power BI is a business analytics service developed by Microsoft that provides interactive visualizations and business intelligence capabilities with an interface simple enough for end users to create their own reports and dashboards. Data Availability, packet misses, lags and losses can be observed through power bi.

10.3 NMDL (NETWORK MANAGEMENT DATA LOGGER)

NMDL is designed to monitor and log data from various networks and systems, providing real-time insights and historical data analysis. It is typically used in critical infrastructure sectors like railways, power, and water supply systems.

1. Real-Time Monitoring
2. Data Logging
3. Alerts and Notifications
4. Technological Integration

10.4 REPORTS

Efftronics Systems Pvt. Ltd. offers a variety of software solutions, including their Reports Software, which is designed to facilitate efficient data reporting and analysis.

1. Customizable Reports
2. Automated Reporting
3. Data Integration
4. Real-Time Data Processing
5. User-Friendly Interface

10.5 RDPM PORT CONFIGURATION TOOL

1. SEL ports are configured as per the requirement
2. 8 ports mandatory ports for communication
3. RS485
4. Voice Modem
5. Zigbee

6 Aggregator ports

CONCLUSION

. The implementation of Battery Health Monitoring Systems (BHMS) represents a critical advancement in the management and maintenance of battery systems across various applications. BHMS ensures the reliability, safety, and longevity of batteries by providing real-time monitoring and comprehensive analysis of their health parameters.

In conclusion, Battery Health Monitoring Systems are essential for maintaining the performance and safety of battery systems in various industries, including electric vehicles, renewable energy storage, and uninterruptible power supplies. The adoption of BHMS leads to more reliable, efficient, and safe battery operations, supporting the growing demand for energy storage solutions.

The integration of remote diagnostics and predictive maintenance technologies has significantly enhanced the management and maintenance of complex systems across various industries. These advancements offer substantial improvements in operational efficiency, cost savings, and system reliability.

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