

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

By

MOHAMAD FAUZI BIN ZAKARIA



PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

**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.



PTTA UTHM
PERPUSTAKAAN TUNKU TUNJUNG AMINAH

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

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

By

MOHAMAD FAUZI BIN ZAKARIA

July 2007

Chairman : Associate Professor Ishak bin Aris, PhD

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

Oleh

MOHAMAD FAUZI BIN ZAKARIA

Julai 2007

Pengerusi : Profesor Madya Ishak bin Aris, PhD

Fakulti : Kejuruteraan

Diagnostik atas papan II (OBD-II) merupakan perisian piawai 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. Tesis ini membincangkan rekabentuk dan pembangunan sebuah sistem maklumat pemanduan berasaskan protokol OBD-II. Perkakas dan perisian sistem ini direkabentuk berdasarkan empat pertimbangan iaitu kebolehnaiaktaratan, 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.



PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

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 Mahmud 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.



PTTAUTHM
PERPUSTAKAAN TUNKU TUN AMINAH

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:

Ir. Norman Mariun, PhD

Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Hashim Hizam, PhD

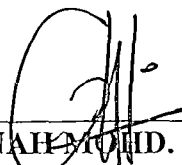
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Syed Javaid Iqbal, PhD

Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Shamsudin Hj Mohd. Amin, PhD

Professor
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
(External Examiner)



HASANAHMOID. GHAZALI, PhD

Professor / Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 16 August 2007

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Ishak Aris, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Senan Mahmud Abdullah, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Roslina Mohd Sidek, PhD

Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)



PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

A handwritten signature in black ink, appearing to read 'Aini Idaris', is written over a horizontal line.

AINI IDERIS, PhD
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 13 September 2007

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



PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	vii
APPROVAL	viii
DECLARATION	x
LIST OF TABLES	xiii
LIST OF FIGURES	xv
LIST OF ABBREVIATIONS	xx
 CHAPTER	
1 INTRODUCTION	1.1
1.1 Background	1.2
1.2 Problem Statement	1.3
1.3 Objectives	1.5
1.4 Scopes	1.6
1.5 Contributions	1.6
1.6 Thesis Outline	1.7
2 LITERATURE REVIEW	2.1
2.1 Introduction	2.1
2.2 OBD-II Technology	2.1
2.2.1 Diagnostic Standards	2.1
2.2.2 Diagnostic Communication Protocol	2.2
2.2.3 Diagnostic Connector	2.3
2.2.4 Diagnostic Message Format	2.3
2.2.5 Generic Diagnostic Service Modes	2.5
2.2.6 Enhanced Diagnostic Service Modes	2.6
2.2.7 Diagnostic Trouble Code	2.7
2.2.8 Scan Tools Technology	2.9
2.3 Existing System And Related Work	2.11
2.3.1 Overview of Existing Product	2.11
2.3.2 OBD-II System Interface	2.16
2.3.3 DTC Scanning System	2.17
2.3.4 Trip Information System	2.18
2.3.5 Data Logging System	2.23
2.4 Portable Flash Storage	2.24
2.4.1 Flash Memory Card	2.25
2.4.2 MMC Technology	2.28
2.4.3 File System Format Overview	2.33
2.5 Summary	2.35

3	METHODOLOGY	3.1
	3.1 Project Overview	3.1
	3.2 System Requirement	3.3
	3.3 System Architecture	3.5
	3.4 Hardware Design	3.7
	3.4.1 Microcontroller Unit	3.8
	3.4.2 Buffer Memory Unit	3.11
	3.4.3 Alphanumeric Liquid Crystal Display Unit	3.12
	3.4.4 Navigation Buttons Unit	3.15
	3.4.5 Real Time Clock Unit	3.16
	3.4.6 MultiMediaCard Unit	3.17
	3.4.7 OBD-II Interface Unit	3.19
	3.4.8 Main Power Supply Unit	3.20
	3.5 Software Design	3.22
	3.5.1 Low-Level Software	3.22
	3.5.2 High-Level Software	3.42
	3.6 Summary	3.63
4	RESULT AND DISCUSSION	4.1
	4.1 Introduction	4.1
	4.2 Hardware Development	4.1
	4.3 Software Development	4.3
	4.4 System Interfacing Testing	4.3
	4.4.1 Navigation Buttons	4.4
	4.4.2 Buffer Memory and LCD	4.5
	4.4.3 Real Time Clock	4.8
	4.4.4 MultiMediaCard	4.9
	4.4.5 OBD-II	4.15
	4.5 System Testing	4.18
	4.6 Benchmark and Discussion	4.23
	4.7 Summary	4.26
5	CONCLUSIONS AND FUTURE WORK	5.1
	5.1 Conclusions	5.1
	5.2 Recommendations for Future Work	5.3
	5.2.1 OBD-II Data	5.3
	5.2.2 Operating System Improvement	5.3
	5.2.3 DTC Description	5.3
	5.2.4 Graphical LCD	5.4
	5.2.5 Prompt Warning	5.4
	5.2.6 Fuel Consumption	5.4
	5.2.7 Data Performance Logging	5.4
	5.2.8 Service Reminder	5.5
	REFERENCES	R.1
	APPENDICES	A.1
	BIODATA OF THE AUTHOR	B.1
	LIST OF PUBLICATIONS	B.2

LIST OF TABLES

Table	Page	
2.1	Some of OBD-II Standards	2.2
2.2	Communication Protocol	2.2
2.3	Message Format for ISO 9142-2, ISO 14230-4 and SAE J1850	2.4
2.4	Message Format for ISO 15765-4	2.5
2.5	OBD-II Service Mode	2.6
2.6	Subsystem Groups for Generic DTC	2.9
2.7	Gauge Abbreviation and Support	2.15
2.8	ELM327 and OE90C2600 Comparison	2.17
2.9	Data Type and Triggering Mode of CarChip's Data Recording	2.24
2.10	Portable Flash Memory Card (Normal Specification) Comparison	2.27
2.11	MMC Product Technology	2.28
2.12	System Specification and Pin Arrangement Comparison	2.29
2.13	Operating System Support for Common File System	2.35
3.1	Main Components for Each Unit	3.8
3.2	AT89S8252 Specification	3.9
3.3	UT62256 Specification	3.11
3.4	LCD Specification	3.13
3.5	LCD Pin Function	3.14
3.6	DS1307 Specification	3.17
3.7	MMC Pin Connection of Proposed System	3.18
3.8	Component's Maximum Power Supply Current of Proposed System	3.21
3.9	DS1307 Timing Diagram Explanation	3.27

3.10	The Selected Command List	3.34
3.11	MMC Command Format	3.34
3.12	R1 Response Format	3.34
3.13	Data Token	3.35
3.14	Data Response	3.35
3.15	Data Error Token	3.35
3.16	Events and Sub-Tasks in Ready State Operation	3.57
3.17	OBD-II Data for Data Collection	3.58
3.18	Data Logging for CSV Format	3.62
4.1	Interface Testing Tools	4.4
4.2	System Testing Status	4.21
4.3	Proposed System Specification	4.24
4.4	The Proposed System and Current Systems Comparison	4.25



PTTA UTHIM
PERPUSTAKAAN TUNKU TUN AMINAH

LIST OF FIGURES

Figure		Page
2.1	Data Link Connector	2.3
2.2	OBD-II DTC Identification Format	2.8
2.3	PDA-Dyno Scan Tool Connection	2.12
2.4	Screen shoots of PDA Scan Tool	2.12
2.5	CarChip Fleet and DriveRight 600	2.13
2.6	RPM Data Logging	2.14
2.7	ScanGauge II	2.15
2.8	Gauge Data Display	2.15
2.9	DTC Report using CarChip Fleet	2.18
2.10	Graphical User Interface for ScanGauge's DTC Display	2.18
2.11	ScanGauge's Trip Information Display	2.20
2.12	Trip Information System in the Selected Hyundai Getz	2.21
2.13	AVR-Based Fuel Consumption System	2.21
2.14	MMC Architecture and Register Description	2.30
2.15	Overview of MultiMediaCard Bus Protocols	2.31
2.16	Two Clusters and Eight Sectors	2.34
3.1	System Overview of Proposed System	3.1
3.2	Project Activities	3.2
3.3	Proposed System Features	3.3
3.4	System Architecture of Proposed System	3.6
3.5	Basic Microcontroller Circuit of Proposed System	3.10
3.6	Buffer Memory Circuit of Proposed System	3.12
3.7	Alphanumeric LCD Architecture	3.13

3.8	Timing Comparison Between LCD and Microcontroller	3.14
3.9	Schematic of LCD of Proposed System	3.15
3.10	Navigation Buttons Circuit of Proposed System	3.16
3.11	DS1307 Real Time Clock Schematic Diagram of Proposed System	3.17
3.12	MMC Circuit of Proposed System	3.19
3.13	OBD-II Interface Circuit of Proposed System	3.20
3.14	Main Power Supply Circuit of Proposed System	3.21
3.15	Address Mapping for Buffer Memory and LCD of the Proposed System	3.23
3.16	Initialization, Write Command and Write Data Subroutines of LCD	3.24
3.17	Data and Menu Area for 20x4 LCD	3.24
3.18	LCD Subroutines for Graphical User Interface Display	3.25
3.19	Navigation Buttons Flow Chart	3.26
3.20	DS1307 Timing Diagram	3.27
3.21	I ² C Start and Stop Condition Flow Chart	3.28
3.22	I ² C Transmit and Receive Flow Chart	3.29
3.23	Data Write Mode	3.30
3.24	Data Read Mode	3.31
3.25	DS1307 Register Address	3.31
3.26	Write and Read Mode of RTC Low-Level Flow Chart	3.32
3.27	SPI Master-Slave Interconnection and Communication Flow Chart	3.36
3.28	Send Command, Set, Write, and Read a Block Subroutine	3.37
3.29	Single Block Write and Read Operation in SPI Mode	3.38
3.30	Initialization Subroutine	3.39

3.31	Data Byte frame of Transmission and Receiving Format	3.40
3.32	UART Setup and Receive Subroutines	3.41
3.33	UART Transmit and Busy Checking Subroutine	3.42
3.34	High-Level Operation	3.43
3.35	Flow Control of Basic Software	3.45
3.36	FAT Structure on a MMC	3.46
3.37	FAT16 Boot Record	3.47
3.38	FAT Table	3.48
3.39	Directory Table	3.49
3.40	Intel. <i>hex</i> File Format	3.51
3.41	Stage 1 Operation Flow Chart	3.53
3.42	Tasks States	3.56
3.43	Default to Menu Display Operation	3.59
3.44	Live Data Display Operation	3.59
3.45	Diagnostic Trouble Code (DTC) Display Operation	3.60
3.46	Trip Information Display Operation	3.61
3.47	Service Reminder Display Operation	3.61
3.48	Clock Setting Display Operation	3.61
3.49	About Display Operation	3.61
3.50	Stage 3 Operation Flow Chart	3.63
4.1	Board 1	4.2
4.2	Board 2	4.2
4.3	Complete System in a Box	4.2
4.4	Interfacing Test with Logic Analyzer	4.4
4.5	Bouncing Signal of the Button	4.5

4.6	Zoom-in of First 22.84ms Area	4.5
4.7	Simulation Snapshot	4.6
4.8	LCD Output Display	4.7
4.9	LCD Data Communication	4.7
4.10	Buffer Memory Content in Simulation Software	4.8
4.11	Write and Read Operation in External RAM	4.8
4.12	Write Mode Operation	4.9
4.13	Write and Read Operation	4.9
4.14	Generate 8 Clock for 10 Times with SS Active Low	4.10
4.15	CMD0 and Response (01h)	4.10
4.16	MMC in Idle Mode	4.11
4.17	CMD1 and Response (00h)	4.11
4.18	Write Operation	4.12
4.19	Write Command and Response	4.12
4.20	Start Data Token (FEh) and Data	4.12
4.21	Checksum Transmission and Response from Card	4.12
4.22	Busy Signal After Write Operation for 1200 Clock Pulses	4.13
4.23	MMC Data View in the WinHex Software	4.13
4.24	Read Operation	4.14
4.25	CMD17 and Response	4.14
4.26	Clock Pulses Delay For Data Token Start Signal	4.14
4.27	Read Operation Data and Checksum Bytes	4.14
4.28	OBD-II Connector and Pin Designation	4.15
4.29	OBD-II Testing Setup in Hyundai Getz	4.16
4.30	Battery Voltage Reading	4.16

4.31	Searching Data Message	4.17
4.32	OBD-II Data	4.17
4.33	No Data Message	4.18
4.34	Unable to Connect Message	4.18
4.35	System Testing	4.19
4.36	Pattern 1 of Cooperative Kernel	4.19
4.37	Pattern 2, 3, 4 and 5 of Cooperative Kernel	4.20
4.38	Trip Information Summary in Microsoft Excel and Notepad	4.22
4.39	Service Reminder Data in Microsoft Excel and Notepad	4.22
4.40	Folder Allocation in MMC	4.23



PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

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



PTTHM
PERPUSTAKAAN TUNKU TUN AMINAH

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].

REFERENCES

- [1] J. Erjavec, *Automotive Technology*, 4th ed., New York: Thomson Delmar Learning, 2005.
- [2] W. B. Ribbens, *Understanding automotive electronics*, 6th ed., MA: Newnes, 2003.
- [3] *On-Board Diagnostics for Light and Medium Duty Vehicles Standards Manual*, SAE International, 2003.
- [4] *PDA-Dyno and OBD II Scan Tool Operating Manual*. Nology Engineering, Inc. San Marcos, MA. [Online] Available: <http://www.nology.com>. Accessed on Feb. 23, 2007.
- [5] *How Can CarChip Help You*. Davis Instruments. Hayward, CA. [Online] Available: <http://www.davis.com>. Accessed on Sept. 23, 2006.
- [6] *DriveRight: Solution for Vehicle Safety and Management*. Davis Instruments. Hayward, CA. [Online] Available: <http://www.davis.com>. Accessed on Sept. 23, 2006.
- [7] *The ScanGauge II: Installation and Operation Manual*. Linear logic. [Online] Available: <http://www.scangauge.com>. Accessed on Sept. 23, 2006.
- [8] D. H. James and D. M. Chase, *Automotive Technology: Principle, Diagnosis, and Service*, 2nd ed. New Jersey: Prentice Hall, 2003.
- [9] N. Tom, "Automotive Protocols & Standards", in *Motor Mag*. Troy, MI: Hearst Business Publishing Inc., Jul. 2005, pp 34-38.
- [10] *Road vehicles - Keyword protocol 2000 for diagnostic systems - Part 3: Application Layer*, ISO Standard 14230-3, 1999.
- [11] B. Sam, "How Not To Get MIL-Stoned", in *Motor Mag*. Troy, MI: Hearst Business Publishing Inc., Apr. 2004, pp 34-38.
- [12] D. L. Bruce, "AVR-Based Fuel Consumption Gauge", in *Circuit Cellar Mag*. Vernon: Circuit Cellar Inc., Oct. 2005, pp. 59-67.
- [13] "DriveRight 600 User Guide". Davis Instruments. Hayward, CA. [Online] Available: <http://www.davis.com/driveright.pdf>. Accessed on Sept. 23, 2006.
- [14] P. Bob, "Scan Tool Assessment", in *Motor Mag*. Troy, MI: Hearst Business Publishing Inc., Jul. 2005, pp 20-30.
- [15] M. Jorge, "Choosing the Right Scan Tool", in *Motor Mag*. Troy, MI: Hearst Business Publishing Inc., Jul. 2002, pp. 26-38.

- [16] P. Bob, "Bidirectional Scanner Controls: The 2-Way", in *Motor Mag*, Troy, MI: Hearst Business Publishing Inc., Apr. 2005, pp. 38-46.
- [17] *ELM 327: OBD to RS232 Interpreter*. ELM Electronics, Canada. [Online]. Available: <http://www.elmelectronics.com>. Accessed on Sept. 23, 2006.
- [18] *OBDII/EOBD to RS232 Gateway*. Ozen Elektronik, Turkey. [Online]. Available: <http://www.ozenelektronik.com>. Accessed on Sept. 23, 2006.
- [19] G. Muller, "Vehicle Diagnostics Adapter", in *Elektor Electronics Mag*. UK: Elektor Publishing, Nov. 2002, pp. 24-29.
- [20] *Hyundai Getz Owner's Manual*, Hyundai Motor Corp. 2004.
- [21] H. Barry, *Classroom Manual for Automotive Fuels & Emissions*, New York: Thomson Delmar Learning, 2005.
- [22] C. Ed, "The Case for Portable Electronics Health Records", in *J. AHIMA*, Sept. 2004, pp. 70-71.
- [23] *MultiMediaCard User's Manual*, 3rd ed., Hitachi Kodaira Semiconductor Co., Ltd., Japan, 2003.
- [24] T. Totsuka and K. Furusawa, "Large-Capacity Flash Memories and Their Application to Flash Card", in *J. Hitachi Review*, vol. 48, 1999, pp. 68-73.
- [25] *Samsung MultiMediaCard*. Samsung Electronics Co., Ltd. [Online]. Available: <http://www.samsung.com/Products/Semiconductor/FlashCard/MMC/index.htm>. Accessed on Jan. 12, 2007.
- [26] *MultiMediaCard System Specification Ver. 3.1*, MultiMediaCard Association, Cupertino, CA, 2001.
- [27] A. L. Vyssotski *et al.*, "Miniature Neurologgers for Flying Pigeons: Multichannel EEG and Action and Field Potentials in Combination With GPS Recording," in *J. Neurophysiol*, vol. 95, 2006, pp. 1263-1273.
- [28] T. Deniz and Y. Yilmaz, "Design and Implementation of a Digital Ambulatory ECG Recorder Based On Flash MultiMediaCard Memory," in *Proc. 46th IEEE Int. Midwest Symp. Circuit and Systems*, Cairo, Egypt, 2003, pp. 368-371.
- [29] *Application Note 189: MMC Data Logger Example*, Silicon Laboratories Inc., Austin, 2004.
- [30] K. R. Irvine, *Assembly Language for Intel-based Computer*, 4th ed., New Jersey: Prentice-Hall, 2003.

- [31] J. B. Peatman, *Embedded Design with the PIC18F452 Microcontroller*, New Jersey: Pearson Education, 2003.
- [32] *AT89S8252 Datasheet*. Atmel Corp., San Jose, CA, 2003.
- [33] K. J. Ayala, *The 8051 Microprocessor: Architecture, Programming and Applications*, 2nd ed., St. Paul: West Publishing, 1997.
- [34] M. A. Mazidi, J. G. Mazidi, *The 8051 Microcontroller and Embedded System*, New Jersey: Prentice-Hall, 2000.
- [35] *UT62256 Datasheet*. Utron Technology Inc., Taiwan, ROC, 2000.
- [36] *LCD PC2004LRS-AWA-B (Ver. A) Datasheet*. Powertip Corp., Taiwan, ROC, 2003.
- [37] Dallas Semiconductor. *DS1307/DS1308: 64 x 8 Serial Real Time Clock Datasheet*. 1999.
- [38] *Application Note 95: Interfacing the DS1307/1308 with an 8051-Compatible Microcontroller*, Maxim Integrated Products, Sunnyvale, CA, 2006.
- [39] A. Astarloa *et al.*, "Multiprocessor SoPC-Core for FAT Volume Computation," in *Elsevier J. Microprocessors and Microsystems*, vol. 29, 2005, pp. 421-434.
- [40] F. Eady, "Construct an ATA Hard Drive Controller." in *J. Atmel Application*, no.2. 2004, pp. 12-16.
- [41] W. S. Thomas, *C and the 8051 vol. 2*, New Jersey: Prentice-Hall, 1999.
- [42] J. Farmer, *Application Note 585: A Real-Time Operating System for PICmicro™ Microcontrollers*, Microchip Technology Inc., Chandler, AZ, 1997.
- [43] J. Field, *Application Note 1262: Simple Real-Time Kernels for M68HC05 Microcontrollers*. Motorola Ltd., Scotland, 1995.