DEVELOPMENT OF A DRIVER INFORMATION SYSTEM BASED ON ON-BOARD DIAGNOSTIC II COMMUNICATION PROTOCOL

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MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA

2007

DEVELOPMENT OF A DRIVER INFORMATION SYSTEM BASED ON ON-BOARD DIAGNOSTIC II COMMUNICATION PROTOCOL

By

MOHAMAD FAUZI BIN ZAKARIA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

July 2007

DEDICATION

I dedicate this thesis to my family especially my mother and wife who prayed all the time for my success.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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July 2007

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Faculty : Engineering

An On-Board Diagnostic II (OBD-II) is a standard diagnostic software management that is installed in a Powertrain Control Module (PCM). It provides some useful data to the driver. There are four different devices using the OBD-II protocol exists in the market that can be used as a driver information system. They are personal digital assistant Dyno/OBD-II scan tool, CarChip Fleet, DriveRight 600, and ScanGauge II. Each of these four devices has some limitation in term of supporting all features for live data monitoring, diagnostic trouble code scanning, trip information, and data logging system. Thus, there is a need for a device that supports all these features together with scheduled service reminder. This thesis describes the design and development of a driver information system based on OBD-II protocol. Its hardware and software systems were designed based on four design considerations: upgrade capability, high data storage capacity, back-up capability, and user friendly. The proposed system consists of an 8-bit microcontroller, a buffer memory, a liquid crystal display, a real time clock, a MultiMediaCard, an OBD-II interpreter unit, and

power supply unit. This system was successfully interfaced and tested with the PCM of Hyundai Getz car.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN SATU SISTEM MAKLUMAT PEMANDU BERASASKAN KOMUNIKASI PROTOKOL DIAGNOSTIK ATAS PAPAN II

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Diagnostik atas papan II (OBD-II) merupakan perisian piawaian pengurusan diagnostik yang dimasukkan ke dalam modul kawalan kuasa enjin (PCM). Ia menyediakan maklumat tertentu kepada pemandu. Terdapat empat peralatan di pasaran yang menggunakan protokol OBD-II ini yang boleh digunakan sebagai sistem maklumat pemanduan. Peralatan-peralatan ini adalah Dyno/OBD-II alat pengesan berasaskan pembantu digital peribadi, *CarChip Fleet, DriveRight 600*, dan *ScanGauge II*. Setiap peralatan ini mempunyai kelemahan dalam memaparkan data semasa, mengesan kod masalah diagnostik, melaporkan maklumat perjalanan, dan penyimpanan sistem data. Oleh itu, sebuah sistem yang mempunyai ciri-ciri tersebut beserta ciri tambahan pengingat servis berjadual perlu dibangunkan. Thesis ini membincangkan rekabentuk dan pembangunan sebuah sistem maklumat pemanduan berasaskan protokol OBD-II. Perkakas dan perisian sistem ini direkabentuk berdasarkan empat pertimbangan iaitu kebolehnaiktarafan, penyimpanan data berkapasiti tinggi, kemampuan penyimpanan kekal, dan mesra pengguna. Sistem

cadangan ini menggunakan satu unit mikropengawal 8-bit, memori sementara, paparan kristal cecair, jam masa sebenar, kad multimedia, penterjemah OBD-II, dan bekalan kuasa. Sistem ini berjaya diuji dengan PCM kereta Hyundai Getz.

ACKNOWLEDGEMENTS

Thanks to Allah S.W.T that finally I can complete my thesis.

First and foremost, I would like to express my appreciation and gratitude to my supervisory committee; Associate Professor Dr. Ishak bin Aris (Chairman), Associate Professor Dr. Senan Mahmod Abdullah, and Dr. Roslina Sidek for their continuous trust and support throughout my master's research. I would also like to thank for their careful review, corrections and suggestions for the improvement of this thesis.

Special thanks to Mr. Khairul Nizam for his support, and other members of ECU group that give some advice and valuable ideas.

I certify that an Examination Committee has met on 20th July 2007 to conduct the final examination of Mohamad Fauzi bin Zakaria on his Master of Science thesis entitled "Development of a Driver Information System Based on On-Board Diagnostic II Communication Protocol" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MOHAMAD FAUZI ZAKARIA

Date: 27 July 2007

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LIST OF ABBREVIATIONS

ABS	Antilock Braking System
CAN	Controller Area Network
CRC	Cyclic Redundancy Check
DTC	Diagnostic Trouble Codes
Dyno	Dynamometer
ECG	Electrocardiogram
ECU	Electronic Control Unit
EEG	Electroencephalographic
EOBD	European On-board Diagnostic Systems
ERR	Error Detection Byte
FAT	File Allocation Table
GUI	Graphical User Interface
ISO	International Standards Organization
MAF	Mass Air Flow
MIL	Malfunction Indicator Light
MMC	MultiMediaCard
MMCA	MultiMediaCard Association
MPG	Miles per Gallon
MSB	Most Significant Bits
NTFS	New Table File System
OBD-I	On-board Diagnostic Generation –I
OBD-II	On-board Diagnostic Generation –II
OEM	Original Equipment Manufacturer
PCM	Powertrain Control Module

PDA	Personal Digital Assistant
RTC	Real Time Clock
SAE	Society of Automotive Engineers
SD	Secure Digital
SPI	Serial Peripheral Interface
SRAM	Static Random Access Memory
SRS	Supplemental Restraint System
UART	Universal Asynchronous Receiver Transmitter
VPM	Variable Pulse Modulation
VSS	Vehicle Speed Sensor

CHAPTER 1

INTRODUCTION

Every automobile is equipped with electrical instrumentation panel as a driver information centre, formerly known as a dashboard. It contains various gauges, indicators and warning lights that provide valuable information to the driver [1]. Gauges provide scaled indication of the system condition. Normally, they come with five basic gauges that are found on all instrumentation panels: a speedometer, an odometer, a tachometer, a fuel level gauge, and a temperature gauge. Whereas, the indicator lights supply information of something that has been turned on, such as high beam and turn signal. While, warning lights give notification to the driver about the functioning problems in some systems or there is a situation exists that must be fixed. The examples of the systems that have warning lights are an engine management system (emission related system), an airbag of supplemental restraint system (SRS), an antilock braking system (ABS), an oil pressure, a brake fluid level and a charging system.

Another system that has been integrated in some of instrumentation panel is a trip information system. This system provides vital data such as average or instantaneous fuel consumption, fuel remaining, average speed, miles to empty fuel tank, estimated time of arrival, time, and date [2]. With this technology, the driver can know the journey cost and try to minimize fuel consumption by controlling the acceleration pedal with suitable gear at certain speed.

Since the on-board diagnostic generation two (OBD-II) exists, there have been two systems appeared in the market: the data logging system and the diagnostic trouble codes (DTC) scanning system.

The data logging system records trip, performance and accident data that provide valuable information to the fleet management, parents, and personal drivers. Drivers can use this data for future analysis especially to monitor their driving pattern for certain trips or to find out the cause of the accident, either by the driving habit or the vehicle problem. The data analysis can be done in a personal computer (PC).

The DTC scanning system has capability like a mechanic's scan tool or a code reader. It informs specific problems that occur in the electronics control units (ECUs) especially powertrain control module (PCM). This system solves the limitation of a malfunction indicator light (MIL). The MIL is warning indicator light that will be set when a malfunction problem of an emission related component arise. Other components are not notified by MIL. However, by using the DTC scanning system, all problems can be detected and zoomed to specific area of the ECU's subsystem components.

1.1 Background

The OBD-II technology is a diagnostic software management compulsory installed inside vehicles PCM in the United State since 1996. It has been standardized by Society of Automotive Engineers (SAE). This standardization includes the common terms and acronyms, common diagnostic link connector and location, common diagnostic test modes (generic and enhanced), common scan tools, common diagnostic trouble codes, and common protocol standard [3]. The standardization emerged after difficulties to apply on-board diagnostic generation one (OBD-I) that was installed on vehicles produced from 1988 to 1995. Consequently, the OBD-II standards help the diagnostic manufacturer to design the universal scan tool and aid the mechanic to repair the vehicle systematically and quickly. With the success of the OBD-II, European countries require all petrol cars since 2001 and diesel cars manufactured from 2003 onwards, must be equipped with European onboard diagnostic systems (EOBD) which is equivalent to OBD-II standard [4].

The OBD technology is not only protecting the environment but also protecting drivers, by identifying minor problems before they become major repair bills. For example, by recognizing a relatively inexpensive repair like the replacement of a malfunctioning oxygen sensor, OBD can save the cost of replacing the catalytic converter later. Besides, OBD is also to ensure that the vehicle operates within its original design specification.

1.2 Problem Statement

Thanks to OBD-II standards that was primary developed to control vehicles emission level [2], many supporting systems to the driver have been developed to overcome the limitation of instrumentation panel. Four devices are available in the market that can be used as the driver information system are personal digital assistant (PDA) Dyno/OBD-II scan tool, CarChip Fleet, DriveRight 600, and ScanGauge II [4-7].

They support some features such as live data (gauges) monitoring, trip information, data logging, and DTC scanning system.

The PDA Dyno/OBD-II scan tool is a handheld computer of diagnostic scan tool that enables access to the vehicle's diagnostic information. Due to its main purpose for home mechanic, it just provides additional data of fuel economy information and selected sensor data logging [4]. Some of the information is not necessary to the driver.

The CarChip Fleet and DriveRight 600 are more powerful for data logging where they are capable to do the complete data logging which is good for fleet management [5], [6]. The CarChip Fleet can log vehicle and driver performance including DTC and 'accident' data for every trip. However, it does not provide trip information except the trip start and stop. In addition, it does not have live data display on LCD. However, its limitation is overcome by the DriveRight 600. The DriveRight 600 has data logging feature similar to the CarChip but does not support for DTC monitoring and recording.

The most suitable device to solve the limitation of instrumentation panel is ScanGauge II. It provides the live data display, trip information, and DTC scanning system [7]. In trip information, it provides the data logging for one trip data of previous day only and does not support for accident data recording. Another drawback of this system is its graphical user interface that is not user friendly.

1.4

Each of these four devices has some limitations in term of supporting all features for live data, trip information, data logging, and DTC scanning system. Thus, there is a need of one system that supports all these systems together. As all the data and information gained from the above features, another system application can possibly be developed is a scheduled service reminder. This reminder will replace a current sticker service reminder and prompt drivers based on distance and day remaining.

The hardware platform of the proposed system could be a PDA-based computer system or low cost embedded system. Of course, PDA system has many advantages in term of superb graphical user interface (GUI) display, high-speed processing, and high memory support. However PDA itself is expensive so it is not worth to have a PDA just for running the system unless there are other applications involved like navigation system or personal organizer. Therefore, the embedded system is the right platform for low cost system. Fortunately, the portable flash technologies have high memory capability up to 4G bytes or more where the low cost embedded system can use this memory technology to support the huge data logging application.

1.3 Objectives

The objectives of this project are:

1.3.1 To design and develop the driver information system (hardware and software) based on the communication protocol of the OBD-II by using an 8-bit microcontroller system.

1.3.2 To analyse the performance of the proposed system by testing it with the OBD-II PCM of Hyundai Getz passenger car.

1.4 Scopes

The scopes of this project are:

1.4.1 Application software of the proposed system just provides features of live data monitoring, DTC scanning, trip information, data logging, service reminder, and clock. The live data is limited to display an engine speed (rpm), a vehicle speed (km/h), a coolant temperature, and a battery voltage. The DTC scanning provides the MIL status, confirmed and pending codes without codes description. The trip computer data is limited to supply an elapsed time and a distance for every trip. The data logging records trip summary information, accident log (vehicle speed of 60s before and 60s after hard deceleration), and update service reminder that only keeps engine oil and spark plug replacement data.

1.4.2 The data logging file is using the comma separator value (CSV) format.

1.4.3 ISO9141-2 is used as a diagnostic communication protocol for collecting OBD-II data because of only this protocol supported by Hyundai Getz's ECU.

1.4.4 The 8-bit microcontroller of 8051 family microcontroller system is chosen and its programming software is in the Assembly language.

1.5 Contributions

The contributions of this project are:

1.5.1 Proposing the novel system architecture (hardware design) of proposed system that has four characteristics: (1) upgradeable capability, (2) high data storage capacity, (3) data back-up capability, and (4) user friendly. This system architecture is suitable for data monitoring and recording application.

1.5.2 Developing a group of low-level and high-level software of the proposed system. The low-level software is hardware drivers for liquid crystal display (LCD), navigation buttons, MultiMediaCard (MMC), real time clock (RTC), OBD-II interface. The high-level software is divided into basic and application software. The main function of basic software is to load the application software's program code from MMC into buffer memory and provides the status of operation. While, application software is more concerns on the output of system features and it as well interacts with low-level software.

1.5.3 Developing the file allocation table 16 (FAT16) data logging system by using MMC as a storage device. The proposed system will read and write the file based on this format. When a file has been saved in FAT16 formatted MMC, the PC will automatically recognize the file. If not, it will be invisible and needs special software to recognize it in the PC.

1.5.4 Implementing the CSV format in the 8-bit microcontroller system for data logging application. The technique of saving the data logging file based on this file format is to eliminate the development of software support where the CSV file can be read directly in Microsoft Excel or Notepad software.

1.6 Thesis Outline

Chapter 2 will review on three major sections related to the research. The first section describes the concept of OBD-II. The second section explains the existing system and some related works that covers the OBD-II system interface, DTC scanning system, trip information system, and data logging system. The last section reviews the portable flash storage that covers detail on MMC technology and file system format.

Chapter 3 will explain five major sections related to the research methodology. The first section describes the project overview. The second section explains the system requirements where some of application had been defined. The third section describes the system architecture where the novel system architecture has proposed. Hardware design had discussed in fourth section where the 8-bit microcontroller unit had been chosen. In this chapter, the details on microcontroller unit, buffer memory unit, alphanumeric LCD unit and so forth were explained. The last section explains the software design where low and high level software had been discussed.

Chapter 4 will discuss the result of the system development and testing on hardware and software. The testing is broadened into two parts: interface testing and system testing. The interface testing discusses all hardware's unit that interfacing to the microcontroller. The system testing focuses the high-level software operation. Besides, this chapter also provides the system comparison with current product before ending with summary section.

Chapter 5 is the final chapter that provides conclusion of the system design and development. In addition, it discusses the possible direction of recommendation in future work based on the results presented in Chapter 4.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will review three major sections that related to the research. The first section describes the concept of OBD-II that needs to be understood before developing the proposed system. It covers the diagnostic standard, communication protocol and connector, format of message and trouble code, data request parameters (diagnostic service modes), and scan tool technology. The second section explains the existing system and some related works that covers the OBD-II system interface, DTC scanning system, trip information system, and data logging system. The last section reviews the portable flash storage that covers detail on the MMC technology and the file system format. This flash storage is essential to a low cost microcontroller system that needs to handle huge recording data.

2.2 OBD-II Technology

2.2.1 Diagnostic Standards

The standardization was prepared by the SAE Vehicle E/E Systems (Diagnostic Committee). This committee was formed in June 1987 to address concerns of the automotive manufacturers and automotive repair industry about the uniformity the increasingly complex electronic systems on new vehicles [3], [8]. Seven important standards shown in Table 2.1 commonly used for helping the vehicle and diagnostic system manufacturer to design the system. Some standards are equivalent to standards produced by the International Standards Organization (ISO) that are used as references in worldwide regulations. Other standards have been complemented by ISO, especially on data communication interface.

Table 2.1: Some of OBD-II standards [3]

No	Standard	SAE	ISO
1	Data Communications Network Interface	J1850 VPW and J1850 PWM	9141-2, 14230-4 (KWP2000), and 15765-4 (CAN)
2	Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations and Acronyms	J1930	15031-2
3	Diagnostic Connector	J1962	15031-3
4	OBD II Scan Tool (generic function)	J1978	15031-4
5	E/E Diagnostic Test Mode	J1979	15031-5
6	Diagnostic Trouble Code Definitions	J2012	15031-6
7	Enhanced E/E Diagnostic Test Modes	J2190	-

2.2.2 Diagnostic Communication Protocol

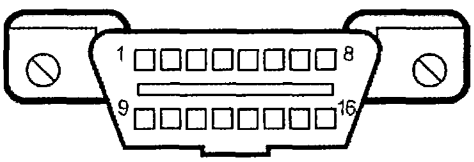
There are five serial communication protocols support the OBD-II standard as shown in Table 2.2. Three of them appeared in the early 1990 that widely used by Ford (SAE J1850 PWM), General Motors (SAE J1850 VPW), and Chrysler (ISO 1941-2). While, KWP 2000 appeared in model year 2000 and mostly used in European and Asian vehicles. Then CAN diagnostic protocol first appeared in model year 2003 vehicles and scheduled to be the only OBD-II protocol allowed for new vehicle designs by 2008 [12].

Table 2.2: Communication Protocol [3]

No	Protocol	Speed
1	SAE J1850 (PWM)	41.6 kbps
2	SAE J1850 (VPW)	10.4 kbps
3	ISO 9141-2	10.4 kbps
4	ISO 14230-4 (KWP 2000)	10.4 kbps
5	ISO 15765-4 (CAN)	500 kbps

2.2.3 Diagnostic Connector

Each OBD-II vehicle has a standardized 16-pin diagnostic connector (Figure 2.1), which has standard shape and size, and uses the same pins for the same information. The 16-pin connector is located underneath the dash near the driver's seat. Alternatively, it may be behind ashtrays or concealed by an easily removed plastic cover, sometimes with the letters "OBD" stamped on the outside.



SAE J1850	PWM	Pins 2, 4, 5, 10, and 16.
	VPW	Pins 2, 4, 5, and 16.
ISO 9141-2 ISO 14230-4		Pins 4, 5, 7, and 16. Pin 15 may or may not be present.
ISO 15765-4		Pins 4, 5, 6, 14, and 16.

Pin	Assignments
1	Manufacturer's Discretionary
2	Bus positive line of SAE J1850
3	Manufacturer's Discretionary
4	Chassis Ground
5	Signal Ground
6	CAN_H line of ISO 15765-4
7	K line of ISO 9141-2 and ISO 14230-4
8	Manufacturer's Discretionary
9	Manufacturer's Discretionary
10	Bus negative line of SAE J1850
11	Manufacturer's Discretionary
12	Manufacturer's Discretionary
13	Manufacturer's Discretionary
14	CAN_L line of ISO 15765-4
15	L line of ISO 9141-2 and ISO 14230-4
16	Permanent Positive Voltage (Battery)

Figure 2.1: Data Link Connector [1]-[3], [8]

2.2.4 Diagnostic Message Format

The SAE J1979 describes the format of emission related diagnostic message for all OBD-II communication protocol. The message formats for ISO 9141-2, ISO 14230-4, and SAE J1850 are shown in Table 2.3. The first 3 bytes of these diagnostic messages are the header bytes. For SAE J1850 and ISO 9141-2 interfaces the value of the first header byte is dependant on the bit rate of the data link and the type of message. The second header byte has a value that depends on the type of message, either request or response. Whereas, for ISO 14230-4 interface, the first header byte indicates the addressing mode (physical or functional) and the length of the data field. The second header byte is the address of the receiver of the message. The third header byte for these three interfaces is the physical address of the sender of the message. The scan tool has the address *F1h*. The first data byte following the header is the diagnostic service identifier, and the remaining data bytes vary depending on specific diagnostic service. All diagnostic messages will use a cyclic redundancy check (CRC) as in SAE J1850 as the error detection (ERR) byte. In-frame response (RSP) is required in all request and response messages at 41.6 kbps, and not allowed for messages at 10.4 kbps. While, in ISO 9141-2 and ISO 14230-4, messages will include a checksum, after the data bytes as the error detection byte (ERR). There is no provision for an in-frame response.

Table 2.3: Message Format for ISO 9141-2, ISO 14230-4 and SAE J1850 [3], [9]

Header Bytes (hex)			Data bytes								
Priority/Type	**Target**	**Source**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**ERR**	**RSP**
Diagnostic request at 10.4 kbit/s: SAE J1850 and ISO 9141-2											
68	6A	F1	Maximum 7 data bytes							Yes	No
Diagnostic response at 10.4 kbit/s: SAE J1850 and ISO 9141-2											
48	6B	ECU addr.	Maximum 7 data bytes							Yes	No
Diagnostic request at 10.4 kbit/s: ISO 14230-4											
11LL LLLLb	33	F1	Maximum 7 data bytes							Yes	No
Diagnostic response at 10.4 kbit/s: ISO 14230-4											
10LL LLLLb	F1	ECU addr.	Maximum 7 data bytes							Yes	No
Diagnostic request at 41.6 kbit/s: SAE J1850											
61	6A	F1	Maximum 7 data bytes							Yes	Yes
Diagnostic response at 41.6 kbit/s: SAE J1850											
41	6B	ECU addr.	Maximum 7 data bytes							Yes	Yes

Note: LL LLLL – Length of data bytes; RSP – In-frame response; ERR – Error Detection

The diagnostic message format for ISO 15765-4 (CAN) is given in Table 2.4, which is different with other interfaces. Each CAN frame is identified by a CAN Identifier. The size of the identifier is either 11-bit or 29-bit. The CAN identifier shall always be followed by an eight byte CAN frame data field.

Table 2.4: Message Format for ISO 15765-4 [3]

Header bytes	CAN frame data field							
CAN Identifier (11 or 29-bit)	#1	#2	#3	#4	#5	#6	#7	#8

2.2.5 Generic Diagnostic Service Modes

These generic modes allow the scan tool to request the emission related data from a vehicle. There are nine generic service modes can be accessed using OBD-II scan tool as described in Table 2.5. The detail on every service mode operation can be obtained in SAE J1979 standard [3].

Table 2.5: OBD-II Service Mode [3]

Mode	Request	Description
1	**Current Powertrain Diagnostic Data**	Show the real time data from specific parameter identification (PID) including input or output signal, calculated value and system status.
2	**Powertrain Freeze Frame Data**	Show the data at the moment a DTC is stored and the MIL is commanded to illuminate. The supported PID data is the same as mode 1.
3	**Emission-Related DTC**	Show the "confirmed" DTCs.
4	**Clear/Reset Emission-Related Diagnostic Information**	Clear all emission-related diagnostic data that stored in the ECUs.
5	**Oxygen Sensor Monitoring Test Results**	To read the on-board oxygen sensor-monitoring test results.
6	**On-Board Monitoring Test Result for Specific Monitored Systems**	Test results for systems those are not continuously monitored, such as catalytic converters and evaporative canisters.
7	**Emission-Related Diagnostic Trouble Codes Detected During Current or Last Completed Driving Cycle**	Show the "pending" DTCs that detected for emission-related components or systems that are tested or continuously monitored during normal driving conditions
8	**Control of On-Board System, Test or Component**	This bidirectional control used to determine specific system or component response to individualized tests.
9	**Vehicle Information**	To request the vehicle specific information such as vehicle identification number (VIN), calibration IDs, ECU IDs, and control software level.

2.2.6 Enhanced Diagnostic Service Modes

The enhanced modes of SAE J2190 are defined for access to emission-related test data beyond what is included in SAE J1979 [3], and for non-emissions related data. The diagnostic service modes in SAE J1979 are involved in powertrain information only. Therefore, this enhanced modes standard (SAE J2190) allows the scan tool to communicate with other ECUs' parameters like ABS and SRS system. Besides that, the message length for this standard is different, for instance, data length for

KWP2000 in SAE J2190 is 255 bytes maximum, whereas in SAE J1979 is 7 bytes maximum [10].

2.2.7 Diagnostic Trouble Code

The format structure of DTC consists of five characters alphanumeric code in which each character has a specific meaning. The specific meaning is controlled by generic (ISO/SAE standard) or original equipment manufacturer (OEM). The Figure 2.2 shows P0457 code that indicates evaporative emission system leak detected (fuel cap loose/off). The code has two bytes message format where the first two most significant bits (MSB) point to the first character, the next two bits used for the second character, the next nibble represents to the third character and the last one byte assigned for specific fault designation.

There are four system codes are needed to report in OBD-II [3], [11]. They are Powertrain codes (P-codes), Body codes (B-codes), Chassis codes (C-codes), and network codes (U-codes). The MIL will be illuminated whenever a P-code that related to emission system is set, or other types of codes such as B-codes or U-codes might raise emissions levels unacceptably [10]. One fault sometimes can set more than one code. For example, loss of a wheel-speed sensor signal might set both a P-code and a B-code if the sensor is used for VSS input and ABS system. Besides that, any communications fault that prevents the PCM from exchanging information with other modules may set both P- and U-codes.

Each specified fault code has been assigned a description to indicate the circuit, component, or system area problem. Most circuit, component, or system fault codes are specified by four basic categories:

i. General circuit

ii. Range or performance problem

iii. Circuit low

iv. Circuit high

The terms “low” and “high” are the input signals refer to the voltage, frequency, etc.

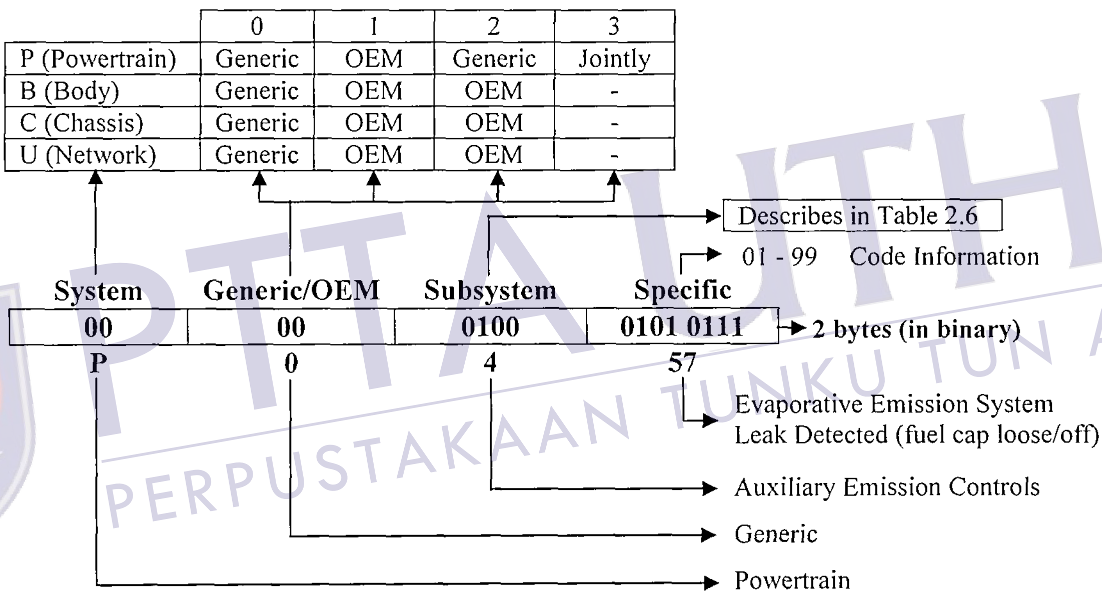


Figure 2.2: OBD II DTC Identification Format [1]-[3]

Table 2.6: Subsystem Groups for Generic DTC [3]

DTC	Subsystem Group	Quantity
P00XX	Fuel and Air Metering and Auxiliary Emission Controls	100
P01XX	Fuel and Air Metering	100
P02XX	Fuel and Air Metering	100
P03XX	Ignition System or Misfire	92
P04XX	Auxiliary Emission Controls	100
P05XX	Vehicle Speed or Idle Control and Auxiliary Inputs	100
P06XX	Computer and Auxiliary Outputs	100
P07XX	Transmission	100
P08XX	Transmission	100
P09XX	Transmission	100
P0AXX	Hybrid Propulsion	30
P20XX	Fuel and Air Metering and Auxiliary Emission Controls	100
P21XX	Fuel and Air Metering and Auxiliary Emission Controls	100
P22XX	Fuel and Air Metering and Auxiliary Emission Controls	100
P23XX	Ignition System or Misfire	48
P24XX	Auxiliary Emission Controls	48
P25XX	Auxiliary Inputs	78
P26XX	Computer and Auxiliary Outputs	72
P27XX	Transmission	96
P2AXX	Fuel and Air Metering and Auxiliary Emission Controls	5
P34XX	Cylinder Deactivation	98
U00XX	Network Electrical	100
U01XX	Network Communication	100
U02XX	Network Communication	36
U03XX	Network Software	32
U04XX	Network Data	32
Total		**2067**

2.2.8 Scan Tools Technology

The SAE J1978 standard has described the minimum capabilities that must be supported by a scan tool that is intended to communicate with an OBD-II compliant vehicle [3]. There are some criteria or testing that scan tool needs to pass and may be labelled as “CONFORMS to SAE J1978”. The testing on automatic determination of interface and protocol will be done as well as the application support to all generic diagnostic service modes (except mode 8). Furthermore, the scan tool shall operate normally within a vehicle battery voltage and not interfere with the normal operation of vehicle modules. In addition, the scan tool manufacturer also needs to provide the user manual and help facility to pass this test.

Currently, three categories of scan tool available are OBD-II generic tools, aftermarket tools and vehicle manufacturer tools [14]. In the generic scan tools, there are three basic types: Dedicated scan tools (for instance, AutoXray EZ-Scan 6000, InjectoClean CJ-15 and SPX/OTC ScanPro), PDA-based tools (offered by InjectoClean, AutoEnginuity and EASE), and PC-based scan tools (e.g.; InjectoClean, AutoEnginuity, EASE and others offer PC-based solution). The dedicated and PDA units are designed to be inexpensive, simple and quick diagnostic scanning tool.

Aftermarket scan tool is advance than generic scan tool due to its capability to access the enhanced diagnostic service modes and provides bidirectional controls. Therefore, it can communicate with other systems like ABS, air bag and suspension system [15]. However, this scan tool cannot be challenged with manufacturer scan tool. The manufacturer scan tool provides more supporting enhanced parameters and advanced bidirectional controls that cover the most ECUs' modules. Bidirectional controls are the most difficult feature to implement by considering liability of the system and safety factors [16]. Consequently, this scan tool costs very expensive compared to others. Moreover, this scan tool which is specially designed by vehicle's manufacturer allows the advanced features that only support their vehicle product. Nevertheless, it can be used to other vehicles but works as a generic scan tool.

2.10

2.3 Existing System and Related Work

2.3.1 Overview of Existing Product

This section reviews four existing products that is available in the market that related to the live data monitoring, the DTC scanning, the trip information, and the data logging system. These products supports all OBD-II compatible vehicle and described in three parts.

2.3.1.1 PDA-Dyno/OBD-II Scan Tool

The product comes with an application software and an OBD-II interfacing system that produced by Nology Engineering, Inc. [4]. Its software is based on Palm operating system 3.0 or higher. This software and its hardware interface (not included PDA) cost RM1368.08 (US$369.75). Figure 2.3 shows its hardware setup. Figure 2.4 shows the screens displaying some of its features. It relays data from diagnostic service mode 1 to mode 7 and other applications feature. It can provide the pending and stored DTCs with fault descriptions. Other features that distinguish it from other scan tools are the trip information, a playback function (data logging) and a dynamometer (Dyno). In the trip information, only fuel economy (MPG) can be displayed and its data depends on mass airflow (MAF) sensor. The data logging can record and playback the live data in a list, a meter or a graph format. The powerful feature of this device is the Dyno that used to measure horsepower and torque. It takes into account all variables such as a vehicle weight, an air temperature, and an elevation. Thus, this product is most suitable used by mechanics.

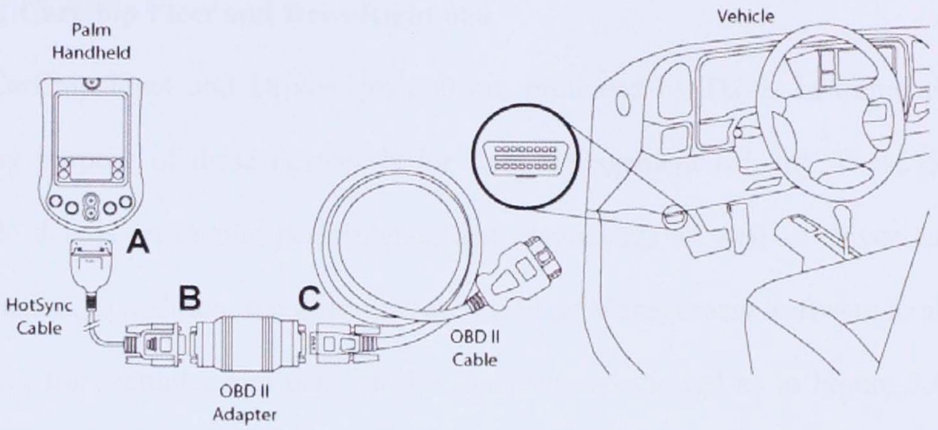


Figure 2.3: PDA-Dyno Scan Tool Connection [4]

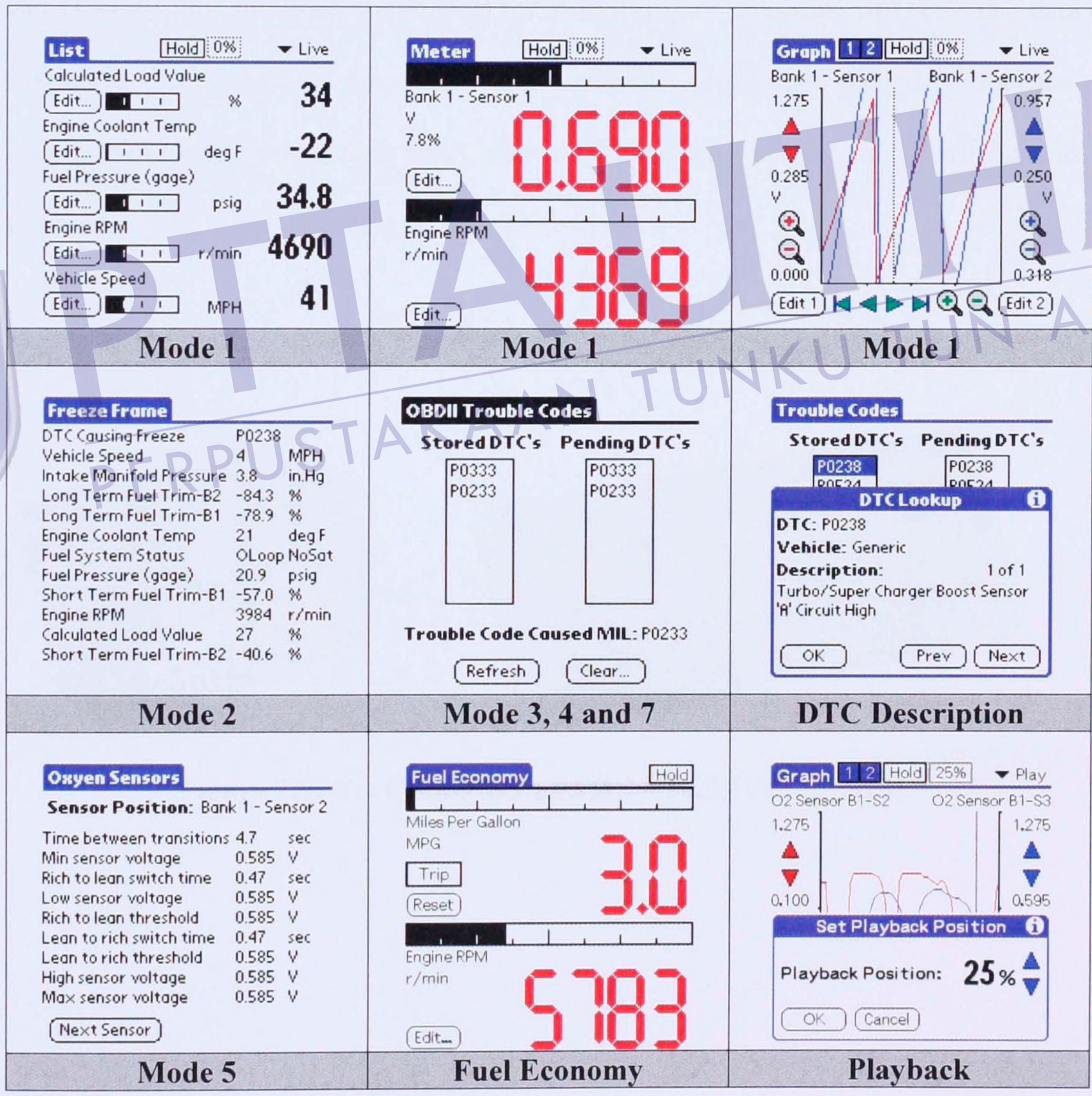


Figure 2.4: Screen shoots of PDA Scan Tool [4]

2.3.1.2 CarChip Fleet and DriveRight 600

The CarChip Fleet and DriveRight 600 are produced by Davis Instruments. The primary purpose of these devices is for fleet management [5], [6]. These devices provide details on engine performance and diagnostics as well as driver and trip information. In addition, these devices need a Fleet Management Software to analyse the data, for example, rpm data can be analysed and viewed as in Figure 2.6. The CarChip Fleet like a black box, come without real time data display as shown in Figure 2.5. Conversely, the DriveRight 600 allows the driver to monitor some data in the LCD display, but does not support for monitoring or recording of DTC. The data displayed on LCD are vehicle's current reading (speed, distance, acceleration/deceleration, and time), driver ID, and trip information (start/end and parameters like current reading) [13].

Figure 2.5: CarChip Fleet and DriveRight 600 [5], [13]

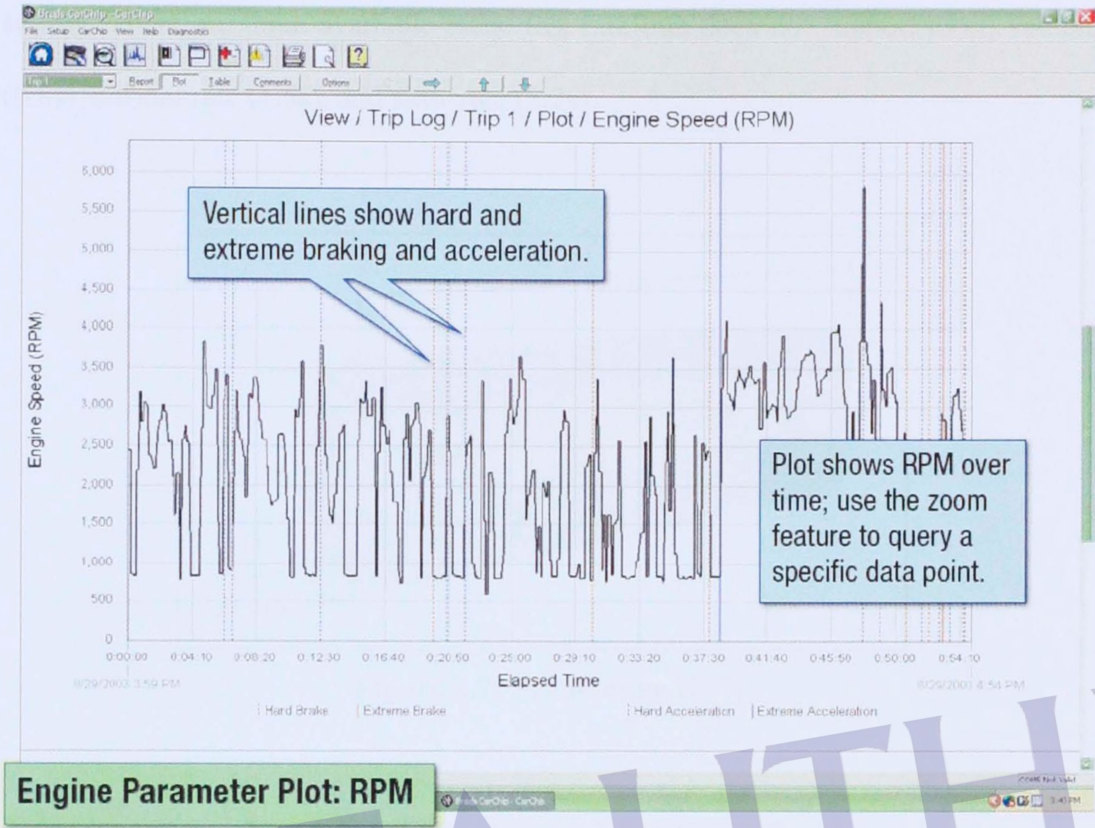


Figure 2.6: RPM Data Logging [5]

2.3.1.3 ScanGauge II

The ScanGauge II is an accessory device that support the vehicle's instrumentation panel. This device is produced by Liner Logic. There are four navigation buttons and a home button as shown in Figure 2.7 [7]. This device provides three main functions namely, the DTC scanning, a gauge reading, and the trip information display. The 'more' function as shown in Figure 2.7, provides the setting and calibration to all those functions system. Through this device, the confirmed and pending DTC can be monitored as well as displayed the freeze frame data. The gauge data is shown in Figure 2.8 and capable of informing 13 data as listed in Table 2.7. The trip data can provide 14 valuable data that will be described in detail in the following section of the trip information system. The ScanGauge's data display depends on its rate setting. There are three available rates: fast rate that does not support to all vehicle (0.8s), normal rate (1.6s), and slow rate (3.2s).

Figure 2.7: ScanGauge II [7]

Figure 2.8: Gauge Data Display [7]

Table 2.7: Gauge Abbreviation and Support [7]

No	Abbreviation	Gauge Name
1	CLSD LP/OPEN LP	Fuel system loop status
2	FIA/CIA	Intake Air Temperature
3	FWT/CWT	Water/Coolant Temperature
4	FPR	Fuel-Pressure
5	GPH/LPH	Gallons-per-Hour/Liters-per-Hour
6	IGN	Ignition timing
7	LOD	Engine Loading
8	MPG KPG MPL KPL	Miles per Gallon Kilometres per Gallon Miles per Liter Kilometres per Liter
9	MPH/KPH	Miles-per-hour/Kilometres-per-Hour
10	MAP	Manifold Absolute Pressure
11	RPM	Revolutions per Minute
12	TPS	Throttle Position Setting
13	VLT	Battery Voltage

2.3.2 OBD-II System Interface

Requesting the raw diagnostic data from ECUs needs both hardware and software interfaces that support certain vehicle's communication protocol. The hardware interface must have capability to convert the vehicle's voltage battery (+12V) to standard electronics' voltage (+5V) and can support to certain speed of baud rate communication. With this capability, the software can be designed and programmed in microcontroller to access the specific data with correct communication timing. The microcontroller that has this software capability is named an interpreter chip. The combination of the OBD-II hardware interface and the interpreter chip is called an OBD-II adaptor [19].

Two popular companies that provide the low cost interpreter chip and adaptor are ELM Electronics (Canada) and OZEN Elektronik (Turkey). Their chips and adaptors can be interfaced directly from the serial PC port and the OBD-II vehicle diagnostic connector. Two chips related to universal OBD-II protocol will be discussed further: ELM327 (by ELM Electronics) and OE90C2600 (by OZEN Elektronik). The main comparison between these chips is presented in Table 2.8. The ELM327 has two advantages in providing high-speed RS232 communication (38400 bps) and have capability to monitor vehicle's battery.

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