

**Development of Energy Management System (EMS) with
Driver Interface for Retrofit-Conversion Hybrid Electric Vehicle**

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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May 2013

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.

Yuhendri Kurniawan

ABSTRACT

Hybrid electric vehicle (HEV) is considered as one of the ways to reduce world's dependency on fossil fuel. It combines the features of conventional internal combustion engine with benefits of electric vehicle. However, the high price of HEV becomes a major drawback for its growth. As an alternative, retrofit conversion kit is being developed to convert a conventional internal combustion engine vehicle into HEV. This report discusses the development of energy management system (EMS) with driver interface based on National Instrument's CompactRIO embedded controller for retrofit hybrid conversion. The EMS acts as main controller that governs both electric propulsion system and conventional propulsion system. Different parameters of the moving car, such as vehicle speed, engine rpm and fuel consumption are monitored by the EMS. A graphical driver interface is implemented, on tablet PC platform, connected to the CompactRIO via Ethernet TCP/IP. LabVIEW-based interface appears on a dynamically-controllable HTML page hosted on the web server part of the CompactRIO, enabling the driver to control and monitor vehicle operation on the Tablet PC via an ordinary web browser.

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LIST OF ABBREVIATIONS

BCI: Battery Council International
CAN: Controller Area Network
ECU: Engine Control Unit
EMS: Energy Management System
FPGA: Field Programmable Gate Array
GUI: Graphical User Interface
HEV: Hybrid Electric Vehicle
HTML: Hyper Text Markup Language
I/O: Input/Output
ICE: Internal Combustion Engine
LAN: Local Area Network
NI: National Instrument
PC: Personal Computer
REEV: Range Extended Electric Vehicle
SoC: State of Charge
USB : Universal Serial Bus

CHAPTER 1

INTRODUCTION

Environmental pollution has become one of the critical issues in recent years; various solutions have been introduced to resolve the problem. In general, the solutions range from gradually decreasing dependency on fossil fuel to fully replace the fossil fuels into relatively cleaner energy sources such as solar, wind, biomass, etc. However, for time being, the approach of gradually decreasing our dependency on fossil fuel is more realistic considering that the energy generation cost of relatively cleaner energy sources is still very high.

Automotive sector is one of the sectors that contribute for high percentage of fossil fuel usage. Therefore, many believe that gradually decreasing our dependency on fossil fuel in automotive sector is an effective way to help resolving environmental pollution issue.

As an answer, auto industries have started to launch their eco-friendly vehicles to the market. Eco-friendly vehicles are mostly achieved by either hybrid electric technology where it combines petrol and electricity as the energy source to propel the car or full electric technology which uses only electric motor to propel the vehicle. Both technologies have their advantages and disadvantages over each other. For example, hybrid electric vehicle allows the user to have flexible use of energy source; however, it still uses fossil fuel. Electric vehicle on the other side, emit almost zero pollution but it has the drawback in the duration of charging.

In line with the idea of reducing dependency on fossil fuel, this project proposes a new approach to develop eco-friendly vehicle, which is by converting a conventional internal combustion engine (ICE)-based vehicle into a hybrid electric vehicle (HEV). The project's ultimate goal is to develop a retrofit conversion kit for conventional ICE vehicle. Perodua MyVi is used as prototype vehicle for this project.

1.1 Background of Study

A conventional internal combustion engine (ICE) vehicle can be converted into a hybrid electric vehicle (HEV) with minimal mechanical modification by replacing the two non-driven wheels with in-wheel motors to produce a split-parallel configuration through-the-road coupling HEV. A central controller is required for operating the HEV since the original ECU (Engine Control Unit) only controls the ICE.

This project aims to develop the central controller – the Energy Management System (EMS) - based on National Instruments' embedded, real-time controller - CompactRIO and LabVIEW software. Basic control of the two in-wheel motors is implemented by a proprietary motor controller (Kelly Controls) but motor operation will be monitored and can be bypassed by the central EMS, via serial or CAN bus communications.

Different parameters of the moving car, such as vehicle speed and engine rpm will also be monitored by the EMS, for the control algorithm to determine the hybrid operation - turning on/off the ICE and electric motors and torque command of the electric motors. Additional sensor required includes an instantaneous fuel consumption flow meter, to measure and quantify fuel consumption and savings under hybrid operation. A graphical driver interface will also be implemented, on tablet PC platform, connected to the CompactRIO via Ethernet TCP/IP. LabVIEW-based interface will appear on a dynamically-controllable HTML page hosted on the web server part of the CompactRIO, enabling the driver to control and monitor vehicle operation on the Tablet PC via an ordinary web browser.

1.2 Problem statement

Conversion from ICE requires a central EMS that is able to control both ICE and electric motor simultaneously. The original ECU of ICE-based vehicle is not sufficient for this application since it can only control ICE alone. Therefore, the development of new EMS is needed for conversion, in addition, the new EMS has to be equipped with driver interface to enable the driver to monitor and control the vehicle operation.

1.3 Objective & Scope of Study

1.3.1 Objectives

To develop an Energy Management System (EMS) with driver interface for retrofit conversion hybrid electric vehicle.

1.3.2 Scope of study

- Integration of various vehicle sensors into National Instrument's CompactRIO (hardware/physical connectivity)
- Programming on LabVIEW of various vehicle measurements for display & data logging
- Development of a Graphical User Interface (GUI) for in-vehicle monitoring and data logging of various vehicle parameters
- Development of algorithm to monitor battery state of charge
- Implementation of basic parallel electric assist control algorithm for energy management of the hybrid electric vehicle

1.3.3 Relevancy of the Project

Findings from this project are expected to address the following:

- *Reducing dependency on fossil fuel*; Consumption of fossil fuel is reduced significantly since ICE is not the only power source to propel the vehicle.
- *Supporting Eco-friendly movement*; reducing the consumption of fossil fuel is corresponding to decrement of environmental pollution.
- *Economical option*; Availability of hybrid EMS as conversion kit to convert conventional internal combustion engine based vehicle to hybrid is considered more economical rather than purchasing a new hybrid vehicle.
- *Reducing transportation cost*; Energy usage efficiency in hybrid mode is significantly improved, therefore it can reduce transportation cost.
- *Big market target*; Having Perodua MyVi as target vehicle opens up big market opportunity in Malaysia since Perodua MyVi is one of the most used vehicle in Malaysia, besides, the architecture of Perodua MyVi is

very similar to Daihatsu Sirion which is marketed globally, therefore the conversion kit can be implemented in Daihatsu Sirion as well.

1.4 Feasibility of the Project

The project is designed in two parts; the first part is mainly focusing on finalizing project planning and getting familiar with all tools required in this project while the second part focuses on building the prototype and fine tuning. This is aligned with final year project completion framework which is divided into two semesters.

CHAPTER 2

LITERATURE REVIEW

2.1 Hybrid Electric Vehicle

Hybrid Electric Vehicle (HEV) uses two sources of energy namely fuel and electricity to propel the vehicle. The main parts of HEV are: Internal combustion engine, Fuel tank, Electric motor, Generator, Batteries, Transmission and Energy management system. Energy management system (EMS) plays a very important role in HEV since it acts as the “brain” of the vehicle. EMS continuously monitors the operation of the vehicle through various sensors and driver input. The input data is then used to calculate and determine the most efficient use of energy (i.e. internal combustion engine, electric motor or both of them) [1]. HEV holds some advantages as compared to conventional vehicle:

- High fuel efficiency: HEV needs significantly lesser fuel than conventional vehicle
- Low emission : Lesser fuel consumption leads to cleaner operation and ultimately lowering dependency on fossil fuel
- Internal combustion engine is set to operate at average load therefore the engine weight can be reduced
- HEV uses regenerative braking which can generate electricity to charge the battery during braking. This reduces energy loss.

Graphs below show the typical efficiency map between conventional internal combustion engine and electric motor:

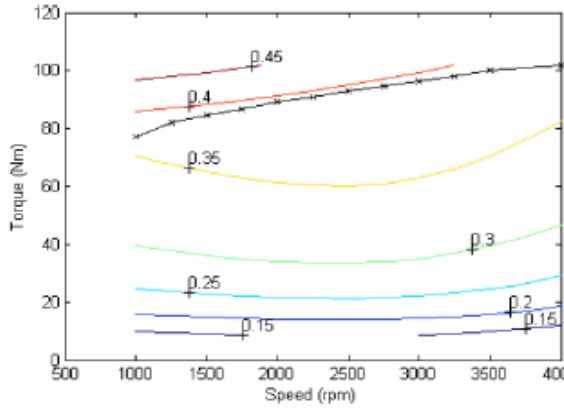


Figure 2: Efficiency map of ICE

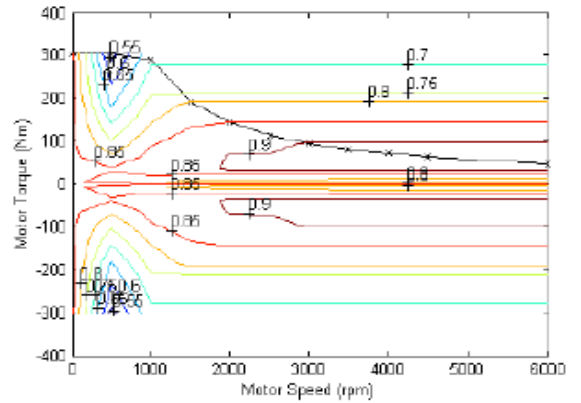


Figure 1: Efficiency map of electric motor

The above figures suggest that the efficiency of ICE is considered low at low speed; the speed at which the driver runs on city driving. Thus, it consumes fuel inefficiently. Electric motor on the other side, provides higher efficiency at low speed, therefore utilization of electric motor at low speed can reduce fuel consumption significantly [2].

Based on the characteristic of both ICE and electric motor, power management map can be generated to ensure highest efficiency at every level of speed. Three modes exist in typical HEV; motor only, ICE and power assist. Figure 3 describes the mapping of each mode at different engine speed level:

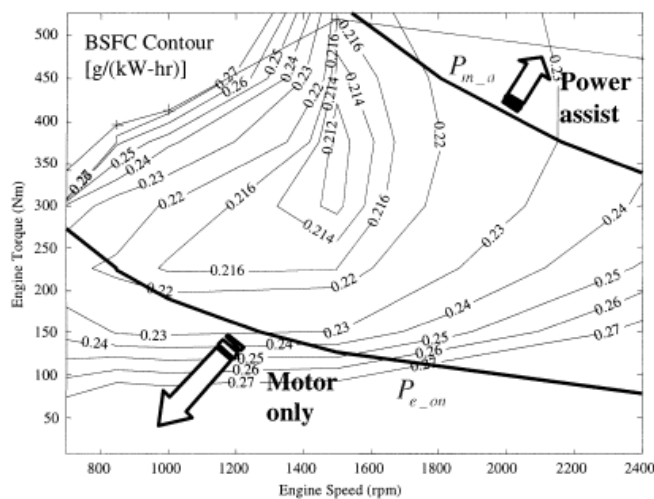


Figure 3: Power management in HEV

2.2 Drive train of Hybrid Electric Vehicle

- *Parallel hybrid*; electric motor and internal combustion engine are coupled to a common transmission line. This allows the transmission to be driven by either one source of power or combination of both according to the need. Parallel hybrid has an advantage over series hybrid when driving at high speed considering that internal combustion engine can operate at average load while electric motor provides additional power to transmission line, by doing so, efficiency can be improved [3].

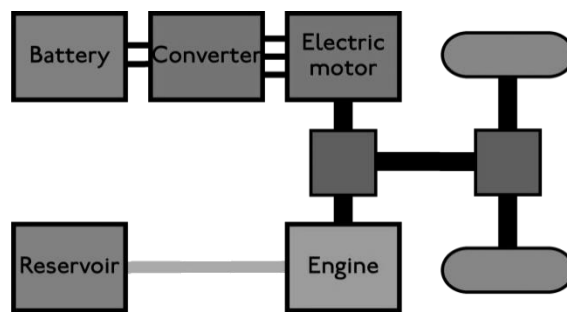


Figure 4: Parallel hybrid drive train

- *Series hybrid*; is essentially an electric vehicle with internal combustion engine as generator, it is also known as Range Extended Electric Vehicle (REEV) [4]. Electric motor is the only force that is connected to transmission line while internal combustion engine is used as generator to charge the battery pack. This configuration requires large battery but smaller internal combustion engine compared to parallel hybrid. Large battery pack is proportional to higher price point, however series hybrid is considered more efficient in city driving (low speed) due to several factors such as higher power to weight ratio of electric motor as compared to internal combustion engine [5].

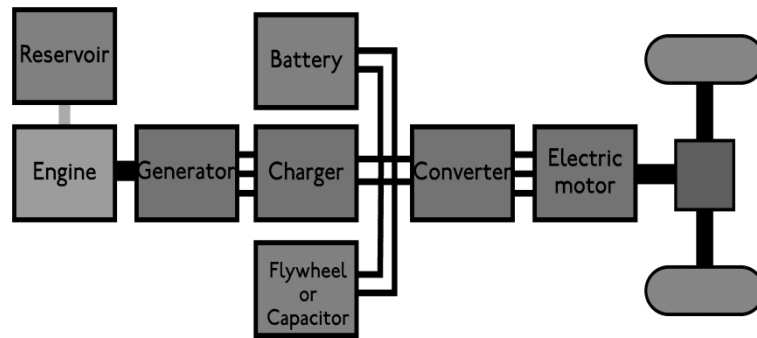


Figure 5: Series hybrid drive train

- *Power-split hybrid*; takes advantage of both parallel and series hybrid by connecting both power source to transmission line (parallel hybrid concept) and also enabling internal combustion engine to act as generator to charge the battery pack for electric motor. This configuration allows the system to get work efficiently in both city driving (lower speed) and highway driving (higher speed) [6].

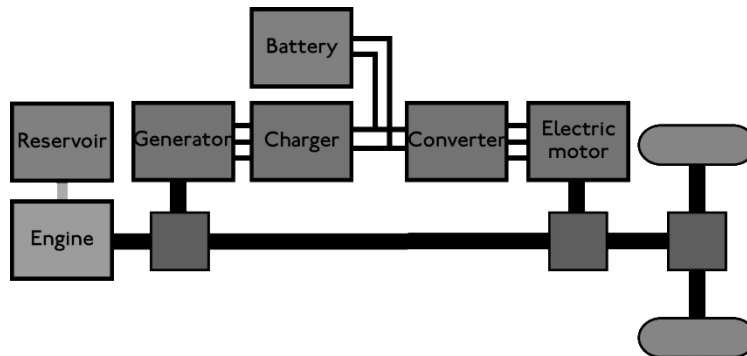


Figure 6: Power split hybrid drive train

- *Split parallel hybrid*; sets more independent approach in propelling the vehicle. ICE drives one driveshaft while Electric motors drive the other driveshaft. This configuration offers more flexibility to drive train system. Moreover, it is considered very suitable for retrofit conversion application [7].

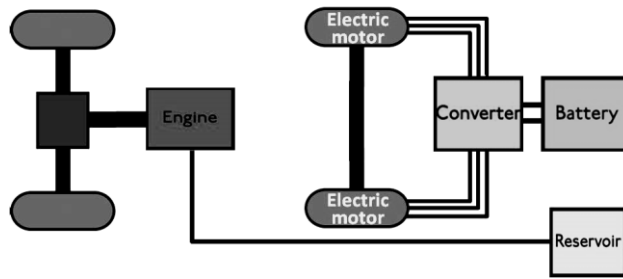


Figure 7: Split parallel hybrid drive train

2.3 Energy Management System (EMS)

EMS is a controller that is based on powerful microprocessor that uses closed loop control in which it receives the input from various sensors in the vehicle, calculate and determine the most efficient required energy based on pre-set configuration and command electric motor and/or internal combustion engine to drive the drivetrain. EMS in hybrid vehicle is far more complex as compared to conventional vehicle since it is not only controlling internal combustion engine but also electrical motor. Moreover, it also provides Graphical User Interface (GUI) to enable the driver to monitor the operation of the vehicle as well as selecting vehicle setting & configuration [8]. For application in retrofit conversion HEV, a flexible yet highly reliable EMS is needed. The new EMS has to be able to take over the control of default ECU of conventional internal combustion engine system and integrate it with the newly installed electric motor. In order to control electric motor, EMS has to establish solid communication system with motor controller.

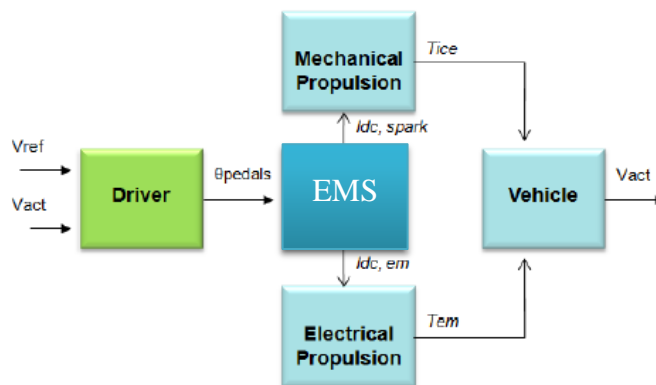


Figure 8: EMS operation diagram

Figure 8 shows basic operation of EMS in typical HEV, EMS holds control of both mechanical propulsion (from ICE) and Electrical propulsion from electric motor.

In parallel and split parallel HEV, the following operation modes are controlled by EMS:

1. Motor only; ICE is off, vehicle is driven by electric motor only. Occurs at low speed
2. ICE only; electric motor is off, vehicle is driven by ICE only, Occurs between low and high speed
3. ICE + Motor; both propulsion system is on, electric motor acts as auxiliary power to assist ICE
4. Power split mode; ICE is used for both propel the vehicle and charging the battery, electric motor becomes generator
5. Stationary charging mode
6. Regenerative braking; electric motor becomes generator when the vehicle is in braking state

2.4 EMS Control Strategy

There are three control strategies that are normally implemented in HEV, which are [9]:

1. *Parallel Electric Assist*; Normally used in parallel HEV where ICE acts as main propulsion source and electric motor acts as auxiliary power. It maintains Battery State of Charge (SoC) at certain level by changing vehicle operation mode.
2. *Fuzzy Logic*; Based on the concept of “load levelling” in order to put ICE at highest efficiency level and using electric motor to compensate the needed power. It first determines the required power for vehicle and then calculates the power distribution between ICE and electric motor.
3. *Adaptive Control*; More complex control strategy that considers both fuel economy and emission level. It monitors the systems in real time; therefore better decision can be made.

In this project, parallel assist control strategy is considered to be the most suitable considering that it is relatively simpler and more flexible in term of implementation. High level of simplicity and flexibility are highly needed for the conversion kit since the newly added system has to be integrated seamlessly to the current ICE-based system.

Electric motors are set to work in several manners [9]:

- For all driving torque below certain minimum speed
- When the torque required by vehicle is higher than the torque that ICE can produce at its operating speed
- At regenerative braking, to charge batteries
- In the case that engine efficiency is very low, ICE will be set inactive and electric motors act as the main propulsion
- At low SoC level, ICE will produce more torque than the vehicle require. The excess torque is used for motor to charge the batteries

The following diagrams visually describe the above mentioned operations.

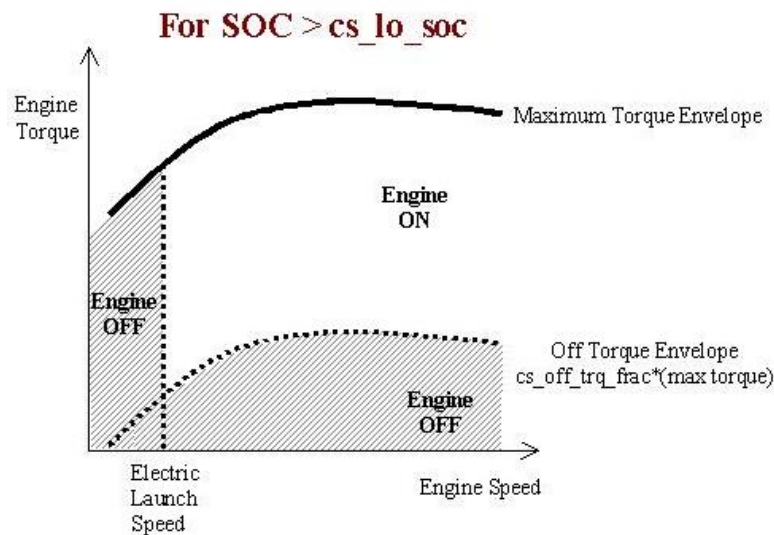


Figure 9: Parallel assist control at SoC > cs_lo_soc

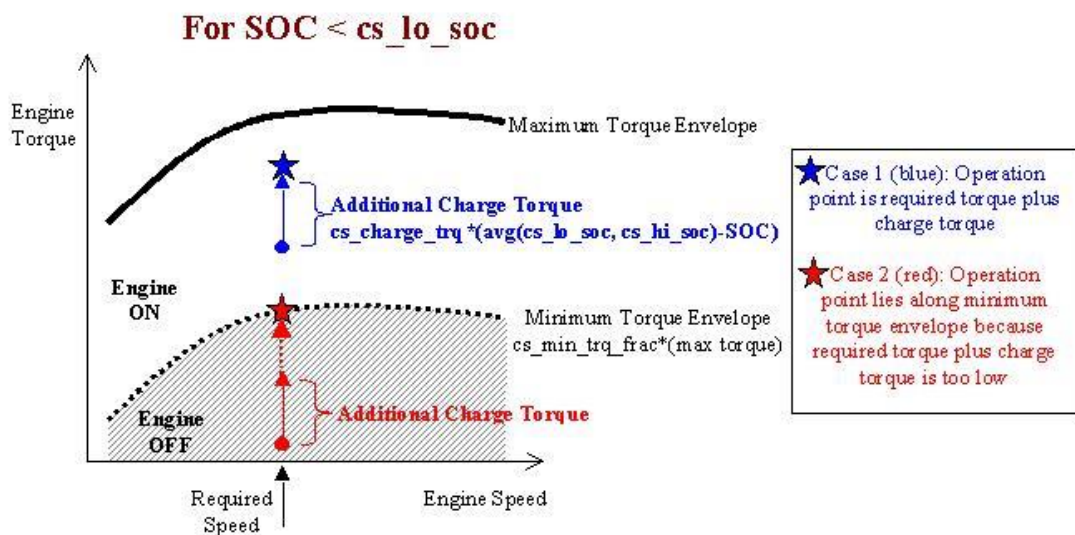


Figure 10: Parallel assist at SoC < cs_lo_soc

Legend:

- **cs_hi_soc**: highest desired battery state of charge
- **cs_lo_soc**: lowest desired battery state of charge
- **cs_electric_launch_spd**: vehicle speed below which vehicle operates as a Zero Emissions Vehicle
- **cs_off_trq_frac**: $cs_off_trq_frac * (\text{torque capability of engine at current speed}) = \text{minimum torque threshold}$; when commanded at a lower torque, the engine will shut off if $SOC > cs_lo_soc$
- **cs_min_trq_frac**: $cs_min_trq_frac * (\text{torque capability of engine at current speed}) = \text{minimum torque threshold}$; when commanded at a lower torque, the engine will operate at the threshold torque and the motor acts as a generator if the $SOC < cs_lo_soc$
- **cs_charge_trq**: $cs_charge_trq * ((cs_lo_soc + cs_hi_soc) / 2 - SOC) = \text{an accessory like torque loading on the engine to recharge the battery pack whenever the engine is on.}$

2.5 CompactRIO and LabVIEW

National Instrument's CompactRIO offers reconfigurable embedded control and acquisition system that is suitable to be used as EMS for retrofit conversion hybrid electric vehicle. This is due to the fact that it has very flexible hardware architecture which allows user to select and configure variety of I/O modules not only from National Instrument but also from third party. In term of programming, CompactRIO is designed to be configured by well-known National Instrument's LabVIEW. In general, CompactRIO can be divided into three main parts as shown below:



Figure 11: Main parts of CompactRIO

- *Real-Time Controller*: consists of industrial rate processor, 9-30 VDC supply input, Ethernet port, RS232 port, USB port and built-in storage. The processor is capable of executing LabVIEW real-time applications
- *Reconfigurable Chassis*: offers high performance access to I/O modules since it is directly connected to FPGA rather than a bus therefore it creates almost no control latency for system response.
- *I/O Modules*: more than 50 National Instruments C Series I/O modules are available to be connected to CompactRIO's reconfigurable chassis. These I/O modules can be connected to almost any types of sensor. I/O modules are also equipped with FPGA libraries to ease customization.

To perform real time control and monitoring, CompactRIO can be configured according to illustration below [10]:

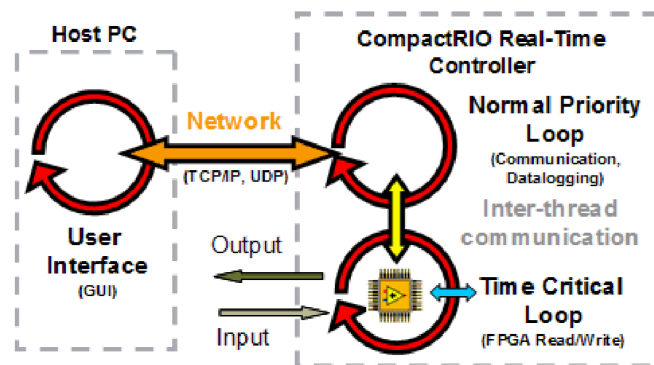


Figure 12: Real time control & monitoring

2.6 Fuel flow measurement

Fuel flow measurement is one of the most essential parts in developing a retrofit conversion system that will consume fuel in the most efficient way possible. Fuel flow rate is essential for two main reasons; to know the default fuel consumption of the target vehicle in internal combustion engine mode and to continuously monitor the fuel flow rate in hybrid mode. FUEL-VIEW DFM-50C-K is to be used as fuel flow meter in this project.



Figure 13: FUEL-VIEW DFM-50C-K

According to manufacturer's datasheet, three schemes of installations are available for FUEL-VIEW DFM-50C-K [11]:

- *Suction Side:* Fuel flow meter is positioned between feed pump and rough filter; however, in order to ensure clean fuel being feed to fuel flow meter, additional fine filter has to be installed between rough filter and fuel flow meter. The return fuel from the return line is omitted from fuel flow calculation since does not exceed 1%-2% of total fuel consumption.

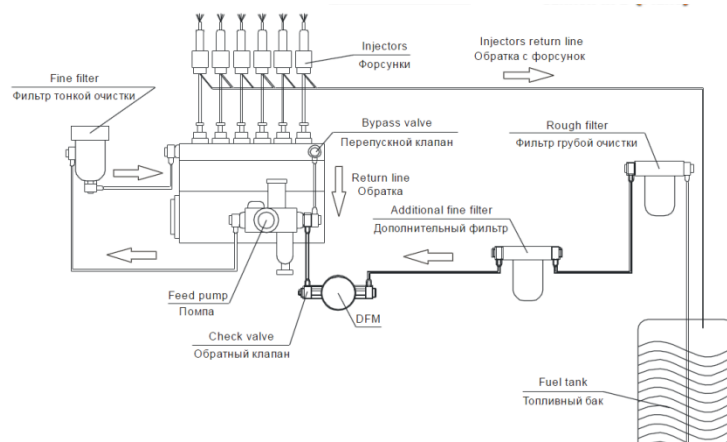


Figure 14: FUEL-VIEW installation on suction side

- *Pressure Side:* Fuel flow meter is installed after vehicle's stock fine filter, in this scheme; fuel return flow path from additional filter to the tank has to be prepared in order to avoid recounting of fuel flow in fuel flow meter. As advantages, the fuel flows to the fuel flow meter is under pressure. In addition, it also reduces the load of feed pump.

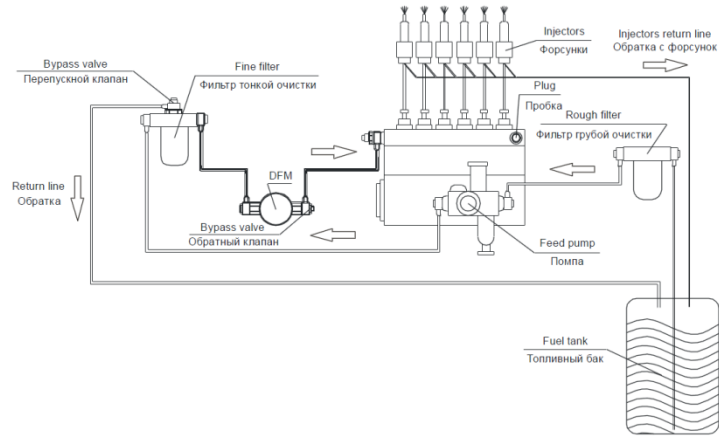


Figure 15: FUEL-VIEW installation on pressure side

- Differential:* two fuel flow meters are needed in this scheme since it takes into account both direct flow and return flow of fuel. As a result, the fuel flow is obtained from the differential between direct and return flow. Fuel flow meters can be installed on either pressure side or suction side. This scheme is normally used only on large fuel flow applications where 1-2% return flow greatly affects the measurement accuracy.

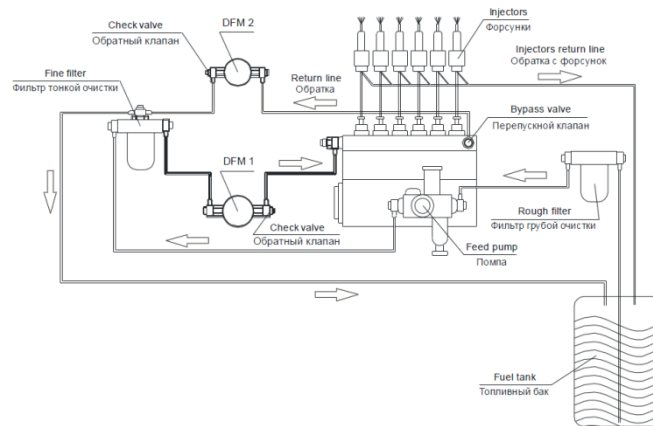


Figure 16: FUEL-VIEW differential installation on pressure side

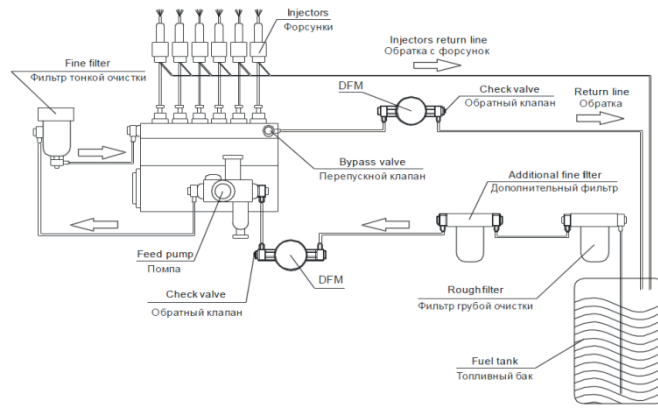


Figure 17: FUEL-VIEW differential installation on suction side

Output of FUEL-VIEW DFM-50C-K is represented in term of pulse signal where single pulse represents 5ml flow. Flow rate of this particular fuel flow meter ranges from 1 l/h to 50l/h with 25l/h nominal. The output signal of fuel flow meter can be connected to NI 9401 (8 Channel, 5 V/TTL High-Speed Bidirectional Digital I/O Module). Below is the impulse parameter of output signal:

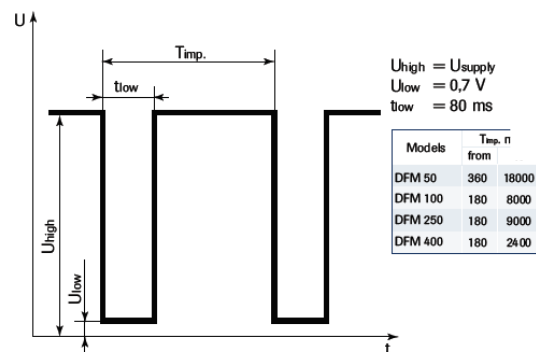


Figure 18: FUEL-VIEW impulse parameter

2.7 Battery State of Charge

There are few methods that can be utilized to monitor battery state of charge such as:

- Voltage Method:* It is considered to be the simplest method in determining the state of charge since it only takes into account voltage levels of battery from fully charged to fully discharged. However, this method produces high level of inaccuracy due to the fact that the voltage drop in most of batteries from fully charged to fully discharged is very minimum, therefore slight error in voltage reading causes big difference in state of charge value.

Furthermore, different cell types have different chemical compositions that produce varied voltage profile [12] [13] [14].

- *Hydrometer*: This method only applicable for flooded lead acid and flooded nickel-cadmium batteries. Sulphuric acid becomes heavier when battery is charging; it leads to increase of specific gravity (SG). The opposite phenomenon occurs when battery is discharging. Below is table that show BCI (Battery Council International) standard for SoC estimation of a maintenance-free starter battery with antimony:

Table 1: BCI standard for SoC estimation

Approximate state-of-charge	Average specific gravity	Open circuit voltage			
		2V	6V	8V	12V
100%	1.265	2.10	6.32	8.43	12.65
75%	1.225	2.08	6.22	8.30	12.45
50%	1.190	2.04	6.12	8.16	12.24
25%	1.155	2.01	6.03	8.04	12.06
0%	1.120	1.98	5.95	7.72	11.89

The values are based on measurement in room temperature environment (26°C) and the battery had rested for 24hours after charge or discharge [13] [12].

- *Impedance Spectroscopy*: Suitable for sealed and flooded lead acid battery. It monitors the battery based on impedance values of the Randles model. Unlike the measurement based on BCI, impedance spectroscopy method can perform accurate measurement while battery under the load or charging [13].



Figure 19: Accurate SoC reading by impedance spectroscopy



Figure 20: Inaccurate SoC reading by BCI standards

- Quantum Magnetism: It works in lead acid and lithium-ion batteries. Negative plate of battery changes from lead to lead sulphate in discharge cycle, this change causes the lead to have different magnetic susceptibility which is linear to SoC value [13].
- Coulomb Counting & SoC Drift: Coulomb counting is a method that continuously monitors the amount of current flowing in and out of battery while SoC drift is open-voltage map when the battery is charging or discharging (similar to voltage method). This method is very reliable in application that requires high accuracy when battery is in operation. However, battery capacity has to be known in order to define 100% state of charge and certain computation power is needed to accurately calculate battery capacity [13]. Below are the graphs showing coulomb counting (red) and SoC Drift (blue) in a battery in discharging cycle:

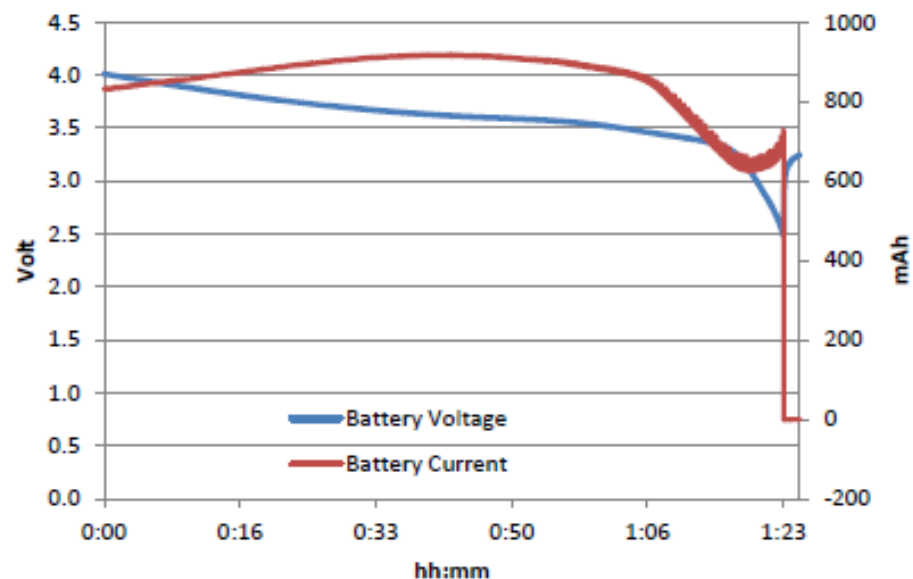
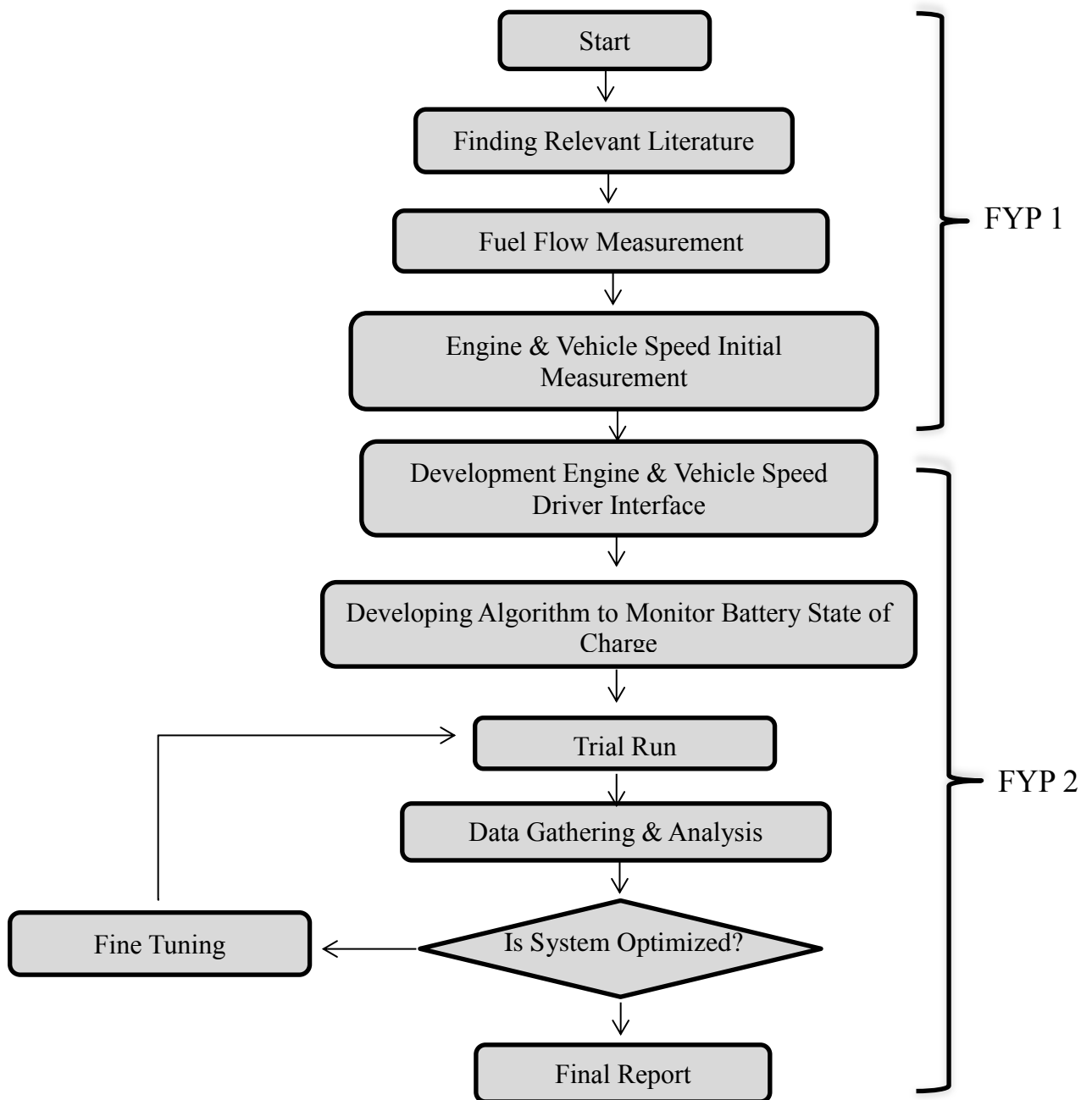


Figure 21: Coloumb counting & SoC drift

This method is therefore the most suitable to dynamically monitor battery state of charge in vehicle application since the measurement has to be done when the battery is in operation. In addition, the newly developed EMS can perform computation of battery capacity via CompactRIO.

CHAPTER 3 METHODOLOGY

3.1 Research Methodology



3.2 Implementation Concept

3.2.1 Pictorial Schematic

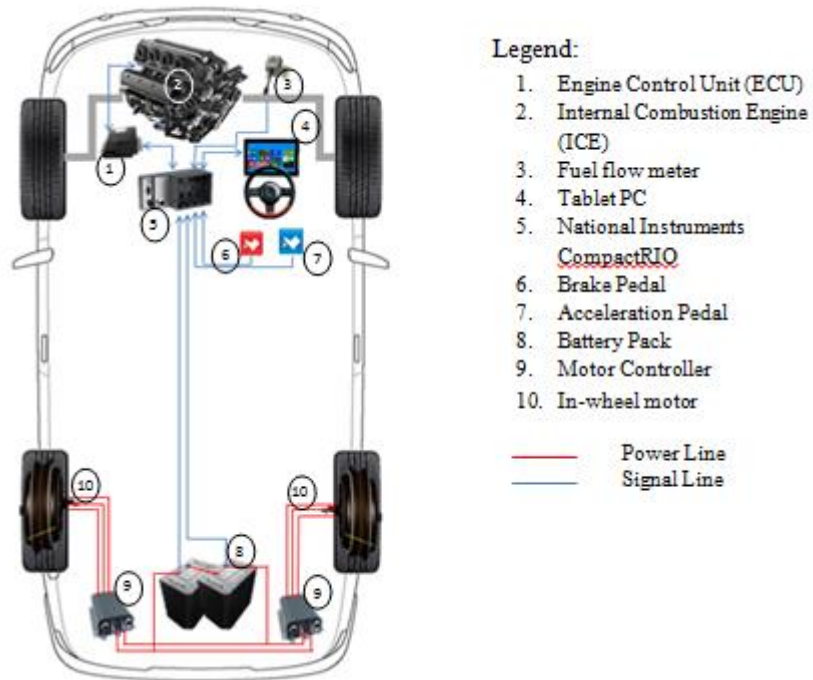


Figure 22: Pictorial schematic

3.2.2 Block Diagram

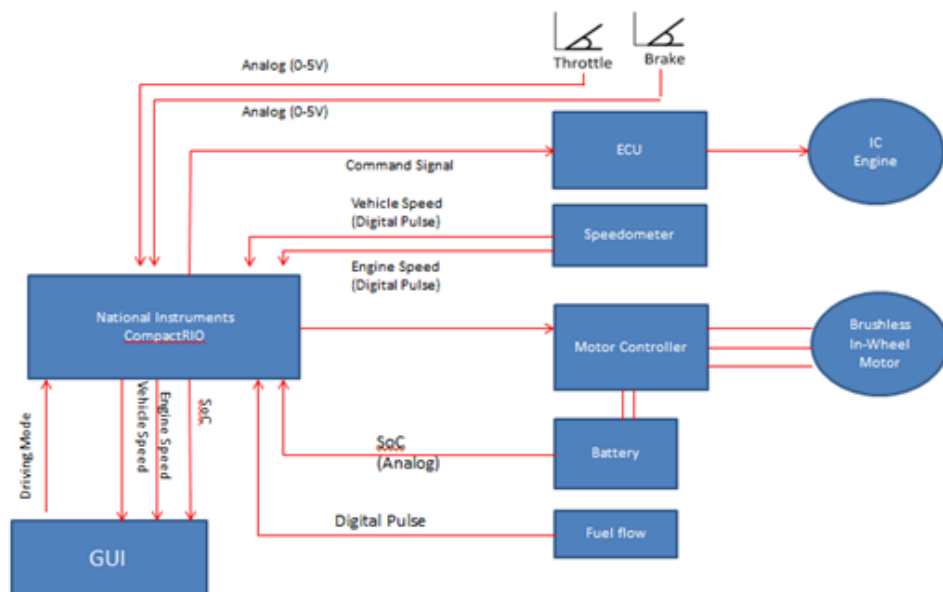


Figure 23: Block diagram

3.2.3 Input/ Output List

Table 2: Input/Output list

No	Subsystem	I/O Type	Description
1	Fuel flow	Digital	Scaled pulse, 5ml/pulse
2	Engine speed	Digital Pulse	Tapped from speedometer
3	Vehicle speed	Digital Pulse	Tapped from speedometer
4	Brake pedal position	Analog	0-5V
5	Acceleration pedal position	Analog	0-5V
6	Battery state of charge	Analog	Vbatt, Vshunt

3.3 Project Activities

3.3.1 Finding relevant literatures

The project was started by finding relevant literatures related to the topic. It is intended to get deeper insight on current trend and work done on similar field. By having such information, effective and structured strategy can be developed to achieve the objectives of the project. The finding are focused on eight topics, which are; Hybrid electric vehicle's general knowledge, degree of hybridization of HEV, drivetrain system, energy management system, control strategy, CompactRIO & LabVIEW, fuel flow measurement and battery SoC.

3.3.2 Learning CompactRIO & LabVIEW

For the purpose of retrofit conversion, the stock ECU is replaced by new EMS that is based on National Instrument's CompactRIO embedded controller and driven by LabVIEW programming. Basic knowledge on CompactRIO architecture and LabVIEW is highly needed before proceeding to simulation and on vehicle installation.

Learning process is divided into two sections;

- Self-learning; by reading CompactRIO and LabVIEW learning module as well as going through tutorial package provided in National Instrument forum
- Intensive training by National Instrument; engineer from National Instrument Malaysia conducted short yet compact training on CompactRIO and LabVIEW in Universiti Teknologi PETRONAS

3.3.3 Learning fuel flow measurement technique

According to project framework, the first instrument to be monitored by CompactRIO is fuel flow meter. Fuel flow meter serves two purposes:

- Analysing the fuel consumption of the vehicle before hybrid conversion
- Continuously monitor fuel flow after conversion to hybrid

There are three installation schemes available for measuring fuel flow by using FUEL-VIEW DFM-50C-K fuel flow meter as explained in section 2.6. A study was done to select the most suitable installation scheme for this project by considering the fuel flow system in target vehicle, accuracy of measurement and also cost effectiveness. Pressure side installation scheme is considered the most suitable installation scheme (Figure 15) for Perodua MyVi since it does not require extra fine filter to be implemented.

3.3.4 Purchasing Required Tools

Required hardware and tools were ordered after finalizing the concept of the project. This process may take several weeks in total since some of the purchase has to go through approval and bidding process in UTP.

3.3.5 Preparing LabVIEW program for fuel flow measurement

A LabVIEW program is required to display the fuel flow meter reading on vehicle's tablet pc. Scaled pulse train is provided by fuel flow meter as output signal, LabVIEW program has to be able to continuously monitor and translate the reading into instantaneous and accumulated flow rate. National Instrument's 9401 digital I/O module is used to read the scaled pulse from fuel flow meter.

3.3.6 Engine & vehicle speed measurement

Since engine and vehicle speed have already part of the original system of Perodua MyVi, it will not be necessary to develop a new system to monitor these variables. Stock Perodua MyVi's ECU provides the two variables in its pinout. However, in order to identify the pins we have to either refer to ECU wiring diagram which is considered confidential or manually check each pinout that goes to speedometer. Type of signal produce from both engine and vehicle speed has to be determined and scaled to match with actual reading on dashboard.

3.3.7 Battery State of Charge

Coulomb counting and SoC drift method is used to dynamically monitor battery state of charge in the vehicle. Several preliminary works have to be performed on the battery in order to get base variables such as voltage level map and current level map in charging and discharging cycle. These values are then used in dynamic calculation performed by CompactRIO.

3.3.8 Trial run

Few sets of trial run are performed before and after the conversion of vehicle. The first trial run is intended to get benchmark fuel consumption when the vehicle is in stock configuration.

3.4 Key Milestones

Table 3: Key milestones

No	Activities	Start Date	End Date
1	Briefing on project framework	15/01/2013	23/01/2012
2	Getting familiar with required software & hardware	24/01/2013	06/04/2013
3	Purchasing required tools & equipment	24/01/2013	01/03/2013
4	Fuel flow measurement	25/02/2013	05/04/2013
5	Engine & vehicle speed measurement	24/06/2013	28/07/2013
6	Trial run	04/07/2013	04/07/2013

3.5 Gantt chart

Table 4: Gantt chart

		June 2013				July 2013				Aug 2013				
No.	Work Description	3 Jun	10 Jun	17 Jun	24 Jun	1 Jul	8 Jul	15 Jul	22 Jul	29 Jul	5 Aug	12 Aug	19 Aug	26 Aug
A Energy Management & Supervisory Control (EMS)														
1	Fuel meter installation, configuration & interfacing to cRIO EMS		■	■										
2	Fuel meter testing OTR - non-conversion vehicle (ICE only) for benchmarking			■	■									
3	cRIO EMS testing of fuel measurement OTR - non-conversion vehicle				■	■								
4	Interfacing engine rpm & vehicle speed to cRIO EMS (stationary)				■									
5	cRIO EMS testing of rpm & speed measurement OTR - non-conversion vehicle					■								
6	cRIO EMS testing of data-logging & graphical driver Interface (GDI) (stationary & OTR)					■	■	■						
7	Develop SOC measurement algorithm & testing with IWM lab set-up					■	■							
8	Interfacing & commissioning brake pedal position (BPP) & accel. pedal position (APP) sensors to cRIO EMS (stationary & OTR)							■	■	■				
9	cRIO EMS programming of control strategy for hybrid vehicle operation							■	■	■				
10	OTR testing of retrofit HEV operation - sensors, measurements, strategy & fuel consumption										■	■	■	
11														

3.6 Tools

3.6.1 Software

- LabVIEW 2012
- LabVIEW run-time engine 2012
- LabVIEW FPGA module 2012
- LabVIEW Real-time module 2012
- NI- RIO 3.2
- Microsoft VISIO
- Microsoft Office

3.6.2 Hardware

- CompactRIO 9076
- NI 9401 (8 Channel digital I/O)
- FUEL-VIEW DFM-50C-K
- 24 VDC Power supply

- Acer Iconia Tab A501
- USB to LAN adapter
- DC to DC adapter (12-24V)
- Car cigarette lighter socket
- Digital multimeter
- Ethernet cable
- 24V battery
- ETI Tech EV410GGC2 52V battery
- Omega OM-DAQPRO-5300
- High power wire wound resistor 2R2 1500W

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Fuel Flow Measurement

4.1.1 Signal conditioning

According to manufacturer's installation manual, FUEL-VIEW DFM 50C-K has the following specification:

Table 5: FUEL-VIEW specification

Item	Value
Output	Scaled pulse, Min. 0.7V, Max. U _{supply}
Power	Battery powered
External power supply	10...50 Vdc
Current consumption	For 12 Vdc - 50 mA
Minimum flow	1 l/h
Nominal flow	25 l/h
Max flow	50 l/h

In this project, Fuel flow meter runs on 12V supply from battery, therefore the maximum voltage level of pulse is 12V. The representation of the pulse generated from FUEL-VIEW DFM 50C-K in our system is as below:

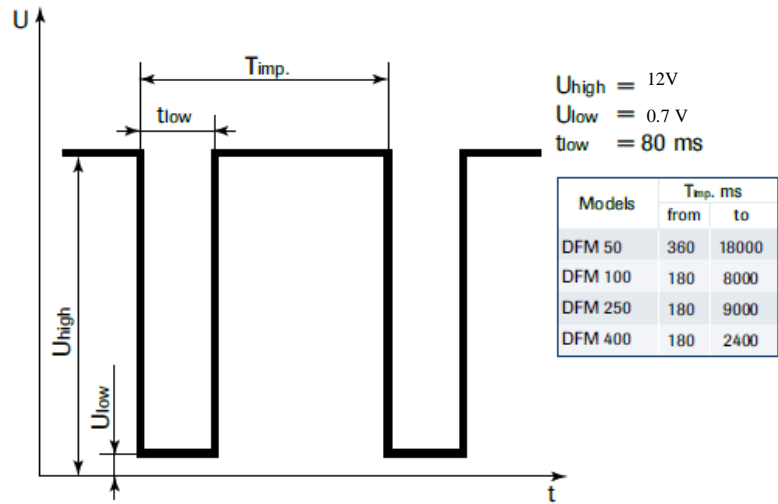


Figure 24: FUEL-VIEW scaled pulse

Although fuel flow meter runs normally on 12V system, the digital I/O module NI 9401 can only take input of maximum 5.25V. To overcome this mismatch, additional circuit is needed as adapter to convert 12V pulse to 5V pulse. This can be achieved by diode clipper circuit as below:

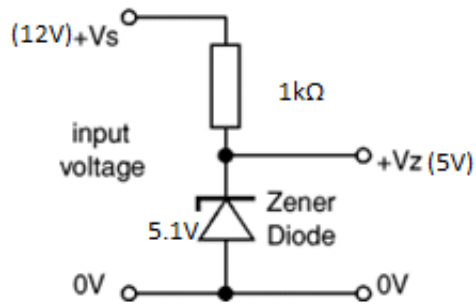


Figure 25: Diode clipper schematic as adapter circuit

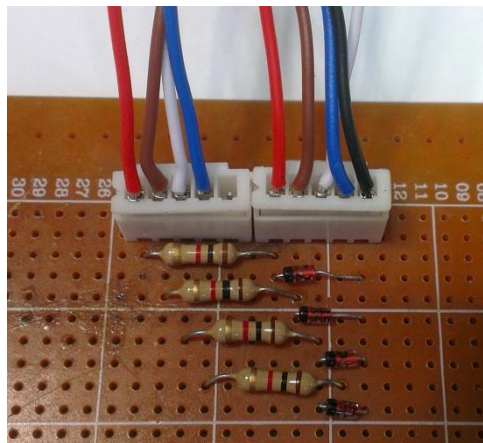


Figure 26: 4 sets of diode clipper circuit

Four sets of diode clipper were prepared for signal conditioning of fuel flow measurement and other purposes.

The following is the signal obtained after installing diode clipper as adapter circuit:

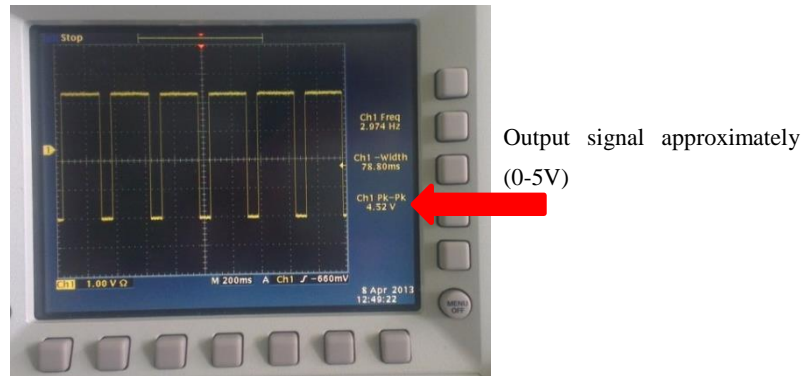


Figure 27: Output signal from diode clipper

Diode clipper adapter circuit limits its output from exceeding a predefined voltage level (in this case is 5V) without distorting the remaining part of the applied signal. Zener diode is the main component that makes this application possible, the difference between zener diode and normal diode is that it lets the current flow in reverse direction if the voltage exceeds its breakdown voltage, in this case is 5.1V. Thus, when 12V input voltage is applied, V_z will produce 5V output due to the drop at $1k\Omega$. The value of $1k\Omega$ is determined by satisfying two conditions:

- R value must be set in a way that the zener diode is kept at reverse breakdown. In this case, reverse current of zener diode is 5mA, and the current that flows through diode is 7mA $((12V-5V)/1k\Omega)$
- R value should be able to prevent device breakdown due to excessive power. $I_d V_b < P_{max}$, where I_d is current flow through diode, V_b is diode's breakdown voltage and P_{max} is the maximum power dissipation

4.1.2 Hardware configuration for fuel flow measurement

There are four components involved in fuel flow measurement which are: vehicle's battery, FUEL-VIEW, diode clipper and NI 9401 digital I/O module that is attached to CompactRIO. The following diagram describes the connection configuration of these four components.

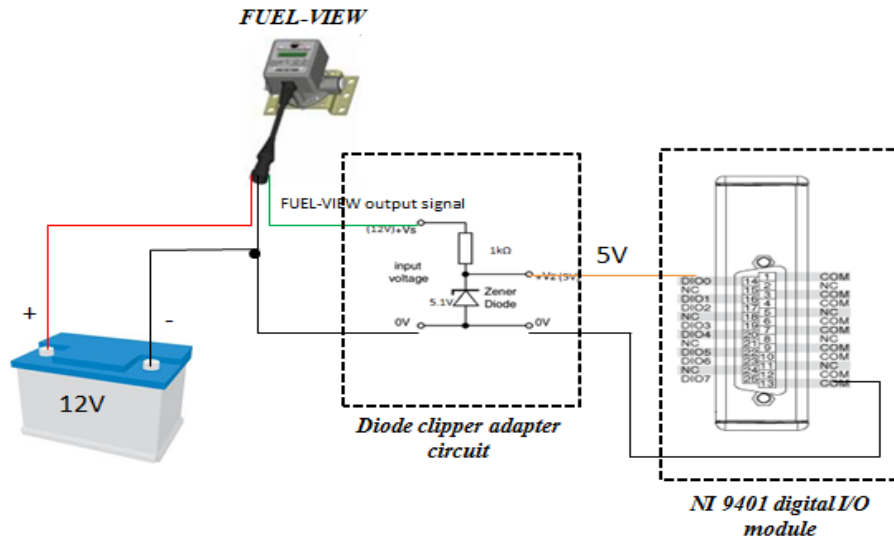


Figure 28: Fuel flow measurement hardware configuration

4.1.3 Development of LabVIEW program for fuel measurement

LabVIEW program development is divided into three parts which are:

- *Setting Scan Interface for NI 9401 digital I/O module*; pin D0 is set as input pin which will receive pulse signal from fuel flow meter. In order to count the number of pulse, D0 is set as counter that will increment counting value when it senses falling edge.

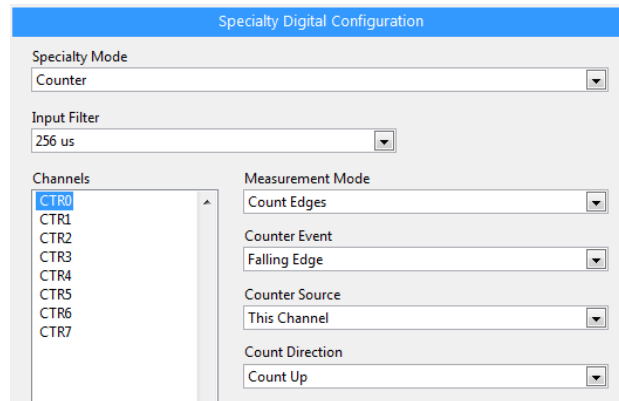


Figure 29: Scan interface setting for pin D0 on NI 9401

As shown in the figure above, pin D0 (represented as CTR0) is set as counter to allow it to count the pulse read from fuel flow meter at each falling edge. To prevent noise, input filter is set to 256us. It means that any change on signal in interval of 256us is ignored as it is considered to be noise. The value 256us is chosen after analysing the minimum time needed for fuel flow meter to send new pulse. Considering that 1 pulse is

equivalent to 5ml and the minimum time needed for the vehicle to consume 5ml is in the range of second, therefore it is saved to set filter at 256us as a real new pulse cannot be generated within this period.

- Data processing*; two kinds of calculation are performed in this part, instantaneous flow rate and accumulated fuel consumption. For instantaneous flow rate, shift register is used to determine number of pulse in a second. It obtains the difference between current counter reading and previous counter reading. Reading is taken every 500ms, therefore the value obtains from shift register is number of pulse in 0.5 second. This value has to be multiplied by 2 to convert it into pulse per second, because flow measurement is represented by 5ml/s for each pulse. The amount of fuel flowing every reading is called instantaneous flow rate. Instantaneous flow rate is then summed to obtain accumulated fuel consumption. The two parameters (instantaneous flow rate and accumulated fuel consumption) are then displayed in front panel for driver interface.

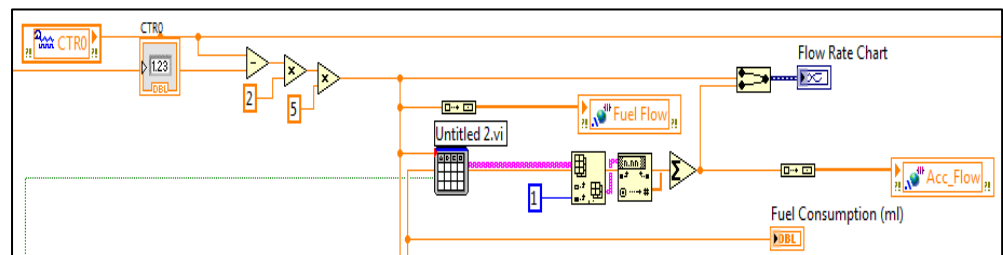


Figure 30: Fuel flow measurement LabVIEW program

- Data Acquisition*; one of the important factors from every measurement is data acquisition. The monitored data need to be recorded for record and further analysis. In this case, measurement data is logged into USB drive that is plugged to CompactRIO. Instantaneous flow rate and accumulated fuel consumption are the parameters that are logged into memory, the following is LabVIEW program that log data into memory.

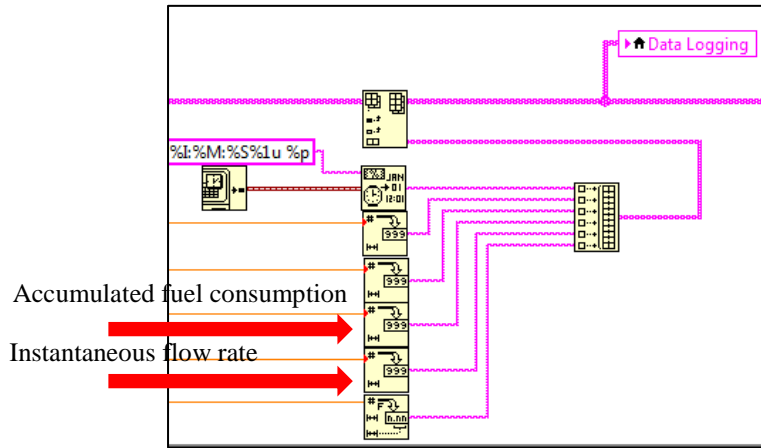


Figure 31: LabVIEW program for fuel flow measurement data logging

- Front Panel; in user interface part, data is presented in three forms; individual display, logging display and graph indicator.

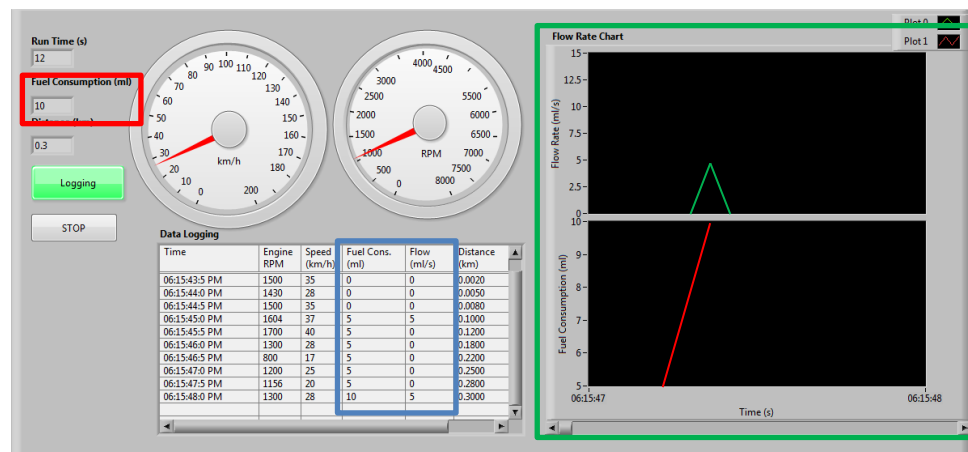


Figure 32: User interface for fuel flow measurement

Fuel consumption shown in red box is updated every new pulse detected from fuel flow meter, the blue box shows data logging of both instantaneous flow and accumulated fuel consumption in table form, it allows user to dynamically monitor vehicle's fuel consumption in real time. Last part is two graphs in green box that represent instantaneous fuel flow and fuel consumption trend. It is shown that fuel consumption is raised as instantaneous flow is detected.

4.2 Engine & Vehicle Speed Measurement

4.2.1 Signal Conditioning

In order to obtain engine & vehicle speed for CompactRIO, two wires that carry digital pulse of RPM signal (engine speed) and vehicle speed need to be identified. These signals are manually identified from input socket of speedometer in vehicle's dashboard.

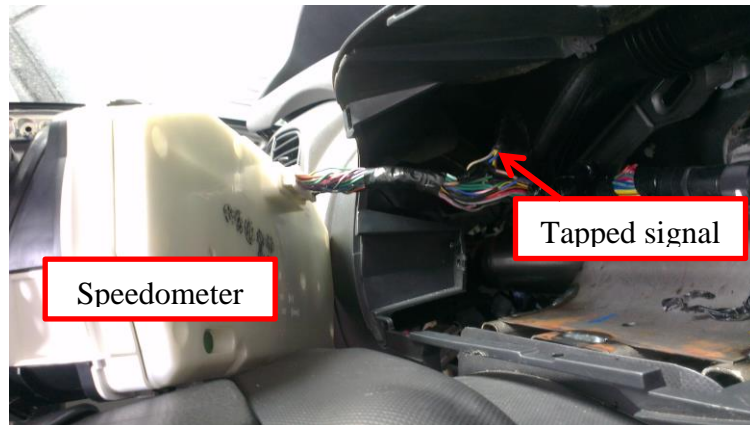


Figure 33: Tapping RPM & engine speed signal from speedometer socket

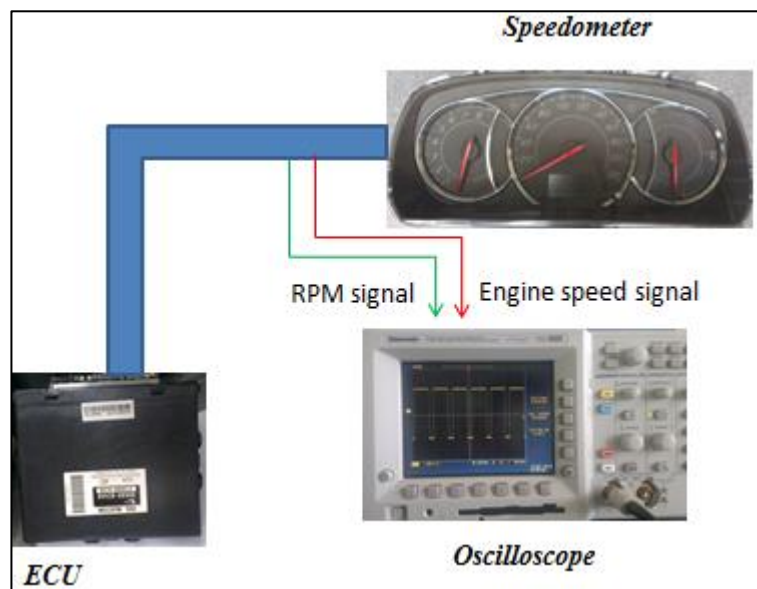


Figure 34: Connection for analyzing RPM & engine speed signal pattern

Upon determining corresponding engine and vehicle speed wire, characteristic of its output signal were analysed.

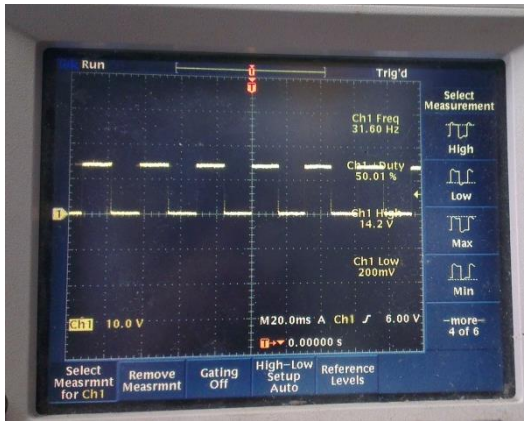


Figure 35: Vehicle speed output (31 Hz at 43km/h)



Figure 36: RPM output signal (70Hz at 2000rpm)

From the experiments, it is observed that the signals are frequency dependent since only frequency values varies when engine & vehicle speed is varied, duty cycle and voltage level remain constant. It is also noted that the signal amplitude ranges from 0 to 14.2V. Numbers of experiments were performed to map the relation between engine & vehicle speed with its corresponding frequency value. Below are the selected experiment results that show linear relation between engine & vehicle speed with frequency:

Table 6: RPM vs. Frequency

f (Hz)	RPM
25	500
40	1000
52	1500
70	2000
90	2500
100	3000
124	3500
140	4000

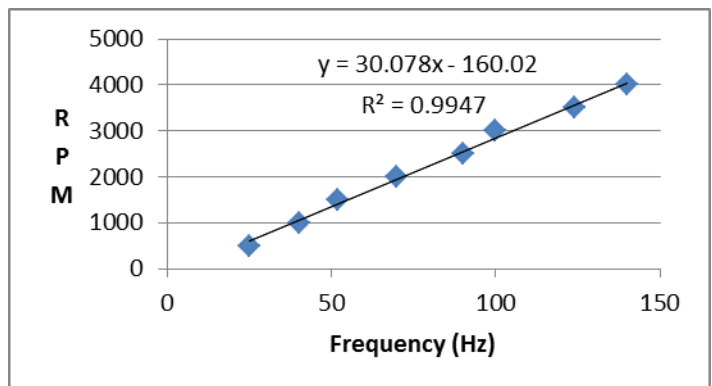


Figure 37: Linear regression of RPM vs. Frequency

Table 7: Vehicle speed vs. Frequency

f (Hz)	Speed
8.3	10
15	20
20	30
28.5	40
35	50

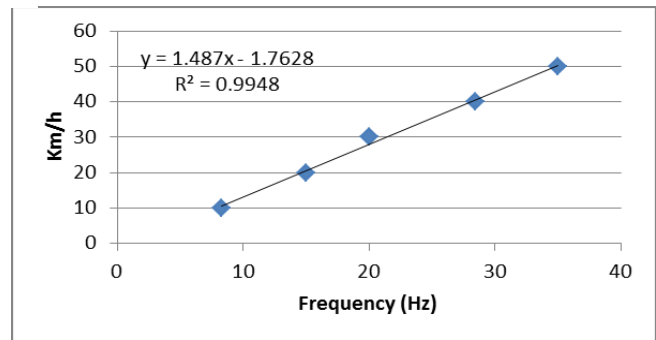


Figure 38: Linear regression of vehicle speed vs. Frequency

Experiments were performed while the vehicle was jacked so that it is easier to monitor the data and maintaining throttle stability to produce steady rpm and vehicle speed. Measurement was limited to certain point (4000rpm for rpm measurement and 50km/h for vehicle speed) due to various concerns such as emission, noise pollution and strong vibration when vehicle is operating at high rpm or speed. Linear regression approach is used to obtain the equation to model the output signals relations. R^2 value gives information about how good are the data points represented by the linear line, maximum value of R^2 is 1 which mean that all data points is represented by the line. In this experiment, R^2 value of 0.9947 for rpm measurement and 0.9948 were obtained. These values imply that 99.47% data points are represented by linear line for rpm measurement and 99.48% data points are represented by linear line for speed measurement. Therefore, the linear lines are considered acceptable and the equation of the linear lines can be used to convert frequency readings into rpm and vehicle speed. The following are the formula for conversion:

$$\text{RPM} = 30.078 (\text{frequency from rpm sensor}) + 160.02$$

$$\text{Vehicle speed in km/h} = 1.487 (\text{frequency from vehicle speed sensor}) + 1.768$$

4.2.2 Hardware configuration for rpm and vehicle speed measurement

As mentioned in section 4.2.1, the amplitude of output signal from rpm and vehicle speed sensor range from 0 to 14.2V. This mean that the signals have to be clipped first to have the range of 0 to 5V only, since NI 9401 digital I/O module can only accept signal with maximum amplitude of 5.25V. Diode clipper is again used to condition the output signal. Below is the diagram that shows the hardware configuration for rpm and vehicle speed measurement:

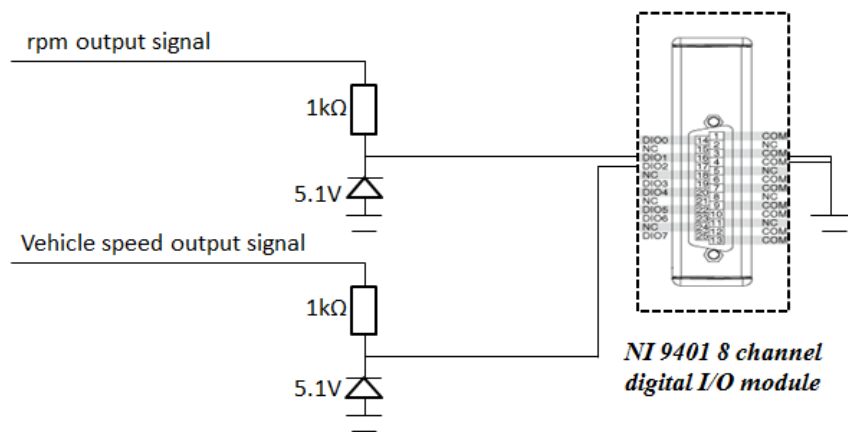


Figure 39: Hardware configuration for rpm and vehicle speed measurement

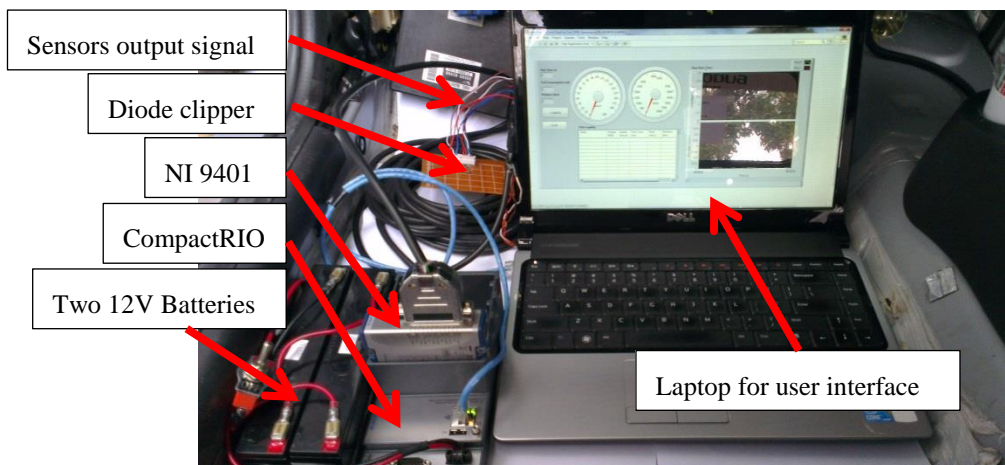


Figure 40: Implementation on vehicle

4.2.3 LabVIEW Program for Engine & Vehicle Speed

Programming is divided into three parts, which are vehicle speed calculation, rpm calculation and data logging.

- Vehicle speed calculation; it is performed according to the obtained formula from linear regression approach in section 4.2.1

$$\text{Vehicle speed in km/h} = 1.487 (\text{frequency from vehicle speed sensor}) + 1.768$$

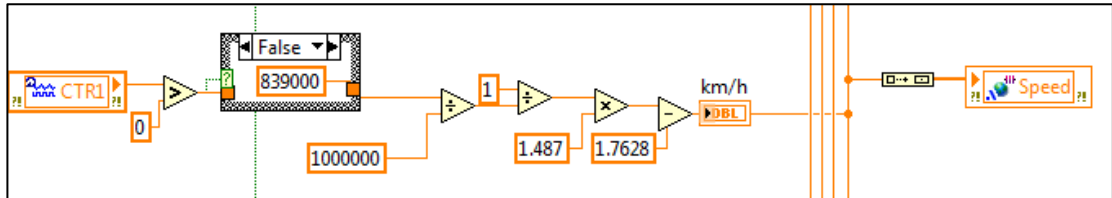


Figure 41: LabVIEW program for vehicle speed calculation

vehicle speed sensor output is connected to pin D1 on NI 9401 module, it is represented by CTR1 in LabVIEW block diagram. CTR1 is set to read the period of output signal from vehicle speed sensor. The reason why CTR1 is set to read period instead of directly read frequency is hardware accuracy limitation of NI 9401 module. The module can only read frequency above 500Hz accurately due to its pre-set sampling time, however for period reading, the reading is not dependent on sampling time, and therefore it can perform higher accuracy. The drawback of this method is there is possibility that period reading is zero which will cause infinite frequency and ultimately infinite speed. Case structure is used in this program to detect if period reading is zero, if period is not zero then period reading is directly fetched for conversion to frequency, but if period reading is zero the value of 83900 is fetched into frequency conversion. The value of 839000 is chosen to give negligible speed increase as the output of calculation. $((1/(839000/1000000)) \times 1.487) - 1.7628 = 0.0095 \text{ km/h}$.

- RPM calculation; it is performed in similar manner as vehicle speed calculation. Formula is obtained from linear regression approach in section 4.2.1. rpm sensor output is connected to pin D2 in NI 9401 which is represented by CTR2 in LabVIEW program. CTR2 is also set to read period reading from output sensor.

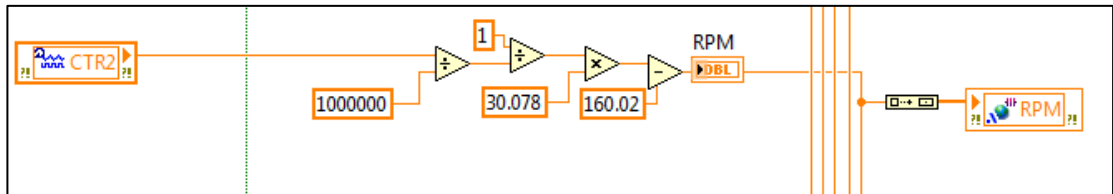


Figure 42: LabVIEW program for rpm calculation

- Data logging; data logging has to be performed upon vehicle speed and rpm calculation. Data of vehicle speed and rpm are first sent to global variable “Speed” and “RPM” respectively. Each reading is also sent to front panel user interface as shown below:

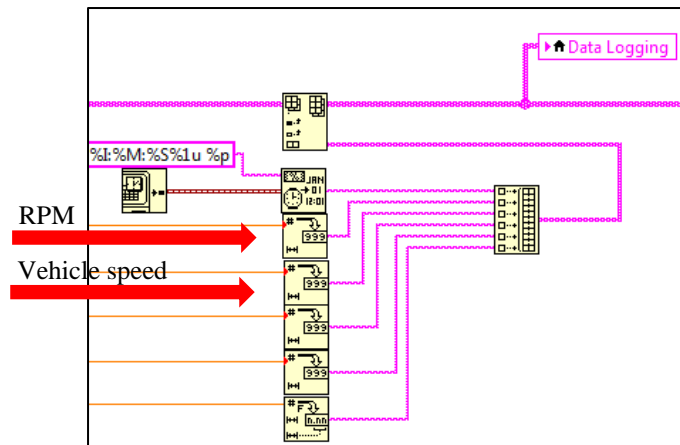
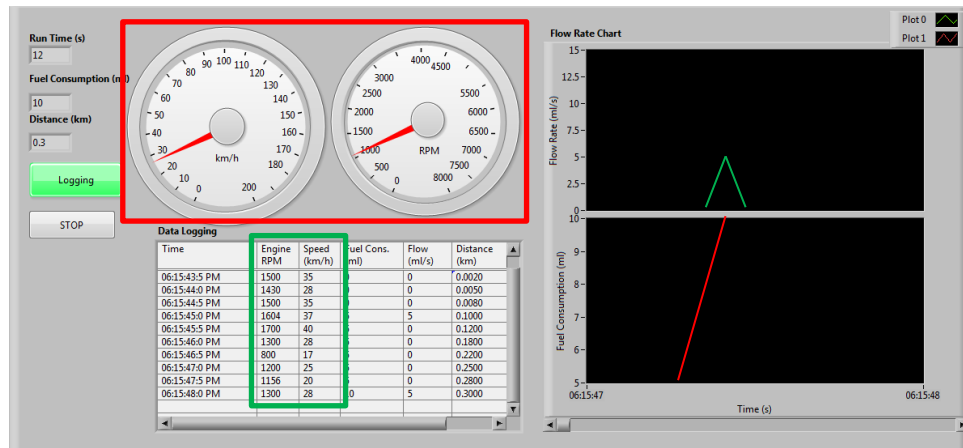


Figure 43: Logging vehicle speed & rpm data

- Front panel; the following is the user interface of vehicle speed and rpm measurement.



Red box indicates vehicle speed and rpm gauges while green box shows vehicle speed and rpm data over time.

4.3 Distance Calculation

Distance is calculated by finding the average of 2 consecutive vehicle speed value and multiply it with the time between these two readings. The instantaneous distance value is then accumulated into previous distance value.

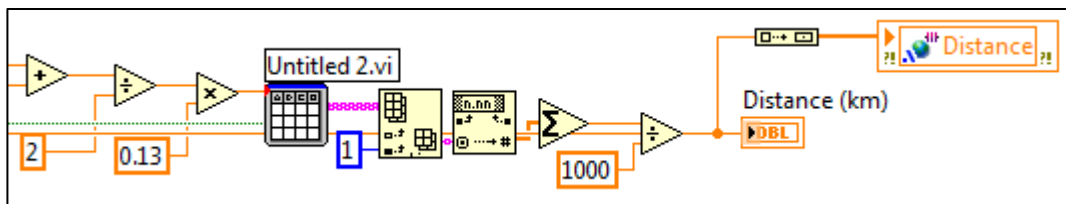


Figure 44: LabVIEW program for distance calculation

4.4 Saving logged data into memory

For the purpose of further analysis and documentation, the logged data has to be saved into memory. In this case, logged data is saved into USB drive that is attached into CompactRIO. The following is LabVIEW program that saves logged data. It has the feature of flexible data logging by providing a “Data Log” button as user interface. Data will only be saved to memory if the button is pressed. All logging data is saved in format of .tdms which can be easily imported and opened in Microsoft Excel.

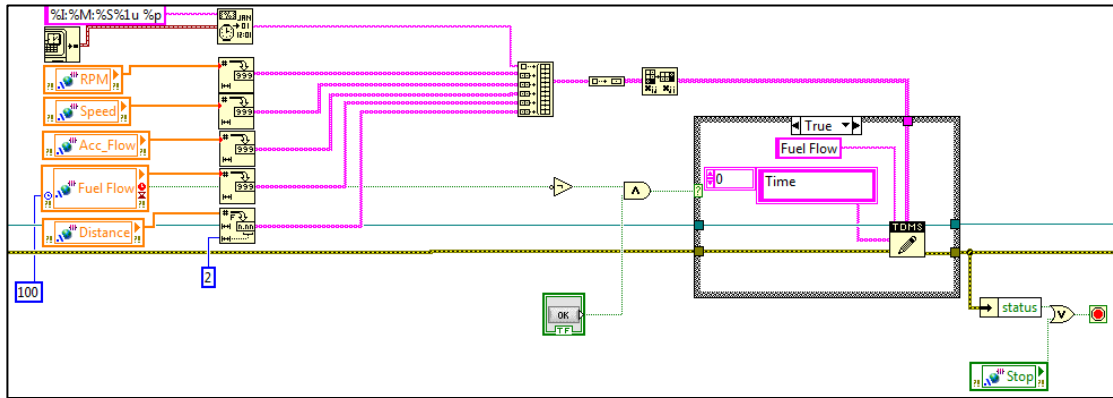


Figure 45: LabVIEW program to save logged data into memory

4.5 Battery State of Charge

4.5.1 Algorithm to monitor battery state of charge

In section 2.7, it is explained that coulomb counting and SoC drift method is used to dynamically monitor battery state of charge. Before performing dynamic measurement, two reference parameters have to be obtained first; SoC drift map and battery capacity. As for battery capacity, the manufacturer provides the rating in battery specification. In this project, ETI Tech EV410GGC2 battery is used. It has capacity of 40000mAh. However, for SoC drift map, it has to be obtained manually by charging the battery to 100% and discharge down to 0%. The voltage values from charging and discharging cycle are graphed and values at 10%, 20%, 80% and 90% are noted. The reason being is that, at these percentages the voltage normally varies quite significantly unlike during 20% to 80%, the voltage value is almost constant. These values are to be used to perform correction to coulomb counting afterwards. Next stage is to perform coulomb counting, below is the schematic to dynamically read voltage and current value from and to battery:

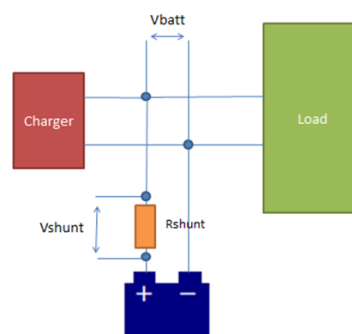
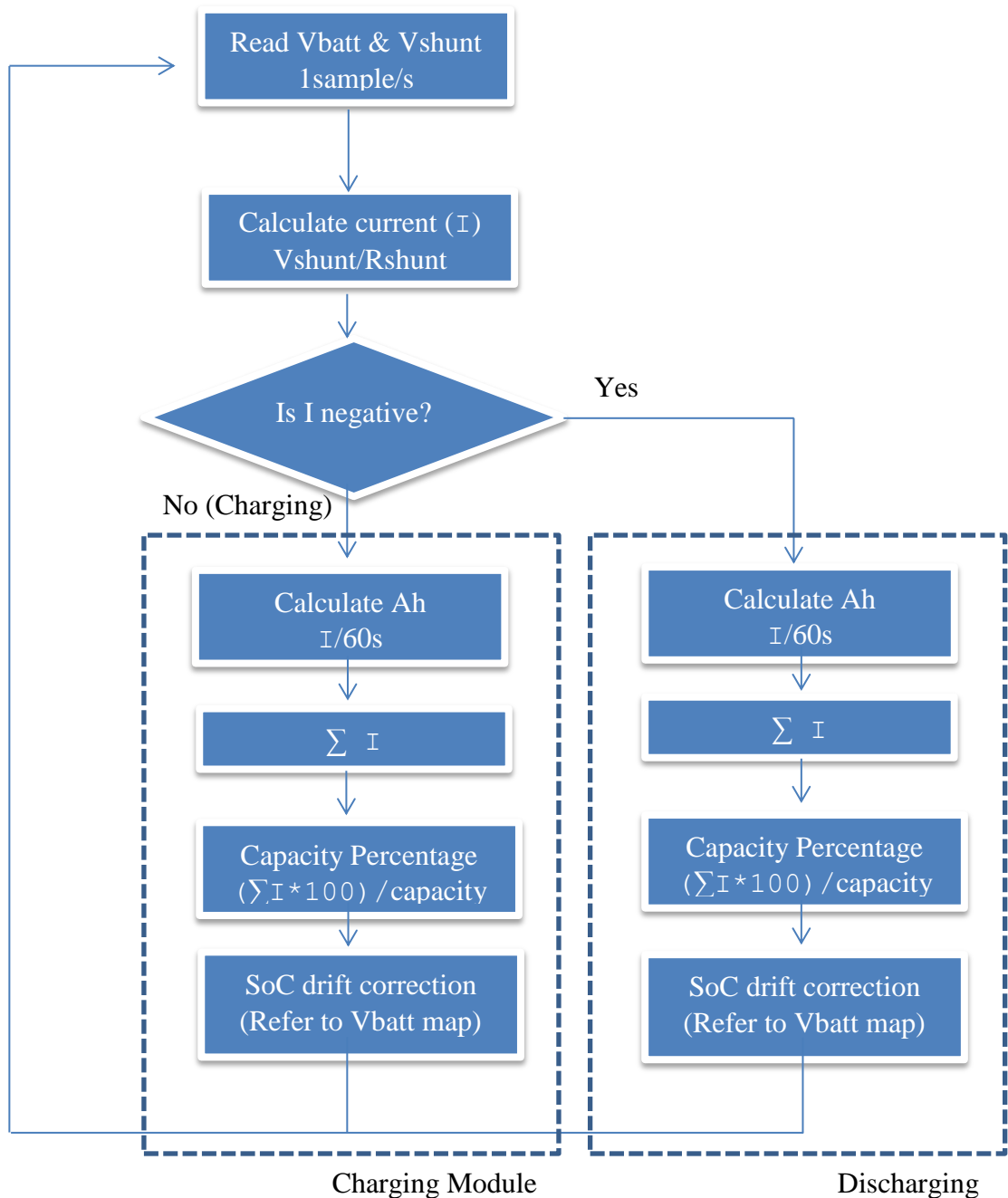


Figure 46: Schematic to perform coulomb counting

It is shown from the schematic that there are two values being monitored in the system namely V_{batt} and V_{shunt} . V_{batt} is actual battery voltage which later be compared with SoC drift values, the other one is V_{shunt} which is the voltage drop across shunt resistor. This value is used to calculate current flowing in and out of battery by dividing V_{shunt} with R_{shunt} value. The reason of using R_{shunt} is to interface with CompactRIO, we know that the amount of current flowing in and out the battery is quite big and it is beyond the limit of available module for CompactRIO.

The following is overall algorithm to be used in determining state of charge:



4.5.2 Mapping SoC drift value

As explained in previous section, SoC drift value is essential to provide correction to SoC reading. SoC drift value can be obtained by monitoring the voltage level of battery in one full charging and discharging cycle. Data logger is used to record the battery voltage value over charging and discharging cycle. Below is the schematic to obtain SoC drift value:

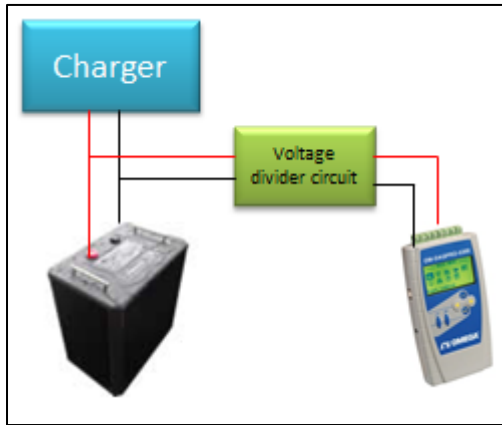


Figure 48: Schematic of SoC drift measurement (Charging)

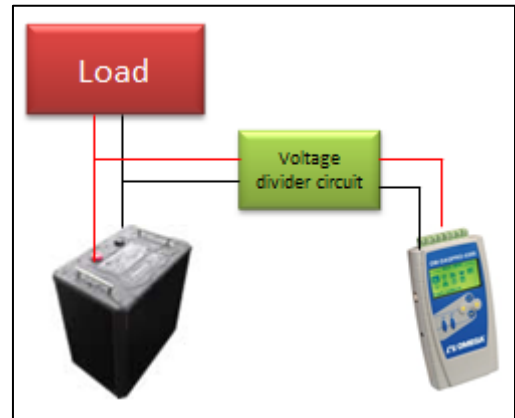


Figure 47: Schematic of SoC drift measurement (Discharging)

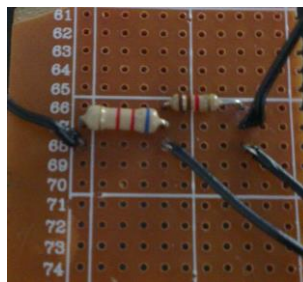


Figure 49: Voltage divider circuit

Voltage divider circuit is needed in for measurement because data logger can only work with voltage below 10V, therefore a voltage divider circuit that is able to scale the input voltage into 1/7.2. Voltage division rule dictates:

$$V_{\text{out}} = \frac{Z_2}{Z_1 + Z_2} \cdot V_{\text{in}}$$

For this project $Z_2 = 1\text{k}\Omega$ and $Z_1 = 6.2\text{k}\Omega$, $V_{\text{in}} = 52\text{ V}$. As a result, $V_{\text{out}} = 7.2\text{V}$.

Unfortunately, a complete SoC drift measurement cannot be completed for this project due to time constraint and delivery delay.

4.6 Trial Run Result

Trial runs were performed several times to record vehicle's operation before retrofit hybrid conversion. Below are the graphs showing engine RPM & vehicle speed in duration approximately 15 minutes.

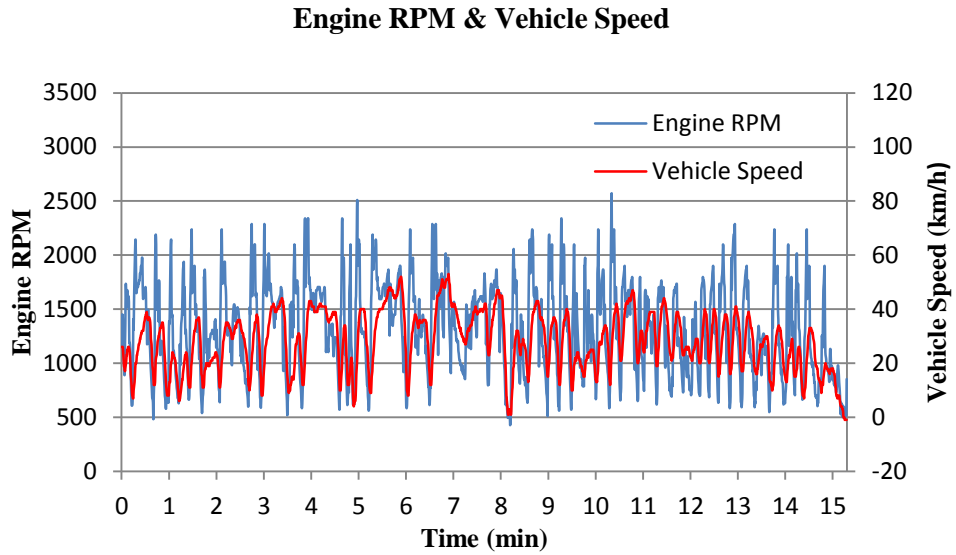


Figure 50: Trial run result for engine RPM & vehicle speed

The following is fuel consumption & distance graph generated from the trial run

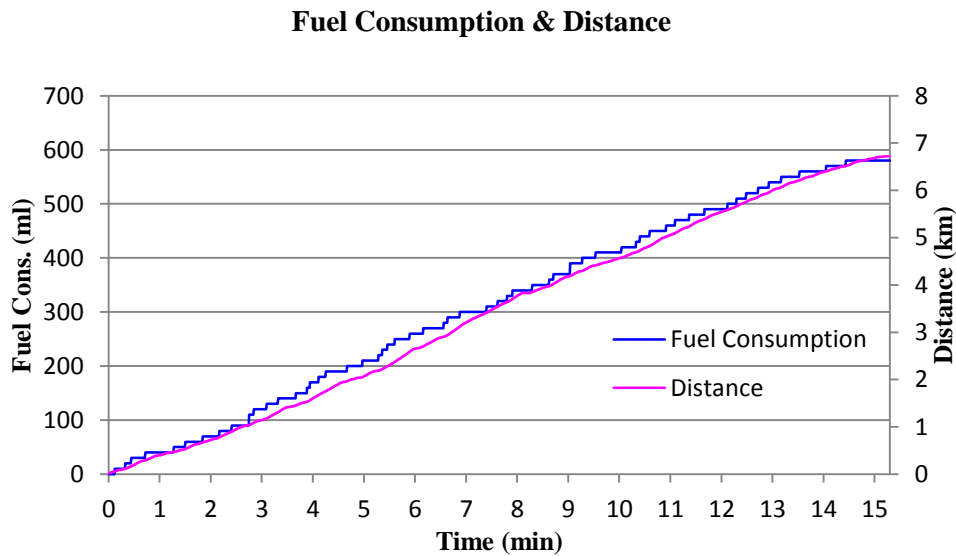


Figure 51: Trial run result for fuel consumption & distance

CHAPTER 5

CONCLUSION

Development of Energy Management System (EMS) with driver interface for retrofit-conversion hybrid electric vehicle is an essential part in building conversion kit that is able to convert conventional internal combustion engine vehicle into hybrid electric vehicle. The newly developed energy management system stands at highest hierarchy in the system since it monitors and governs vehicle's operation. Development of energy management system makes retrofit conversion for HEV feasible in order to provide consumers with alternative for low emission vehicle graphical user interface gives driver complete vehicle driving information as well as flexible driving mode options. National Instrument's CompactRIO reconfigurable controller and LabVIEW software provide reliable and flexible mean of monitoring and controlling various parameters in the vehicle, therefore, it serves well as a platform in developing EMS. Various vehicles' sensors have been successfully integrated into EMS for data logging and user interface purpose.

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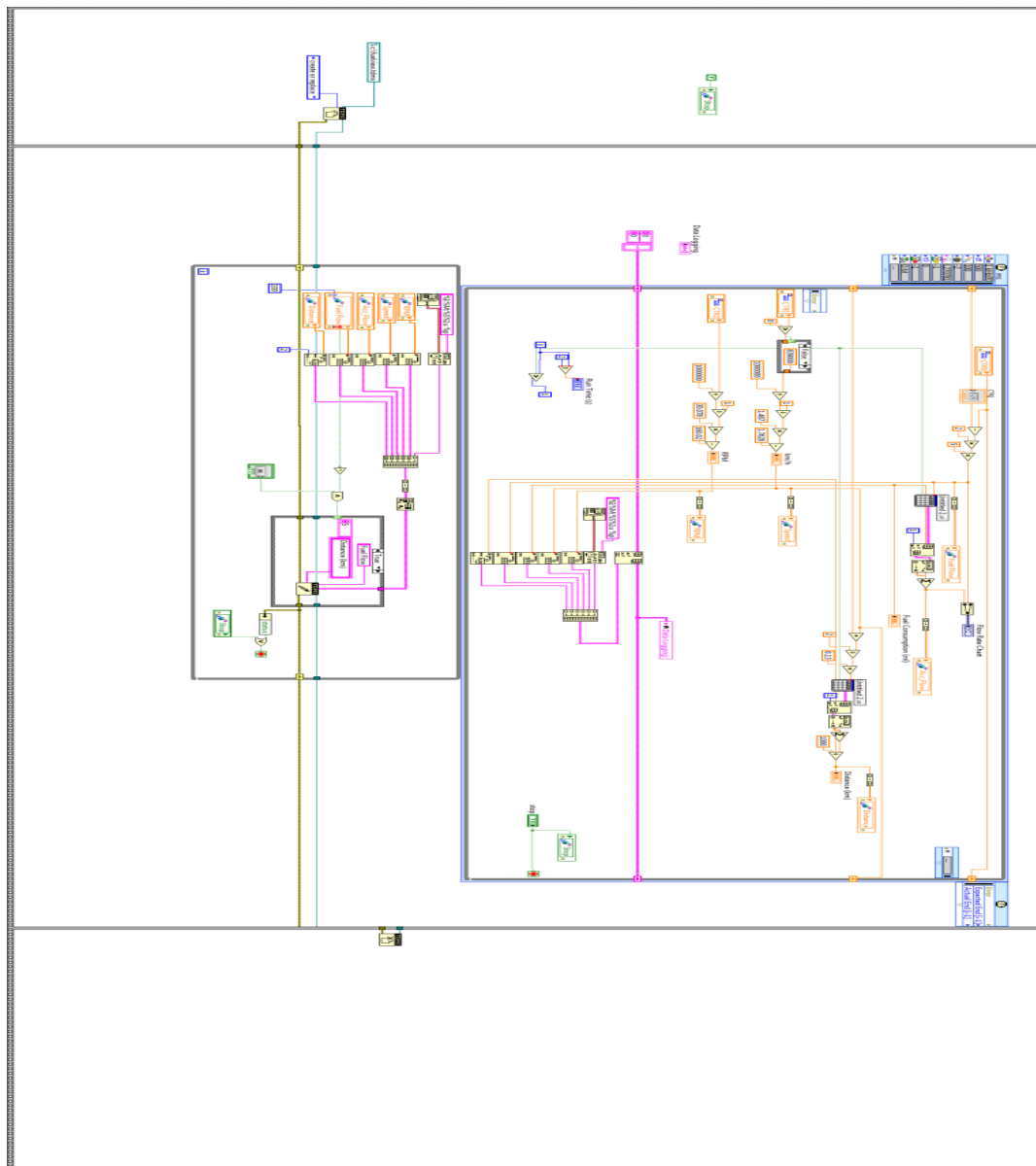
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APPENDICES

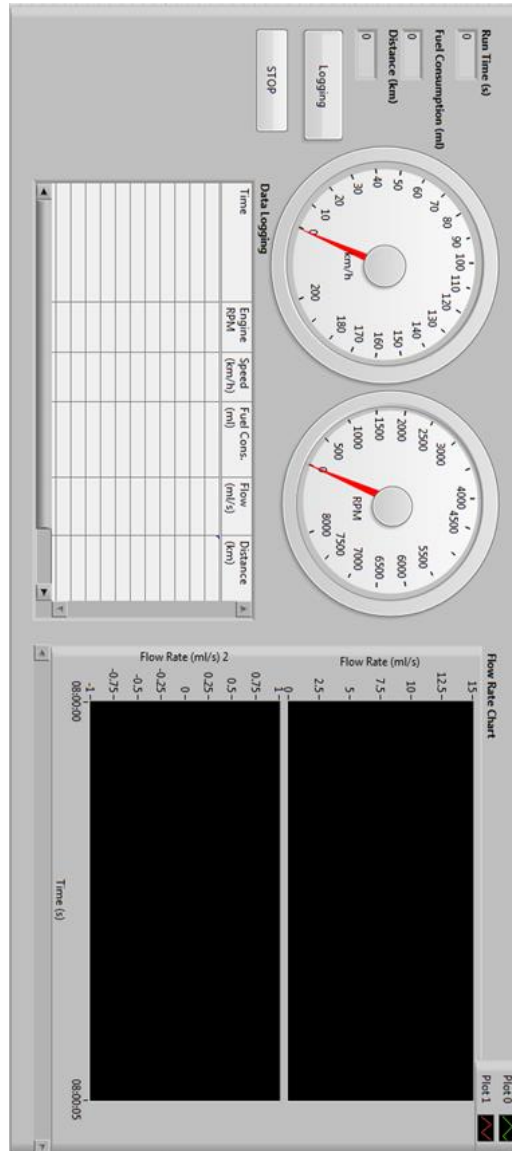
APPENDIX A

LABVIEW BLOCK DIAGRAM



APPENDIX B

LABVIEW FRONT PANEL



APPENDIX C

FUEL VIEW BROCHURE

FUEL VIEW

The compact and light weight fuel flow meter for monitoring fuel consumption

> Introduction

Mass Flow ONLINE B.V. sells flow measuring and controlling products through the internet. From the website www.massflow-online.com flow meters or controllers can be ordered 24 hours a day 7 days a week. Most products are on stock and will be shipped world wide within two working days.

> Description

The new FUEL-VIEW series of flow meters offer a compact, light weight and very cost-effective solution for measuring fuel consumption and operating time of vehicles, tractors, river vessels or any mobile or fixed installations with diesel engines. Its unique features for protecting and preventing theft of fuel, the protection against overstatement of readings and intervention and the patented method of measuring different engine operating times makes FUEL-VIEW the best solution on the market today. The FUEL-VIEW offers a local display and has several secure onboard counters that can be operated via the selector magnet as supplied rather than by user contact.

> FUEL-VIEW series

The FUEL-VIEW series operate on the principle of a rotary piston that is mounted into a chamber ring which rotates in a chamber case. The rotating speed is measured by electronic sensors which measure a magnetic pulse. The number of pulses in time is proportional to the fuel flow rate. The unique design of the flow meter allows fuel flow, even if the chamber is locked or clogged up. A fuel filter effectively protects the measuring chamber from contamination and can be removed and washed without disassembling the flow meter. FUEL-VIEW flow meters can be supplied in full scale ranges from 50 l/h up to 400 l/h with the standard configuration being a blind meter together with a signal cable. As an option, an LCD display allows reading of actual flow [l/h], total flow consumption [l], total engine operating time [h], engine operating time in "idling", "optimal" and "overload" mode. The instruments can work with an external power supply or with an embedded battery. We have a differential fuel flow meter for special applications. This meter has a separate input and output connection for the supply and return line to measure the consumption of the fuel.



> FUEL-VIEW features

- ◆ Indication in:
 - Actual flow [l/h]
 - Consumption in "normal" mode [l]
 - Consumption in "tampering" mode [l]
 - Engine operating time [h]
 - Engine "idling" time [h]
 - Engine "optimal" time [h]
 - Engine "overload" time [h]
 - Interference time [h]
- ◆ Strong metal moulded case
- ◆ Flow meter design provides a fuel flow even when measuring ring has stopped, for example, by clogging the chamber
- ◆ Ease of mounting and operation
- ◆ Special model for measuring the difference (consumption) between supply and return line
- ◆ Protection from overstatement of readings and intervention
- ◆ Mounting in any position
- ◆ Wide flow ranges
- ◆ Built-in fuel filter
- ◆ Optional pulse output with external power
- ◆ Extended work range and accurate measurement ensured by digital processing of signal
- ◆ Stable to vibrations and hydraulic shock
- ◆ Wide clearing section minimizes hydraulic resistance of fluid flow
- ◆ Sustainable product design
 - Battery powered model available and low battery indication
 - Low power consumption
 - Lightweight and compact



> Technical specifications

Performance

Acceptable liquids	- diesel fuel, petrol*, mineral oil Other liquids with kinematic viscosity from 1.5 to 60cSt/sec are possible but maximal flow rate could be lower than the specified flow range and pressure drop over the instrument can be higher
Operating pressure	- 2 ... 25 bar(a)
Operating temperature	- -40 ... 80°C for flowmeters with blind cover -30 ... 80°C for flowmeters with display
Accuracy	- DFM-60, ± 2%RD DFM-250D ± 0.9%RD per chamber; all other models, ± 1%RD
Rangeability	- up to 1:50
Repeatability	- <0.1% RD typical
Humidity	- 85% at environmental temperature of 40°C
Vibration	- with acceleration of 100 m/s ² in frequency range of 5 ... 200 Hz
Aggressive environment	- steady to fuel and lubricant materials

Mechanical specifications

Materials (wetted parts)	- housing: Zinc-Aluminium alloy (ZnAl) O-ring: aluminium gasket: oil-resistant rubber chamber bridge: steel bushing with magnetic plastic nut flange: plastic and steel gnd chamber cover: Zinc-Aluminium alloy
Protection	- IP64

Electrical specifications

Output	- scaled pulse, Min. 0.7V, Max. Usupply
Power	- Battery powered if LCD screen is present (2 years of life)
External power supply	- 10 ... 30 Vdc
Current consumption	- For 12 Vdc - 50 mA For 24 Vdc - 25 mA

Process connections (in/out)

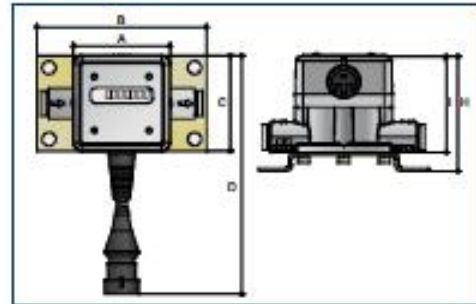
Each model has an R female M14 x 1.5 thread. Optional connection kits are available.

* DFM fuel flowmeters are manufactured of petrol-proof materials. While working with petrol, national legislation safety measures must be applied.



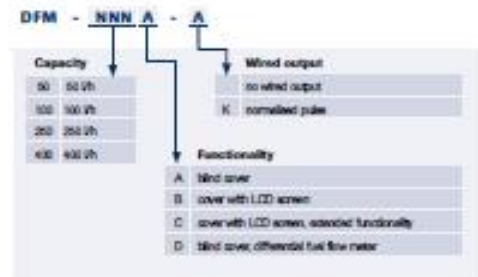
Wired FUEL-TEMP meter with selector key

> Dimensions



Model	A	B	C	D	H	I
DFM-60	60	108	60	280	90	85
DFM-100	60	108	60	280	90	85
DFM-260	60	108	60	280	90	75
DFM-250D	120	180	90	280	72	80
DFM-600	60	108	60	280	90	75

> Model number identification



> Flow ranges

Modelcode	Nom. diameter	Min. Flow	Nom. Flow	Max. Flow	Scaled pulse (ml/pulse)	Engine power (kW)
DFM-60	6 mm	1 l/h	25 l/h	50 l/h	8	60
DFM-100	6 mm	2 l/h	60 l/h	100 l/h	8	100
DFM-260	6 mm	8 l/h	120 l/h	260 l/h	12.5	200
DFM-250D	6 mm	25 l/h	120 l/h	260 l/h	12.5	200
DFM-600	12 mm	30 l/h	300 l/h	600 l/h	20	> 300

> Counter modes

	Operating mode	Flow rate	D*	D*
Normal Flow Rate	idling mode	0 < Q < 0.1 Qnom	*	*
	Optimal mode	0.1 Qnom < Q < 1.5 Qnom	*	*
	Overload mode	1.5 Qnom < Q < 2 Qnom	*	*
Tampering Rate	Tampering mode	2 Qnom < Q < 10 Qnom	*	*
	Air blowing submode	Q > 10 Qnom	*	*

* Corresponds to the model number.

> FUEL-VIEW counters

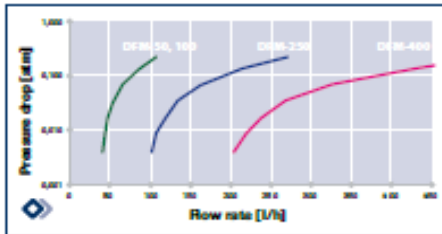
Counter	Resolution	Maximum value	IP	C*
Total fuel consumption	0.1 litre	9999 litre	*	*
Total fuel consumption	0.001 litre	999 litre	*	*
Increased resolution				
Total fuel consumption in "stopping" mode	0.1 litre	9999 hour	*	*
Total engine time in "interference" mode	0.1 hour	9999 hour	*	*
Total engine time	0.1 hour	9999 hour	*	*
Total engine time in "optimal" mode	0.1 hour	9999 hour	*	*
Total engine time in "idle" mode	0.1 hour	9999 hour	*	*
Total engine time in "overload" mode	0.1 hour	9999 hour	*	*

* Corresponds to the model number

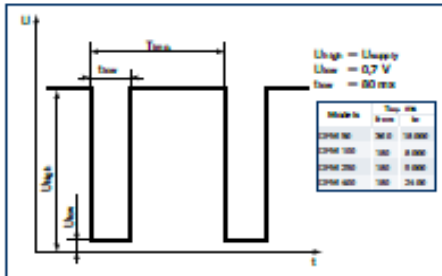
> Interference protection

Interference	security method
Blowing with air	If flowrate is higher than 10 x nominal flowrate the "fuel consumption counter" does not count but the "air blowing submode" counter counts.
Magnetic field interference	Special reed switch is activated when exposed to static magnetic field interference for more than 5 seconds and the time of interference is counted by "interference time" counter.
Supply power switched off	Embedded battery supplies autonomous operation of the flowmeter up to 2 years.
Disconnection from the fuel system	Installation kit elements have openings for sealing.

> Pressure drop



> Impulse parameters



> DFM models



> Applications

- ◆ Fuel consumption on:
 - vehicles
 - river vessels
 - diesel generators
 - burners/boilers
- ◆ Engine performance testing
- ◆ Engine time monitoring to pro-actively signal maintenance
- ◆ Real-time fuel monitoring and consumption reduction
- ◆ Signalling fuel theft

> Fuel flow meter mounting kits



Purpose

Mounting kit N2 is a multipurpose kit and is designed for connection of the fuel flow meters DFM to the fuel system or engine using the fuel pipe $\varnothing=8$ mm.

To ensure minimal resistance to the fuel flow is recommended to use multipurpose mounting kit N2 4, designed for the fuel tube $\varnothing=10$ mm.

Advantages

- ◆ Unions, valves, bolts of a rotary square have bores for sealing;
- ◆ High-quality components: seal rings (D18-055F) and sealing washer (08 Cu) made of high quality soft copper (not aluminum); square rotary - from a steel (not aluminum), calibrated valve, mounting kit components have corrosion protection.

Attention! The longevity and accuracy of the fuel flow meters depend on mounting kit components quality.

The manufacturer reserves the right to put changes in the composition of sets, as well as replace the components to similar without notice to the buyer.

> Mounting kit parts

Part	Symbol	Name	Kit N2	Kit N2 4
	Screw 028	The square rotary screw	2 pcs	2 pcs
	Screw 027	The square rotary screw	1 pc	1 pc
	Screw M4x6	Screw	4 pcs	4 pcs
	Nut M4	Nut	4 pcs	4 pcs
	Washer 4	Washer	4 pcs	4 pcs
	Washer 4x20 G	Lock washer	4 pcs	4 pcs
	Washer CU D-18	The sealing washer copper	16 pcs	8 pcs
	Washer CU 20x6	The sealing washer copper	1 pc	1 pc
	V1	The return valve	1 pc	1 pc
	V2	The bypass valve	1 pc	1 pc
	TR 4	The rotary angle	4 pcs	-
	TR 10	Anchor with a ring tip	-	4 pcs
	Clamp 008	The worm clamp	4 pcs	4 pcs
	Connection 012	Connection-adaptor double	1 pc	1 pc
	Connection 015	Connection-adaptor usary	1 pc	1 pc
	Connection 018	Connection-adaptor usary	1 pc	1 pc
	Connection 014-011	Connection-adaptor double	1 pc	1 pc
	Stopper	The carving stopper	1 pc	1 pc

Authorized distributor



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