2-Wheeler Communication Rig User Manual

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DOCUMENT HISTORY:

Version	Date	Details	Author	Checked by	Approved
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Vehicle Overview

Simple E-Pluto 7G is a compact and efficient electric vehicle designed for urban commuting and short-distance travel. As part of our MCU (Motor Control Unit) Test Rig manual, understanding the specifications and features of the E-Pluto 7G is essential for conducting thorough testing and analysis.

Specifications:

Specification	Details
Battery Type	Portable 60V 1.2 kWh Lithium-Ion
Battery Capacity	1.2 kWh
Charging Time	2 hours (with 60V 10A Charger)
Range (per charge)	~65 kms
Top Speed	32 km/h
Motor Type	BLDC Hub Motor
Motor Power	1.5 kW (nominal)
Peak Power	2.2 kW
Torque	60 Nm
Brakes (Front & Rear)	Front: Disc; Rear: Drum
Suspension	Front: Telescopic; Rear: Coil Spring
Tire Size	3.00-10 (Front and Rear)
Kerb Weight	76 kg
Loading Capacity	150 kg
Dimensions (LxWxH)	1345 mm x 640 mm x 1115 mm
Ground Clearance	165 mm
Display	Digital Display
Headlamp	LED
Driving Modes	Eco, Sport
Controller	60V (Smart Controller)

Safety-related instructions for vehicle testing

Following the guide for safer handling of the rig

1. **Safety Gear:**
   Always wear appropriate personal protective equipment (PPE) including safety goggles, gloves, and non-conductive footwear. Ensure any conductive accessories or jewellery are removed from the hand or wrist.
   This gear minimizes the risk of injury from electrical shocks, burns, or accidents.
2. **Training:**
   Ensure comprehensive training on the safe operation of electric vehicle (EV) components, tools, and equipment before starting work on the rig. This includes understanding electrical systems, battery handling, and emergency procedures.
3. **Power Down:**
   Before beginning any work, power down the electric vehicle rig completely. Disconnect the battery and ensure all systems are deactivated to prevent accidental shocks or injuries.
4. **Qualified Personnel:**
   Ensure there is always a qualified instructor or technician present to provide guidance.
5. **Tool Safety:**
   Use insulated tools and equipment specifically designed for electrical work. Inspect tools regularly for damage and replace them if necessary. Avoid using damaged or malfunctioning tools to prevent accidents.
6. **Workspace Organization:**
   Keep the work area clean and organized.
   This minimizes the risk of tripping hazards and makes it easier to identify potential safety hazards such as exposed wires or loose connections.
7. **Electrical Isolation:**
   When working on electrical components, always isolate the power source to prevent accidental contact with live circuits. Use lockout/tagout procedures if necessary to ensure the power remains off while work is being performed.
8. **Fire Safety:**
   Be aware of the potential fire hazards associated with lithium-ion batteries used in electric vehicles. Have appropriate fire extinguishing equipment nearby and know how to use it in case of an emergency.
9. **Emergency Procedures:**
   Familiarize yourself with the location of emergency exits, first aid kits, and fire extinguishers. In the event of an accident or injury, follow established emergency procedures and seek medical attention if

necessary.

10. **Reporting Hazards:**
    If you identify any safety hazards or concerns while working on the electric vehicle rig, report them to your instructor or supervisor immediately. Do not attempt to address safety issues on your own unless you are properly trained to do so.

Electrical and Electronics Architecture

Vehicle architecture respectively describes the physical layout of a vehicle and the way it realizes its function by a given set of basic architecture parameters and modules. Refer to the image below for a detailed overview

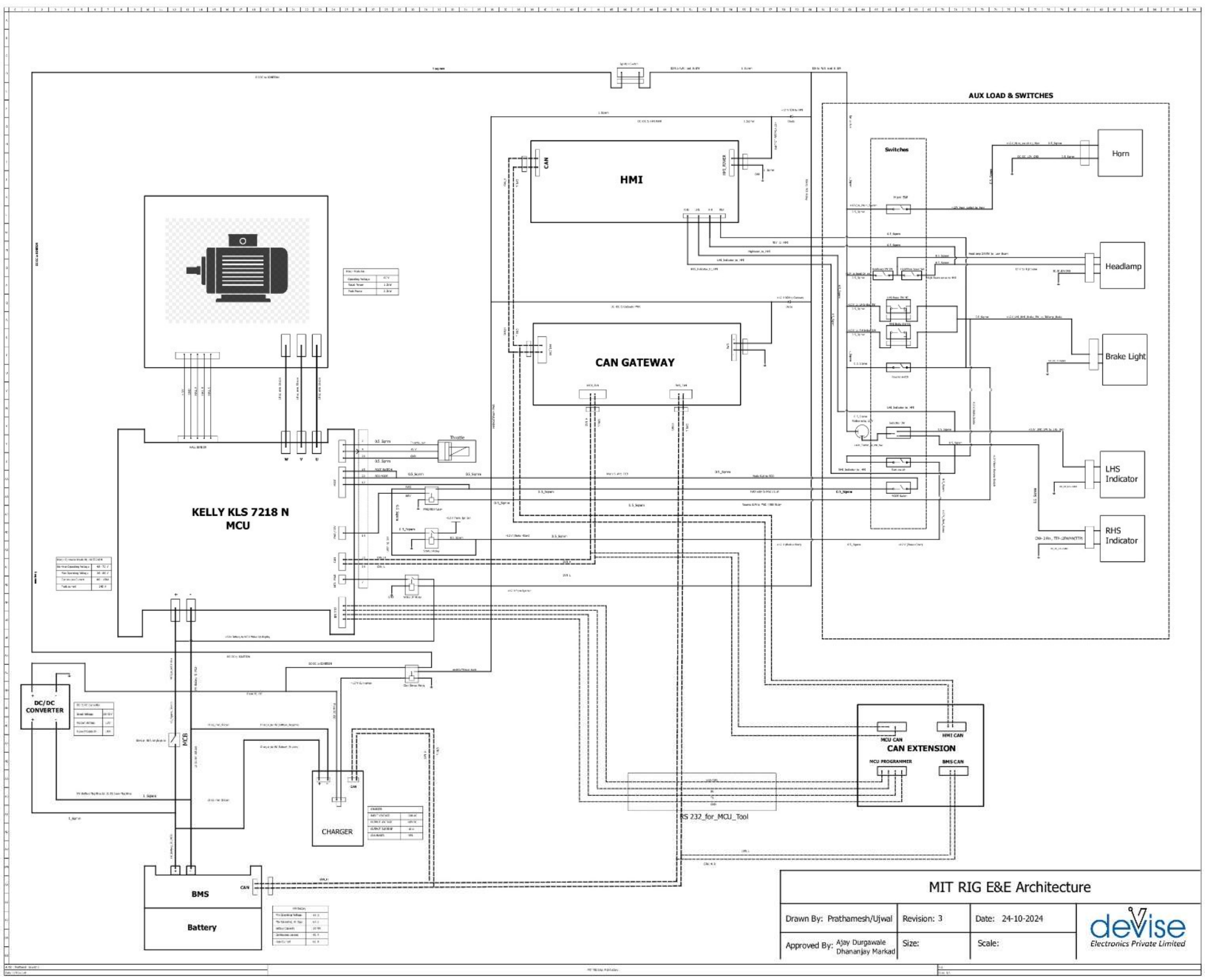


Figure 1: Vehicle Electrical Architecture

Low Voltage Components and their Power Consumption.

Low voltage system comprises components operating on a 12V circuit. These are also categorized as Auxiliary components. These consist of

1) Headlamp
2) Indicators
3) Horn
4) Tail lamp
5) Relays and controls
6) CAN Gateway

The specifications for the LV components are mentioned below

Head Lamp - 35 Watt

Voltage - 12 V

Current - 2.91 A

Indicators– 5 W each

Voltage- 12 V

Current- 0.41 A each

Total consumption per channel is **10 W**

Horn – 30 W

Voltage -12 V

Current - 2.5 A

Tail Lamp - 2 W

Voltage - 12 V

Current - 0.17 A

HMI Screen- 1.2 W

Voltage - 12 V

Current - 0.1 A

CAN Gateway- 0.5 W

Voltage - 12 V

Current - 0.04 A

The total load on the LV system is ~ **79 watts** for all the components turned on.

High Voltage System

For the HV architecture following components are part of the system,

1. Motor
2. Battery Pack
3. Charging System
4. DC-DC Converters

The total power provided by the battery pack is high due to the elevated voltage and high current draw. The wires have to be sized accordingly. For the existing architecture, the wire size was selected as 4 Sq.mm for all the HV connections.

Passive Safety Element Overview

Passive safety components are integral parts of systems designed to ensure safety without active intervention. In the context of electrical systems, these components play a crucial role in preventing hazards and mitigating risks.

Fuse:

A fuse is a passive safety component designed to protect electrical circuits from overcurrent conditions. Consisting of a metal wire or strip that melts when excessive current flows through it, a fuse interrupts the circuit, preventing damage to connected devices or even fire. Fuses are essential in both residential and industrial settings, safeguarding against electrical faults and ensuring the integrity of electrical systems.
The current system is equipped with a blade fuse in the battery pack. A second fuse is located in series to the DC-DC output.

MCB (Miniature Circuit Breaker):

MCBs are another vital passive safety component commonly used in electrical installations. Similar to fuses, MCBs protect circuits from overcurrent situations. However, unlike fuses, MCBs can be reset after tripping, offering a more convenient and cost-effective solution for circuit protection. With their ability to quickly disconnect circuits in case of overloads or short circuits, MCBs provide an added layer of safety, contributing to the overall reliability of electrical systems.

MCB Specifications

1. Make: Schneider.
2. Model No: C60H - 1 pole - 63 A - C curve
3. Compliance Standard: IEC -IEC 60947-2
4. Product Name: Miniature Circuit Breaker; 1 Pole
5. Rated Current: C63
6. Rated Voltage: DC 250V
7. Operating Frequency: 50/60 Hz
8. Mounting support: 35 mm DIN rail
9. Dimensions (Approx.): 70 x 75 x 18mm
10. Operating Temperature: -25 Deg C to 70 Deg C
11. Weight: 129g

Vehicle Test Point Description

The vehicle is equipped with test point provided on the Electrical Harness. These test points, strategically placed throughout the system, serve as vital checkpoints for assessing voltage levels, monitoring data transmission, and verifying component functionality.

Battery Management System (BMS) CAN Line:

1. Purpose: To monitor data related to battery management.
2. Location: Accessible via DB9 connector.
3. Test Method: Connect monitoring equipment to the DB9 connector to collect data.
4. Data Expected: BMS-related data such as battery state, temperature, and health.

Motor Control Unit (MCU) CAN Line:

1. Purpose: To monitor data related to motor control.
2. Location: Accessible via DB9 connector.
3. Test Method: Connect monitoring equipment to the DB9 connector to collect data.
4. Data Expected: MCU-related data such as motor speed, torque, and status.

Human Machine Interface (HMI) CAN Line:

1. Purpose: To monitor data related to the human-machine interface.
2. Location: Accessible via DB9 connector.
3. Test Method: Connect monitoring equipment to the DB9 connector to collect data.
4. Data Expected: HMI-related data such as display status, user inputs, and system feedback.

Motor Control Unit (MCU) RS232 Line:

1. Purpose: To monitor and diagnose data transmission of motor controller using the RS232 protocol.
2. Location: Accessible via DB9 connector.
3. Test Method: Connect an RS232 monitoring tool or PC to the RS232 test point or DB9 connector using an appropriate serial cable.
4. Data Expected: Communication data related to the motor controller, including motor control commands, diagnostics, error codes, and operational status updates.

MCU High Voltage Input (60V):

1. Purpose: To test the incoming 60V supply to the MCU.
2. Location: High voltage input terminal of the MCU.
3. Test Method: Use a voltage test probe to measure the voltage level.
4. Expected Voltage: 60 volts (± tolerance as per specifications).

These test points are crucial for ensuring the proper functioning and monitoring of the electrical system in the electric vehicle. Regular testing at these points helps in identifying any potential issues early and ensures the vehicle's reliability and safety.

Vehicle Components

Battery Pack:

A battery pack for a two-wheeler is a device that stores electrical energy and provides power to the vehicle's motor. It is an essential component of electric two-wheelers, as it determines the range and performance of the vehicle. The battery pack consists of multiple cells that are connected in series and parallel to achieve the desired voltage and capacity. The battery pack can be either removable or non-removable, depending on the vehicle's design. Removable battery packs are convenient for charging and replacement, while non-removable battery packs are more compact and provide better protection against theft. The battery pack's capacity is measured in kilowatt-hours (kWh), which determines the range of the vehicle. The battery pack's lifespan depends on various factors such as usage, temperature, and maintenance. It is recommended to follow the manufacturer's guidelines for charging and maintenance to ensure the battery pack's longevity.

Battery Management System:

A Battery Management System (BMS) manages a rechargeable battery by protecting it from operating outside its safe operating area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it, and/or balancing it.

A. **Protection**: The BMS protects the battery from operating outside its safe operating area, which includes preventing overcharging, over-discharging, and excessive current flow. It also monitors temperature to avoid overheating, which can lead to thermal runaway or battery damage.

B. **Monitoring**: The BMS continuously monitors the state of the battery, including parameters such as voltage, current, temperature, and state of charge (SOC). Accurate monitoring is essential for maintaining the health of the battery and ensuring it operates within safe limits.

C. **State Calculation**: By analyzing the monitored data, the BMS calculates secondary data such as state of health (SOH), state of power (SOP), and state of energy (SOE). These calculations help in assessing the battery's performance, degradation, and remaining useful life.

D. **Reporting**: The BMS reports critical data to external devices or systems, providing valuable information for users and other system components. This data can be used for diagnostic purposes, performance tracking, and decision-making.

E. **Environmental Control**: The BMS can control the environment of the battery, such as activating cooling systems to dissipate excess heat or heating elements to maintain optimal operating temperatures in cold conditions.

F. **Authentication**: BMS prevents unauthorized usage and ensures the authenticity of the battery, the BMS may include authentication mechanisms.

G. **Balancing**: Battery cells can exhibit variations in capacity and performance over time. The BMS balances the charge across individual cells to ensure uniformity, thereby extending the overall battery life and maintaining optimal performance.

In addition to these primary functions, a BMS enhances the safety, efficiency, and reliability of battery-operated systems in various applications, such as electric vehicles (EVs), renewable energy storage, portable electronics, and uninterruptible power supplies (UPS).
Advanced BMS designs may incorporate features like predictive maintenance, data logging, and integration with smart grid technologies, further expanding their capabilities and importance in modern energy management systems.

Selection Criterion of a Battery Management System.

Selection of a BMS is a critical aspect of battery pack design. As it is responsible for protecting, monitoring and balancing the cells within the pack, additionally should also have the ability to communicate with other systems of the vehicles and diagnose the faults in the system

- **Protection**: Prevents the battery from operating outside its safe limits (overcharging, over-discharging, overcurrent, and overheating).
- **Monitoring**: Continuously measures voltage, current, temperature, and state of charge (SOC) of each cell.
- **Balancing**: Equalizes the charge among cells to maintain uniform performance and prolong battery life.
- **Communication**: Provides data to the vehicle's central control unit and other systems.
- **Diagnostics**: Detects and reports faults and inefficiencies.

For Selection, we should be aware bout the types of BMS available and their operation methodologies

- **Centralized BMS**: All monitoring and control functions are handled by a single unit. Suitable for smaller battery packs.
- **Distributed BMS**: Consists of multiple modules, each monitoring a subset of cells and communicating with a central controller. Ideal for larger battery packs.
- **Modular BMS**: Combines aspects of both centralized and distributed systems, offering scalability and flexibility.

Selection Criteria:

A. Based on the Battery Pack Specification:
   A. **Cell Chemistry**: The BMS being selected must be compatible with the specific cell chemistry (e.g., NMC, LiFePO4). LFP and other specialty chemistries are tricky to configure and may require BMS with critical calibration features as the OCV-SOC Curves are flatter v/s NMC and similar chemistries
   B. **Number of Cells**: Determines the complexity of the BMS. The BMS should support the total number of series and parallel cells in the battery pack.
   C. **Voltage Range**: The BMS must operate within the battery pack's voltage range, supporting both minimum and maximum voltages.
   D. **Capacity**: The BMS should handle the total capacity (Ah) of the battery pack

B. Based on the Functional Requirements:
   A. **Protection Features**: BMS being selected should have Overvoltage, undervoltage, overcurrent, short circuit, and thermal protection for additional protection to the system.
   B. **Cell Balancing**: Passive or active balancing capabilities to reduce the imbalance within the battery pack. The Ability to remove major imbalances is an added advantage.
   C. **SOC and SOH Calculation**: Accurate algorithms for State of Charge (SOC) and State of Health (SOH) estimation help accurate range prediction and life estimation.
   D. **Communication Protocols**: Compatibility with CAN, UART, I2C, or other communication standards for integration with the EV's control systems to communicate with other systems such as motor controller and VCU.

C. Based on the Functional Requirements:
   A. **Accuracy**: Precision in voltage, current, and temperature measurements helps in the accurate gauging of parameters and helps in decision-making.
   B. **Response Time**: The speed at which the BMS responds to changes in battery conditions is critical. Lesser response time is desirable and is a sign of good equipment
   C. **Reliability**: Proven track record and certification for automotive use (ISO 26262 compliance, if applicable).

D. Environmental and Operational Conditions

   A. **Temperature Range**: The BMS should operate effectively within the expected operational temperature range of the EV.
   B. **Vibration and Shock Resistance**: Robustness to withstand the operational environment of an EV

C. **Ingress Protection**: BMS should be compatible to sustain dust and water, Environmental protection ratings like IP and NEMA are desirable.

E. Ease of Integration with the EV System

The selected BMS must seamlessly integrate with the EV's overall system, including:

A. **Motor Controller:** Ensuring synchronization with the motor controller for efficient power delivery.
B. **Charging System:** Compatibility with the vehicle's onboard charger and external charging infrastructure.
C. **Vehicle Control Unit (VCU):** Communication and data exchange with the central vehicle control unit for coordinated operation and diagnostics.

F. Supplier and Support Evaluation

Choosing a reliable supplier is crucial for ensuring the quality and support of the BMS. Consider the following:

A. **Reputation and Experience**: Select based on the supplier's history and expertise in BMS development for automotive applications.
B. **Technical Support and Service**: Ease of availability of technical support, service agreements, and warranty terms.
C. **Customization and Scalability**: Guage the ability to customize the BMS for specific requirements and scalability for future needs.

Technical Specifications of Battery Management System

Figure 2: DALY 16S60V60A BMS

DALY BMS 16S60V60A	
Specification	**Details**
Model	16S60V60A
Manufacturer	Daly
Battery Type Supported	Lithium Iron Phosphate (LiFePO4), Lithium Ion (Li-Ion)
Number of Cells in Series (S)	16S (16 cells in series)
Voltage Range	60V (nominal)
Continuous Discharge Current	60A
Continuous Charge Current	90A
Protection Features	Over-charge, Over-discharge, Over-current, short circuit, Temperature protection

Balance Current	100±30 mA
Balance Method	Passive balancing
Operating Temperature Range	-20°C to 60°C
Storage Temperature Range	-40°C to 85°C
Communication Interfaces	UART, RS485, CAN, Bluetooth
Dimensions	123 mm x 65 mm x 14 mm
Monitoring Functions	Voltage, Current, Temperature, SOC (State of Charge), SOH (State of Health)
Adjustable Parameters	Over-charge voltage, Over-discharge voltage, Over-current, Balance threshold, etc.
Software	PC-based Daly BMS software, Phone Application
Firmware Upgrades	Available via PC software
Application Areas	Electric vehicles, Solar energy storage, Industrial energy storage,
Certifications	CE, RoHS
Mounting	Chassis mount
Max Voltage per Cell	4.25V (Li-Ion), 3.65V (LiFePO4)
Min Voltage per Cell	2.5V (Li-Ion), 2.0V (LiFePO4)
Current Consumption	15mA (operation), 550 μA (standby)

Functional Schematic Block Diagram for the Battery Management System

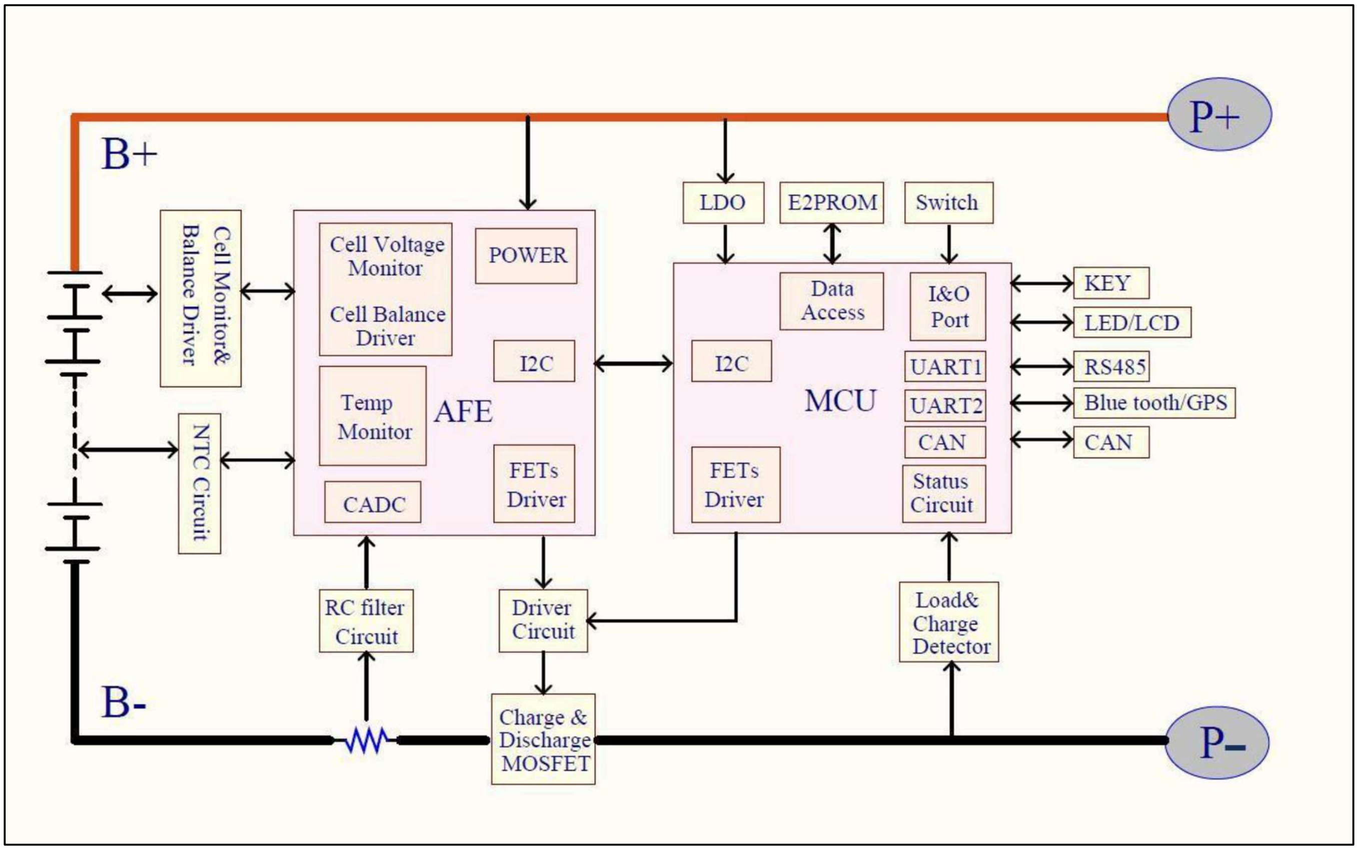


Figure 3: Schematics - Battery Management System

Battery Pack Integration with BMS

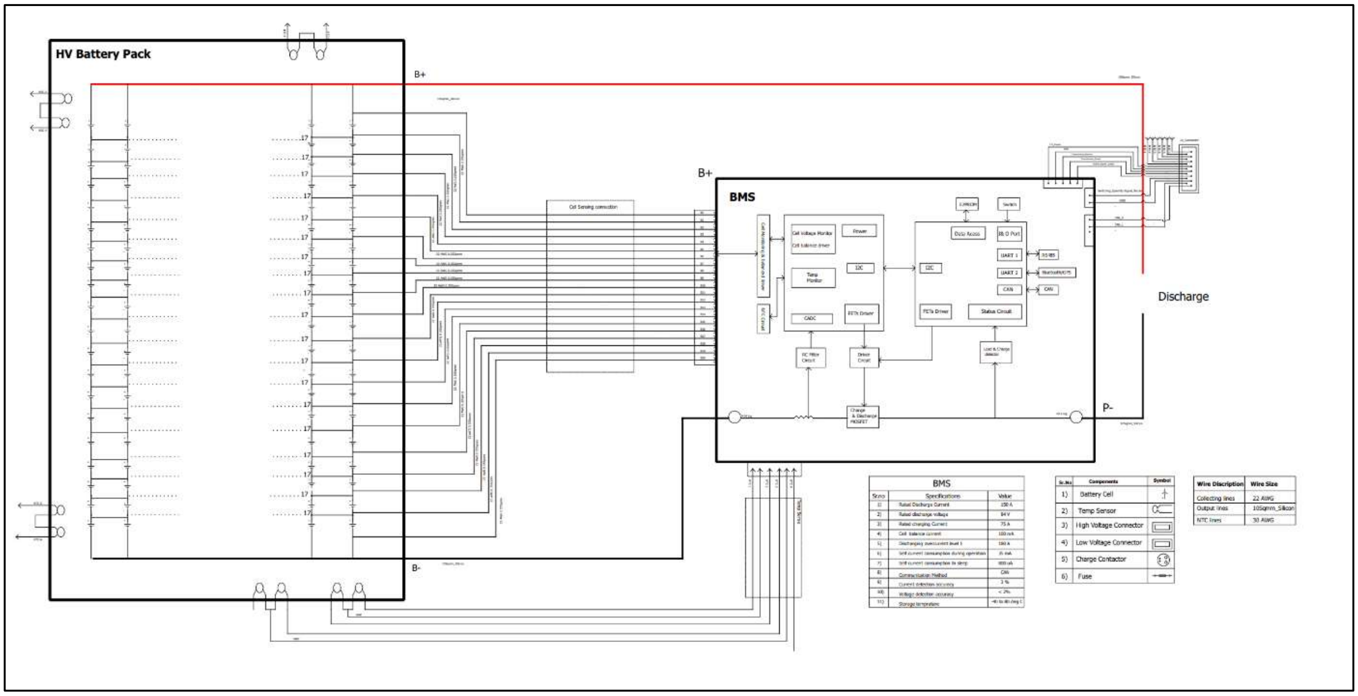


Figure 4: Battery Pack Integration Architecture

1. **FETs Driver and MOSFETs:**
   The architecture includes FET (Field-Effect Transistor) drivers that control MOSFETs (Metal-Oxide-Semiconductor FETs) for switching the battery cells during charging and discharging. These are critical for managing the flow of current and ensuring efficient operation of the battery pack.
2. **Cell Monitoring and Balancing:**
   The system incorporates cell voltage monitors and cell balance drivers. These components ensure that all cells within the battery pack are balanced, which helps in extending the lifespan of the battery and maintaining its performance.
3. **Communication Interfaces:**
   Multiple communication interfaces are included, such as UART (Universal Asynchronous Receiver-Transmitter), I2C (Inter-Integrated Circuit), CAN (Controller Area Network), and RS485. These interfaces allow the BMS to communicate with other systems and components, such as the vehicle's control unit or external monitoring devices.
4. **Temperature Monitoring:**

Temperature monitoring is a critical aspect of BMS to prevent overheating and potential failure of the battery pack. The architecture shows multiple NTC (Negative Temperature Coefficient) thermistors labelled NTC-1, NTC-2, etc., which are used to monitor the temperature of the battery cells.

5. **Low and High Voltage Connectors:**
   The architecture includes connectors for both low-voltage (LV) and high-voltage (HV) systems. This separation ensures safety and efficiency in managing power distribution within the battery pack.
6. **Driver Circuit and RC Filter Circuit:**
   The presence of a driver circuit and an RC (resistor-capacitor) filter circuit indicates additional measures for signal conditioning and protection of electronic components from noise and transients.
7. **EEPROM (Electrically Erasable Programmable Read-Only Memory):**
   The inclusion of an EEPROM suggests that the system can store and retain important data, such as configuration settings, state of charge, and other critical parameters, even when power is removed.
8. **Power and Communication Lines:**
   The architecture uses specific wire sizes (e.g., 22 AWG, 0.35 sq. mm) for power and communication lines. This standardization ensures consistent performance and reliability of electrical connections.
9. **NTC Circuits and Collecting Lines:**
   The NTC circuits are connected to various parts of the battery pack to provide real-time temperature data. Collecting lines gathers these signals for processing by the BMS.
10. **Status Circuit and Communication Receiver/Sender**:
    A status circuit provides operational status, and dedicated communication sender and receiver circuits manage data transmission to and from the BMS.
11. **Specifications and Current Detection:**
    The architecture specifies the system's rated values, such as current detection accuracy (<2%), self-current consumption, storage temperature range, and discharge overcurrent levels. These specifications ensure that the BMS operates within safe and efficient parameters.

Battery Pack Specifications

Technical Specifications of Cell

Figure 5: Panasonic NCR18650GA Cell

Parameter	Value
Brand	Panasonic
Model No.:	NCR18650GA
Capacity (mAh)	3300
Charge Current(A)	1.475
Output Voltage(V)	3.7
Maximum Discharge Rate	3C
Operating Temperature (°C)	-20 to 45
Length (mm):	65.30
Diameter (mm):	18.5
Weight (g):	48

Technical Specifications of Battery Pack

Figure 6: Battery Pack

Sr No	Parameter	Specification
1	Enclosure Material	Mild Steel AISI 1020
2	Handle	Mild Steel AISI 1020. Bolted on
3	Pack Capacity	1.2 KWh (1200 Wh)
4	Pack Voltage	~60V
5	Configuration	16S6P
7	Charging Port	Mounted within the enclosure top cover
8	Dimensions	158x144x260mm (LxWxH)

BMS Configuration Mobile Application

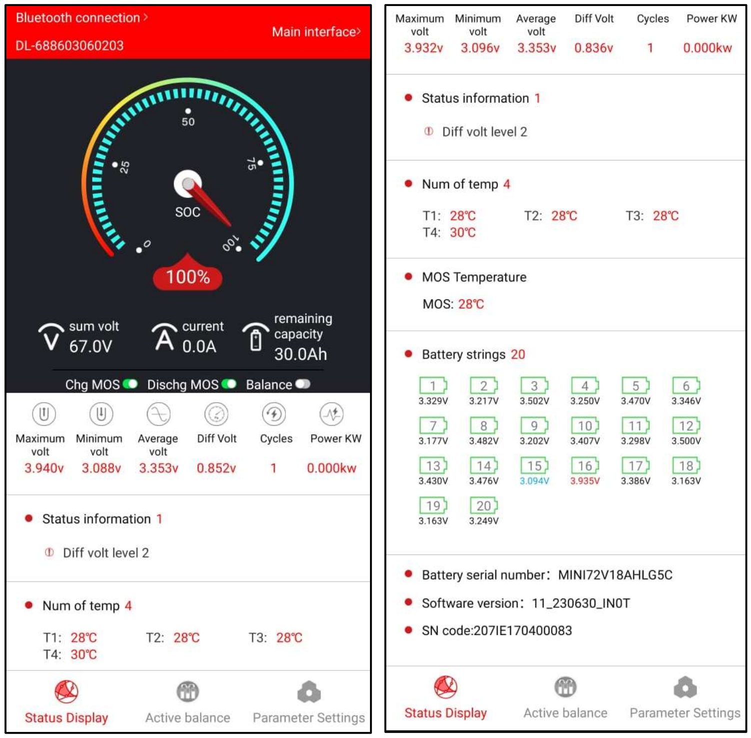


Figure 7: Configuration App Home Screen

Daly BMS offer a smart BMS configuration app to enable used to configure the BMS Based on Bluetooth. The App offers a variety of features including

1. Intuitive Interface: Navigate effortlessly through the app's user-friendly interface, designed for both novice users and seasoned professionals. With clear layouts and intuitive controls, configuring your BMS has never been easier.
2. Customized Configuration: Tailor your BMS settings to meet your specific requirements with ease. Whether you're adjusting voltage thresholds, balancing parameters, or fine-tuning protection limits, the Daly Smart BMS app provides you with the flexibility to customize your configuration to perfection.
3. Real-time Monitoring: Stay informed about your battery system's performance in real-time with comprehensive monitoring capabilities. Track key metrics such as voltage, current, temperature, and state of charge, empowering you to make informed decisions and optimize system performance.
4. Remote Control: Take control of your BMS from anywhere with remote access functionality. Whether you're across the room or across the globe, the Daly Smart BMS app enables you to adjust settings,

monitor performance, and troubleshoot issues remotely, ensuring your battery system operates at peak efficiency at all times.

The app enables the user to configure the following parameters

Protection Parameters	Cell Volt High Protect
	Cell Volt Low Protect
	Sum Volt High Protect
	Sum Volt Low Protect
	Diff Volt Protect
	Charge Overcurrent Protection
	Discharge Overcurrent Protection
Cell Characteristics	Type Of Battery
	Rated Capacity
	Cell Reference Voltage
	Sleep Waiting Time
	SoC Set
	Balance Open Start Voltage
	Balance Open Diff Voltage
Collect Board Settings	Collect Board Num
	Board 1 Num Cell
	Board 2 Num Cell
	Board 3 Num Cell
	Board 1 Temp Num
	Board 2 Temp Num
	Board 3 Temp Num
Temperature Protection Settings	Charge High-Temperature Protection
	Charge Low-Temperature Protection
	Discharge High-Temperature Protection
	Discharge Low-Temperature Protection
	Differential Temperature Protection
	MOS Temperature Protection

For an in-depth experience with the BMS Configuration, Refer to the following Video:

LINK: CLICK HERE

Motor Controller:

A motor controller is an electronic device that regulates the performance of an electric motor in a predetermined manner. It is responsible for starting and stopping the motor, selecting forward or reverse rotation, regulating the speed, limiting the torque, and protecting against overloads and electrical faults. Motor controllers can be used with both direct current (DC) and alternating current (AC) motors. They can be manually, remotely, or automatically operated, and may include only the means for starting and stopping the motor or they may include other functions. Motor controllers may use electromechanical switching or power electronics devices to regulate the speed and direction of a motor. Additionally, the motor controller is also responsible for the following functions and features

A. **Starting and Stopping**: The motor controller is responsible for starting and stopping the motor, providing smooth and controlled transitions. This helps to prevent mechanical shock and prolongs the lifespan of both the motor and the connected machinery.

B. **Direction Control**: It selects forward or reverse rotation, allowing the motor to run in the desired direction. This is essential for applications requiring precise control over the movement, such as conveyor systems, robotics, and electric vehicles.

C. **Speed Regulation**: The motor controller regulates the speed of the motor by adjusting the power supply. This allows for variable speed operation, which is crucial for processes that require different speeds at different stages, enhancing both flexibility and efficiency.

D. **Torque Limiting**: It limits the torque to protect the motor and the machinery from damage caused by excessive force. This is particularly important in applications where over-torque conditions could lead to mechanical failure or safety hazards.

E. **Protection Against Overloads and Electrical Faults**: The motor controller protects against overloads, short circuits, over-voltage, and under-voltage conditions. This ensures the safe operation of the motor and prevents potential damage due to electrical faults.

F. **Compatibility with DC and AC Motors**: Motor controllers can be used with both direct current (DC) and alternating current (AC) motors, making them versatile and suitable for a wide range of applications. This compatibility allows for standardization and simplification in the design and maintenance of motor-driven systems.

G. **Operational Modes**: Motor controllers can be manually, remotely, or automatically operated. This flexibility allows for different levels of control based on the application's requirements, ranging from simple manual switches to sophisticated automated control systems.

- ❖ Additional Functions: In addition to basic start-stop functions, motor controllers may include features such as soft starting, braking, dynamic braking, and regenerative braking. These advanced functions enhance the performance and efficiency of the motor system.

- ❖ Electromechanical and Power Electronics Devices: Motor controllers may use electromechanical switching devices, such as relays and contactors, or power electronics devices, such as transistors and thyristors, to regulate the speed and direction of the motor. Power electronics-based controllers offer higher precision, efficiency, and reliability.

- Integration with Control Systems: Modern motor controllers often integrate with programmable logic controllers (PLCs), human-machine interfaces (HMIs), and other control systems. This integration allows for advanced monitoring, control, and automation capabilities, facilitating complex industrial processes.

The motor controller is a vital component in electric vehicles, significantly impacting their performance, safety, and efficiency. By providing precise control over motor operation, the motor controller enhances the driving experience, ensures optimal energy usage, and maintains the longevity of the electric drivetrain. As EV technology continues to advance, motor controllers are expected to play an increasingly important role in achieving higher performance, efficiency, and safety in electric vehicles.

Selection Criterion of a Motor Controller Unit (MCU):

A Motor Control Unit (MCU) is essential for managing and regulating the operation of an electric motor in various applications, including electric vehicles (EVs). Selecting the appropriate MCU involves matching its capabilities to the specific requirements of your application to ensure optimal performance, efficiency, and reliability. Here are the key considerations and criteria for designing and selecting an MCU.

1. **Assessing Key Functions of an MCU**

A comprehensive MCU performs several critical functions:

A. Motor Control: An MCU should be able to Regulate motor speed, torque, and direction.
B. Feedback Processing: An MCU should be able to process signals from sensors to adjust motor operation.
C. Protection: An MCU should Prevent damages from overcurrent, overvoltage, overheating, and other faults.
D. Communication: An MCU should be able to Interface with other system components for coordinated operation.
E. Efficiency Optimization: An MCU should be able to maximise motor efficiency through advanced control algorithms.

2. **Types of Motors and Their Control Requirements**

Different types of motors have distinct control requirements:

A. DC Motors: These motors are controlled using simple control using pulse-width modulation (PWM) for speed and direction control.
B. Brushless DC (BLDC) Motors: These motors Require precise commutation control using electronic sensors or sensor less techniques.
C. Stepper Motors: These motors are controlled by sending pulses to the motor's windings to achieve precise positioning.
D. Induction Motors: These motors require variable frequency drives (VFD) for speed control.
E. Permanent Magnet Synchronous Motors (PMSM): These motors are controlled using advanced vector control (field-oriented control) for efficient operation.

Selection Criteria:

1. Selection Based on Motor Specifications

   A. **Type of Motor**: Ensure the MCU supports the specific type of motor (DC, BLDC, stepper, induction, PMSM).
   B. **Voltage and Current Ratings**: The MCU should handle the motor's operating voltage and current requirements.
   C. **Power Rating**: Match the MCU's power handling capabilities to the motor's power needs.

2. Selection Based on Control Requirements:

   A. **Speed Control**: Determine the method for speed control. Simple speed control (PWM) or more advanced methods (vector control) are methods with motor speed controlled.
   B. **Torque Control**: The ability to regulate the motor's torque output, critical for applications like EVs.
   C. **Position Control**: Necessary for applications requiring precise positioning, such as robotics and CNC machines.

3. Selection Based on Compatibility with Feedback Mechanisms

   A. **Sensors:** Check if the MCU Hardware can support various sensors (Hall effect sensors, encoders, resolvers) to provide accurate feedback.
   B. **Sensor less Control**: Use of Advanced algorithms can be done for sensor less operation to reduce cost and complexity.

4. Selection Based on Availability of Communication Interfaces

   A. **Protocols**: Explore compatibility with communication protocols like CAN, UART, SPI, and I2C for integration with other system components.
   B. **Real-time Data Exchange**: The ability to provide real-time data to central controllers for coordinated operation is critical.

5. Selection Based on Performance and Reliability

   A. **Processing Power**: MCU should have sufficient computational power to handle control algorithms and feedback processing.
   B. **Response Time**: MCU should react to a fast response to changes in motor conditions to maintain performance and safety.
   C. **Reliability**: MCU should have a proven track record and compliance with industry standards for automotive or industrial applications.

6. Selection Based on Environmental and Operational Conditions

   A. **Temperature Range**: The MCU should operate effectively within the expected temperature range of the application.
   B. **Vibration and Shock Resistance**: Robustness to withstand the operational environment of the application.

7. Additional Features for value addition

   A. **Thermal Management**: Ease of Integration with cooling systems to prevent overheating is an important aspect of the selection of hardware.

B. **Safety Features**: Built-in protection mechanisms for overcurrent, overvoltage, and thermal shutdown.
C. **Firmware Upgradability**: Ability to update the MCU firmware for improvements or bug fixes.

8. Selection Based on Ease of Integration with the Overall System

The selected MCU must seamlessly integrate with the overall system, including:

A. **Motor**: To ensure compatibility and optimal control of the motor.
B. **Power Supply/ Battery Pack**: To Match the MCU's power requirements with the available power supply.
C. **Vehicle Control Unit**: To enable Communication and data exchange with the central control unit for coordinated operation and diagnostics.

Technical Specifications:

Figure 8: Kelly MCU KLS7218NC

Specification	Details
Model	KLS7218NC
Manufacturer	Kelly Controls, LLC
Voltage Range	48V - 72V
Continuous Current	Up to 120A
Peak Current	240A
Motor Type Supported	PMSM (Permanent Magnet Synchronous Motor)
Operating Temperature	-40°C to 100°C
Storage Temperature	-40°C to 70°C
Cooling Method	Natural cooling, Additional fan connector thermal performance
Efficiency	≥ 98%
Communication Interfaces	CAN Bus
Control Modes	Torque mode, Speed mode, Position mode
Input Signal	0-5V throttle, CAN bus
Protection Features	Over-voltage, Under-voltage, Over-temperature, Over-current, short circuit
Dimensions	126 mm x 106 mm x 72 mm
Software	PC-based Kelly Programming Software (KLS)
EMC Compliance	EN 61000-6-4:2007+A1:2011, EN 61000-6-2:2005
Certifications	CE, RoHS
Mounting	Chassis mount
Adjustable Parameters	Acceleration, Deceleration, Max Speed, Min Speed, Torque limit, etc.
Max RPM Supported	Up to 10,000 RPM (depending on the motor)
Firmware Upgrades	Available via PC software
Application Areas	Electric vehicles, Electric bikes, Industrial machinery, Robotics, Marine applications

Motor Controller Configuration Specifications

Figure 9: MCU Configuration Screen

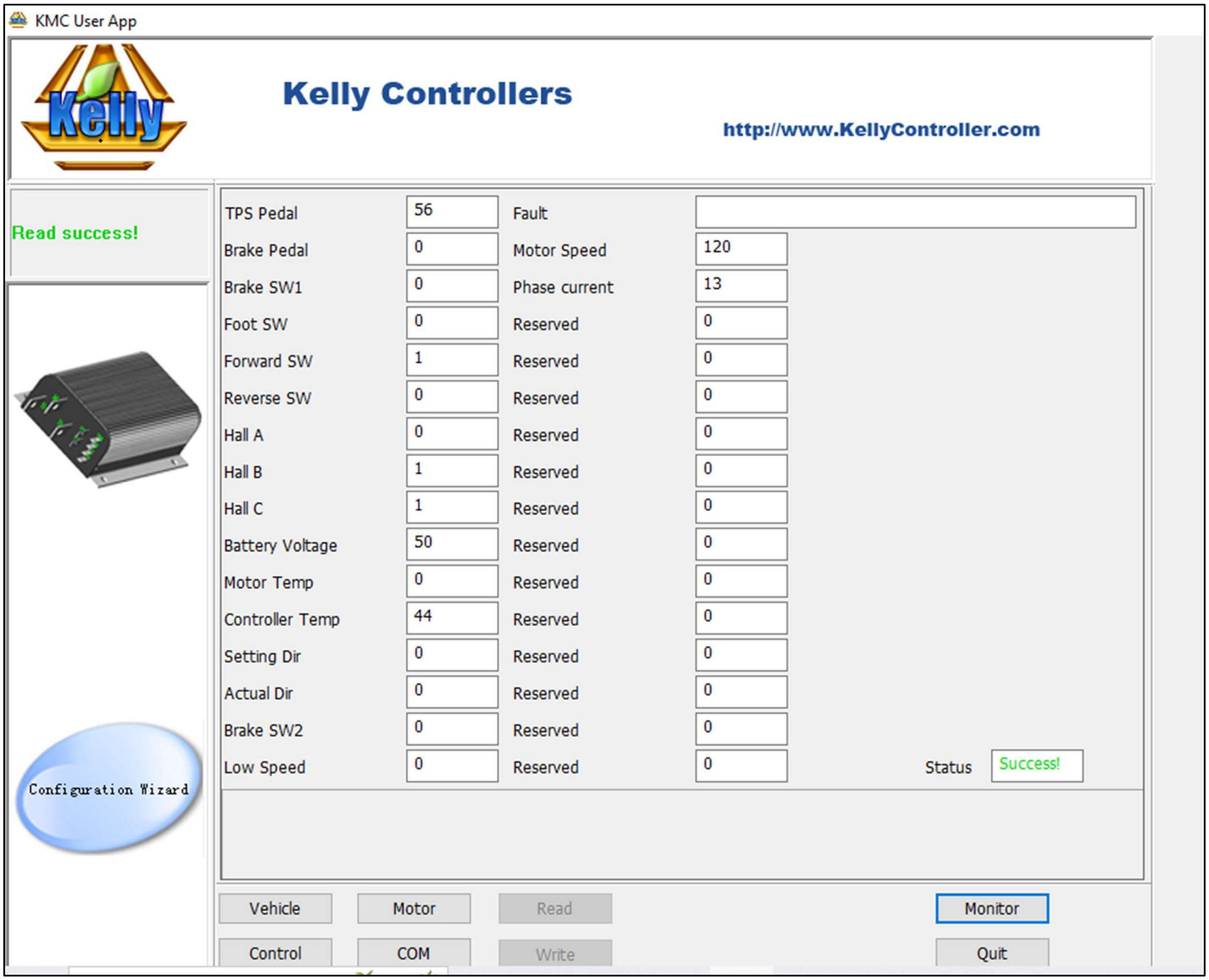


Figure 10: MCU Monitoring Screen

KAC-N Configuration program allows users to set parameters according to the vehicle's actual working environment to be at its best.

There are three types of programmable parameters: vehicle control parameters, motor control parameters and controller parameters. The default parameters of the controller are not recommended for all applications. Make sure to set the proper parameters before making any test to avoid danger

A user will be required to have high-level parameters to configure the MCU:

1. Nominal Motor Voltage
2. Rated Power
3. Rated Speed
4. Rated frequency
5. Motor Poles
6. Hall sensor Output Data

For overview of configuration process please refer to Experiments along with the user manual provided for the hardware.

MCU Error Codes Description

Code		Explanation	Solution
1,1	* *	Automatic error identification	- Wrong wiring of motor phase line or hall. - Please suspend the motor when enable Auto-Identify function.
1,2	* **	Over voltage error	- Battery voltage is too high for the controller. - Check battery volts and configuration. - Regeneration over-voltage. Controller will have cut back or stopped regen. - This only accurate to ± 2% upon Overvoltage setting.
1,3	* ***	Low voltage error	- The controller will clear after 5 seconds if battery volts returns to normal. - Check battery volts & recharge if required.
1,4	* ****	Reserved	
2,1	** *	Motor did not start	- Motor did not reach 25 electrical RPM within 2 seconds of start-up. Hall sensor or phase wiring problem
2,2	** **	Internal voltage fault	- Measure that B+ & PWR are correct when measured to

			B- or RTN - There may be excessive load on the +5V supply caused by too low a value of Regen or throttle potentiometers or incorrect wiring. - Controller is damaged. Contact about a warranty repair. - If this error code occurs, the relay function on plin9 will be deactivated.
2,3	** ***	Over temperature	- The controller temperature has exceeded 100℃. The controller will be stopped but will restart when temperature falls below 80℃
2,4	** ****	Throttle error at power-up	- Throttle signal is higher than the preset ‘dead zone’ at Power On. Fault clears when throttle is released.
3,1	*** *	Reserved	
3,2	*** **	Internal reset	- May be caused by some transient fault condition like a temporary over-current, momentarily high or low battery voltage. - This can happen during normal operation

3,3	*** ***	Hall throttle is open or short-circuit	- When the throttle is repaired, a restart will clear the fault
3,4	*** ****	Angle sensor error	- Speed sensor type error customers may set the correct sensor type through user program or App. - Please download how to use Identification function instruction from the website. - Incorrect wiring. - Speed sensor is damaged or defective. Or feedback signal is faulty.
4,1	**** *	Reserved	
4,2	**** **	Reserved	
4,3	**** ***	Motor over-temperature	Motor temperature has exceeded the configured maximum. The controller will shut down until the motor temperature cools down.
4,4	**** ****	Hall Galvanometer sensor error	Hall galvanometer device is damaged inside the controller.

CAN Gateway board

CAN gateway is customized hardware used to transmit & receive data from vehicles over CAN channels. It is mainly used to build gateways for different baud rate configured powertrain components.

Figure 11: Can Gateway

Following is the configured baud rate of the component:

1. BMS: 250mbps
2. MCU: 250mbps
3. HMI/cluster:500mbps

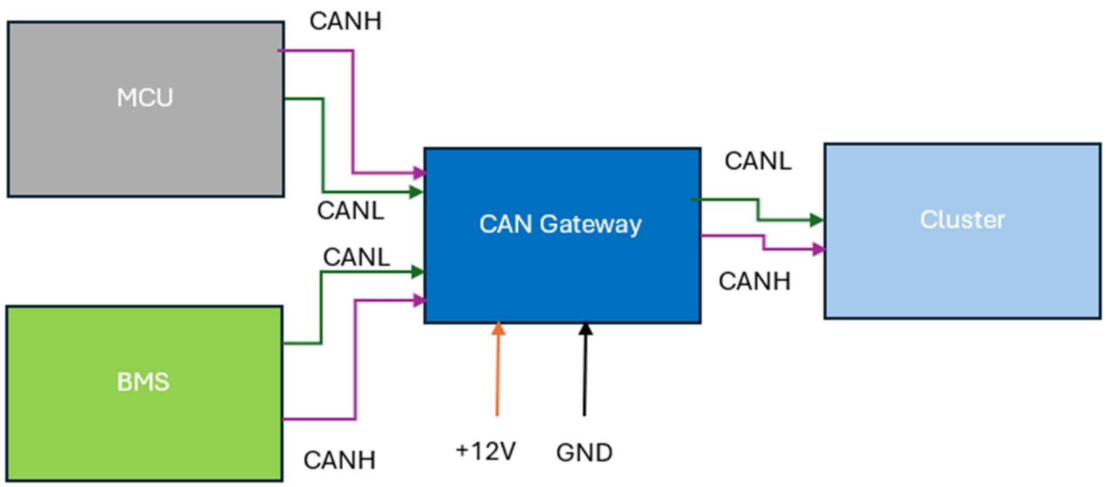


Figure 12: Block diagram of CAN gateway

As shown in the block diagram following is the functionality of the gateway:

1. The motor controller will send data to CAN with a baud rate of 250mbps
2. The battery management controller will send data to CAN with a baud rate of 250mbps
3. CAN gateway has an inbuilt microcontroller of STM32 series which will parse the data coming on the different baud rates.
4. Parsed data will be transmitted to the cluster with the defined ID mentioned on the Cluster configuration with a baud rate of 500mbps.

Flowchart for CAN gateway:

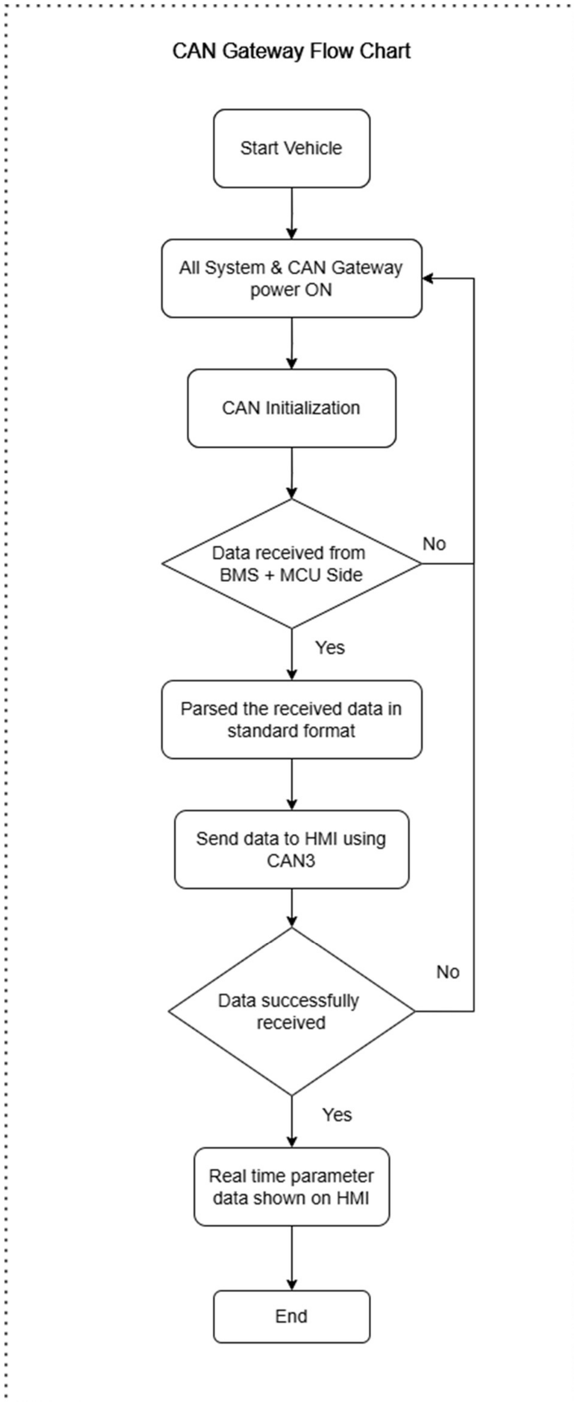


Figure 13: Flowchart

Advantages of CAN gateway in automotive application:

CAN (Controller Area Network) gateways serve as pivotal components in automotive and industrial applications, providing several advantages:

1. **Protocol Translation**: CAN gateways facilitate communication between different CAN networks with varying protocols. They can translate messages from one protocol to another, enabling interoperability between devices and systems that utilize different communication standards.
2. **Integration of Diverse Systems**: CAN gateways enable the integration of diverse systems and subsystems within a vehicle or industrial setup. They allow components from different manufacturers or with different communication protocols to communicate seamlessly, enhancing overall system functionality and interoperability.
3. **Data Filtering and Routing**: Gateways can filter and route CAN messages based on specific criteria such as message ID, data content, or source. This capability optimizes bandwidth usage and reduces processing overhead by directing relevant messages to their intended destinations.
4. **Diagnostic Capabilities**: CAN gateways often include diagnostic features that monitor network health, detect faults, and provide real-time feedback on system performance. These capabilities aid in troubleshooting, maintenance, and ensuring the reliability of connected systems.
5. **Scalability and Flexibility**: CAN gateways offer scalability to accommodate growing network requirements and evolving system architectures. They can be reconfigured or upgraded as needed to support additional functionalities or accommodate changes in system topology.
6. **Reduced Wiring Complexity**: By consolidating communication channels and facilitating data exchange between different subsystems, CAN gateways help reduce wiring complexity within vehicles or industrial machinery. This simplification streamlines installation, reduces weight, and lowers overall manufacturing costs.
7. **Standardization and Interoperability**: CAN gateways adhere to standardized communication protocols, ensuring interoperability between components and systems from different vendors. This standardization promotes ecosystem compatibility and facilitates the integration of third-party devices into existing infrastructures.

Cluster Overview

- Human-machine interface shows the status of the system/vehicle to the user and allows the user to control the system/vehicle.
- Test Rig comprises an HMI display module, which operates on a 12V DC supply and communicates with the CAN GATEWAY using CAN communication.
- There are four connections in use: the first is 12V supply, the second is ground and the remaining two are CAN High and CAN Low indicated with different colours. 12V Supply and Ground connections are connected to a 12V adaptor. CAN High and CAN Low are connected to the White connector Pin connector for communication with Peak CAN.

Figure 14: HMI

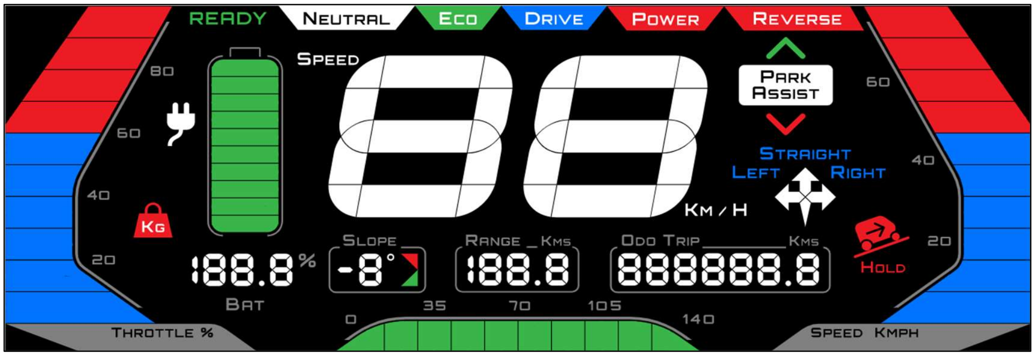
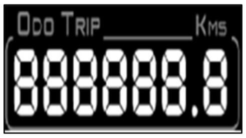


Figure 15: LCD Layout artwork

HMI Parameter List

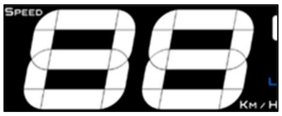
1. **Odo Meter:**



Testing the ODO meter parameter ensures that the distance displayed on the HMI is accurate. This parameter is located within the 0x14234051 CAN ID, covering the first three bytes (0 to 23) with a factor of 0.1, guaranteeing precise mileage readings over the Peak CAN network.

Note: Cluster can calculate ODO value from vehicle speed parameter and vehicle RPM.

2. **Vehicle Speed and Vehicle RPM**



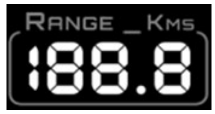
Vehicle speed parameter involves assessing data integrity within the range of 0 to 99 units, using CAN Id 0x14234052 (4th and 5th byte).

3. **Vehicle mode**

Drive modes in two-wheeler electric vehicles (EVs) refer to different operating modes that allow riders to select the level of performance, efficiency, or power delivery based on their preferences or the riding conditions.

1. **Eco Mode**: Limits acceleration and top speed to conserve battery power.
2. **Drive Mode**: Offers a standard or balanced setting for everyday riding.
3. **Power Mode**: Provides quicker acceleration, higher top speed, and more responsive throttle.
4. **Reverse Mode**: This mode shows the vehicle driving in reverse direction, to check this mode try to change CAN id: 0x 14234053(0th byte 1st-bit value).

4. **Distance to Empty**



This evaluation ensures a precise representation of the remaining travel distance on the HMI, crucial for driver awareness and planning. This value change/test by CAN ID: 0x14234052 (2nd and 3rd byte) with 0.1 factor.

5. **Ready Signal:**

This assessment ensures an accurate indication of system readiness on the HMI, essential for operational status awareness.

6. **Park Assist Forward / Reverse:**

Evaluating two separate signals within the CAN ID transmission: 'Forward' and 'Reverse'. Each signal is represented by a single bit with values of 0 or 1, ensuring accurate detection and indication of parking assistance directions on the HMI.

7. **Hill Hold:**

This evaluation ensures an accurate indication of the activation status of the hill hold feature on the HMI, crucial for driver assistance and safety on inclines.

8. **Overload:**

This evaluation ensures a precise indication of overload conditions on the HMI, crucial for maintaining vehicle safety and performance.

9. **Throttle Percentage:**

This assessment ensures an accurate representation of throttle position on the HMI, essential for monitoring vehicle performance and efficiency.

10. **Navigation**

They are representing different navigation states. Values include NAV_OFF (0x00), STRAIGHT NAVIGATION (0x01), RIGHT NAVIGATION (0x02), and LEFT NAVIGATION (0x03). Reserved values include 4, 5, 6, and 7. This evaluation ensures an accurate indication of navigation instructions on the HMI, enhancing driver guidance and awareness.

11. **Error Code:**

They are indicating various error states. Values include No error (0x00), Battery error (0x01), and Malfunction (0x02). Reserved values include 3 through 9. This assessment ensures accurate detection and reporting of vehicle errors on the HMI, facilitating prompt troubleshooting and maintenance.

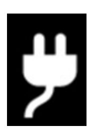
12. **Thermal Runway:**

This evaluation ensures an accurate indication of the thermal runaway status on the HMI, critical for monitoring and preventing potential overheating issues.

13. **SOC percentage:**

This evaluation ensures an accurate depiction of the battery charge level on the HMI, crucial for monitoring and optimizing vehicle performance and range.

14. **Charging Info:**



This assessment ensures an accurate indication of the vehicle's charging status on the HMI, vital for user awareness and monitoring of charging processes.

Experiment 1.1

Title – DBC file configuration and BUSMASTER handling.

Aim - To create a DBC file from the CAN matrix and associate it with the BUSMASTER software.

Tools and software- BUSMASTER, VectorCANdb++ and MSExcel.

Introduction:

The CAN matrix is a table structure, essentially defining which ECU sends which message and with which cycle time. CAN matrix is a simple Excel file containing data about all messages and signals that will be transmitted and received by the specific ECU. From this CAN matrix data, you will have to create a DBC file in VectorCANdb++ software and then associate this DBC file with the BUSMASTER software.

			Byte6-Byte7：SOC（0.1%）
单体最高最低电压 Maximum Minimum Voltage of Monomer	0x91	发送 Send	Byte0~Byte7:Reserved
		返回Return	Byte0~byte1：最高单体电压值（mV）maximum monomer voltage (mV) Byte2：最高单体电压cell号 Maximum Unit Voltage cell No. Byte3~byte4：最低单体电压值（mV）minimum monomer voltage (mV) Byte5：最低单体电压cell号Minimum Unit Voltage cell No.
单体最高最低温度 Maximum minimum temperature of monomer	0x92	发送 Send	Byte0~Byte7:Reserved
		返回Return	Byte0：最高单体温度值（40 Offset，°C） maximum monomer temperature (40 Offset,°C) Byte1：最高单体温度cell号 Maximum monomer temperature cell No. Byte2：最低单体温度值（40 Offset，°C）minimum monomer temperature (40 Offset,°C) Byte3：最低单体温度cell号Minimum Monomer Temperature cell No.
充放电、MOS 状态 Charge/discharge, MOS status	0x93	发送 Send	Byte0~Byte7:Reserved
		返回Return	Byte0：充放电状态（0静止，1充电，2放电）charge/discharge status (0 stationary ,1 charged ,2 discharged) Byte1：充电MOS管状态charging MOS tube status Byte2：放电MOS管状态discharge MOS tube state Byte3:BMS life（0~255循环）BMS life(0~255 cycles) Byte4~Byte7:剩余容量（mAH） residual capacity (mAH)
状态信息1 Status Information 1	0x94	发送Send	Byte0~Byte7:Reserved
		返回Return	Byte0：电池串数 battery string Byte1：温度个数 temperature Byte2:充电器状态（0断开，1接入）charger status (0 disconnected ,1 connected) Byte3：负载状态（0断开，1接入）load status (0 disconnected ,1 access) Byte4： Bit 0: DI1 state Bit 1: DI2 state Bit 2: DI3 state Bit 3: DI4 state Bit 4: DO1 state Bit 5: DO2 state Bit 6: DO3 state Bit 7: DO4 state Byte 5~Byte6 :充放电循环次数charge/discharge cycles Byte7:Reserved

Figure 16: CAN Matrix

Procedure:

1) Open kvaser Database Editor software, go to the file tab → Create database.
2) **Open the Database File**:
   - Open the Kvaser Database Editor.
   - Load or create a new database file (e.g., CANtemplate.dbc).
3) **Create a New Message**:
   - In the main toolbar, select the **Messages** tab.
   - Right-click in the message window and select **Add Message** or **New Message**.
   - In the properties window, assign a name for the message.
   - Set the **CAN Type** as **Standard**.
   - Assign a unique **ID** for the message.
   - Set the **DLC** (Data Length Code) to 8 bytes to specify the message length.
   - Click **Apply** and **OK** to save your changes. You should now see your created message in the message window.
4) **Add a Signal**:
   - Go to the **Signals** tab.
   - Right-click in the signal window and choose **Add Signal** or **New Signal**.
5) Enter a name for the signal.
6) Set the **length** of the signal in bits. This will depend on the maximum value that the signal represents:
7) For example, to represent a pack voltage of up to 60V, set the length to **6 bits** (since 60 in binary requires 6 bits).
8) **Configure the Signal Properties**
   - Adjust any additional parameters for the signal, such as the start bit, scaling, offset, and unit (if necessary for your application).
9) Click **Apply** and **OK** to save your settings.
10) After defining your messages and signals, save the database file.

In this way you can create the DBC file and associate it in BUSMASTER software by converting it to a dbf.

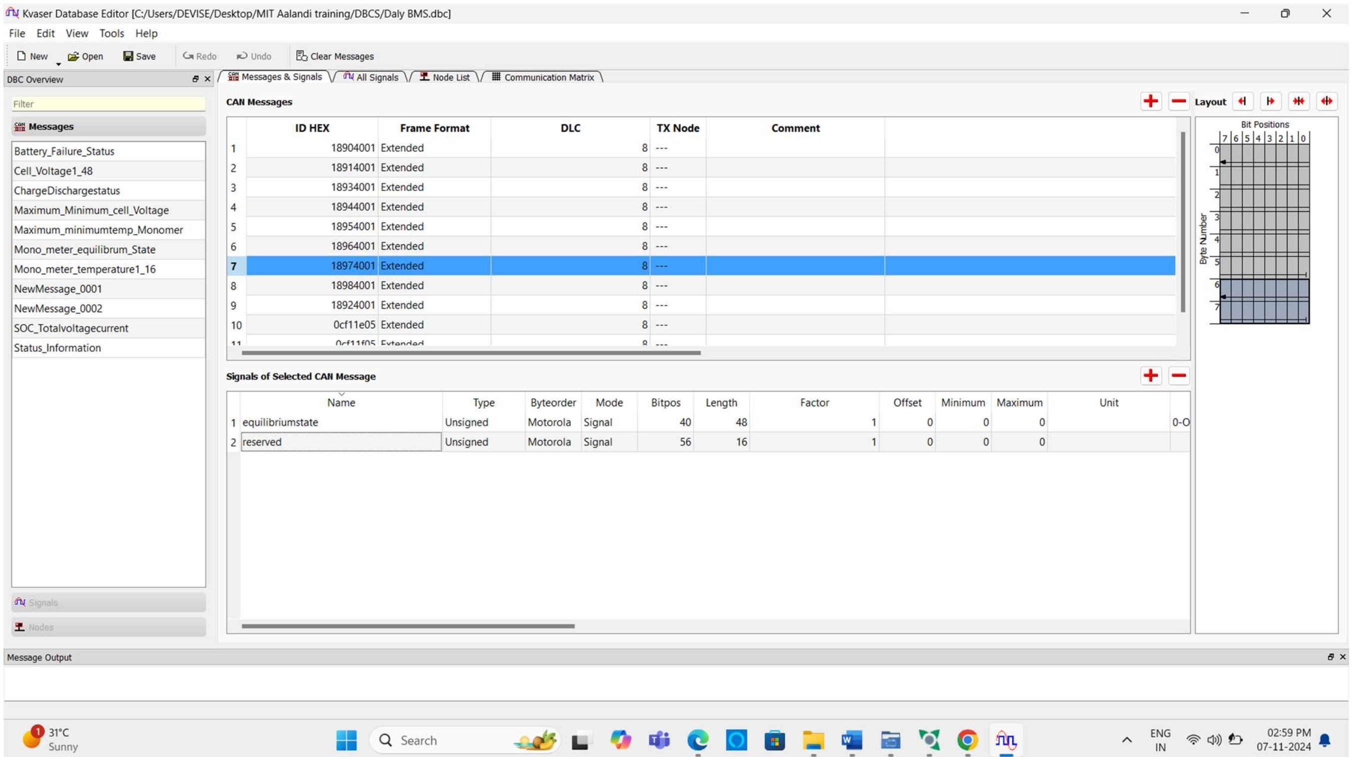


Figure 17: kvaser Database Editor

Experiment 1.2

Title – CAN data logging and signal plotting.

Aim - To log the CAN data into a .txt file plot the signal and observe the trends.

Tools and software – BUSMASTER, Signal Excel and signal plot app.

Procedure:

1) After associating the .dbf file in BUSMATSER.
2) Connect the Peak CAN USB connector to your PC and DB9 connector to the CAN node given to your vehicle.
3) Go to driver selection→ select Peak USB → add the Peak USB → set baud rate to 250 or 500 kbps → OK.
4) Now you will be able to see the messages received in the message window. To interpret these messages, click on the message window tab and check on the interpret option.
5) To log CAN data, click on the logging tab in BUSMASTER → configure → Add →select path→ file mode "append" → OK.
6) You are done with the file setup of the CAN log, now to activate the log, make sure you are connected to the CAN and receiving the messages.
7) Go to the logging tab and click on Activate to start data logging after you have taken a log, uncheck the activate option to stop data logging.
8) Open the .txt file of the CAN data log from your PC in Notepad, you will find some text written in between *** …… *** format at the start and end of the log file.
9) Open the file in Signal Excel, Browse DBC and apply.

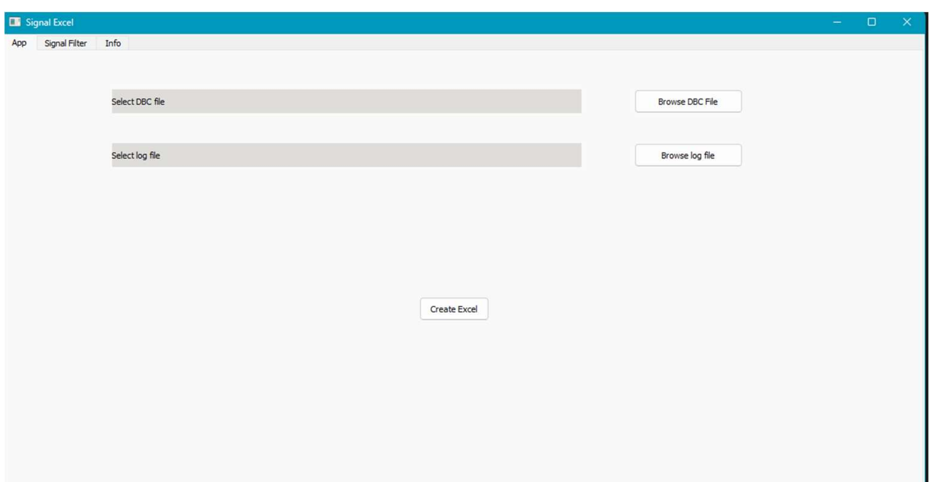
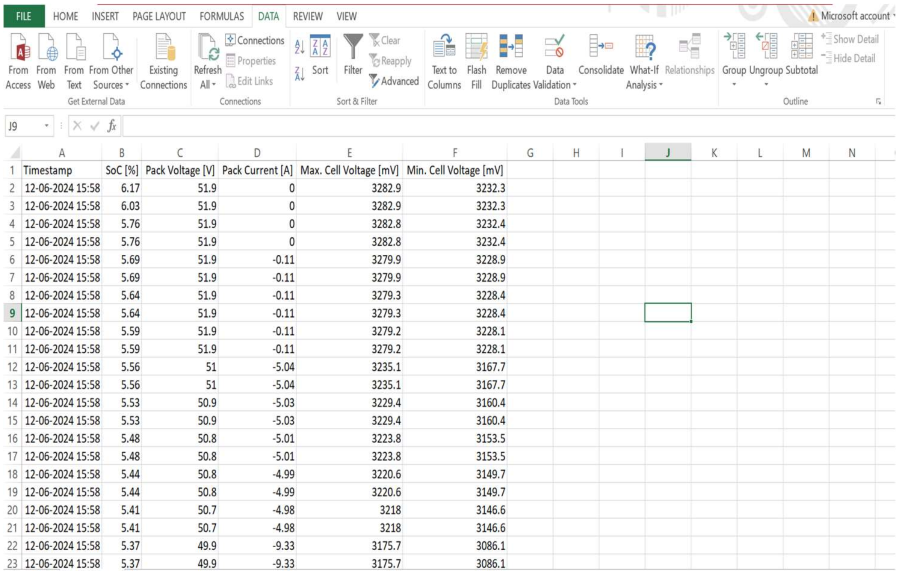


Figure 18: Signal Excel

10) The Software then creates an xls file which can be used for plotting



Timestamp	SoC [%]	Pack Voltage [V]	Pack Current [A]	Max. Cell Voltage [mV]	Min. Cell Voltage [mV]
12-06-2024 15:58	6.17	51.9	0	3282.9	3232.3
12-06-2024 15:58	6.03	51.9	0	3282.9	3232.3
12-06-2024 15:58	5.76	51.9	0	3282.8	3232.4
12-06-2024 15:58	5.76	51.9	0	3282.8	3232.4
12-06-2024 15:58	5.69	51.9	-0.11	3279.9	3228.9
12-06-2024 15:58	5.69	51.9	-0.11	3279.9	3228.9
12-06-2024 15:58	5.64	51.9	-0.11	3279.3	3228.4
12-06-2024 15:58	5.64	51.9	-0.11	3279.3	3228.4
12-06-2024 15:58	5.59	51.9	-0.11	3279.2	3228.1
12-06-2024 15:58	5.59	51.9	-0.11	3279.2	3228.1
12-06-2024 15:58	5.56	51	-5.04	3235.1	3167.7
12-06-2024 15:58	5.56	51	-5.04	3235.1	3167.7
12-06-2024 15:58	5.53	50.9	-5.03	3229.4	3160.4
12-06-2024 15:58	5.53	50.9	-5.03	3229.4	3160.4
12-06-2024 15:58	5.48	50.8	-5.01	3223.8	3153.5
12-06-2024 15:58	5.48	50.8	-5.01	3223.8	3153.5
12-06-2024 15:58	5.44	50.8	-4.99	3220.6	3149.7
12-06-2024 15:58	5.44	50.8	-4.99	3220.6	3149.7
12-06-2024 15:58	5.41	50.7	-4.98	3218	3146.6
12-06-2024 15:58	5.41	50.7	-4.98	3218	3146.6
12-06-2024 15:58	5.37	49.9	-9.33	3175.7	3086.1
12-06-2024 15:58	5.37	49.9	-9.33	3175.7	3086.1

Figure 19: Log Data in Excel

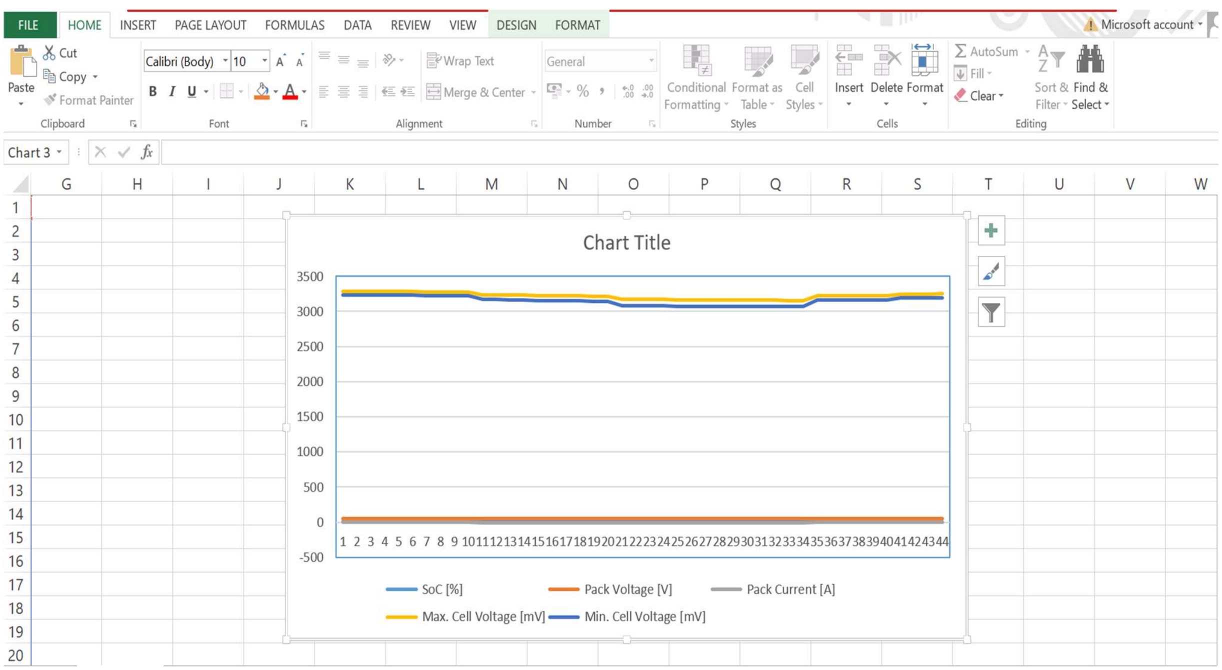


Figure 20: Plot data

11) Plot data: Insert tab, select 2-D line graph.
12) Each signal appears in a different colour with the corresponding timestamp and value.
13) In this way you can log the CAN data and plot to observe and monitor the trends in signal over time.

Learnings 2.1

Title: Kelly motor controller integration with EV Powertrain

Aim: To Study integration of Kelly motor controller with EV powertrain, Battery Power connection, Motor Power, Speed, Integration of Throttle and control Switch Inputs.

Inputs:

- Kelly motor controller
  - Part No: -KLS 7218N
  - Nominal Voltage Range: 48-72V
  - Max Operating Voltage: 36-86V
  - Peak Current 1 Minute: 240A
  - Continuous Current: Up to 120A
- Motor
- Battery
- Brake
- Throttle
- Mode Switch
- Powertrain

Outputs: Powertrain Integration with Kelly Motor Controller

Procedure:

1. Make sure the wire is connected correctly
2. Turn the PWR switch on.
3. With the brake switch open, select a direction and operate the throttle. The motor should spin in the selected direction. Verify wiring or voltage and the fuse if it does not. The motor should run faster with increasing throttle. If not, refer to the Table 1 code, and correct the fault as determined by the fault code.
4. Run the motor in standstill position. It should have smooth acceleration.

Integration Circuit Diagram:

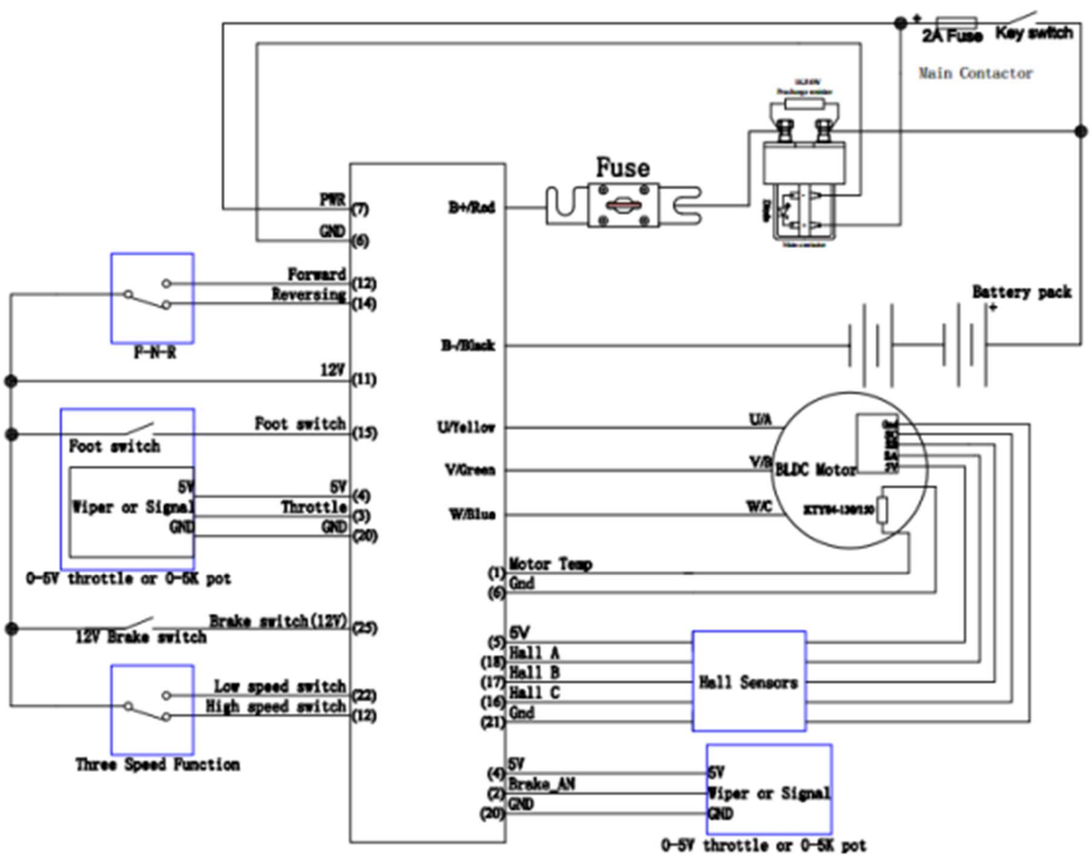
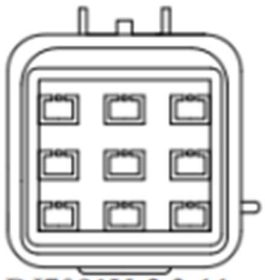


Figure 21: Integration Diagram

Pin Connections:



DJ7091Y-2.3-11
See from output side

Orange REV-SW (14)	Black GND (6)	White FWD (12)
Red 12V (11)	Yellowish 12V Brake (25)	Blue ECO (22)
Greenish CAN_H (33)	Pink PWR (7)	Brownish CAN_L (34)

Figure 22: Motor Controller Connector (DJ091Y-2.3-11) Pin Outs

DJ7091Y-2.3-21
See from output side

Gray Foot_SW (15)	Green Throttle (3)	
Black GND (20)	D-Gray Meter (8)	
Purple 5V (4)	Brown Brake_AN (2)	Red 12V (11)

DJ7061Y-2.3-21
See from output side

Black GND (21)	Raddle Temp (1)	Purple 5V (5)
Yellow Hall A (18)	D-Green Hall B (17)	D-Blue Hall C (16)

Figure 23: Motor Controller Connector (DJ091Y-2.3-21) Pin Outs

DJ7091Y-2.3-11 Pin Definition:

(14) REV_SW: Reverse switch input. Orange

(6) RTN: Signal return or power supply return. Black

(12) FWD: Forward switch or can be enabled as a High-speed switch function. White

(11) 12V:12V Source Red

(25) 12V brake switch. Yellowish

(22) ECO: Low-speed switch function. Blue

(33)CAN-H: Greenish (Optional function) (7) PWR: Controller power supply (input). Pink

(34)CAN-L: Brownish (Optional function)

DJ7091Y-2.3-21 Pin Definition:

(15) Micro_SW: Throttle switch input. Gray

(3) Throttle: Throttle analog input, 0-5V. Dark Green

(20) RTN: Signal return. Black

(8) Meter: Copy signal of hall sensors. Dark Gray

(4) 5V: 5V supply output, Purple

(2) Brake_AN： Brake variable regen or Boost function. Brown

DJ7061Y-2.3-21 Pin Definition:

(21) RTN: Signal return. Black

(1) Temp: Motor temperature sensor input. Raddle.

(5) 5V: 5V supply output,

(18) Hall A: Hall phase A. Yellow

(17) Hall B: Hall phase B. Dark Green

(16) Hall C: Hall phase C. Dark Blue

Notes:

1. All RTN pins are internally connected.
2. The meter function is to copy either of the hall sensors.
3. Switch to 12V is active. The open switch is inactive.
4. F-N-R control and three-speed function cannot be used at the same time. They both used the same pin as pin12=FWD

Experiment 2.2

Aim:To Study Communication port interface with MCU for Parameter configuration and monitoring.

Inputs:

- Kelly motor controller
  - Part No: -KLS 7218N
  - Nominal Voltage Range: 48-72V
  - Max Operating Voltage: 36-86V
  - Peak Current 1 Minute: 240A
  - Continuous Current: Up to 120A

- Configuration Tool
- Motor
- Battery
- Integrated Powertrain

Outputs: Understanding of communication port interface with Kelly motor controller for monitoring and calibration.

Procedure:

1. Download the drivers for the Tool and Kelly Motor Controller PC Software.
2. Make sure the Tool is connected to the MCU properly.
3. Make sure the PWR connection is connected properly
4. After the making connection open Kelly Software allows the permission and configures the parameters as described in the below experiments.
5. After the writing new parameters make the power OFF-ON cycle, then reconnect the tool for parameter monitoring.

Experiment 2.3

Aim: To study the Mapping and configuration of motor and controller parameter.

Inputs:

- Kelly motor controller
  - Part No: -KLS 7218N
  - Nominal Voltage Range: 48-72V
  - Max Operating Voltage: 36-86V
  - Peak Current 1 Minute: 240A
  - Continuous Current: Up to 120A
- Configuration Tool
- Motor
- Battery
- Integrated Powertrain
- Toggling switch to Eco & Sport mode.

Outputs:

- Learning parameter configuration and behavior of the motor.

(Warning: Modifying these values can be risky and should only be done with proper knowledge of your specific Motor and Motor controller. Refer to the MCU manual or manufacturer recommendations before making any changes.)

Procedure of Parameter Configuration

1. KLS Configuration program allows users to set parameters according to the vehicle's actual working environment to be at its best.
2. The default parameters of the controller are not recommended for all applications. Make sure to set the proper parameters before making any test to avoid danger.
3. Students can do programs on PC software. First of all, people need to do the Identification angle function for the KLS controller before running the motor.
4. The controller needs to be connected to batteries, motor and throttle before Identification operation.
5. That is to say, it is not enough to connect only the power supply (PWR=pin7) to batteries for Identification Angle operation.

Vehicle Configurable Parameters –

(1) Low Volt:
The minimum voltage for reporting this fault is - Range 20~86, depending on the model.
The controller will not operate when the battery voltage is near the value to protect the battery.

(2) Over Volt:
The max voltage of reporting this fault is - Range 20~86, depending on the model.
The controller will not operate when the battery voltage is higher than the value to protect the battery and controller.

(3) Current Percent:
Phase Current Percent. Range: 20~100 Functional description: The max motor current is (The Value * Peak Current of the Controller).

(4) Battery Limit:
Battery Limit Current, Limits the max value of Battery Current.
Range: 20~100 Functional description: Set max battery current to protect the battery. A lower value means a lower battery output current and a better protective effect. However, the excessively low value will affect acceleration.

(5) Identification Angle:
If you can read 85 in the Identification Angle item, that is to say, the system is stable and normal. Please fill in 170 for the Identification Angle item in the user program. Then please click the Write button in the user program. Please wait a few seconds before restarting the power supply. You will see some info on the Monitor screen after the power supply is reset. If you see a Reset Error on the Monitor screen, that is to say, the auto_Identification is finished. You can see 85 in the Identification Angle item again. And the controller will blink the error code. This is normal operation for the controller. Please reset the power supply again. The motor is ready to be derived by the KLS controller.
Range: 85 or 170, nothing else.

(6) TPS Low Err:
Hall active pedal, if lower than the value, reports the fault of TPS Type. Range: 0~20

(7) TPS High Err:
Hall active pedal, if higher than the value, reports the fault of TPS Type.
Range: 80~100 As you may know, the output of the hall throttle from Kelly is about 0.86V to 4.2V.

(8) TPS Type:
TPS Type, 1:0-5V 3-wire 0-5K pot,5K is normal,2K-20K can be used;2: Hall active throttle or pedal. Range: 1~2

(9) TPS Dead Low:
TPS Dead Zone Low. Range: 5~40
Functional description: Set throttle effective starting point Suggestion: Set according to the practical situation, factory default is 20%*5V=1.0V.

(10) TPS Dead High:

TPS Dead Zone High. Range: 60~95
Functional description: Set throttle effective ending point Suggestion: Set according to the practical situation, factory default is 80%*5V=4.0V.

(11) Brake sensor type:
Brake sensor type for brake variable regen mode: 1:0-5V 3-wire 0-5K pot,5K is normal,2K-20K can be used;2: Hall active throttle or pedal. Range: 1~2

(12) Brake sensor Dead Low:
Brake sensor Dead Zone Low. Range: 5~40
Functional description: Set throttle effective starting point Suggestion: Set according to the practical situation, factory default is 20%*5V=1.0V.

(13) Brake sensor Dead High:
The brake sensor is Dead Zone High. Range: 60~95
Functional description: Set throttle effective ending point Suggestion: Set according to the practical situation, factory default is 80%*5V=4.0V.

(14) Max output Fre:
Max output frequency. Unit: Hz
Functional description: It will affect the top speed of the motor. Suggestion: Set according to the practical situation, the factory default is 1000Hz.Please don't set it to 1000Hz above.

(15) Max Speed:
Max Speed [rpm]. Range: 0~15000 By default, it is set at 4000. Software version 0109 can support 15000 RPM settings in the user program.

(16) Max Fwd. Speed %:
The forward speed of the percentage of maximum speed. Range: 20~100 By default, it is set at 100%

(17) Max Rev Speed %:
The reverse speed of the percentage of maximum speed. Range: 20~100
By default, it is set at 100% Mid-speed Forward speed, Mid-speed Rev speed, Low-speed Forward speed and Low-speed Rev speed. Range: 20~100 By default, it is set at 100%. Both F-N-R control and three-speed function.
Three-speed: This item is used to enable or disable the three-speed function. By default, it is at 0 0: The speed function is disabled.1: Two-speed function 2: Three-speed function is enabled.

(18) PWM Frequency:
Frequency of PWM operation. Unit: KHz Functional description:20KHz is better for a hub motor with strict quiet control. Suggestion: Set according to the practical situation, the factory default is 20KHz.Please don't set it to 20KHz above. Value Range:10KHz or 20KHz

(19) Start-up H-Pedal:
Value range: Enable and Disable Functional description: If enabled, the controller will detect the current pedal status at power up. If the throttle gets effective output, the controller will report fault and not operate. Suggestion: Set according to the practical situation, factory default is Enable.

(20) Brake H-Pedal:
Releasing Brake High Pedal Disable Value range: Enable and Disable Functional description: If enabled, the controller will detect the current pedal status when releasing the brake. If the throttle gets effective output, the controller will report fault and not operate. Suggestion: Set according to the practical situation, the factory default is disabled.

(21) NTL H-Pedal:
Neutral position High Pedal Disable. Only useful when The gears switch function is enabled. If enabled, the controller will detect the current pedal position or signal When the switch is in the neutral position. If the throttle gets an effective output signal, the controller will not operate and report a fault code. Suggestion: Set according to the practical situation, the factory default is disabled.

(20-A) Three Gears Switch Value range:
Enable and Disable Functional description: If enabled, the Forward switch will be activated.

(20-B) Foot Switch Value range:
Enable and Disable Functional description: If enabled, the foot switch will be activated. The controller will not accept the throttle signal if the foot switch is turned off.

(24) Boost:
If enabled, the controller will output max power for a while. The boost function is just a full throttle position when you turn on the boost switch even if the throttle is not operated at all. The boost function is still based on limiting the motor current and battery current settings in the user program.

(25) Footswitch:
It is used for the micro switch. If enabled, the controller will only accept the throttle signal after receiving the valid foot switch signal. If there is no foot switch signal, the controller will ignore the throttle signal. Suggestion: Set according to the practical situation, the factory default is disabled.

(26) Cruise Control:
Value range: Enable and Disable If enabled, if you hold the throttle at a certain position for about 5 seconds, the controller will get into Cruise control. The Cruise function cannot be activated in a reversing direction. If the motor speed is below 500RPM, the Cruise control cannot be activated. Release the throttle and turn the throttle again or turn on the brake switch will make the Cruise control quit. Suggestion: factory default is disabled.

(27) Anti-Slip:
If enabled, the controller will try to prevent the vehicle from rolling back downhill faster and faster. If the ratio of the gearbox is high, it can try to help the motor stop the downhill. But usually, this function only helps the motor stop rolling back too fast. Suggestion: factory default is disabled.

(28) Change Direction:
If the direction is not what you expected after finishing the Identification angle operation, please just choose the Change Direction item. Please click the Write button to activate the Change Direction function. The motor direction will be what you expected after the power supply is reset. Suggestion: The factory default is Disable

Motor Configurable Parameters:

(1) Motor Nominal Current:
When the controller is doing identification angle operation without load on the motor shaft, there is a current requirement for identification operation. If the motor-rated power is very high, please increase this parameter to a higher value. Otherwise please keep it at 80 by default. If the motor power is very low such as hundreds of watts, please reduce this parameter to a lower value to match the low-power motor for identification angle operation.

(2) Motor Poles:
Motor Poles, The pair pole number*2. Range: 2~128 Suggestion: Set according to the real motor poles on the nameplate of the motor, factory default is at 8.

(3) Speed Sensor Type:
Speed Sensor Type, 2: Hall, 3: Resolver, 4: Line Hall. Range: 2~4 Different sensor types. By default, it is set to 2

(4) Resolver Poles:
Resolver Poles, The pair pole number*2. Range: 2~32 It is only used for the Resolver sensor type.

(5) Motor Temp Sensor:
Motor Temp Sensor, 0：None, 1: KTY84-130 or 150, 2: KTY83-122.
Range 0-2 High Temp Cut Out °C: Motor High Temp Cut Out, nominal value 130°C. Range: 60~170 Resume °C: Motor High Temp Resume Temp, nominal value 110°C. The controller will resume work when the motor temp is at 110 degrees inside. Range: 60~170

(6) Line Hall Zero:
It is only useful when the speed sensor is at 4. Useless for KLS-N or KLS-M model.

Control Configurable Parameter:

(1) RLS_TPS Break %:
RLS TPS Braking Percent, the percent of Releasing Pedal BRK in max braking. Range: 0~50 This is used to adjust the regen current of releasing throttle regen mode type. The regen will happen as long as the throttle is released completely. Factory set is 0

(2) NTL Break %:
NTL Braking Percent, the percent of Neutral Braking in max braking. Range: 0~50 Only useful when you enable the Three gears switch in the user program. The regen will happen when you turn the F-N-R switch from Forward or backwards to a Neutral position. Factory set is 0

(3) Acceleration Time:
Acceleration Time, the time of TPS Torque from 0 to max, accuracy 0.1s, 5 is equal to 0.5s. Range: 1~250 Factory set is 10

(4) Acceleration Release Time:
Acceleration Release Time, the time of TPS Torque from max to 0, accuracy 0.1s. Range: 1~250 Factory set is 1

(5) Brake Time:
Brake Time, the time of Brake Torque from 0 to max, accuracy 0.1s. Range: 1~250 Factory set is 15

(6) Brake Release Time:
Brake Release Time, the time of Brake Torque from max to 0, accuracy 0.1s. Range: 1~250 Factory set is 1

(7) BRK_SW Break %:
BRK_SW Braking Percent, the percent of BRK_SW in max braking. Range: 0~50 the brake switch regen mode. You have to turn on the brake switch after the throttle is released for the regen to occur. Factory set is 10

(8) BRK_AD Break%:
It is used to adjust the max regen percentage of brake variable regen mode. This regens mode doesn't need a brake switch to support any more for the KLS controller.

(9) Torque Speed KP:
Speed Percent Kp in Torque Mode. Range: 0~10000 Factory set is 3000 Torque Speed KI: Speed Integral Ki in Torque Mode. Range: 0~500 Factory set is 80 Speed Err Limit: Speed Error Limit in Torque Mode. Range: 50~4000 Factory set is 1000 these three parameters are used for PID adjustment. If you think the acceleration performance is very strong, please adjust it to a lower value respectively.

(10) Change Dir brake:
Value range: Enable and Disable It is only useful when you enable the joystick function. If you want to get swift direction changing by using the joystick function, you may enable the Change Dir brake item in the user program. It will help the motor change the direction of motor quickly after you shift the throttle from 0V to 5V, or from 5V to 0V. Suggestion: factory default is disabled.

(11) Compensation Per% Tried to increase the current usage during Anti-Slip operation.

(12) IVT BRK MAX and IVT BRK MIN:
These two items are only useful when the Joystick function is enabled in the user program. When you want to use the Change Dir Brake to reduce the delay time when you shift the direction under joystick operation, there is an RPM limitation to use the Change Dir Brake function which is only activated when the motor RPM is between IVT BRK MIN and IVT BRK MAX. Suggestion: factory default is disabled.

(13) Torque Speed Kp:
3000 Torque Speed Ki: 80 Speed Err Limit: 1000

Learning 3.1

Title: Introduction to BMS parameters and terminology.

Aim: Identify key BMS parameters such as cell voltage, current, temperature, and State of Charge (SOC).

Important Definitions:

- **Battery Management System (BMS):** A computer system that manages a battery pack by monitoring its performance and health. –The role of the BMS in:
  - **Monitoring:** Cell voltage, current, temperature, State of Charge (SOC), etc.
  - **Protection:** Implementing safety features to prevent overcharge, over-discharge, overheating, etc.
  - **Optimization:** Balancing cells, maximizing battery life, and improving efficiency.

- **Cell Voltage**: The electrical potential difference between the positive and negative terminals of a single battery cell.
- **Cell Current**: The rate of flow of electric charge through a battery cell, measured in amperes (A).
- **State of Charge (SOC)**: An estimate of the remaining capacity of a battery, expressed as a percentage.
- **Cell Balancing**: Actively managing voltage differences between cells in a battery pack to ensure even wear and longer lifespan.
- **Overcharge/Over-discharge Protection**: Safety mechanisms that prevent damage to the battery by stopping charging/discharging at critical voltage levels.
- **Thermal Management**: Monitoring and controlling battery temperature to prevent overheating and ensure optimal performance.

Conclusion:

This experiment briefly summarizes the key parameters and functionalities of a BMS. With the importance of the BMS in ensuring safe, efficient, and reliable battery operation in various applications.

Experiment 3.2

Title: BMS Parameter monitoring with software

Aim: To investigate how a Bluetooth app can be used to monitor various parameters of a Battery Management System (BMS).

Procedure:

Data Monitoring using the App –

1) Download the "Smart BMS" app on your smartphone.
2) Once connected via Bluetooth, launch the BMS mobile app on your smartphone.
3) Press the button on the BMS Bluetooth module.
4) On the app click on "Local Monitoring".
5) Now click on "Single Cell".
6) Press the add button corresponding to the Bluetooth name mentioned on the BMS Bluetooth module.
7) Now click on the added Bluetooth module.
8) The app should connect to the BMS and start displaying various battery parameters.
9) Based on the app we are using; the displayed information includes:
    a) Battery voltage: This indicates the overall electrical potential of the battery pack, typically in volts (V).
    b) Battery current: This shows the rate of electron flow into or out of the battery, typically in amperes (A). A positive value indicates charging, while a negative value indicates discharging.
    c) State of Charge (SOC): This is an estimate of the remaining capacity of the battery, usually expressed as a percentage.
    d) Battery temperature: This is crucial for monitoring battery health and safety, as extreme temperatures can negatively impact performance and lifespan.
    e) The cell with the lowest voltage is shown in blue colour and the cell with the highest voltage is shown in red colour.
10) Set the throttle at 100% to discharge the battery in a uniform way.
11) Monitor and note these parameters at 10 min intervals and prepare manual logs.

Conclusion:

This experiment demonstrates how a Bluetooth app can be a convenient tool for monitoring various parameters of a BMS. By monitoring voltage, current, temperature, and SOC, users can gain valuable insights into the battery's health, performance, and remaining capacity.

Experiment 3.3

Title: BMS Parameter configuration with software

Aim: To explore how to set various configurations on a Battery Management System (BMS) using a mobile app.

Procedure:

Parameter setting using the App –

1) Download the "Smart BMS" app and connect it to the BMS Bluetooth module as mentioned in Experiment 7.
2) Cell voltage protection: This sets the maximum and minimum voltage limits for individual battery cells. Exceeding these limits can damage the cells.

(Warning: Modifying these values can be risky and should only be done with proper knowledge of your specific BMS and battery pack. Refer to the BMS manual or manufacturer recommendations before making any changes.)

3) Charging/Discharging current: This might allow you to set limits for the maximum current allowed during charging and discharging. Higher currents can enable faster charging/discharging but can also stress the battery more.

(Warning: Similar to voltage protection, refer to the BMS manual or manufacturer recommendations before making any changes.)

4) Temperature protection: This sets the maximum and minimum temperature limits for the battery. Operating the battery outside of these limits can reduce its performance and lifespan.

(Warning: Like voltage protection, refer to the BMS manual or manufacturer recommendations before making any changes.)

5) Cell Balancing:
   a. Balanced open Start Voltage: If a cell is charged above the voltage mentioned by this configured value, then it will start cell balancing.
   b. Balanced open difference voltage: If the difference in voltage between any two cells goes beyond this set value, then cell balancing will start.

Conclusion:

This experiment has provided a basic overview of how a mobile app can be used to set BMS parameters. It is important to note that modifying these parameters can impact battery safety, performance, and lifespan.