SYSTEM INTEGRATION AND EVALUATION OF MOTOR DRIVE, ENERGY AND BATTERY MANAGEMENT SYSTEM IN A HYBRID ELECTRIC VEHICLE

By

MUHAMMAD HAIKAL BIN ZAKARIYA

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in partial fulfilment of the requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

SYSTEM INTEGRATION AND EVALUATION OF MOTOR DRIVE, ENERGY AND BATTERY MANAGEMENT SYSTEM IN A HYBRID ELECTRIC VEHICLE

by

Muhammad Haikal bin Zakariya

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

____

AP Dr Nordin bin Saad
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

Muhammad Haikal bin Zakariya

ABSTRACT

In the collective effort of reducing the world's dependency on fossil fuels, the hybrid car technology is implemented. A typical hybrid vehicle combines the engine of a conventional car with an electric motor-generator. Recent enhancements allows a retrofit version of a hybrid car which enables a conventional car to be transformed into a Hybrid Electric Vehicle (HEV) with a few minor changes to the original structure of the car via the In-Wheel Motors (IWM).The three major components of a HEV includes the Motor Controller, Energy Management System (EMS) Controller and Battery Management System (BMS). It is of the utmost importance that these three components are well integrated in the retrofit HEV to ensure an efficient and smooth operation, enabling it to achieve its ultimate objective that is to reduce fuel emission. This paper includes the study of various signals of the HEV sub-systems, Motor Drive assembly and Graphical Driver Interface (GDI) configuration.

ACKNOWLEDGEMENT

First and foremost, I would like to thank God the Almighty for giving me the time and opportunity to do my Final Year Project from the start until the end. I would also like to convey my highest gratitude to my supervisors, A.P. Dr. Nordin Saad and Mr Saiful Azrin Mohd Zulkifli for all the guidance and motivation.

Also, thank you to those involved in the MYVI DASH project team including Mr Ezran, Mr Adz, Mr Firman, Mr Mahfuz and others as well for their assistance and support throughout the project. Not to forget, thank you to the FYP Committees too, for a well-organised programme and for making the flow of Final Year Project smooth.

Last but not least, thank you to all my colleagues of Universiti Teknologi PETRONAS. Without all of your support, I would not have reached where I am now. I would like to apologize if any party was inadvertently excluded from being mentioned above.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ECU	-	Engine Control Unit
EMS	-	Energy Management System
GDI	-	Graphical Driver Interface
ICE	-	Internal Combustion Engine
IWM	-	In-Wheel Motor
BLDC	-	Brushless Direct Current Motor
BMS	-	Battery Management System
CAN	-	Controller Area Network
SOC	-	State of Charge
I/O	-	Input Output
HV DC	-	High Voltage Direct Current
TPS	-	Throttle Positioning Sensor
E-TPS	-	Enhanced Throttle Positioning Sensor
LED	-	Light Emitting Diode

CHAPTER 1: INTRODUCTION

1.1 Background

There are three major sub-systems of a hybrid electric vehicle:

1) A motor drive which controls power flow to the electric motor-generator for propulsion and generation;
2) An energy management controller acting as the brain of the hybrid vehicle, and
3) A battery management system which monitors and controls power flow of the on-board battery pack.

These three components need to be integrated, along with signals from the engine control unit (ECU) and other vehicle parameters, for proper and efficient operation of the hybrid vehicle.

1.2 Problem Statement

Without proper communication between the various additional sub-systems (motor drive, energy management and battery management) and existing ECU of the vehicle, hybrid drive-train operation cannot be realized to its fullest potential.

Different signals need to be integrated and processed by the vehicle's main controller - the energy management system (EMS) controller - in order to achieve objectives of hybrid operation - lower fuel consumption and reduced emissions. Since the signals are of various types, a proper connectivity study, configuration and associated programming are required to ensure proper processing of the various vehicle parameters.

1.3 Objectives

1. To evaluate signal types and requirements of each of the vehicle's sub-systems
2. To conduct cabling termination (high voltage motor to low voltage signals) and in-vehicle Motor Drive testing.
3. To perform GDI configuration and associated programming (EMS) to achieve connectivity

1.4 Scope Of Study

The project requires a comprehensive understanding on HEV in terms of its architecture, operation and configuration. The area of focus is on the integration of three sub-systems of the HEV; Motor Drive, EMS and GDI.

Firstly, a proper signal evaluation study is to be carried out to fulfill the signal requirements of each sub-systems. Once evaluated, the next step is to conduct the cabling termination of the Motor Drive on the vehicle which will then be tested for its operationality to ensure the connections are good. Then, a GDI is developed for the Motor Drive to display its parameters (via the EMS controller). The parameters will be displayed on a remote panel (Tablet PC) using LabVIEW software.

CHAPTER 2: LITERATURE REVIEW

2.1 Hybrid Electric Vehicle

With fossil fuel continuing to deplete over the years, alternative energy is seen as the next focus of research and development for the automotive industry. Various technologies have been developed by utilising other energy sources that pose significantly less environmental risks as compared to fossil fuels such as battery, fuel cell, and photovoltaic (PV) cell [1].

These alternative sources use electrical energy generated from an electric motor for vehicle propulsion [2]. Based on this concept, two types of vehicle are developed; Full-Electric Vehicle (EV) and Hybrid Electric Vehicle (HEV). The former uses electric motor as the only power source by discarding the internal combustion engine (ICE) from its system while the latter maintains the ICE as the power source but with the addition of an electric motor as the auxiliary source [3]. Due to the presence of the ICE and electric motor in the vehicle propulsion system, several drivetrain configurations are possible; series, parallel, series-parallel [2].

A typical hybrid vehicle system architecture would have the electric motor assembled with the chassis. However, recent studies show that the electric motor can be one part of the wheel itself, named the in-wheel motors (IWM) [2]. By applying this concept, the hybrid system can be retrofitted to a conventional vehicle with minimum modifications to the original vehicle architecture by implementing a split-parallel or split-axle configuration. According to a study done via simulation of drive cycles using a retrofitted HEV, the fuel consumption improved up to 19% [4].

A series drivetrain is configured in such a way that the prime mover of the vehicle propulsion system is the electric motor. On the other hand, the ICE which is coupled with the generator produces electricity to either charge the on-board batteries or power the electric motor [3]. For a parallel drivetrain, the configuration of a conventional vehicle is maintained. Additionally, an electric motor is placed on the drive shaft parallel to the ICE [2]. This configuration allows the electric motor to turn the shaft as well.

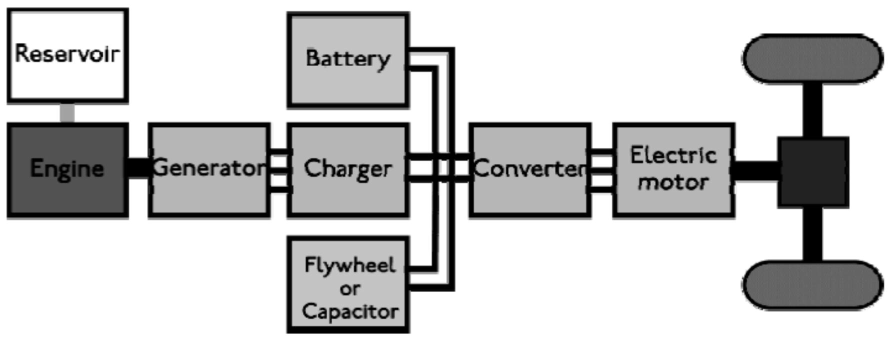


FIGURE 1: Series HEV Configuration

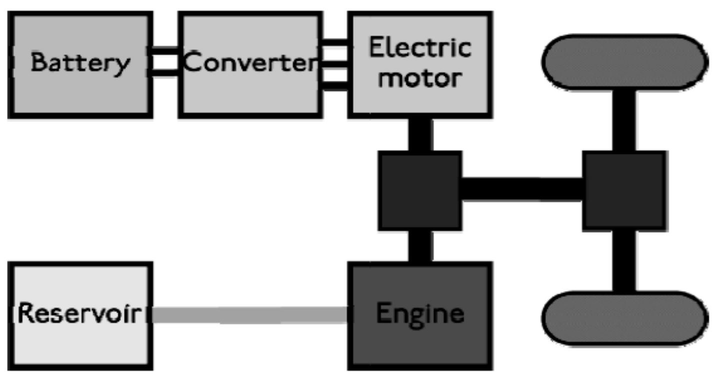


FIGURE 2: Parallel HEV Configuration

A combination of both configurations above, known as the series-parallel drivetrain, allows a more flexible operation of the vehicle propulsion system. It optimises both benefits from a series and parallel configuration. Both the ICE and electric motor is coupled on the same shaft, separated by a power splitting device [2]. This allows power sharing to drive the wheels of the vehicle. Another configuration is the split-parallel, modified from the parallel drivetrain architecture. A split-parallel configuration is considered the most adaptive because it utilises the IWM to generate power without any mechanical link to the drive shaft [3]. The ICE and IWM operates on a different shafts and are coupled to the vehicle chassis. This opens up the possibility of a retrofit conversion of a conventional vehicle with minimal modification to its architecture.

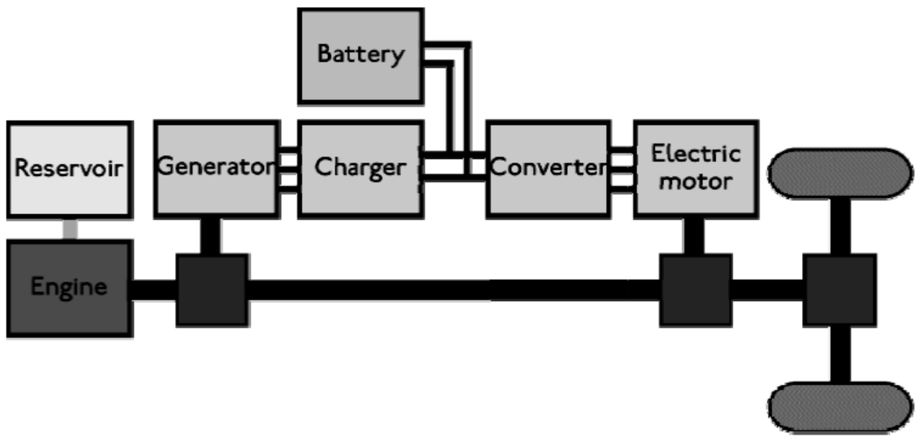


FIGURE 3: Series-Parallel HEV Configuration

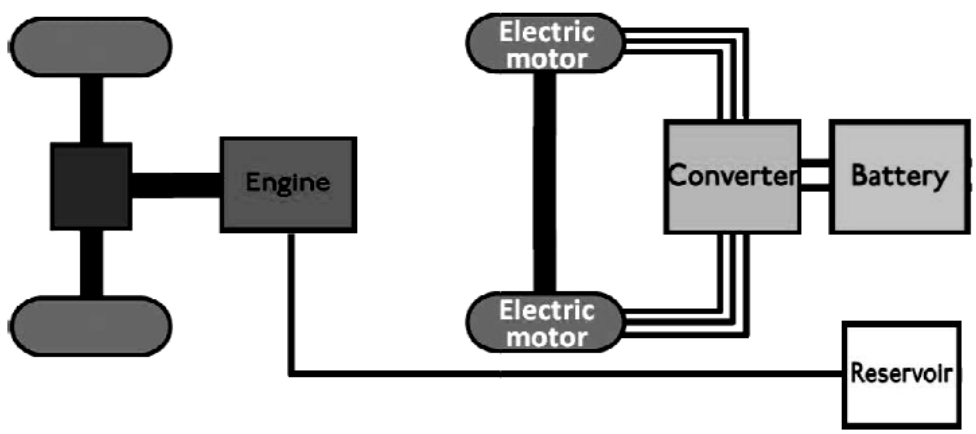


FIGURE 4: Split-Parallel HEV Configuration

2.2 Motor Drive

The propulsion power of a HEV is obtained from the ICE and/or electric motor, depending on the drivetrain configuration. The operation of an electric motor is based on the concept of energy conversion where electrical energy is converted into mechanical energy [5]. The basic construction of the electric motor includes a) rotor which is the moving part that turns the shaft via electromagnets and b) stator which is the stationary part that houses either permanent magnets or windings.

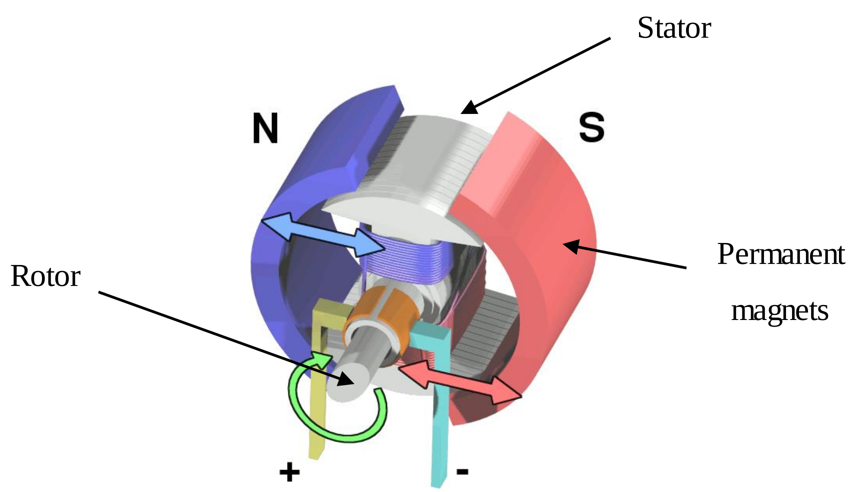


FIGURE 5: Structure of An Electric Motor

However, the conventional electric motor construction has its limitation in terms of smooth operationality, overheating, noises and maximum motor speed due to the presense of brushes [5]. Thus, an improvement is made by eliminating the brushes at the rotor resulting in a new concept of electric motor, which is the Brushless DC Motor (BLDC). The difference between a typical electric motor and the BLDC is the reverse configuration of the rotor and stator. Instead of placing the electromagnets and permanent magnets on the rotor and stator respectively, it is placed vice versa [5]. This configuration allows a more efficient operation of the electric motor by eliminating the previous issues with the original electric motor.

Due to the brushless nature of the BLDC, motor controllers are used to replace the brushes in order to provide the charging of electromagnets at the stator as well as the control algorithms for the motor [5].

In a typical HEV architecture, motor controller is considered as one of the major components. Basically, the function of a motor controller is to provide control methods to improve the overall efficiency of the motor depending on different types of operating environment i.e. uphill or downhill which requires acceleration and deceleration, with respect to different types of load i.e. light load or heavy load [6].

Another aspect that requires control is the minimization of losses and flux balancing of the motor [7]. If these aspects can be controlled, the motor will be able to operate efficiently and effectively. Currently, there are two control methods identified for the motor controller: a) direct torque control and b) vector control [6]. Between the two methods, the latter is more promising in providing a good torque control and is less prone to temperature deviations [6].

2.3 Energy Management System

One of the integral parts of a HEV is the Energy Management System (EMS) which is considered as the ‘brain’ of HEV. Since the HEV operates on two energy sources i.e the ICE and electric motor. Thus, it can be operated in three modes; ICE only, electric motor only, and hybrid [8]. The EMS will ensure the HEV operation is at an optimum level by switching between the modes whenever necessary. In order to do so, the vehicle parameters (e.g. engine rpm, speed, fuel flow, battery state-of-charge, etc.) need to be monitored and analysed via a control strategy. Some of the most used control strategies are the on/off method, fuzzy logic approach, and neural networks [8].

2.4 Battery Monitoring System

The use of battery packs in a HEV is different as compared to a conventional vehicle. Due to the coexistence of the ICE and electric motor, the batteries undergo a dynamic cycle of charging and discharging, depending on the HEV operation modes mentioned earlier. This requires a Battery Monitoring System (BMS) that can monitor the state-of-charge of the batteries individually as well as a whole. By implementing BMS, the longevity of the battery packs can be maximised to fulfill the power needed for the operation of HEV [9].

2.5 System Integration

Other than the ECU, the main subsytems of a HEV are the EMS, Motor Drive and BMS. The EMS Controller acts as the brain of the hybrid system by monitoring, controlling and optimising the performance between all the sub-systems [10]. As for the electric motor, it is controlled by the Motor Controller through pre-determined algorithms [11].

On the other hand, the battery pack of the BMS serves as an auxiliary power source and stores power during regenerative braking mode [3]. An important aspect of the HEV is the integration and connectivity between the sub-systems to ensure an optimised communication between them. There are three types of connection being implemented for the systems as shown in TABLE 1.

CAN Bus can be considered as the replacement of conventional multi-wire looms to connect between sensors and systems. It enables in-vehicle communications up to 1Mbps [12]. As for the TCP/IP, it is an internet protocol used to connect different networks, allowing free data exchange between them [13].

TABLE 1: HEV System Connections

<table>
<tr><th>Connection Type</th><th colspan="2">Connection Link</th></tr>
<tr><td>Controller Area Network (CAN-Bus)</td><td rowspan="5">Energy Management System (EMS)</td><td>Motor Controller</td></tr>
<tr><td>Ethernet TCP/IP</td><td>Tablet PC</td></tr>
<tr><td rowspan="5">Hardwired
(sensor/analog/digital signal interface)</td><td>Instrument Panel (vehicle speed, engine rpm)</td></tr>
<tr><td>Accelerator Pedal/ Throttle Positin</td></tr>
<tr><td>Fuel Flowmeter</td></tr>
<tr><td>Battery Monitoring System (BMS)</td><td>Current, Voltage, Battery SOC</td></tr>
<tr><td>Motor Drive</td><td>Brake Pedal</td></tr>
</table>

CHAPTER 3: METHODOLOGY

3.1 Research Methodology

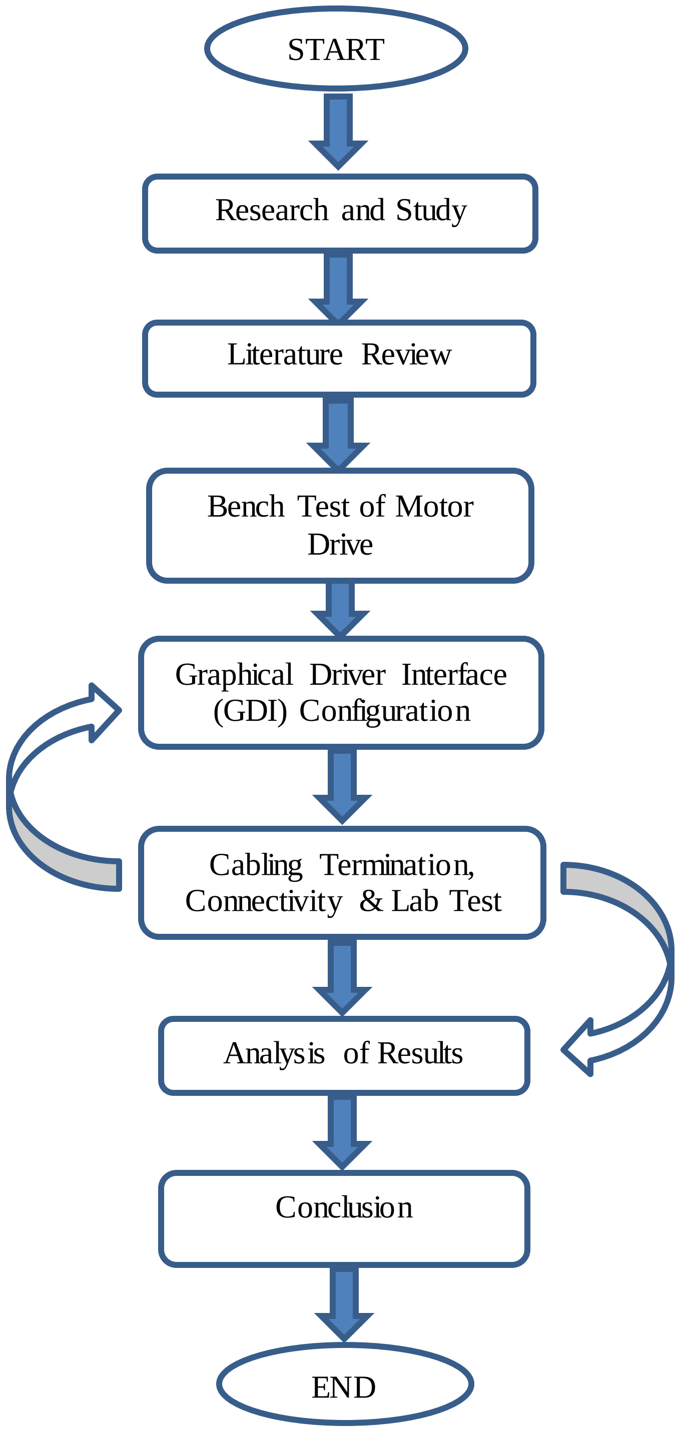


FIGURE 6: Research Methodology Flow

3.2 Project Activities

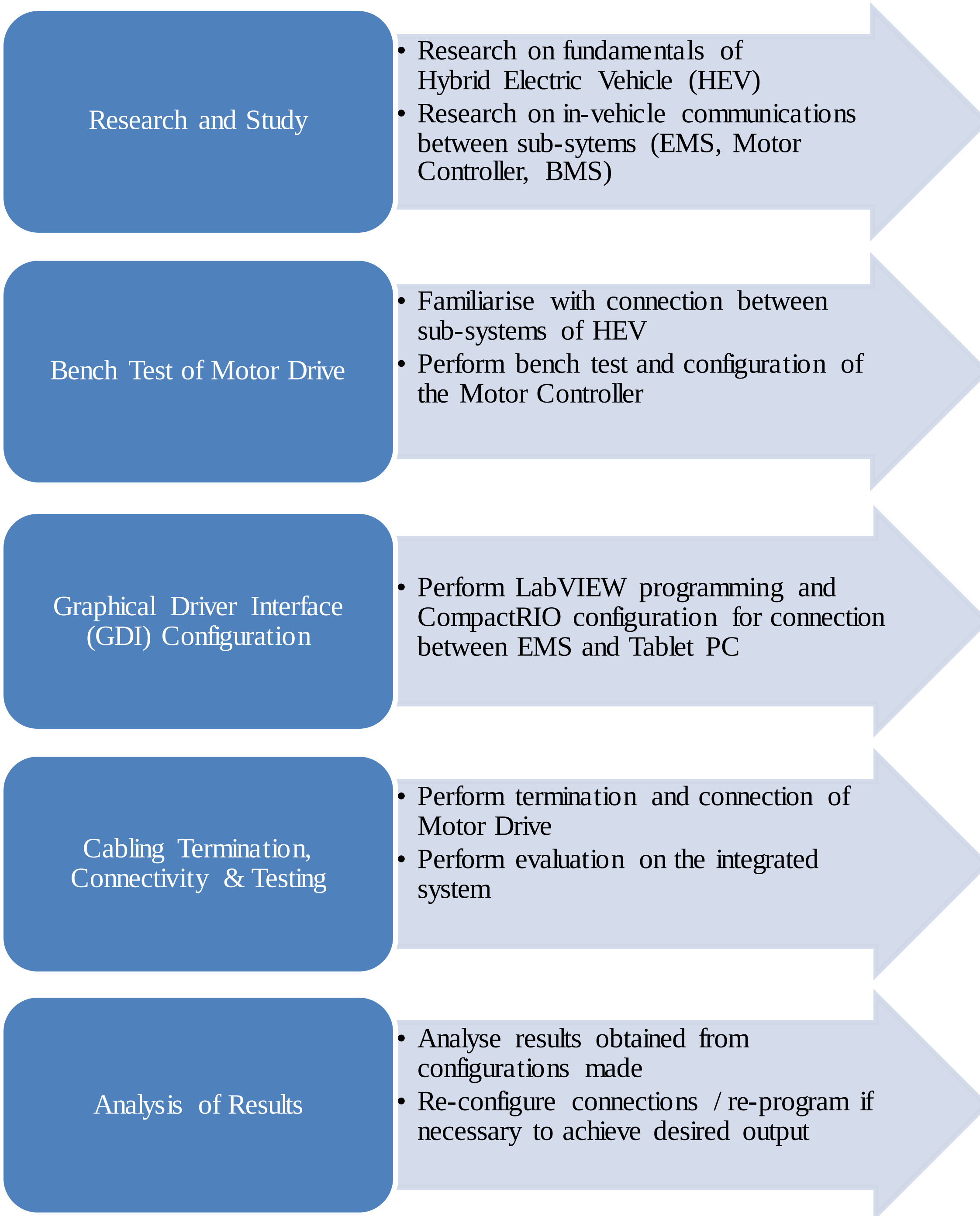


FIGURE 7: Project Activities

3.3 Key Milestones

TABLE 2: FYP I – Key Milestones

No	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Title Selection and Confirmation		✓												
2	Submission of Extended Proposal						✓								
3	Proposal Defense									✓					
4	Submission of Interim Draft Report													✓	
5	Submission of Interim Final Report														✓

TABLE 3: FYP II – Key Milestones

No	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Submission of Progress Report								✓						
2	Pre SEDEX										✓				
3	Submission of Draft Final Report												✓		
4	Submission of Dissertation													✓	
5	Submission of Technical Paper													✓	
6	Viva														
7	Submission of Dissertation (HB)														

3.4 Gantt Chart

TABLE 4: FYP I – Gantt Chart

No	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Title Selection and Confirmation	✓	✓												
2	Preliminary Research / Literature Review			✓	✓	✓	✓								
3	Development of HEV Wiring Diagram							✓	✓	✓	✓	✓	✓		
4	Motor Controller Configuration												✓	✓	✓
5	Motor Controller Bench Test													✓	✓

TABLE 5: FYP II – Gantt Chart

c	Item/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Installation and Test Run of Motor Drive	✓	✓	✓	✓	✓	✓	✓							
2	Programming & EMS Configuration							✓	✓	✓					
3	Graphical Driver Interface (GDI) Configuration								✓	✓	✓				
4	EMS-GDI Connectivity Testing										✓	✓	✓	✓	
5	Analysis of Results												✓	✓	✓

3.5 Tools & Software Required

1. *National Instruments' Compact-RIO* real-time controller (Available in UTP Vehicle research lab)
2. *Kelly Controls'* motor controller (Available in UTP Vehicle research lab)
3. *LabVIEW* Real-time software and various controller proprietary configuration softwares (Available in UTP Vehicle research lab)

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Development Of HEV Architecture

In this project, the types of I/O signal required for each sub-systems of the HEV are identified so that the systems can be integrated accordingly. Each of them are obtained through research. Once the signals are identified, the hardware I/O connections for the HEV are determined. The results are recorded in TABLE 6 and the devices being evaluated are as follows (as illustrated in FIGURE 8):

1. EMS Controller (*NI CompactRIO*)
2. Engine Control Unit (ECU)
3. Internal Combustion Engine (ICE)
4. Fuel Flowmeter
5. Graphical Driver Interface (GDI)
6. Brake Pedal
7. Accelerator Pedal
8. Motor Drive I
9. Motor Drive II
10. Battery Pack
11. In-Wheel Motors

The main connection revolves around the EMS Controller and the Motor Drive. Most of the signals (analog and digital pulses) are fed to the EMS Controller for monitoring, analysis and control, except for the brake pedal, which is fed to the Motor Drive for the purpose of regenerative braking. Nevertheless, the input signal of the brake pedal to the Motor Drive will also be fed to the EMS Controller via CANBus communication. Overall, the EMS Controller will be able to monitor every communication in the HEV.

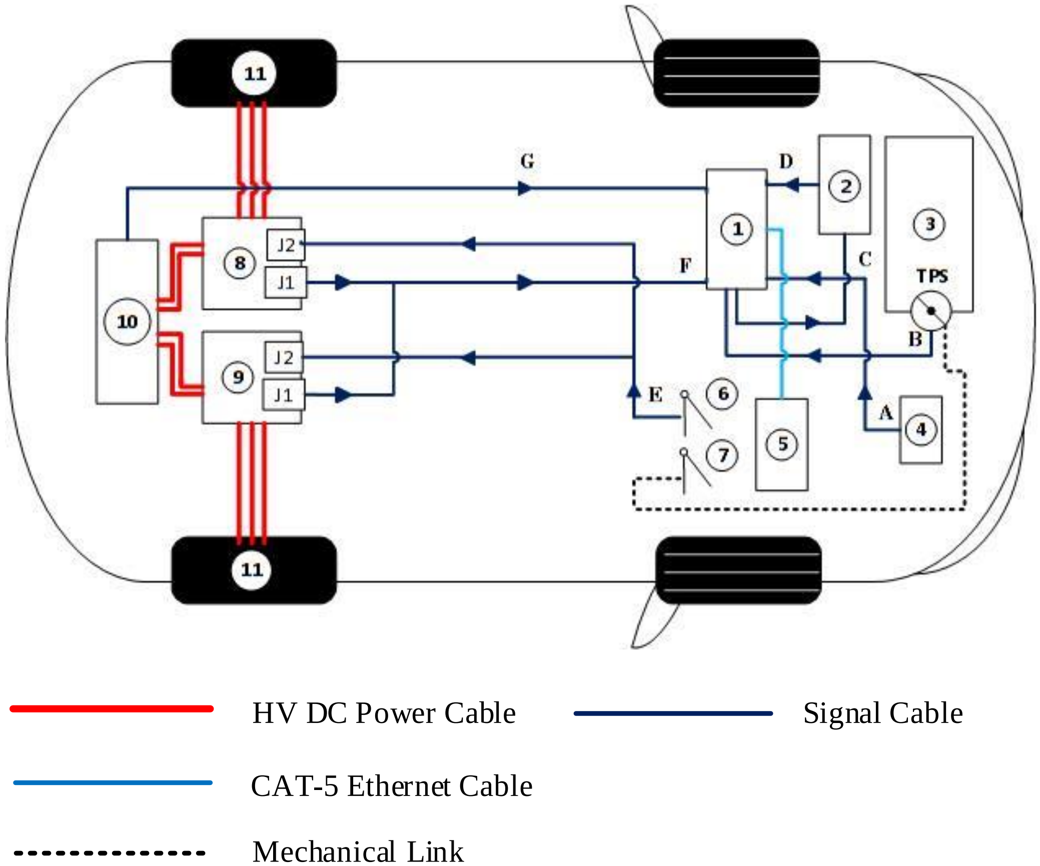


FIGURE 8: HEV General Architecture

TABLE 6: HEV System Requirements

I/O Parameter		Cable Type	Signal Type
A	Fuel Flow	Shielded Twisted Pair (2-core)	Digital (pulse)
B	Throttle Position (TPS)	Shielded Twisted Pair (2-core)	Analog
C	Enhanced Throttle Position (E-TPS)	Shielded Twisted Pair (2-core)	Analog
D	ECU Parameters (engine rpm, vehicle speed, etc.)	Shielded Twisted Pair (4-core)	Digital (pulse)
E	Brake Pedal Position	Shielded Twisted Pair (3-core)	Analog
F	Motor Parameters (motor rpm, status, current, etc.)	Shielded Twisted Pair (2-core)	CANBus
G	Battery State-of-Charge (SoC)	Shielded Twisted Pair (2-core)	Analog

4.2 Development Of HEV Wiring Assembly

As mentioned, there are several sub-systems that need to be integrated in the HEV. The assembly of these systems require a detailed study on the connection requirements. The focus is to ensure a proper connection between the two major sub-systems of the HEV; the EMS controller and the Motor Drive.

For this project, the connection between the EMS controller and the Motor Drive is established through Controller Area Network (CAN). CAN is the most common type of connection being used in the automotive industry for in-vehicle communications nowadays. It is a method created by Robert Bosch that replaces the use of conventional multi-wire looms with a hub called the CANBus.

After studying the manuals and datasheets of each devices, the wiring assembly is drawn using Microsoft Visio. It is important to ensure all the ports are wired accordingly to avoid unwanted damage to the devices. Throughout the process of developing the wiring assembly diagram, technicians are consulted to ensure the connections are correct and the diagram is properly drawn.

The devices involved for the wiring assembly are:

1. NI cRIO 9076 with 3 C-Series Modules
2. Two Kelly BLDC Motor (In-Wheel Motor)
3. Dual Kelly KHB 12601 Controller
4. 60V Battery (five 12V batteries connected in series) + 12V Car Battery
5. Carel IR33A7 Temperature Controller

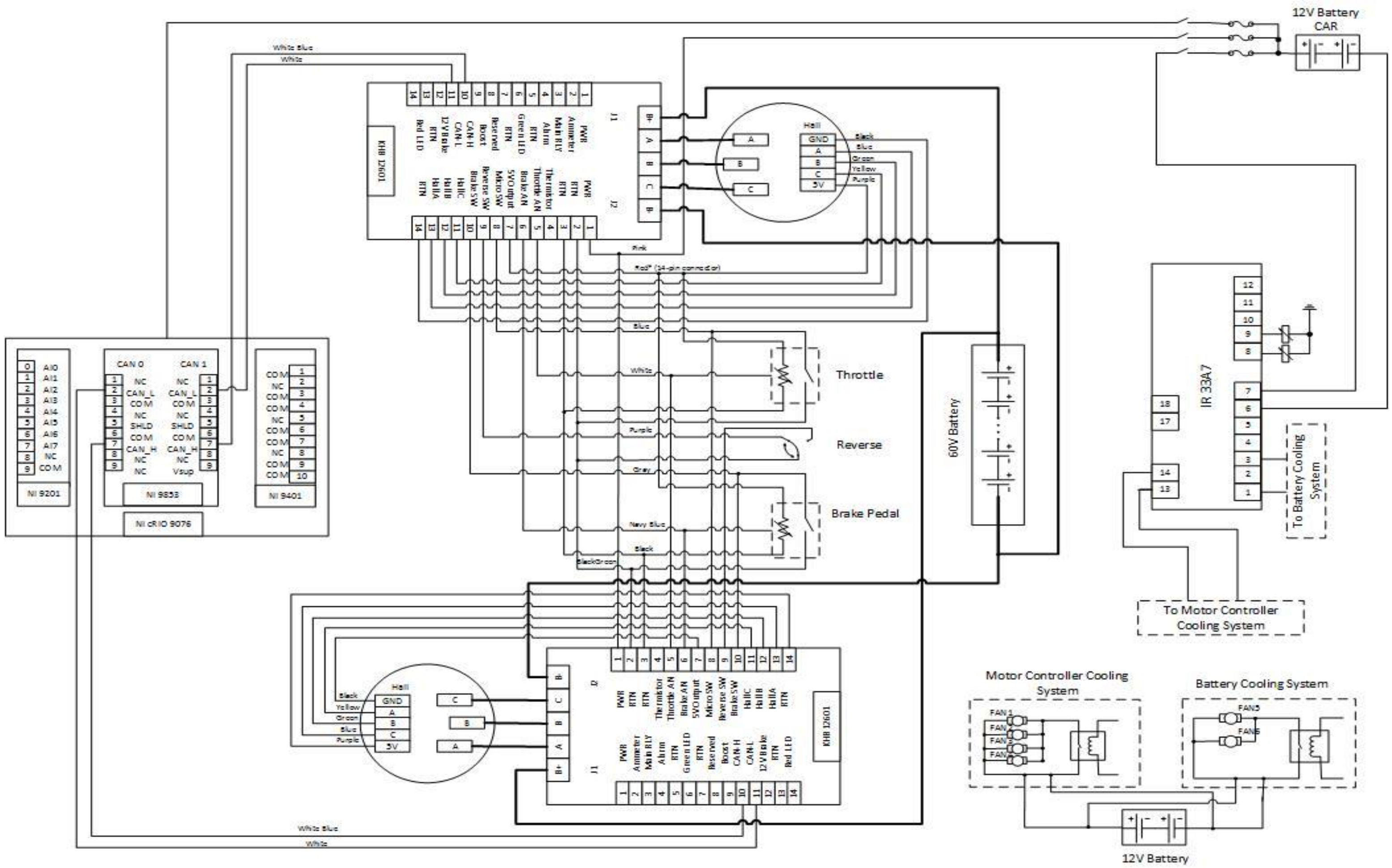


FIGURE 9: HEV Wiring Assembly Diagram

4.3 Motor Controller Assembly

The Kelly Controls' High Power BLDC Motor Controller is used for this project. The connections are setup according to the Dual KHB Controller Assembly Wiring Diagram (Refer APPENDIX A). The table below shows the wiring colours and its respective indications.

TABLE 7: Wiring Colours and Indications

NO	WIRE COLOURS	INDICATION	
		From Motor to Controller	**From Controller to 14-Pin Connector**
1	Black	RTN	RTN
2	Black/Green	-	RTN
3	Blue	Hall C	Throttle Switch
4	Brown	-	From Battery
5	Grey	-	Brake Switch
6	Green	Hall B	-
7	Navy Blue	-	Brake AN
8	Pink	-	PWR
9	Purple	5V Output	Reverse Switch (Controller 1)
10	Red	-	5V Output
11	White	-	Throttle AN
12	Yellow	Hall A	Reverse Switch (Controller 2)

Two cooling fans are mounted on top of each controller to act as a cooling mechanism to prevent overheating. The power supply for the cooling fans are drawn from the same supply for the motor controller and is connected via a 2-pin connector. A general control box which provides the switching for power, throttle, brake and reverse, are connected to the controller via the 14-pin connector.

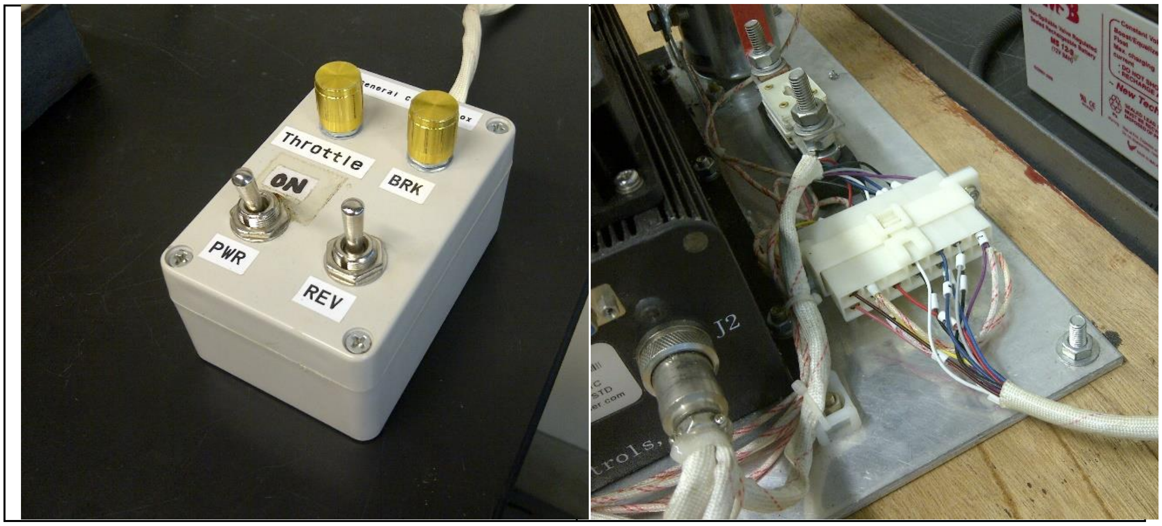


FIGURE 10: Dual KHB Controller Assembly – General Control Box

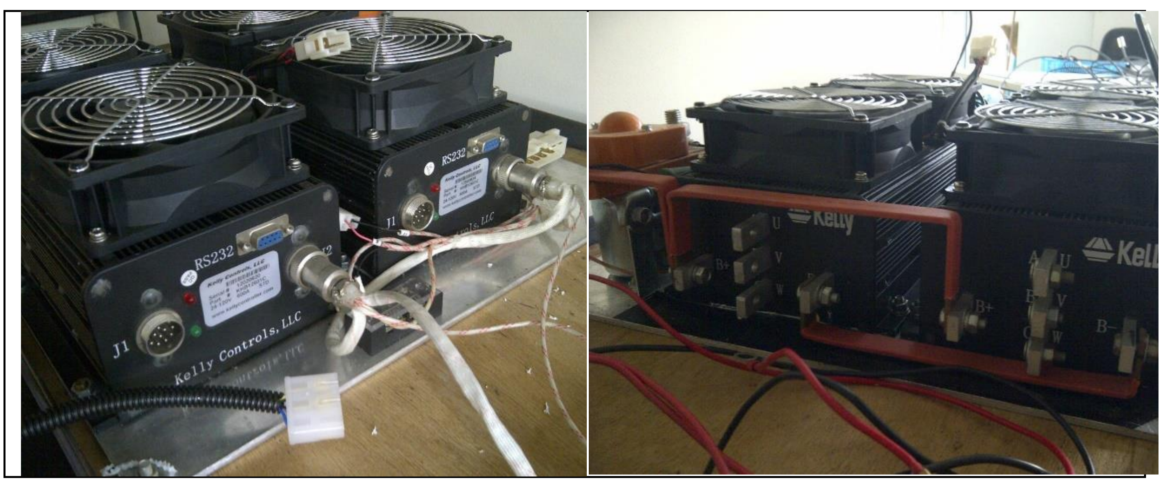


FIGURE 11: Dual KHB Controller Assembly – J2, B+, B-

4.4 Motor Controller Configuration

The first part is the configuration of Motor Controller. Prior to the configuration, there are software and hardware requirements that need to be fulfilled. In terms of software, a Kelly HP KHB User Program is installed to the user computer. Connection-wise, an RS243 cable is used to allow connections from the motor controller to the user computer via USB port.

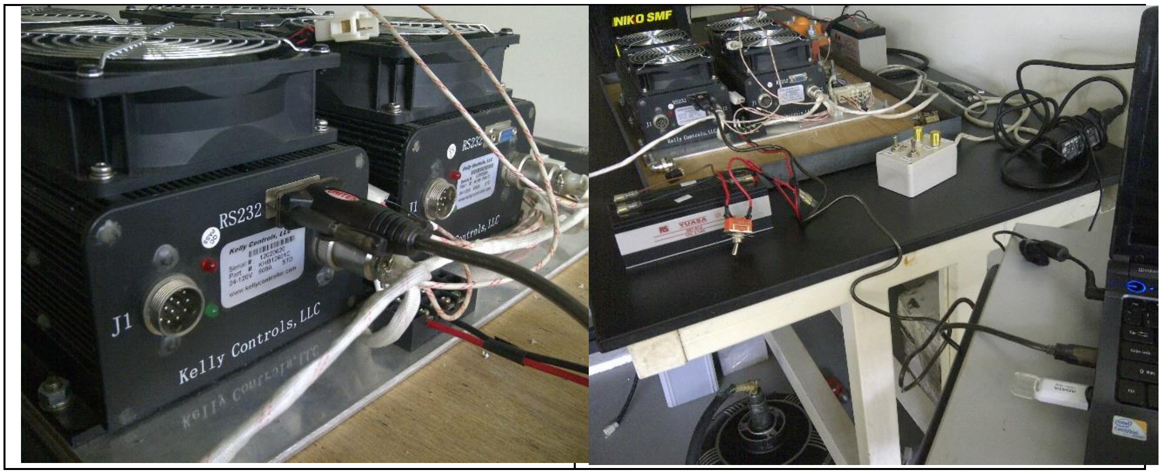


FIGURE 12: USB-RS232 Connection

To initiate the configuration phase, a 24V battery is supplied to the J2 pin1 (PWR) of both controllers. Once properly connected, the battery switch and the power switch (on the control box) is toggled to ON.

Both controllers are turned on and upon observation, the red LED indicators gave the same error codes where it blinked four times and two times (4,2) with a one-second pause in between. The 4,2 flash codes indicate a hall sensor error on both controllers. In general, the hall sensor error may be due to an incorrect, loose wiring, a damaged hall sensor or an incorrect hall angle configuration. In this case, it is because the hall sensors are not connected to the motor.

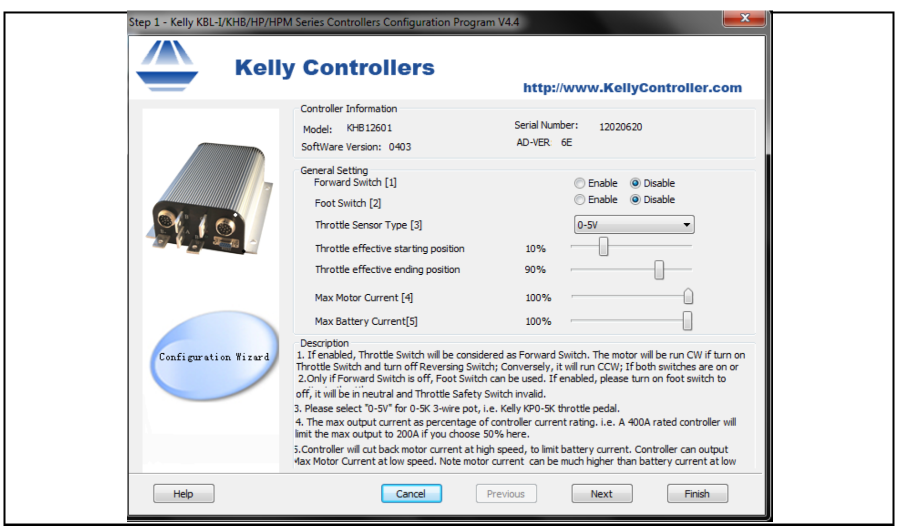
Now that the controllers are ON, the USB port of the user computer is connected to the RS232 port of one of the controllers via the USB to RS232 Converter cable. Then, the Kelly KBL-I/KHB/HP/HPM Series Controllers Configuration Program is run. There are six configuration steps for the motor controller:

Step 1 to 3: General settings involving forward switch, foot switch, throttle, brakes, motor current, hall sensors, control modes, voltage, and some extra functions such as boost

Step 4 : Regeneration settings involving throttle, brake sensors and regeneration current

Step 5 : Sensor settings involving motor temperature sensor and CAN communications

Step 6 : Finish setting – controller power is recycled to activate the configuration



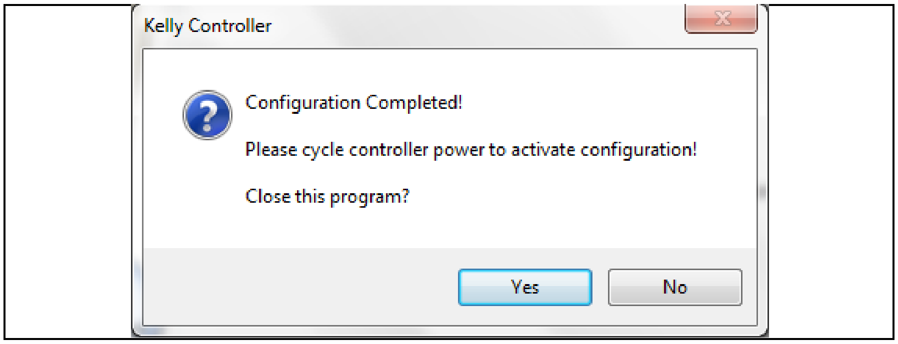


FIGURE 13: Kelly Configuration Program – GUI

4.5 In-House Motor Drive Operation Testing

The purpose of the test run is to evaluate the performance of the Motor Controller to the IWM installed on the back of the HEV.

For the test run, five 12V lead acid batteries are used. The batteries are connected in series using a high voltage power cable to supply a total of 60V power to the Motor Controller. To turn on the Motor Controller, a 24V (preferred) battery is supplied. Without any connection to the 60V batteries and the hall sensors, the Motor Controller will display two red LED codes once it is turned on. The errors are:

1. Hall Sensor Error
2. Low Voltage Error

The first error indicates there is either an incorrect wiring or a damaged hall sensors. It may also be caused by incorrect hall angle configuration. This error is understood because there is no connection to the hall sensors. The second error refers to the insufficient power for the Motor Controller to turn the IWM. This error should clear once the 60V batteries are connected to the Motor Controller.

FIGURE 14: Series-Connected 12V Lead Acid Batteries

Next, the B+ and B- ports of the controllers are connected to the positive terminal and the negative terminal of the battery respectively. Before applying the power, there are several precautions:

1. Ensure that the wiring of the controller is correct before power is applied.
2. Ensure the wiring of B- is correct.
3. The B+ wiring is preferably to be connected in series with the main contactor.
4. Ensure that the main contactor has a precharge resistors, fail to include may cause damage to the controller.

After the controllers are configured, the halls of the IWM (Hall A, Hall B and Hall C) are connected to the hall sensors on one of the controllers. Also, the power cables of the IWM are connected accordingly to the U, V and W output phase of the Motor Controller. Once everything is in place, the toggle switch of the 24V battery is turned on, followed by the power switch on the control box.

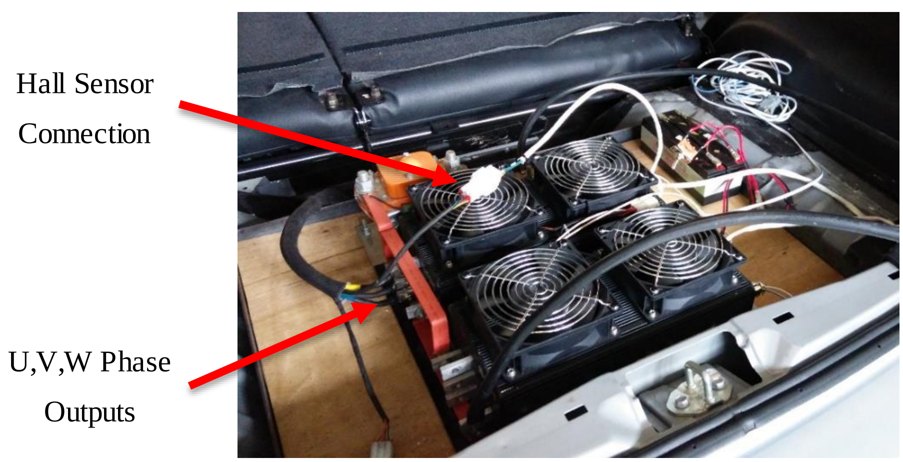


FIGURE 15: Motor Controller Connections

It is observed that the connected Motor Controller displays a green LED code which is an indication that the controller is in normal operation (no errors detected). On the other hand, the other unconnected Motor Controller displays the same red LED codes observed previously which is understood since there is no physical connection to the controller.

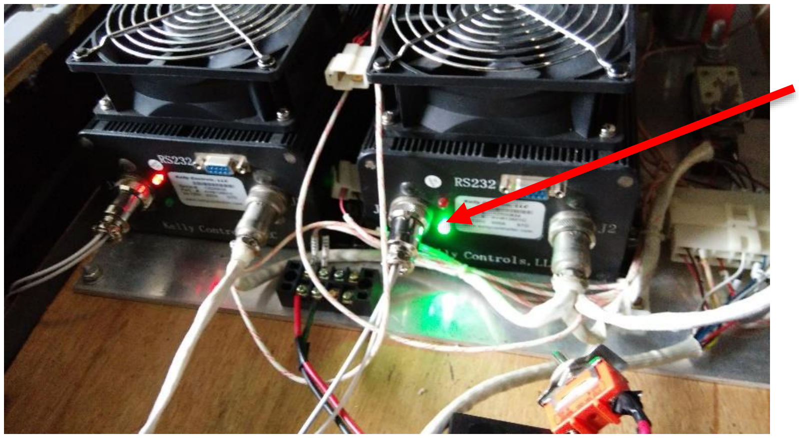


FIGURE 16 : Motor Controller LED codes

Now, the IWM can be tested for throttle, reverse throttle and brake via the control box. Leaving the reverse switch in a neutral position, the turning of the throttle switch turns the IWM in a forward manner. The speed of the IWM is controlled by the degree of turn of the throttle switch. By turning the brake switch slowly, the speed of the IWM decreases. The combination of both throttle and brake controls the speed of the IWM. Another test is done for the reverse movement of the IWM. This time, the reverse switch is toggled. It is observed that the IWM turns in a reverse manner when the throttle is applied.

The test run proves that the Motor Controller is operating well and the associated wirings and connections made are correct.

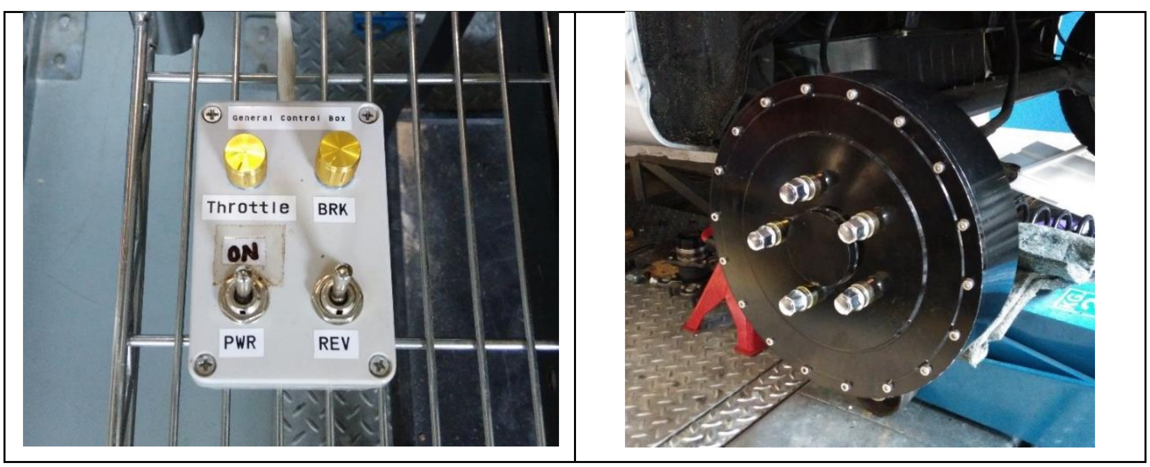
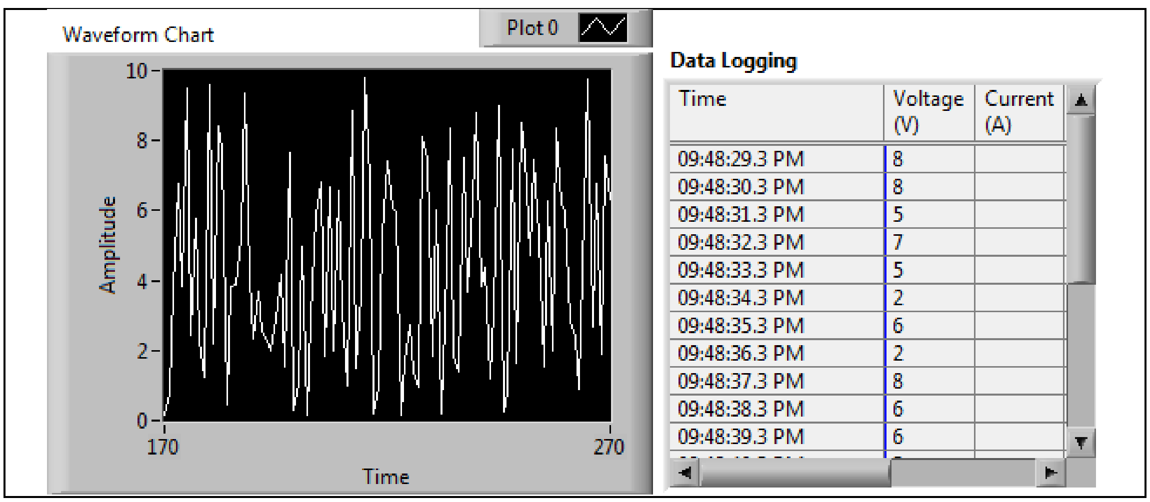


FIGURE 17: Control Box and IWM

4.6 Development Of Graphical Driver Interface

The main process of the HEV revolves around the EMS Controller. Inherently, the EMS controller performs various signal processing and control algorithms to ensure an optimized operation of the HEV. These complex processes need to be analysed and displayed graphically to ensure that the end user will be able to monitor and comprehend the HEV operation. Therefore, a Graphical Driver Interface (GDI) is developed.

In order to realise the GDI development, there are software and hardware requirements. For the software part, the National Instruments LabVIEW 2012 is used. This software utilises graphical or visual programming to perform signal measurement and analysis as well as control algorithms. The basis of LabVIEW programming is its Virtual Instrument or VI which consists of a Front Panel where the user interface is designed and a Block Diagram which define the codes.



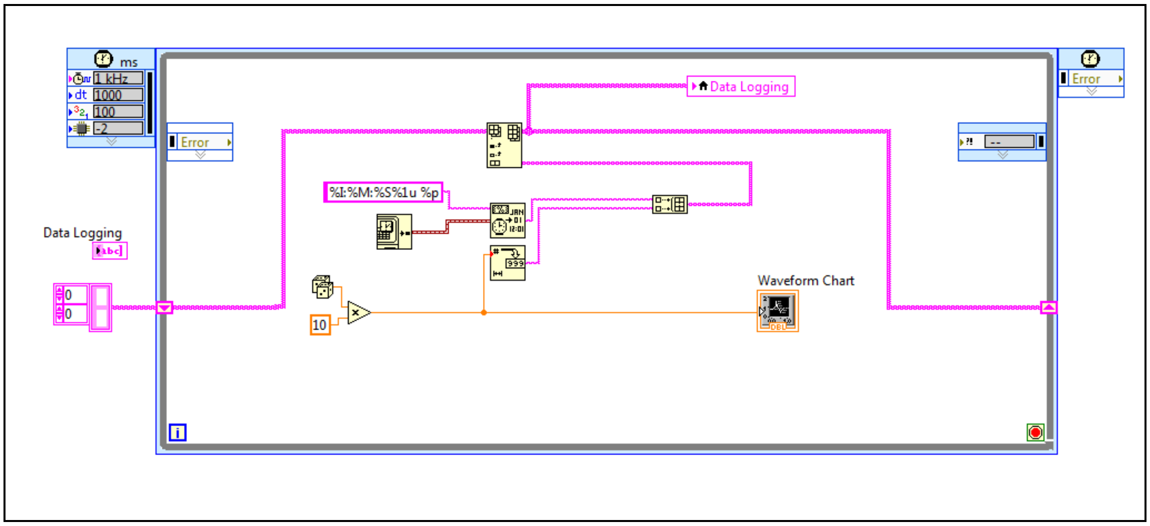


FIGURE 18: Front Panel and Block Diagram of a VI

For the hardware, the National Instruments CompactRIO Real-Time Controller is used which act as the brain of the HEV. It comprises of two parts; a CompactRIO reconfigurable chassis with integrated intelligent real-time controller, and C Series I/O modules.

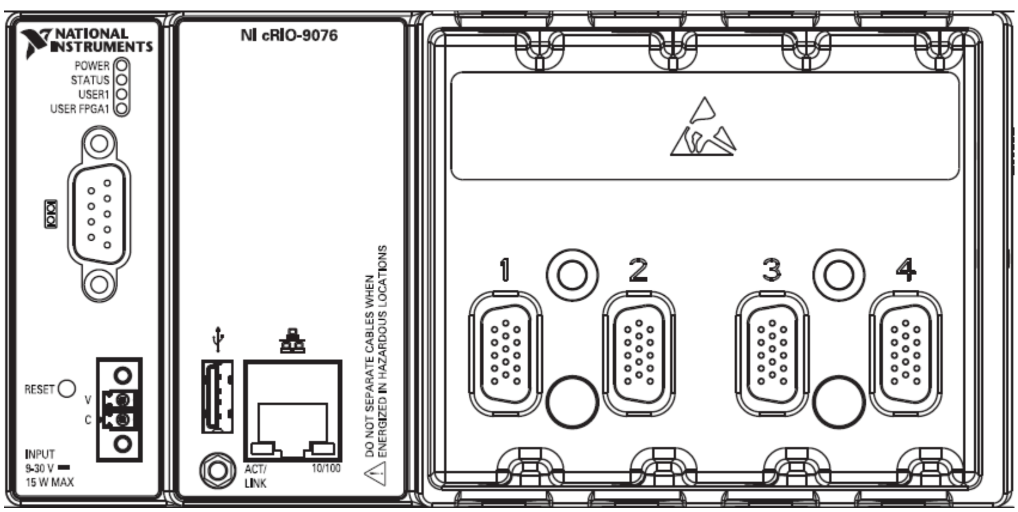


FIGURE 19: cRIO 9076 – Top View

The C-Series modules are used to receive and transmit signal from external devices which will then be measured and analysed by the real-time controller. The measurement and control algorithms are established through the VIs created in LabVIEW. Then, the VIs are loaded into the EMS controller to perform the desired measurement and/or control algorithms.

For this project, there are three C-Series modules being used:

1. NI 9201 – 8-Channel Analog Input Module
   This module is used to receive analog signals from the Throttle Positioning Sensor (TPS), Brake Pedal and Battery

2. NI 9401 – 8-Channel Bidirectional Digital Input/Output Module
   This module is used to receive and transmit digital signals from Fuel Flowmeter, and Engine Control Unit

3. NI 9853 – 2-Port High Speed CAN Module
   This module is used to receive and transmit CANBus signals between the EMS controller and Motor Drive

For the GDI development, NI 9201 is used to simulate an analog input signal to be displayed on the front panel. Other tools and hardwares included are:

1. NI CompactRIO 9076
2. Function Generator
3. Oscilloscope
4. Laptop PC
5. NI LabVIEW 2012 (software)

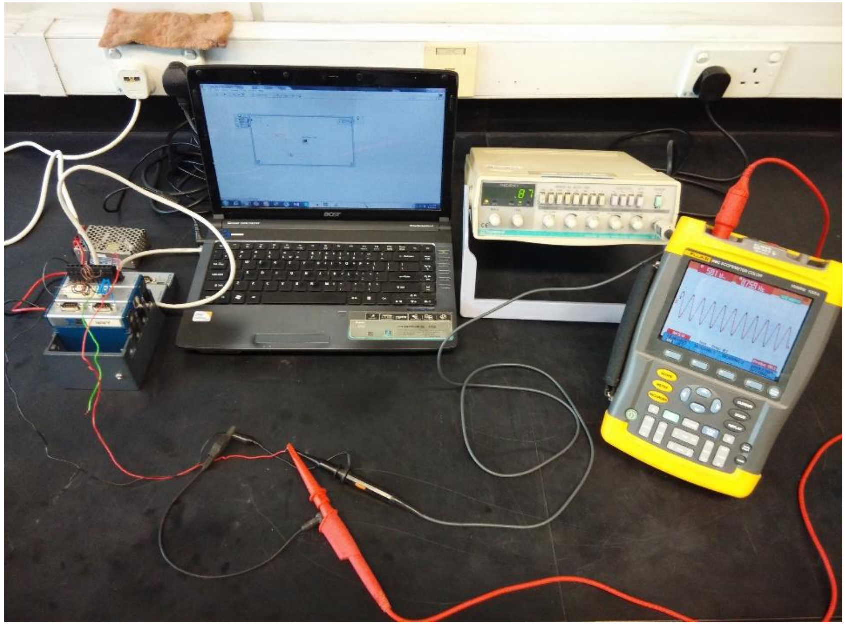


FIGURE 20: Hardware Setup for GDI Development

A program is developed using LabVIEW 2012 to read analog input and provide data logging feature. The program consists of two inter-loops; one to receive the input and store it in a variable (write), another is to read the data from the variable and display it in a tabulated from. It is then tested with a simulated input from the function generator with the below settings:

1. Sinusoidal waveform
2. Frequency ~1kHz
3. Amplitude from -5V to +5V

The result is shown in Figure 22.

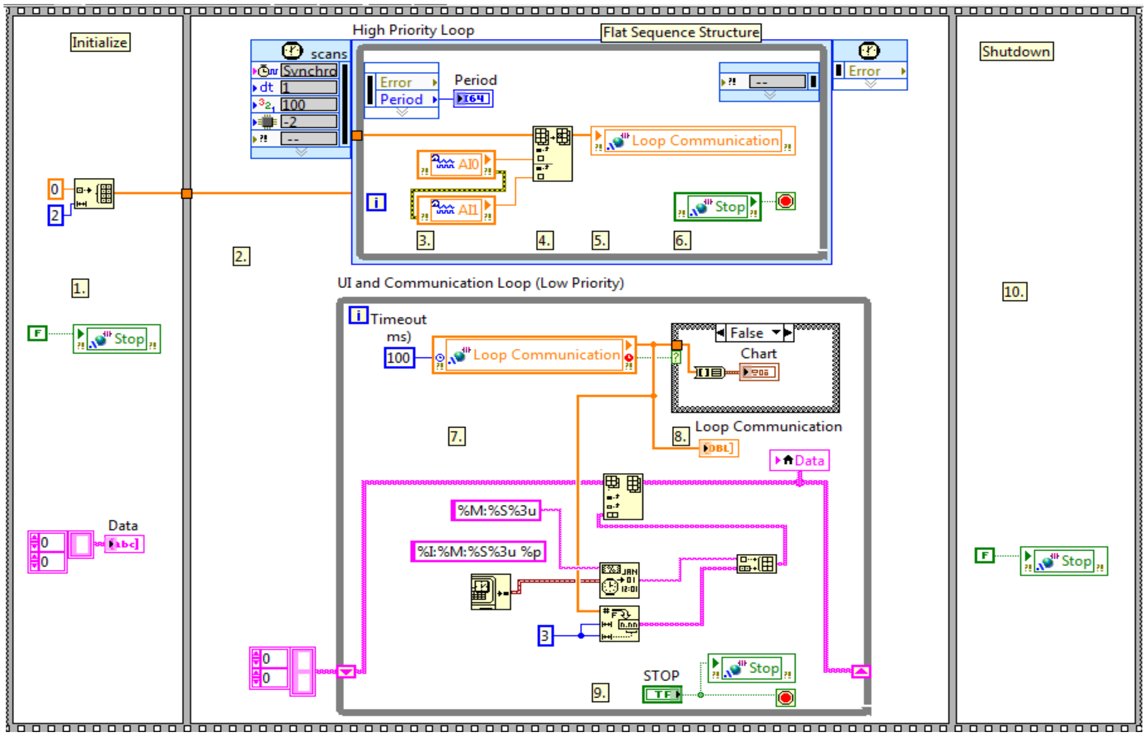


FIGURE 21: Block Diagram for Analog Input and Data Logging

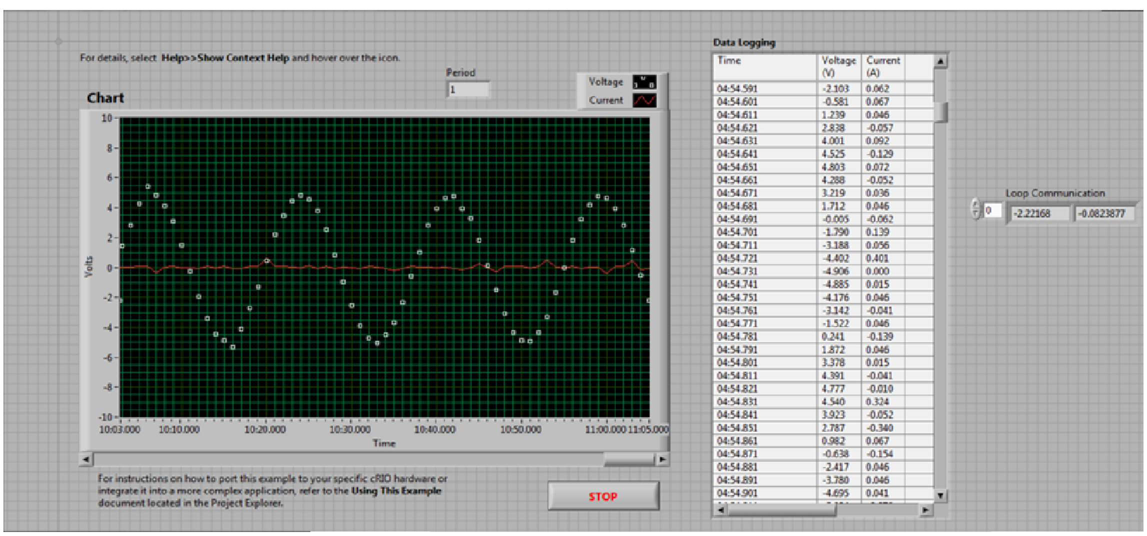


FIGURE 22: Front Panel of LabVIEW Program

4.6 EMS-GDI Web Browser Configuration

Now that the pre-requisites of GDI are completed, the next part is the integration of the EMS controller and a Tablet PC. For this part, it is done through LabVIEW using the Web Publishing Tool. This tool allows the Front Panel of a VI to be displayed or remotely controlled by an external peripheral, in this case, a Tablet PC, via a web browser. To enable the web browser integration, the Tablet PC needs to be installed with LabVIEW Run-Time Engine, a plug-in, to be able to view the Front Panels.

There are several steps to configure the remote front panels on a real-time target via LabVIEW. Below are the simplified steps:

1. Create or select a real-time target to a LabVIEW project

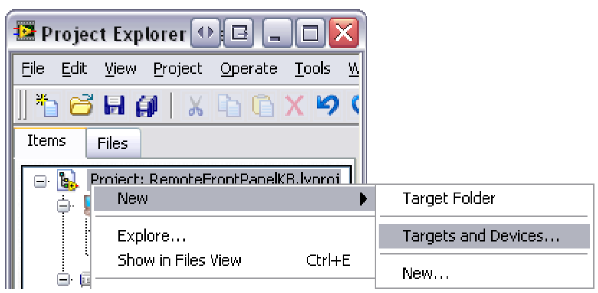


FIGURE 23: Adding an RT Target

2. Enable the Web Server on the RT target

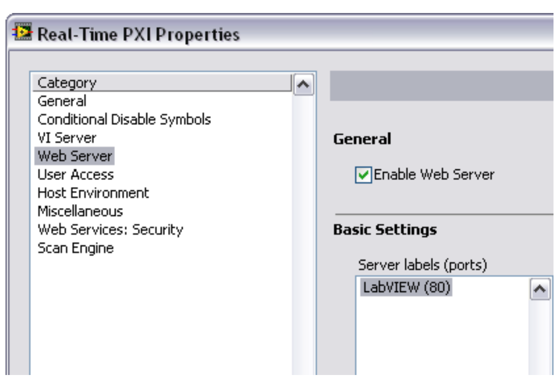


FIGURE 24: Enabling Web Server

3. Generate the HTML file for the Remote Panel

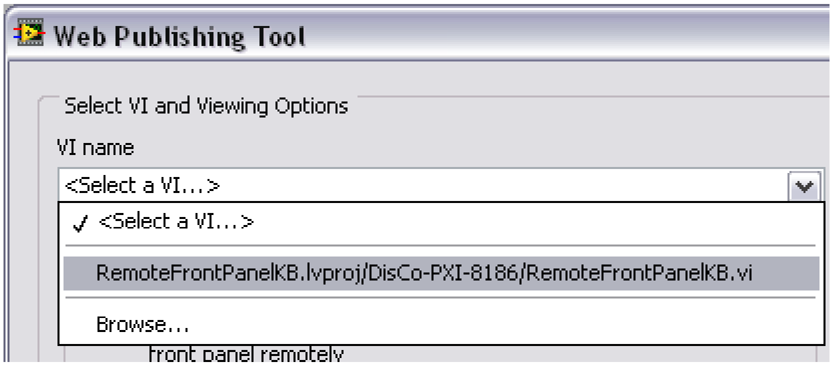


FIGURE 25: Selecting VI

4. Build the real-time application
5. Once built, set the application to run at startup

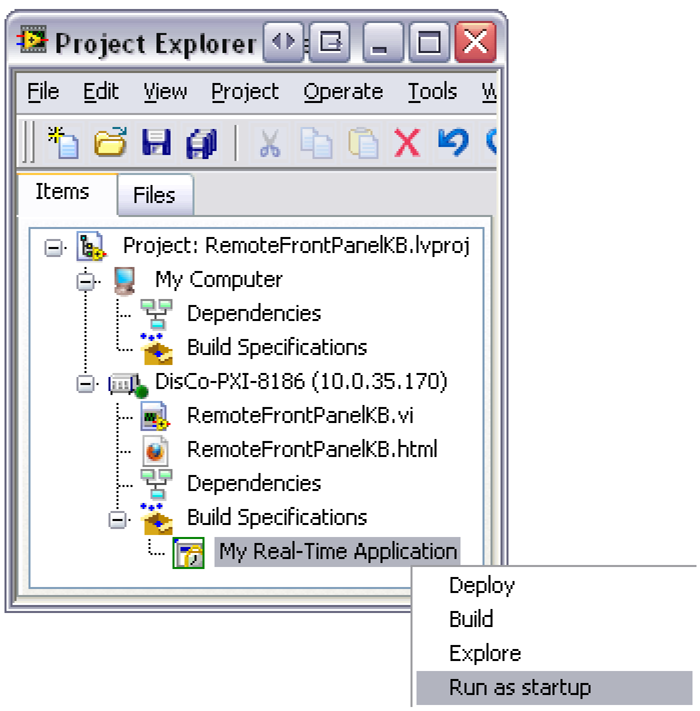


FIGURE 26: Running at Startup

6. After rebooting the real-time target, the Remote Front Panel should be accessible

CHAPTER 5: CONCLUSION AND RECOMMENDATION

In conclusion, the objectives of Final Year Project are achieved. The main contribution of this project are as follows:

1. Signals and I/O Requirement Study
   I/O signals and wiring assembly of the HEV are established which provide a clear overview of the HEV architecture.
2. Motor Drive Configuration and Testing
   The motor controllers were configured properly and the operation of the Motor Drive was tested on the vehicle which proved to be fucntioning properly with no errors (connection validation).
3. The EMS-GDI Integration
   GDI is developed using the web browser application and the Remote Panel is configured via the Web Publishing Tool of LabVIEW which allows the processes of the EMS controller to be displayed and/or controlled on a remote device.

However, there are more areas to work on in order to realise the hybrid operation of a retrofitted HEV. Some way forward may include:

1. Establish CAN communication between the EMS controller and Motor Drive
2. Installation of EMS and Tablet PC on the vehicle
3. Perform overall vehicle cabling termination
4. Perform on-the-road testing and data analysis

REFERENCES

[1] Hannan, M. A., Azidin, F. A., & Mohamed, A. (2014). Hybrid electric vehicles and their challenges: A review. *Renewable and Sustainable Energy Reviews, 29*(0), 135-150. doi: http://dx.doi.org/10.1016/j.rser.2013.08.097

[2] Zulkifli, S. A., Saad, N., Mohd, S., & Aziz, A. R. A. (2012, 6-7 June 2012). *Split-parallel in-wheel-motor retrofit hybrid electric vehicle.* Paper presented at the Power Engineering and Optimization Conference (PEDCO) Melaka, Malaysia, 2012 Ieee International.

[3] Zulkifli, S. A., Mohd, S., Maharun, M., Saad, N., & Aziz, A. R. A. (2012, 12-14 June 2012). *Development of a retrofit split-axle parallel hybrid electric vehicle with in-wheel motors.* Paper presented at the Intelligent and Advanced Systems (ICIAS), 2012 4th International Conference on.

[4] Xiao, G., Williams, J., & Guoping, L. (2012, 3-5 Sept. 2012). *Modelling of hybrid plus retrofit hybrid system*. Paper presented at the Control (CONTROL), 2012 UKACC International Conference on.

[5] How does a brushless motor work? (n.d.). Retrieved April 7, 2014, from http://electronics.howstuffworks.com/brushless-motor.htm

[6] Yafu, Z., Jing, L., Dianting, C., & Wei, W. (2009, 23-26 Jan. 2009). *Motor controller design for hybrid electric vehicles.* Paper presented at the TENCON 2009 - 2009 IEEE Region 10 Conference.

[7] Sergaki, E. S. (2012, 20-22 June 2012). *Electric motor efficiency optimization as applied to electric vehicles.* Paper presented at the Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), 2012 International Symposium on.

[8] Fallahi, N., & Halvaei Niasar, A. (2013, 13-14 Feb. 2013). *Optimized energy management strategy for separated-axle parallel hybrid electric vehicle.* Paper presented at the Power Electronics, Drive Systems and Technologies Conference (PEDSTC), 2013 4th.

[9] Maskey, M., Parten, M., Vines, D., & Maxwell, T. (1999, Jul 1999). *An intelligent battery management system for electric and hybrid electric vehicles.* Paper presented at the Vehicular Technology Conference, 1999 IEEE 49th.

[10] Energy management system. (n.d.). In *Wikipedia*. Retrieved February 18, 2014, from http://en.wikipedia.org/wiki/Energy_management_system

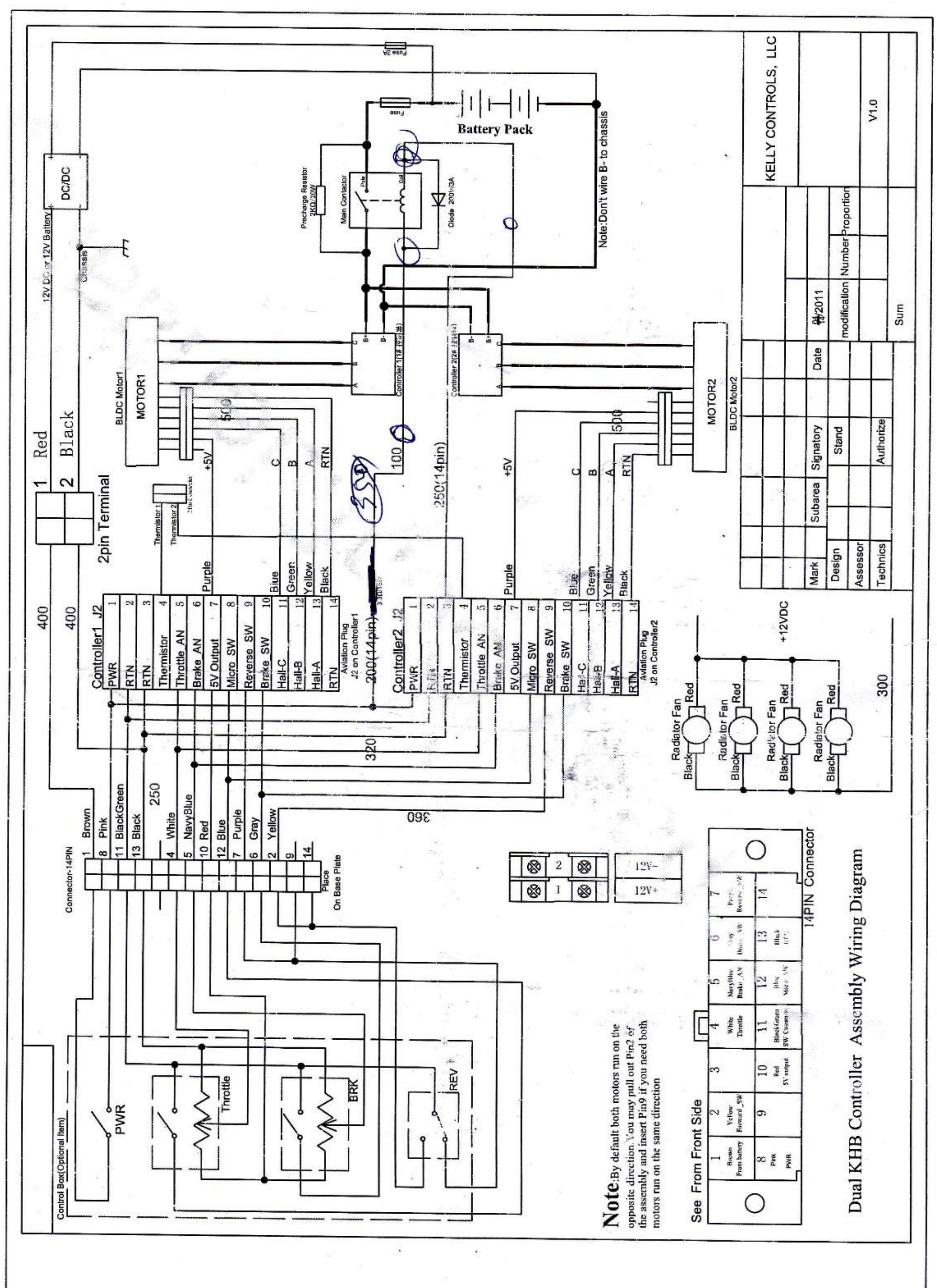
[11] Motor controller. (n.d.). In *Wikipedia*. Retrieved February 18, 2014, from http://en.wikipedia.org/wiki/Motor_controller

[12] What is CAN Bus? (n.d.). Retrieved February 18, 2014, from http://canbuskit.com/what.php

[13] Wanmi, C., & Jinxia, S. (2012, 6-8 July 2012). *Comparison of several communication methods between host computer and compactRIO.* Paper presented at the Intelligent Control and Automation (WCICA), 2012 10th World Congress on

APPENDIX A

KELLY DUAL KHB CONTROLLER WIRING DIAGRAM



APPENDIX B

CONNECTING THE NI 9201/9221

Connecting the NI 9201/9221

The NI 9201/9221 provides connections for eight analog input channels.

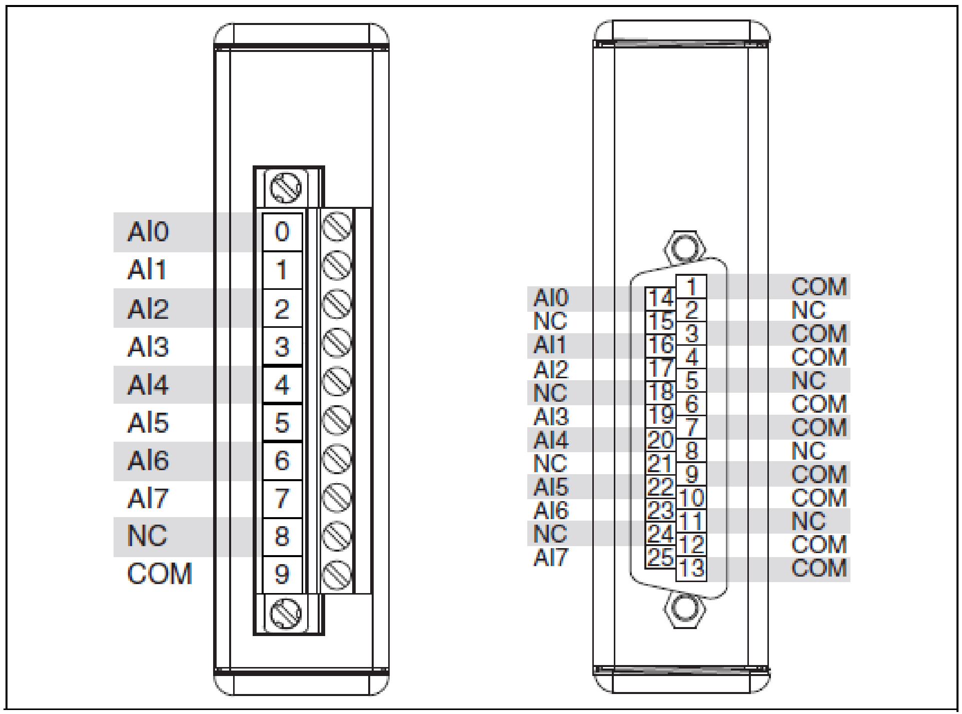


Figure 2. NI 9201/9221 Terminal and Pin Assignments

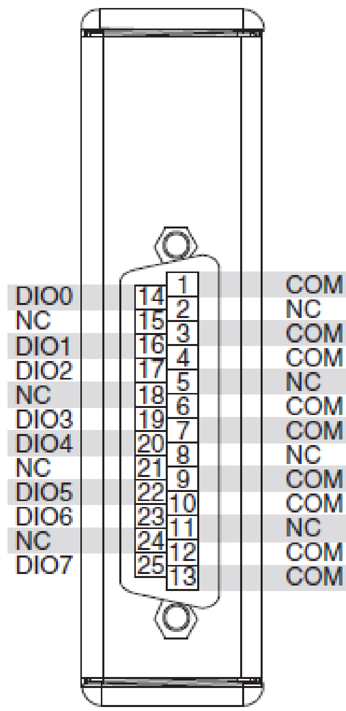
APPENDIX C

CONNECTING THE NI 9401

Connecting the NI 9401

The NI 9401 has a 25-pin DSUB connector that provides connections for eight digital input/output channels.

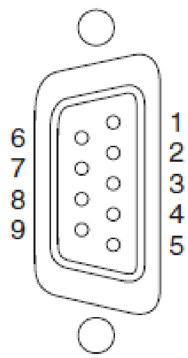
Figure 2. NI 9401 Pin Assignments



APPENDIX D

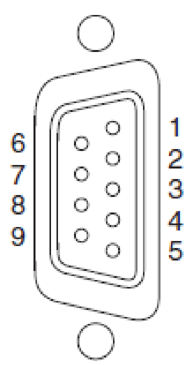
PIN ASSIGNMENT FOR NI 9853

Table 1. Pin Assignments for CAN0



Connector	Pin	Signal
	1	No Connection (NC)
	2	CAN_L
	3	COM
	4	NC
	5	SHLD
	6	COM
	7	CAN_H
	8	NC
	9	NC

Table 2. Pin Assignments for CAN1



Connector	Pin	Signal
	1	No Connection (NC)
	2	CAN_L
	3	COM
	4	NC
	5	SHLD
	6	COM
	7	CAN_H
	8	NC
	9	V_{SUP}

APPENDIX E

CAREL IR33A7 WIRING DIAGRAM