APPLICATION OF AUTOMATIC SPEED REDUCER SYSTEM IN VEHICLE

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JUNE 2010

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by

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Final Report submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Electrical & Electronics Engineering)

JUNE 2010

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Electrical & Electronics Engineering Programme

Universiti Teknologi PETRONAS

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Approved by,

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(Mdm Hanita bt Daud)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

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JUNE 2010

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.

HAIRUL NAZMI BIN SALEH

ABSTRACT

This report discusses the research done and basic understanding of the chosen topic, which is **Application of Automatic Speed Reducer System in Vehicle**. The objective of this report is to study on the integration between Electronic Throttle Control (ETC) drive-by-wire system and Engine Control Unit (ECU) as a mechanism to reduce engine's speed. The research will be more focused on the building up the prototype based on the closed-loop control system model. The scope of study includes studying the operation of Engine Control Unit (ECU), electronic throttle control, operating signal sensor such as Manifold Absolute Pressure (MAP) sensor, Mass Air Flow (MAF) sensor and application of Electronics Fuel Injection (EFI) system in vehicle. The methodology in doing this study is derived in a flow chart and the steps are data collection, data analysis, formulate and develop well model, fabrication and prototype testing.

ACKNOWLEDGEMENTS

First and foremost, praise to Allah The Almighty, who has helped and gave me courage and strength in completing the Final Year Project (FYP). Without His permission, this FYP will not be success.

I would like to take this opportunity to express my deepest gratitude to all parties involved in conducting this project from UTP lecturers, technician, and other external parties who have put a lot of effort in making this project a success.

I am proudly grateful to my supervisor, Mdm Hanita bt Daud who has guided and give me an opportunity to handle this project successfully. The compliment also goes to all Electrical and Electronics Engineering lecturers and technicians for bundles of information and their assistance.

I would like to convey my special thanks to my entire friends for continuously support and motivate each other throughout two semesters in conducting this project. Last but not least, many thanks to those their name not mentioned here. Thank you very much.

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LIST OF ABBREVIATIONS

UTP	Universiti Teknologi PETRONAS
FYP	Final Year Project
ECU	Engine Control Unit
MAP	Manifold Absolute Pressure
TPS	Throttle Position Sensor
TPOS	Throttle Position
WOT	Wide Open Throttle
ECM	Electronic Control Module
MAF	Mass Air Flow
ETC	Electronic Throttle Control
EFI	Electronics Fuel Injection
RPM	Revolution per Minute
PIC	Programmable Integrated Controller
CMOS	Complementary Metal-Oxide Semiconductor
EEPROM	Electrically Erasable Programmable Read
PWM	Pulse Width Modulation
DC	Direct Current

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Road safety has long been considered as one of social responsibilities to the Malaysian Government. In the visibility of this responsibilities, multiples bodies concern on road safety have been formed within the government departments, private agencies and voluntary organizations. A National Road Safety Plan then was formulated to give an attention to road safety research programs, behavioral modification of road users, road engineering and vehicle safety, medical treatment and safety administration [1].

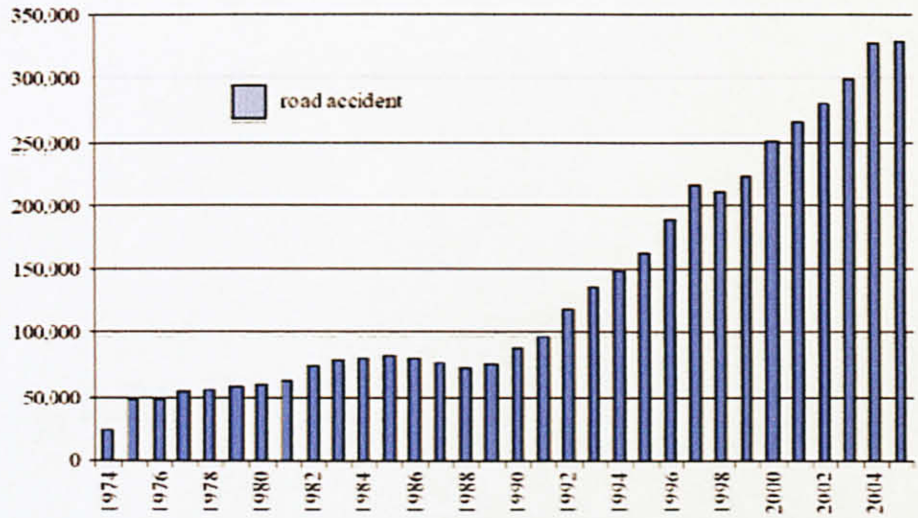

Figure 1: Statistics Road Accident in Malaysia (2005)

Traffic accidents in Malaysia have been increasing at the average rate of 9.7% per annum over the last three decades [1]. Compared to the earlier days, total number of road accidents had increased from 24,581 cases in 1974 to 328,264 cases in 2005, reaching more than 135% increase of accident cases over 30 years. The number of fatalities (death within 30 days after accident) also increased but at slower rate compared to total road accident from 2,303 in 1974 to 6,200 in 2005 [2].

One of the key performance indicators for Road Safety that has been highlighted by the National Road Safety Plan is road engineering and vehicle safety research. In line with that goal, this project is planned to establish one of the option that can be taken for all road users in Malaysia in order to increase the safety features for their vehicle [2]. The basic idea of the project is to implement some sort of device that can work together with the Engine Control Unit (ECU) in vehicle so that the vehicle will slow down automatically in case of emergency or mechanical device failure.

1.2 Problem Statement

1.2.1 Problem Identification

According to the General Road Accident Statistics and Fatality Index in Malaysia, there are certain aspects that need to be looked at when it comes to road traffic accidents such as driver behavior, road conditions and the state of the vehicle at the time of the accident. The figure shows that the numbers of accident caused by the road conditions and vehicle state are quite high. The design of a roadway can contribute to accidents, by making it more difficult to see other vehicles, creating hazardous pinch points, presenting dangerous obstacles for drivers, or increasing susceptibility to weather conditions.

Most of car safety devices that available in the market are often high costs. Sometimes, safety device like automatic braking system fail to perform and this can cause serious injuries or even death. To reduce cost while improving safety features, the idea is to design a device based on the operation of Electronics throttle Control (ETC). It can be controlled by microcontroller like Engine Control Unit (ECU). Since the microcontroller is programmable, it will reduce the risk of device malfunction and at the same time, produce high standard of durability device.

1.2.2 Significant of the Project

The throttle positioning system is the most ideal safety mechanism to be built on the vehicle due to a lot of advantages compared to other system of car safety device. It involves simple programming and integration between ECU and ETC. The system will reduce cost while improving the overall safety features in vehicle.

1.3 Objective of Project

The main objective of this project is to provide full functionality of the ETC system through on-board prototyping rather than directly install the system on the actual vehicle. The objectives of the project are:

- To design and develop an alternative automatic device/mechanism that helps driver increase the control of vehicle in case of emergency by automatically reducing vehicle speed.
- To provide cheap and affordable safety device for vehicle.

1.4 Scope of Study

This project will cover on the configuration setup and integration between electronic throttle control and engine control unit in vehicle. The sensors and actuators will also be highlighted as one of the features in this project. Besides, fundamental operation of closed-loop control system will be tested after the circuit completed. This will include the integration from the circuit to the ECU and the device that actually do the most important role which is to reduce the speed of the vehicle. The devices that will involve are such as electronic throttle control and injectors.

CHAPTER 2
LITERATURE REVIEW

Review for the study was taken abundantly from books, journals and the internet. Basically, in the actual vehicle, set point will be applied into the controller in term of Throttle Position (TPOS) signal, and the Engine Control Unit (ECU) alters the voltage sent to the Electronics Throttle Control (ETC) to reduce the valve opening in order to reach the desired engine's RPM. For the project implementation, on-board prototype will be fabricated. Some components that will be needed are PIC Microcontroller that will represent as ECU, servo motor as ETC and potentiometer as throttle pedal sensor.

2.1 PIC Microcontroller (PIC16F877A)

Microcontroller 16F877A belongs to the high-performance CPU, 40 pins which only 35 single word instruction. This type of PIC also has full static design, low power, high speed Complementary Metal-Oxide Semiconductor (CMOS) Flash / Electrically Erasable Programmable Read – only Memory (EEPROM) technology with interrupt capability up to 14 sources. Figure 3 shows the pin diagram of the PIC16F877A microcontroller, respectively [13].

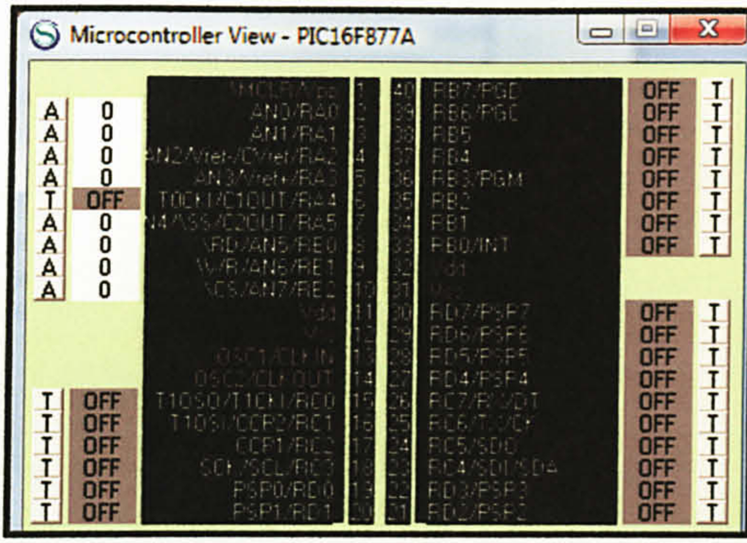

Figure 2: PIC16F877A Pin Diagram [13]

The interesting features in PIC16F877A are:

1. The timer0: 8 bit timer / counter with 8-bit pre-scalar.
2. Timer 1: 16 bit / counter with pre-scalar which can be incremented during SLEEP via external crystal clock.
3. Timer 2: 8 bit timer / counter with 8 bit period.
4. 10 bit multi channel Analogue to Digital Converter (ADC)

Table 1: 16F877A Pin Description [13]

Pin	Description
1	Reset Pin
2 - 7	PORT A pins
8 - 10	PORT E pins
11, 32	Positive Supply
12, 31	Negative Supply
13, 14	Pins assigned for oscillator connection
15 - 18, 23 - 26	PORT C pins
19 - 22, 27 – 30	PORT D pins
33 - 40	PORT B pins

2.2 Electronic Throttle Control (ETC)

2.2.1 Throttle Body

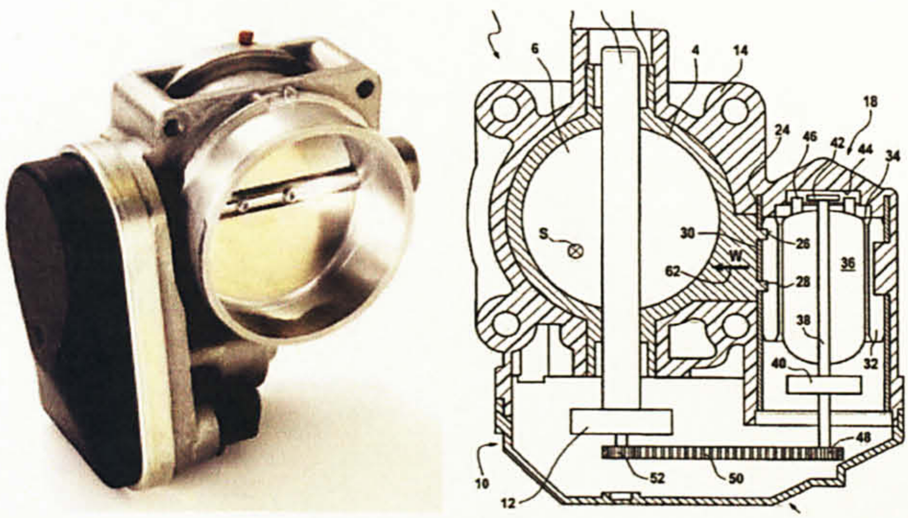

Figure 3: Throttle body with integrated motor actuator [14], [15]

Electronic throttle control (ETC) is an automobile technology which serves the mechanical link between the accelerator pedal and the throttle [3]. Most automobiles already use a throttle position sensor (TPS) to provide input to traction control, antilock brakes, fuel injection, and other systems, but use a bowden cable to directly connect the pedal with the throttle. An ETC-equipped vehicle has no such cable. Instead, the electronic control unit (ECU) determines the required throttle position by calculations from data measured by other sensors such as an accelerator pedal position sensor, engine speed sensor, vehicle speed sensor etc. The electric motor within the ETC is then driven to the required position via a closed-loop control algorithm within the ECU [14].

The benefits of ETC are largely unnoticed by most drivers because the aim is to make the vehicle power-train characteristics seamlessly consistent irrespective of prevailing conditions, such as engine temperature, altitude, accessory loads etc. The ETC is also improving the ease with which the driver can execute gear changes and deal with the dramatic torque changes associated with rapid accelerations and decelerations [14].

The significance of ETC is that it much easier to integrate features to the vehicle such as cruise control, traction control, stability control and others that require torque management, since the throttle can be moved irrespective of the position of the driver's accelerator pedal. ETC provides only a very limited benefit in areas such as air-fuel ratio control, exhaust emissions and fuel consumption reduction, working in concert with other technologies such as gasoline direct injection [11].

There are several reasons why electronic throttle actuation is preferable to a conventional throttle cable [12]:

- The vehicle's on board electronic systems are able to control all of the engine's operation with the exception of the amount of incoming air.
- The use of throttle actuation ensures that the engine only receives the correct amount of throttle opening for any give situation
- The optimization of the air supply will also ensure that harmful exhaust emissions are kept to an absolute minimum and drivability is maintained, regardless of the circumstances. Coupling the electronic throttle actuation to the adaptive cruise control, traction control, idle speed control and vehicle stability control systems also means finer control can be achieved.

The use of such a system has advantages over the conventional cable version by [9]:

- Eliminating the mechanical element of a throttle cable and substituting it with fast responding electronics, reduces the number of moving parts (and associated wear) and therefore requires minimum adjustment and maintenance.
- Greater accuracy of data improves the drivability of the vehicle, which in turn provides better response and economy.

2.2.2 System Variants

The first versions of electronic throttle actuation or EML were based upon the option of becoming a production line 'add on' system. It utilized its own Electronic Control Module (ECM) or ECU, without the requisition of additional hardware (and programming) to the vehicle's original ECM. This was achieved by imputing minimal data into the vehicle's ECM via a serial link from the electronic throttle actuator's separate control unit, as illustrated below [16].

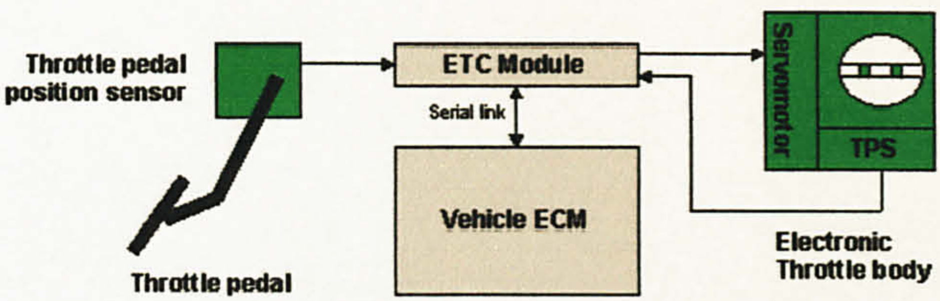

Figure 4: First model of electronic throttle actuation [16]

Today's systems have a specific ECM that incorporates the necessary programming to facilitate the input signals from the throttle pedal potentiometers and signal outputs to the electronic throttle body, as shown below [16].

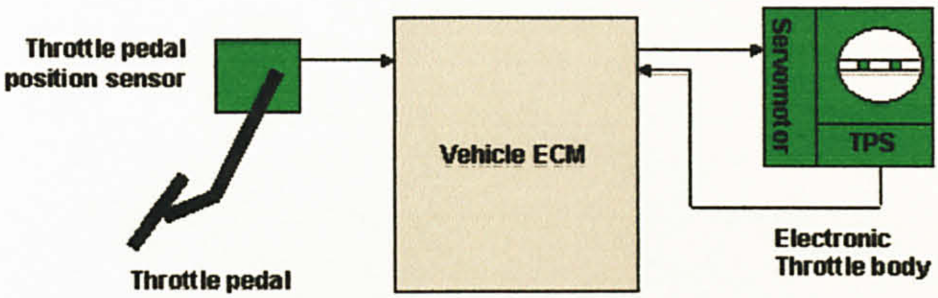

Figure 5: Latest model of electronic throttle actuation [16]

2.2.3 *Failure Modes*

Before drive by wire technology was introduced if a throttle stuck open you could generally put your toe under the accelerator and lift up. Occasionally after servicing or repair the wire or cable between the accelerator and throttle would not be correctly reinstalled causing sudden acceleration. However, with the ETC, the movement is all done by electronic controls moving an electric motor. But just moving the throttle by sending a signal to the motor is an open loop condition and leads to poor control. Most if not all current ETC systems have a closed loop system whereby the ECU tells the throttle to open a certain amount according to an algorithm based on the geometry of the throttle. Then if due to dirt build up in the throttle bore or a damaged TPS the signal sent from the TPS to the ECU, the ECU can make appropriate adjustments to compensate, though it might result in surging, hesitation or uneven idle [14].

There are two primary types of throttle position sensors (a potentiometer) or a Hall Effect sensor (magnetic device). The potentiometer is a satisfactory way for non critical applications such as volume control on a radio, but as it has a wiper contact rubbing against a resistance element. Dirt and wear between the wiper and the resistor can cause erratic readings. The more reliable solution is the magnetic coupling that makes no physical contact so will never be subject to failing by wear [14].

This is an insidious failure as it may not provide any symptoms until there is total failure. All cars having a TPS have what is known as a 'limp-home-mode'. When the car goes into the limp-home-mode it is because the accelerator and engine control computer and the throttle are not talking to each other in a way that they can understand. The engine control computer shuts down the signal to the throttle position motor and a set of springs in the throttle set it to a fast idle, fast enough to get the transmission in gear but not so fast that the car cannot be stopped by the brakes [14].

2.3 Engine Control Unit (ECU)

2.3.1 ECU Functions

The development of electronic throttle control system requires several inputs from the sensors into the ECU in order to control output, actuators. The ECU has the function to calculate the input signal from pedal position sensor and mapping it proportionally to the opening valve at electronic throttle control [7]. Figure below shows the general input-output block diagram into the ECU.

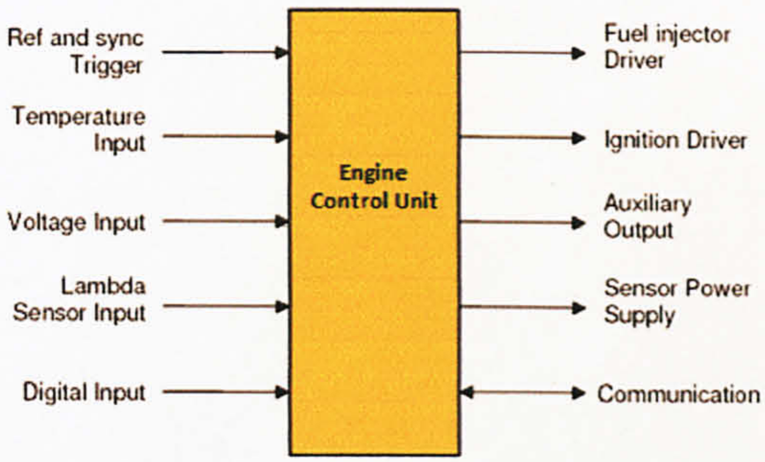

Figure 6: Input and output block diagram of an ECU [4]

The ECU functions through four basic step process which are [6];

a) ECU gathers and accumulates all the data from engine sensors.
b) Identify the engine condition from the sensors signal provided in term of engine temperature, pressure, speed, load and other input sensors.
c) Determine and calculate the next step to control the actuator output on ignition timing and fuel injection timing.
d) Translate the computer output signals into electrical signal that directly control the actuators.

2.4 Sensors

2.4.1 Electromagnetic Sensors

Figure 7: Crank sensor [17]

The electromagnetic sensor is used to sense speed or angular position of a rotating object. In the automotive application, this sensor is applied to measure the vehicle speed and engine speed as well as to determine the crankshaft position for ignition timing and fuel injection timing [10].

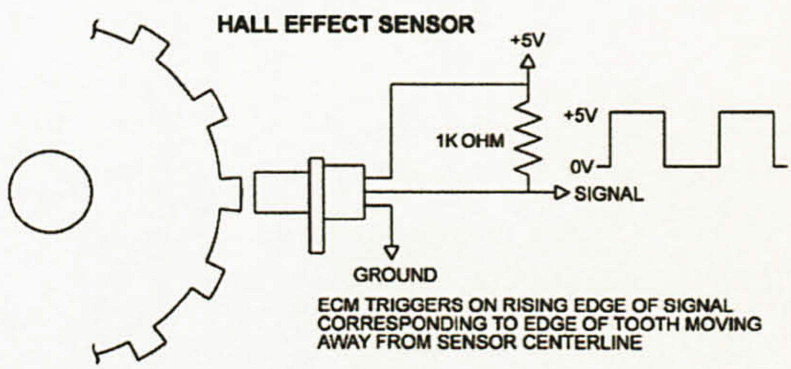

Figure 8: Crank sensor diagram which use a Hall Effect type of sensor [5]

The distance between trigger wheel and pick-up coil is very important where the more gap, the weaker the signal. The input signal from crankshaft sensor give an indication to ECU on engine speed and to determine when cylinder No.1 is in compression stroke. ECU uses this information for fuel injection timing, spark ignition timing and others [8].

2.4.2 Potentiometer

Figure 9: Single Turn Conductive Plastic Potentiometer [18]

A potentiometer is a three-terminal resistor with a sliding contact that forms an adjustable voltage divider. If only two terminals are used (one side and the wiper), it acts as a variable resistor or rheostat. Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment. Potentiometers operated by a mechanism can be used as position transducers, for example, in a joystick [20].

Potentiometers are rarely used to directly control significant power (more than a watt). Instead they are used to adjust the level of analog signals (e.g. volume controls on audio equipment), and as control inputs for electronic circuits.

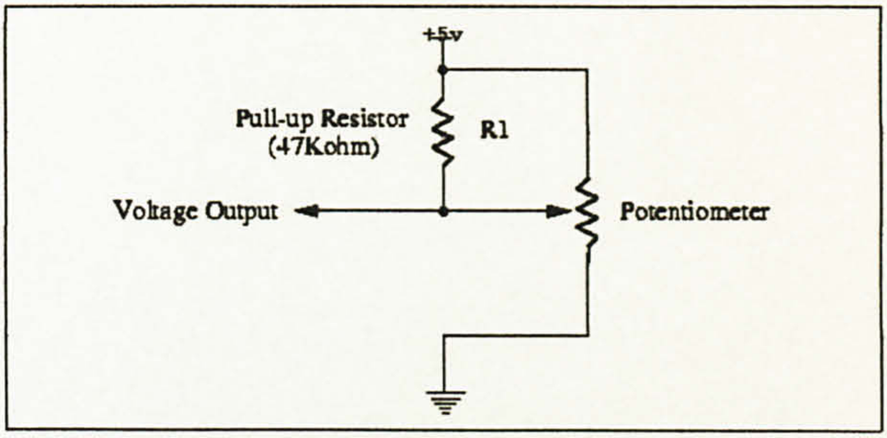

Figure 10: Potentiometer Circuit [19]

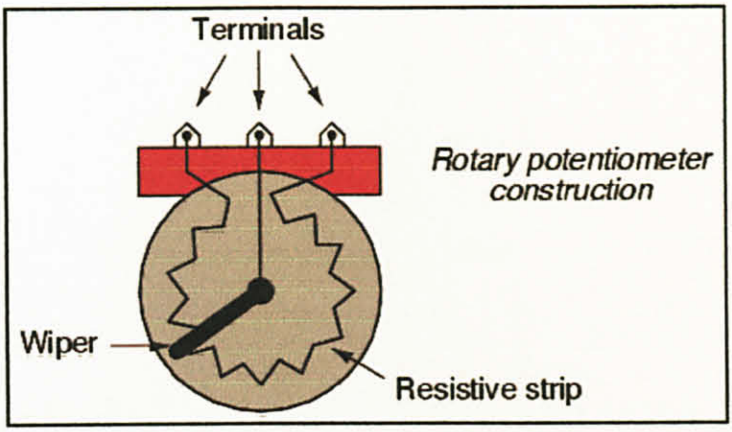

Figure 11: Rotary potentiometer construction [20]

As the shaft is being turned, the resistance between the wiper and lugs 1 and 3 changes inversely. For example, if the shaft is turning to clockwise, the resistance between 1 & 2 increases while the resistance between 2 and 3 decreases [20].

The resistance between lugs 1 and 3 never changes. For a 100k pot, the resistance between 1 and 3 will always be 100k no matter how the knob is being turned. It is the wiper (lug 2) that changes [20].

2.4.3 *Ultrasonic Sensor*

Figure 12: Ultrasonic sensor [25]

Ultrasonic sensors (also known as transceivers when they both send and receive) work on a principle similar to radar or sonar which evaluate attributes of a target by interpreting the echoes from radio or sound waves respectively. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object [24].

This technology can be used for measuring: wind speed and direction (anemometer), fullness of a tank and speed through air or water. For measuring speed or direction a device uses multiple detectors and calculates the speed from the relative distances to particulates in the air or water. To measure the amount of liquid in a tank, the sensor measures the distance to the surface of the fluid. Further applications include: humidifiers, sonar, medical ultrasonography, burglar alarms and non-destructive testing [24].

Systems typically use a transducer which generates sound waves in the ultrasonic range, above 20,000 hertz, by turning electrical energy into sound, then upon receiving the echo turn the sound waves into electrical energy which can be measured and displayed. The technology is limited by the shapes of surfaces and the density or consistency of the material. For example foam on the surface of a fluid in a tank could distort a reading [24].

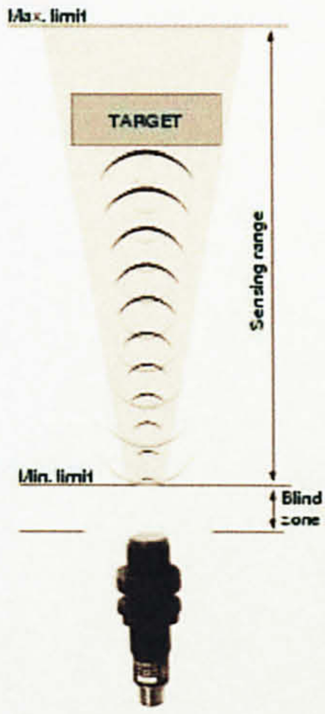

Figure 13: Ultrasonic sensor transmit and receive signal [26]

An ultrasonic transducer is a device that converts energy into ultrasound, or sound waves above the normal range of human hearing. While technically a dog whistle is an ultrasonic transducer that converts mechanical energy in the form of air pressure into ultrasonic sound waves, the term is more apt to be used to refer to piezoelectric transducers that convert electrical energy into sound. Piezoelectric crystals have the property of changing size when a voltage is applied, thus applying an alternating current (AC) across them causes them to oscillate at very high frequencies, thus producing very high frequency sound waves [24].

2.5 Servo Motor

Servos are extremely useful in robotics and other applications which need a specific angle of task. In this project, servo motor will be used as the prototype for automatic barrier. These small motors have built in control circuitry, and are extremely powerful for their size. A standard servo such as the HXT900 Micro Servo has 1.6kg-cm of torque, which is pretty strong for its size [13].

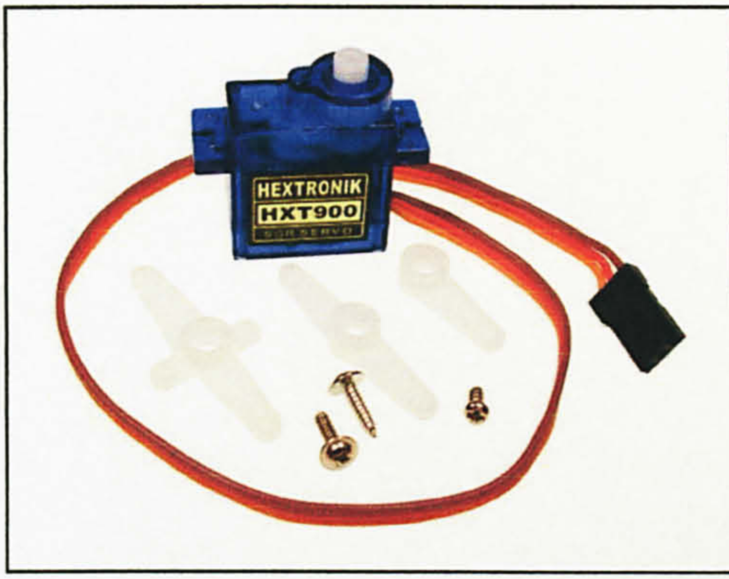

Figure 14: HXT900 Micro Servo [13]

It also draws power proportional to the mechanical load. A lightly servo, therefore, does not consume much energy. The guts of a servo motor includes the control circuitry, the motor, a set of gears, the case and also the three wires that will be connected to the outer part. The black wire is the ground, red for +5V and the white is the control wire. The control wire is used to communicate the angle. The angle is determined by the duration of a pulse applied to the control wire and is called Pulse Coded Modulation [13].

The length of the high pulse will determine the clockwise (CW) or anticlockwise (CCW) rotation of the motor. A 100 cycle will make the motor turns to 90 degree position (neutral position). If the pulse is shorter than 1.0 ms the shaft turns CW and if longer than 1.0ms the shaft turns CCW. Total for 1 pulse have to be 20ms [13].

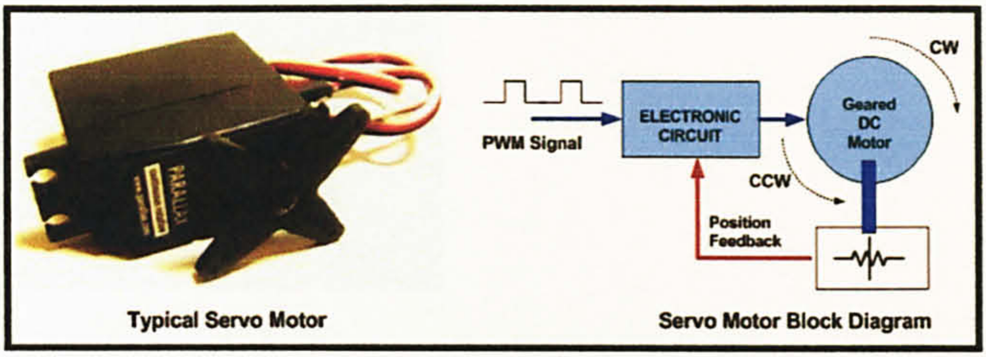

Figure 15: Illustration how servo motor works [13]

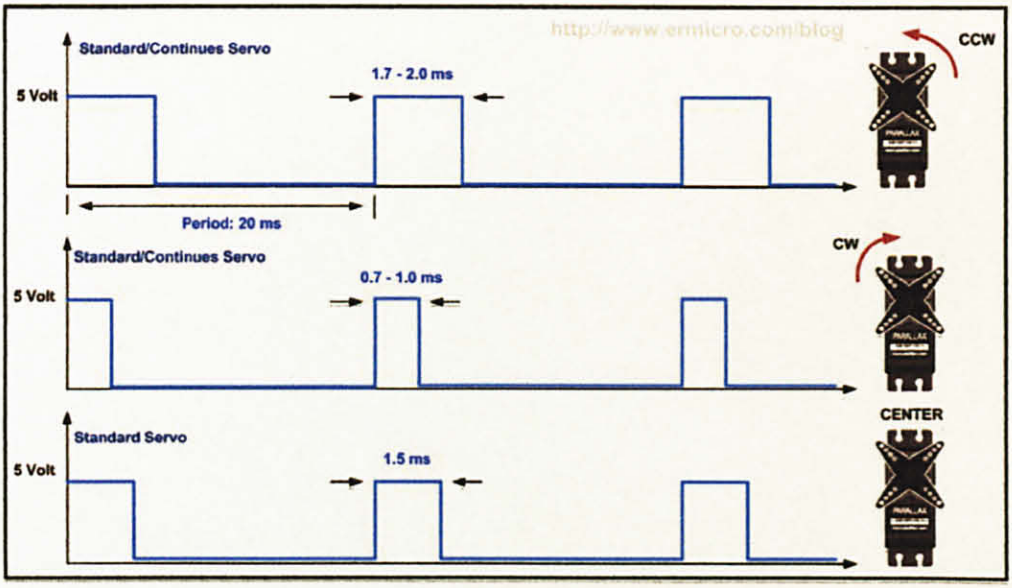

Figure 16: Servo Motor PWM Timing Diagram [23]

CHAPTER 3
METHODOLOGY

3.1 Project Flow Chart

Figure 11 shows the flowchart representation of the step in the design, modelling, simulation, analysis and testing the system prototype throughout this project.

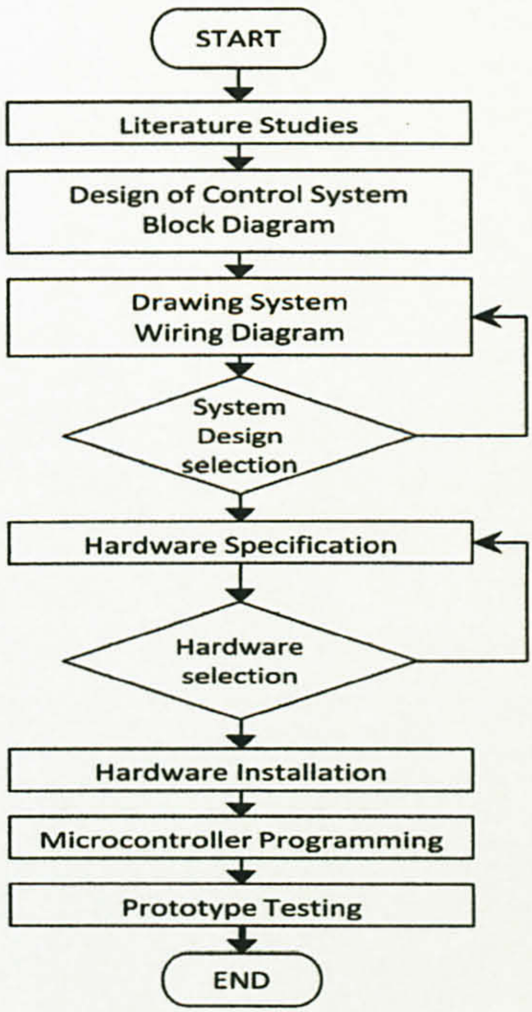

Figure 17: Project flowchart

3.2 Procedure Identification

In order to ensure the project is able to be completed efficiently within two semesters, it have been divided in to two parts where first semester covered from project literature studies until completed the software modelling and second semester covered from hardware installation or prototype system development until testing.

3.2.1 Software Modelling and Simulations

There are two software used for modelling which are Oshon Software (PIC Simulator) and Arduino (Microcontroller Compiler). Oshon is used for simulation of generating Pulse Width Modulation (PWM) signal. Arduino is needed for the working prototype, to send the PWM signal to the servo motor to set it's position angle. For the real implementation of the project, MoTeC ECU Manager will be used to conduct the prototype testing.

3.2.2 Prototype Testing

After completed with hardware installation and microcontroller setup programming, the prototype must be tested. The testing method is controlling the angle of shaft position of servo motor according to analogue voltage input from the potentiometer. This testing was conducted in lab where the PWM signal input to the servo can be visualize. When the interrupt is occur, the prototype is going to safety mode. From there, the prototype functionality is tested.

3.3 Tools and Equipment Required

3.3.1 Hardware

1. PIC16F877 Microcontroller (represents ECU)
2. Servo Motor (represents ETC)
3. Various range of potentiometer
4. Multimeter & oscilloscope
5. Power supply 12V battery
6. Wires and wiring accessories
7. Computer

3.3.2 Software

1. Arduino Software
2. MoTeC ECU Manager
3. MoTeC i2 Pro Data Analysis
4. Oshon Software – PIC Simulator

CHAPTER 4

RESULT AND DISCUSSION

4.1 Electronic Throttle Control Waveform

4.1.1 Throttle Pedal Waveform

Figure 18: Throttle pedal

The throttle pedal has two potentiometers attached to it, achieving the accuracy required from the pedal's movement. The photograph above shows the throttle pedal assembly with the potentiometers attached to the side. The resistance 'felt' when the pedal is depressed is designed to give the same feel as a conventional throttle. The throttle pedal, in this instance, has 6 electrical connections [21].

The waveform shown in the example trace below shows the throttle moving from idle to WOT (Wide Open Throttle) and back once again to idle. The blue trace shows a conventional increasing voltage as the pedal is depressed, while the red trace operates over a lower voltage. Combined signals allow the ECU to calculate a mean voltage output from the two signals. This allows the pedal position to be calculated with greater accuracy than when only a single voltage output is taken into consideration [16].

Figure 19: Throttle Pedal Waveform [16]

4.1.2 Electronic Throttle Control

Figure 20: Throttle Body [22]

The absence of any mechanical linkage between the throttle pedal and the throttle body necessitates the use of an electric actuator motor. The number of electrical connections may differ between different systems, while the example shown here has 6 electrical connections. These are to actuate the control motor and for the throttle position sensor [16].

The actuator, often referred to as a 'servomotor' is operated by DC (Direct Current). The voltage received by the servomotor is in the form of a square wave who's voltage and frequency remain the same. The servomotor responds to the change in 'duty cycle'. The duty cycle is a percentage reading between the 'on and off' time. This change can be monitored on an oscilloscope.

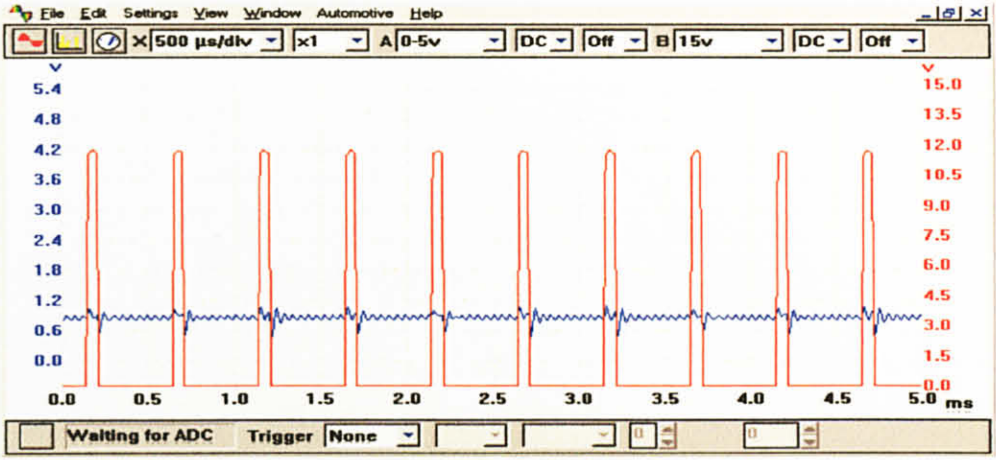

Figure 21: Servomotor Waveform (a) [16]

The waveform seen in the above illustration shows the duty cycle of the servomotor (in red) while the blue trace represents the position of the TPS (Throttle Position Sensor) [16]. As the load is increased, the duty cycle changes and further indexes the servomotor. This can be seen below.

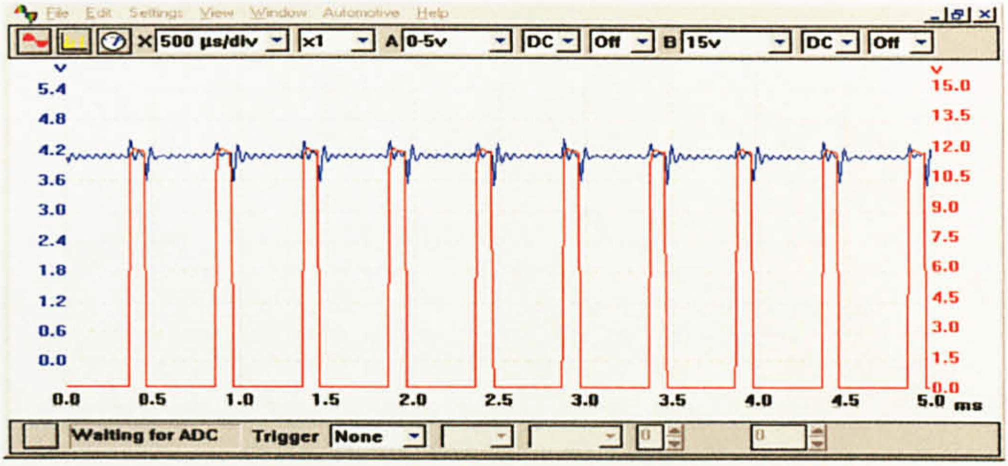

Figure 22: Servomotor Waveform (b) [16]

4.1.3 Throttle Position Sensor

Integral to the servomotor (in this particular instance) is the TPS (Throttle Position Sensor). The voltage output from this particular sensor has to report back to the ECM the exact position of the throttle butterfly. With this in mind, the TPS in the same manner as the throttle pedal position sensor has two voltage outputs. These can be seen below [16].

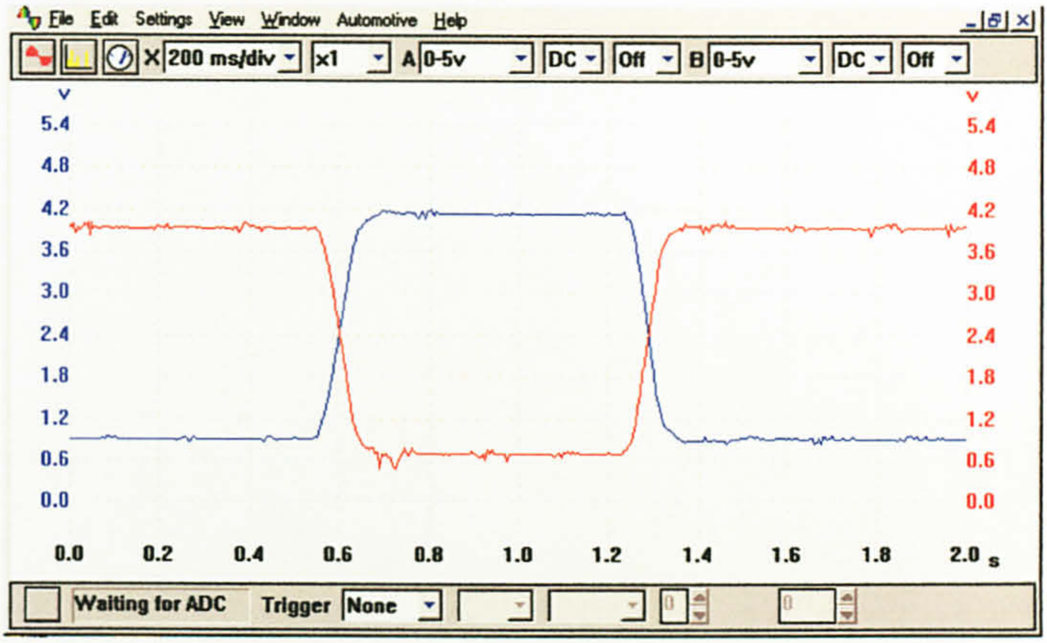

Figure 23: Throttle Position Sensor waveform [16]

The waveform shown in the example trace shows the throttle moving from idle to WOT (Wide Open Throttle) and back once again to idle. The blue trace shows a conventional rising voltage as the throttle butterfly is opened, while the red trace is inverted. The combined signals allow the ECM to calculate a mean voltage output from the two signals allowing the throttle butterfly position to be calculated with greater accuracy.

4.2 Design and Simulated PWM Signal Using Microcontroller

PWM signal is generated by using microcontroller 16F877. The signal is design by understanding the operation of servo motor that determine the certain position angle by using the duty cycle of PWM. Basically, PWM signal is a series of pulse rise and fall signals where it can be programmed into microcontroller.

The experiment is to compare the pulse width modulation produce at the output of the PIC is the same as the simulated PWM in PIC simulator software. To power up the PIC and servo motor, DC power source in the lab is used.

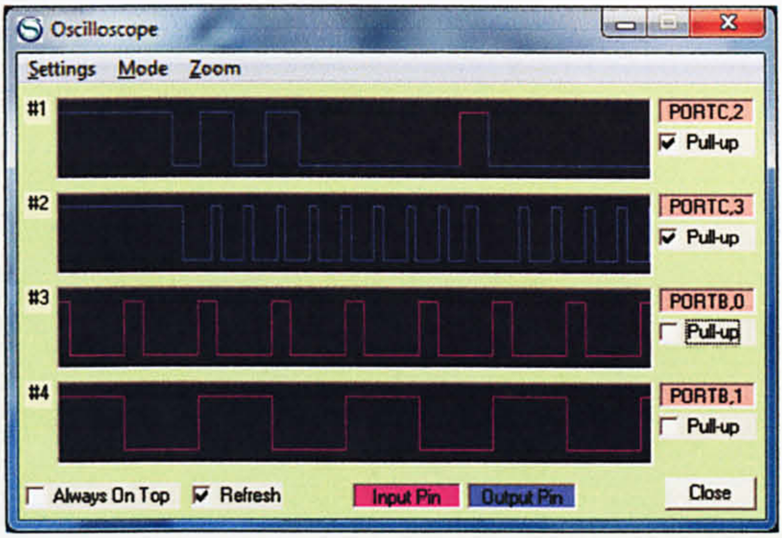

Figure 24: Result of output PWM through PIC simulator

Figure 24 shows the PWM signal on the oscilloscope. The maximum amplitude of output signal is around 4.98-V which is applicable to be supplied to servo motor. If the signal's minimum value is less than 3.0-V, servo will not detect any voltage supply and it will not work. In the real oscilloscope, the signal will contain a lot of noise which sometimes will affect the operation of servo motor.

4.3 Servo Motor System

Servo Motor is important for the operation of Electronic Throttle Control. In order to make the servo motor run, besides powering it up with DC power supply from 3 – 6 V, we have to supply pulse wave modulation (PWM) to the motor. One of the ways to create pulse wave modulation is through programming a Programmable Integrated Controller (PIC). C programming is use to program the coding in the PIC.

For this project, PIC 16LF877 is use to control the HXT 900 servo motor. A few experiments were made to test the programming of the system as well as to gauge the power supply needed to power up the PIC and the servo motor. In order to move the servo motor clockwise or counter clockwise, different type PWM have to be supplied to the servo motor. For this experiment, the PWM supply is:

Table 2: Clockwise and Counter clockwise output

	Output high	**Output Low**
Clockwise	800 us	19200us
Counter Clockwise	1800us	18200us

For servomotor, the total 1 cycle for clockwise or counter clockwise should be 20000us. In order to know when the motor should stop, try and error method is used. To get a 90 degrees movement, 100 loops of cycle is needed. To power up the PIC and servo motor, 3 methods have been tried:

Table 3: Power of each method

Source	Voltage	Current	Power	Results
DC Power Source	5 V	0.3 A	1.5 W	OK
USB	5.07V	0.01 A	50.7 mW	Fail
Battery	5.32 V	0.08 A	0.4256W	OK

From the experiment results, it can be concluded that the servo motor needs a minimum of 0.15W power supply to work.

4.4 Prototype Modeling & Testing

4.4.1 Prototype Model

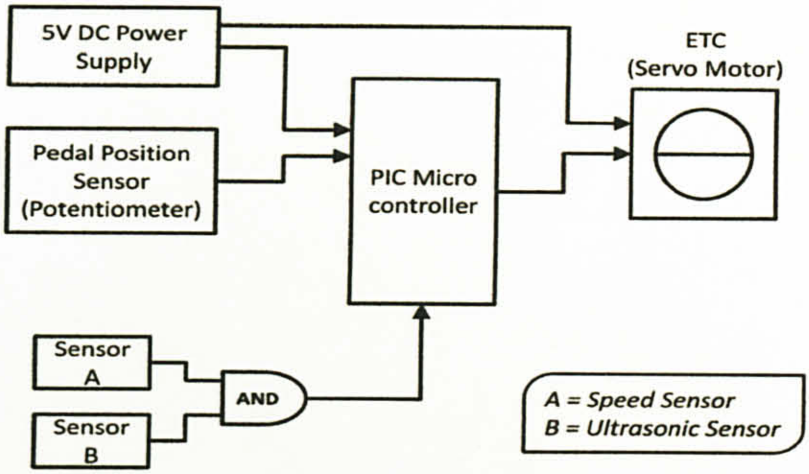

Figure 25: Prototype Model Block Diagram

Figure above shows the model of prototype which includes the DC power supply, potentiometer, sensors, microcontroller and servo motor. The DC power supply will supply voltage to both PIC microcontroller and the servomotor. Microcontroller will accept analogue voltage input from potentiometer and mapping the input directly proportional to the output (servo's shaft angle).

Whenever the microcontroller sense any interrupt signal from the sensor, it will run in safe mode by giving instruction to servo to turn the shaft to 9° - 18° position.

4.4.2 Voltage Regulator Circuit

For the implementation of the prototype in real vehicle, voltage regulator has to be integrated to the system. The reason is car battery produce 12V DC supply, but the on-board circuit only able to accept input voltage up to 7.2V DC maximum. Therefore, the 12V DC from car battery has to be reduced to meet this circuit requirement.

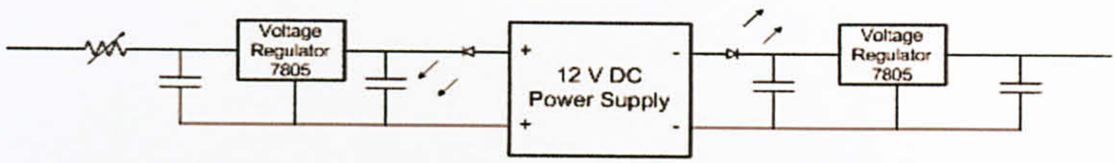

Figure 26: Circuit schematics

After the circuit has been constructed, the output voltage has to be tested. 9V DC source is supplied to the circuit to represents car battery, and the output voltage is being measured using digital multimeter.

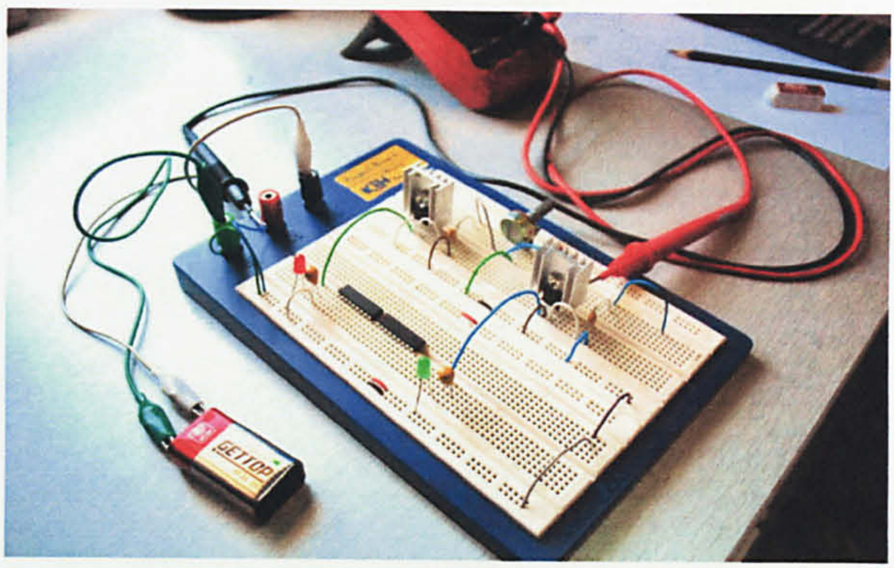

Figure 27: Voltage regulator circuit being tested

The result is as follow:

Table 4: Output Voltage for different value of resistance

Resistor Value (Ω)	Voltage (V)
2	5.05
105	4.58
203	4.08
303	3.62
399	3.14
503	2.65
605	2.13
703	1.67
804	1.17
896	0.73
1032	0.013

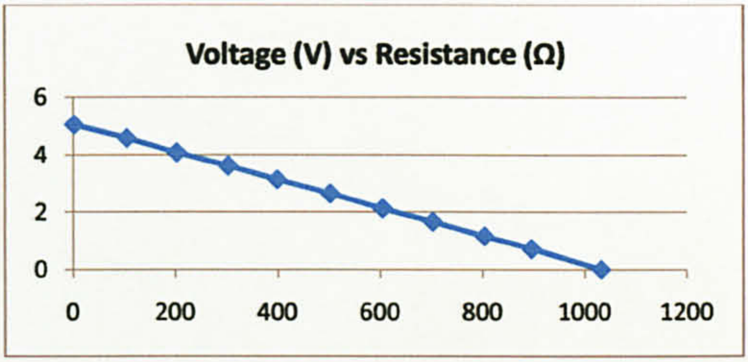

Figure 28: Output Voltage versus Resistance

From the results above, it can be conclude that the maximum input voltage can only reach approximately 5V DC, and this value decrease as the resistance from potentiometer is increase. The range of input voltage which is from 0 – 5 V is considered safe for device to operate.

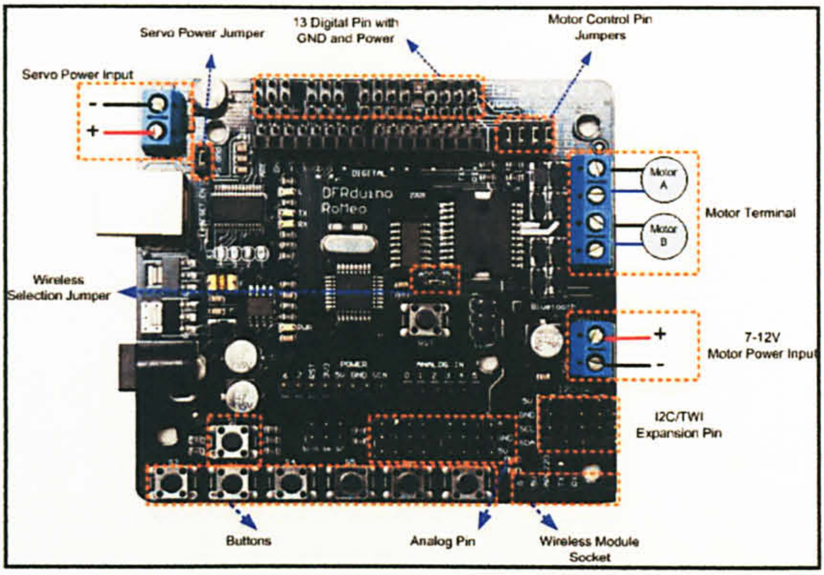

Figure 29: Arduino Development Board

Arduino is an All-in-One microcontroller especially designed for robotics application. The microcontroller has many benefits because it has open source platform and it is supported by thousands of open source codes. The integrated 2 way servo motor driver gives an easier way to deal with any servo motor, by reducing noise and sending most accurate signal waveform to the servo. The Arduino development board includes:

- One Regulated Motor Power Input Terminal (6v to12v)
- One Unregulated Servo Power Input Terminal (you supply regulated 4v to 7.2v)
- Two DC Motor Terminals – Handles motor current draw up to 2A, each terminal.
- One Analog Port with 8 analog inputs – one input is tied internally to the supply voltage.
- One General Purpose I/O Port with 13 I/O lines – 4,5,6,7 can be used to control motors.
- One Reset Button.

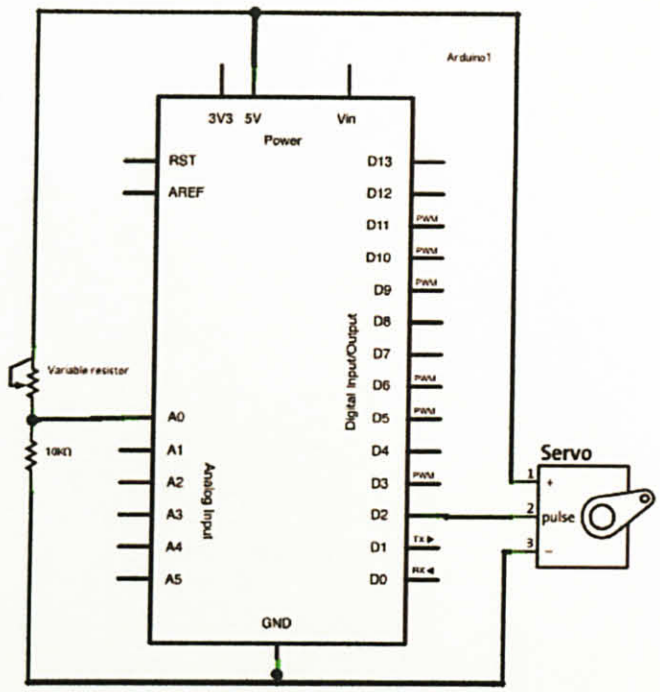

Figure 30: Prototype Circuit Schematic Diagram

After all the parts have been connected together, the prototype was tested with the aid of multimeter and external DC power supply. The position of the servo's shaft is recorded by attaching the angle scale to the servo's body. Different angle is recorded for different value of analogue voltage input.

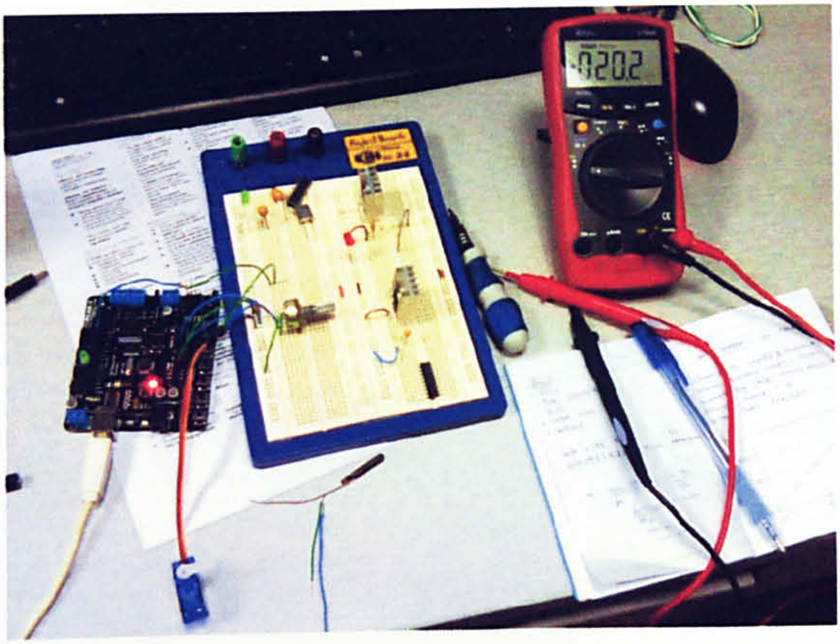

Figure 31: Prototype Testing

4.5 Result Analysis

The range of output position is directly proportional to the analogue input to the microcontroller. The minimum position is 0° when voltage input is approximately zero, and it goes to maximum position which is 90° when the maximum voltage applied to the input pin.

Table 5: Servo Position angle according to Voltage applied

Voltage (V)	Position Angle (Degree)
0.011	0°
0.496	9°
1.012	18°
1.508	27°
2.016	36°
2.493	45°
3.030	55°
3.496	63°
4.052	73°
4.508	81°
4.991	90°

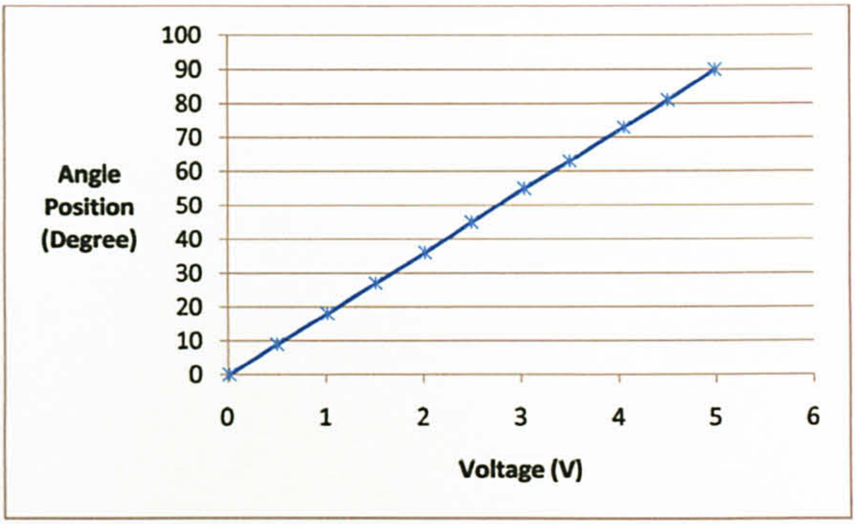

Figure 32: Linearity between input voltage and output position angle

The results above show the relationship between analogue input voltage and the position angle of servo motor. As voltage increase from 0 – 5 V, the angle of servo's shaft also increase from 0° - 90° respectively. This model is successfully represents the Electronics Throttle Control system in real vehicle.

A testing was conducted to see the effect on mass air flow while the servo's shaft angle changes.

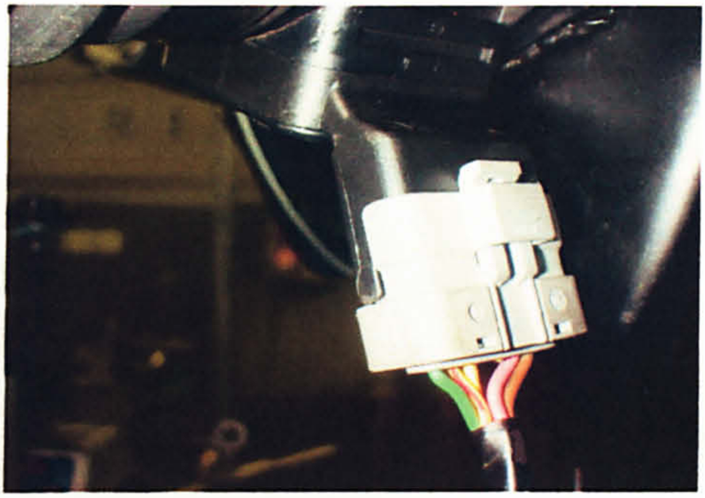

Figure 33: Mass Air Flow sensor on engine test cell

Table 6: Results on Mass Air Flow when shaft position angle varies

Voltage Applied (V)	Shaft Position Angle (Degree)	Mass Air Flow (grams/sec)
0	0°	0
0.5	9°	2
1	18°	5
1.5	27°	8
2	36°	17
2.5	45°	30
3	55°	45
3.5	63°	68
4	73°	100
4.5	81°	153
5	90°	225

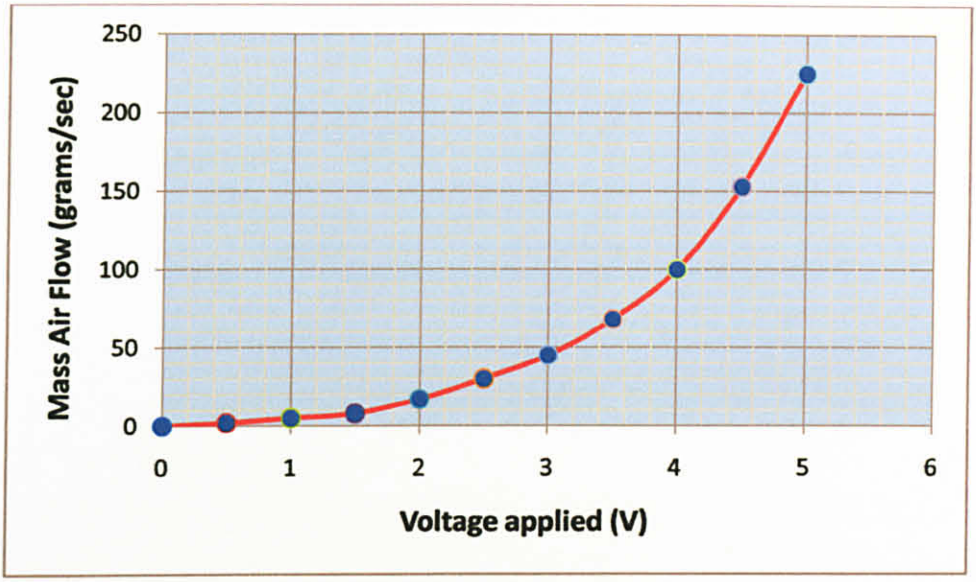

Figure 34: Mass Air Flow versus Voltage Applied

The results show that when angle position increase, mass air flow to the engine will also increase. But the relation between these two variables is not linear. The graph shows that when throttle in wide open state, the maximum value of filtered air will flow into engine intake manifold. When the voltage applied is suddenly going down from 5V to 2V (when device is triggered), the valve opening will also decrease from 90° to 36°. This will results on the mass air flow value which will also decrease to 17grams/sec, and it will eventually decrease the speed of the car.

4.6 Prototype Testing on UTP – Shell Eco-Marathon (SEM) Car

The principle of the Shell Eco-marathon is to design and build a vehicle that uses the least amount of fuel to travel the farthest distance. SEM Asia this year was scheduled for 8-10 July 2010 at the Sepang International Circuit (SIC), Malaysia. In this event, the only design consideration is to reduce drag force and maximizing efficiency.

The speed reducer is to be tested on the prototype car and expected to function as car's speed limiter. The speed of the car will be limited to 30km/h in order to maintain its engine rpm, so that the car can increase its ability to reduce fuel consumption. To meet this requirement, the speed reducer has been modified in term of microcontroller's coding and connection of the component.

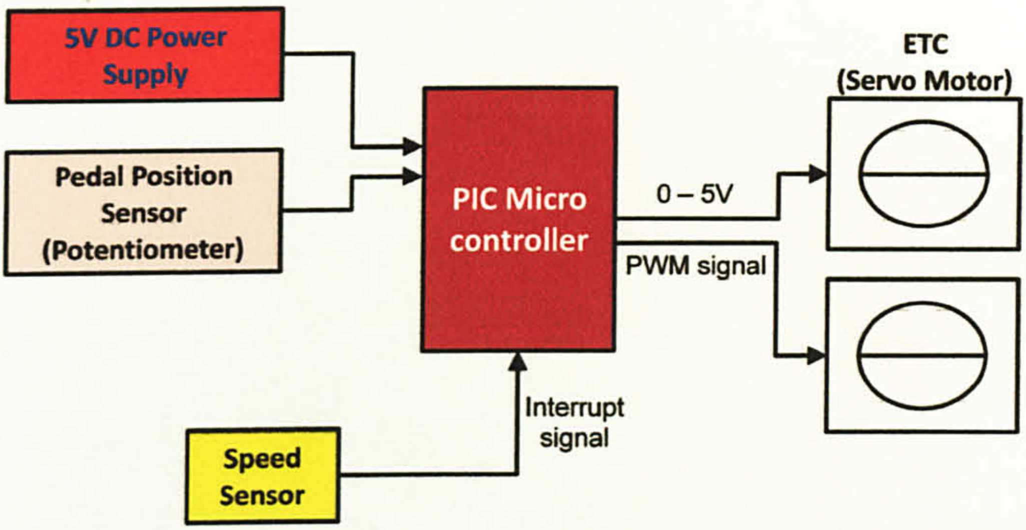

Figure 35: Modified prototype diagram

The modified prototype will have two pieces of servo, one for controlling throttle valve opening (normal operation – valve opening range between 0° to 90°) and the other one will be function as automatic trigger valve. Besides, only one input sensor which is speed sensor will be used. The speed sensor is responsible to give signal to the microcontroller regarding the current state of speed of the car.

In normal mode, servo trigger will always be in wide open throttle state. Only throttle servo will be functioning to control volume of air intake going into engine's combustion chamber.

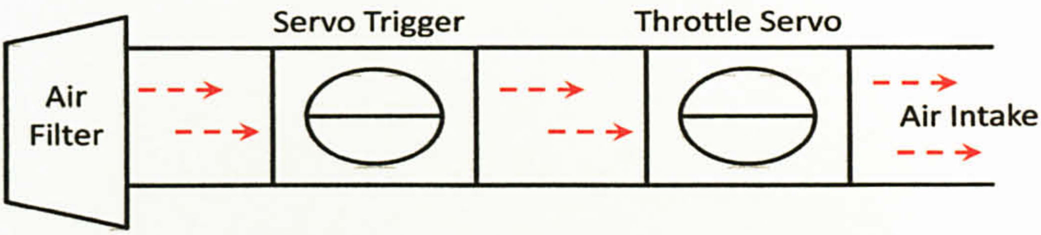

Figure 36: Diagram of engine's intake manifold

When device is triggered (speed over limit), servo trigger will react and modify its opening from WOT state to 70% only. When this happen, any percentage of valve opening which exceeds 70% at throttle servo will be ignored and the speed of the car will remain at approximately 30km/h.

4.6.1 Prototype Fabrication

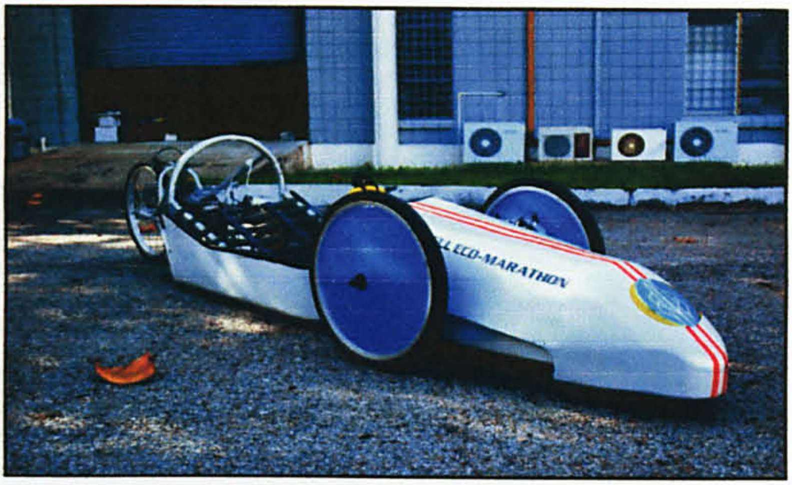

Figure 37: UTP- SEM Prototype car

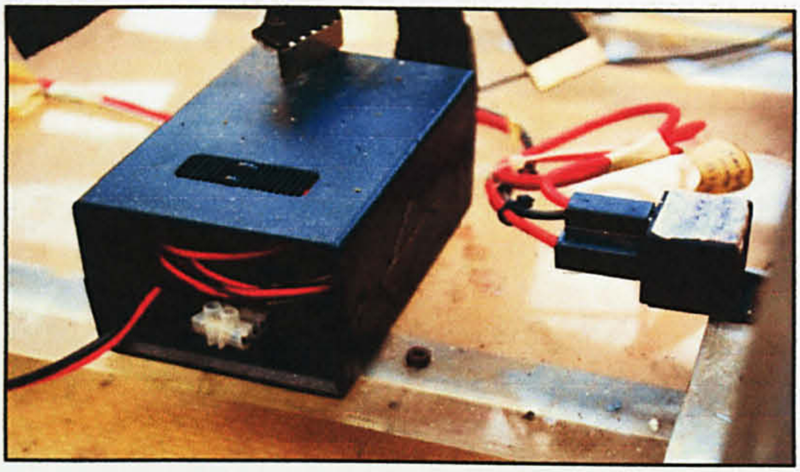

Figure 38: Electronics Box

The electronics box contains microcontroller and other electronics circuit board. It is located below the driver's compartment. For safety purpose, the microcontroller was wrapped using masking tape and sponge to avoid over vibration and to protect it from water or dust.

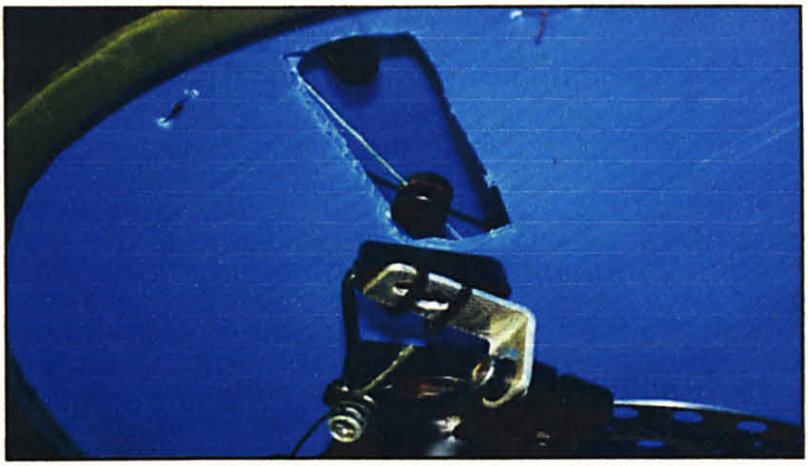

Figure 39: Magnetic pick-up as speed sensor

Circular shape of magnet was attached to the front wheel. Magnetic pick-up will sense the magnetic flux and generate signal to be sent to microcontroller as speed input.

Figure 40: Vehicle control panel

The control panel contains speed panel, toggle switch for circuit breaker, and other switches for starter motor and horn. It was attached to the steering of the car to give better access and viewing angle for the driver, so that the driver can easily monitor the current speed of the car.

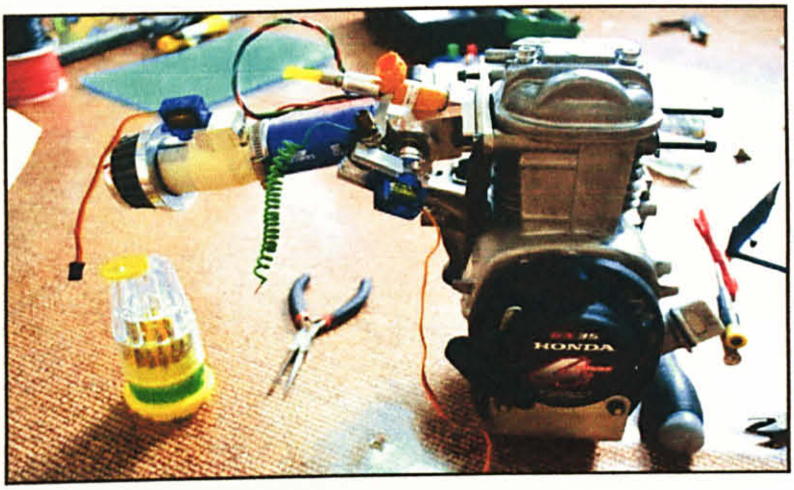

Figure 41: Speed reducer device on the engine

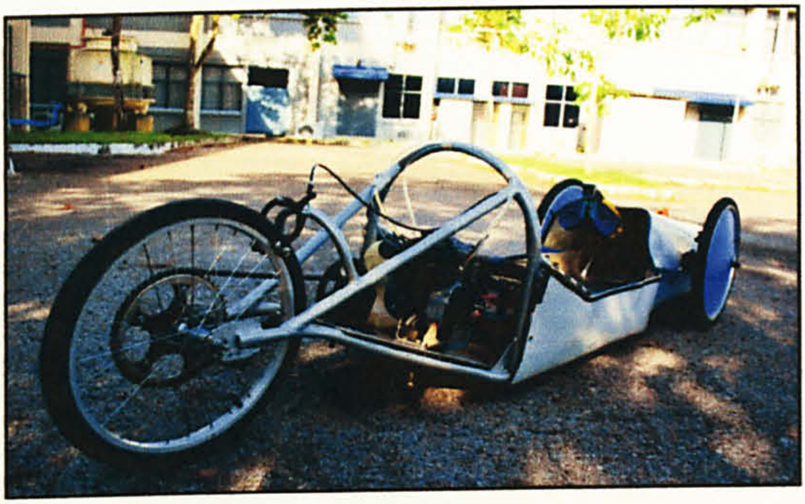

Figure 42: Engine compartment of the prototype car

The speed reducer system was mounted on the engine of the prototype car. It was attached to the intake side of the engine to gain a full control of air intake volume. After that, the engine will be fitted into the engine compartment of the car. For the next step, test run will be executed to test the capability of the device.

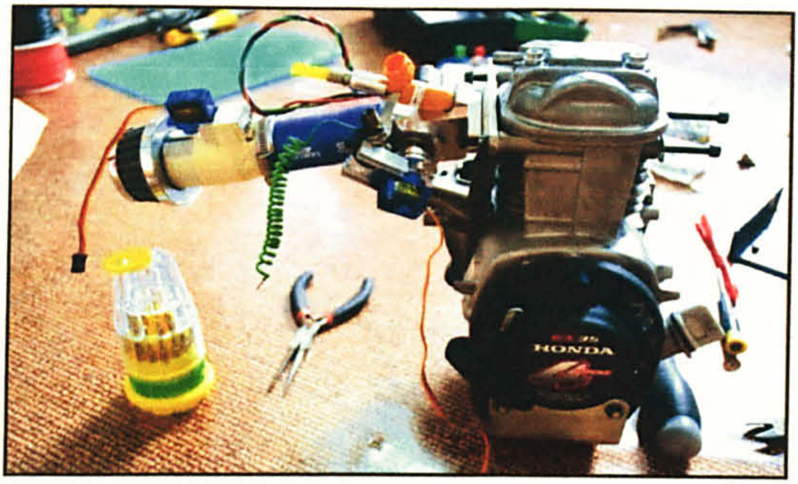

Figure 41: Speed reducer device on the engine

Figure 42: Engine compartment of the prototype car

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4.6.2 Prototype car Test Run

Figure 43: Prototype car Test Run

The speed reducer device is being tested on running vehicle to see its effect on the vehicle speed. For first trial, the device has been disabled to see maximum speed that the car is able to reach. Next, the device is being enabled to see the break point of speed when the device is triggered.

Figure 44(a): Speed with device is disabled

Figure 44(b): Speed with device is enabled

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

To conclude, a prototype of an electronic throttle control has been theoretically examined and experimentally validated. For further development of this project, there are many that still can be improved. Those things are such as implementation of the speed mechanism into the typical closed loop control system in vehicle, and ability of ECU to read the input from the sensor. The usage of microcontroller requires deep study in order to get full understanding on how the system will work.

5.2 Recommendation

For the future work, this project can be improved in several ways which are:

i. Add more input sensor to the device to increase efficiency, at the same time avoiding the case of system accidentally triggered.
ii. Conduct an actual engine testing on engine dynamometer in order to validate the real significant between electronics throttle control and ECU.
iii. Implement a small scale working prototype into a real vehicle to measure the accurate settling time in order to get into safe condition.

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APPENDICES

APPENDIX I

Servo Motor C Code Program

```
/*
 Servo control from an analog input

*/

int servoPin = 2;     // Control pin for servo motor
int minPulse = 500;   // Minimum servo position – 0 degree
int maxPulse = 1500;  // Maximum servo position – 90 degree
int pulse = 0;        // Amount to pulse the servo

long lastPulse = 0;    // the time in milliseconds of the last pulse
int refreshTime = 10; // the time needed in between pulses

int analogValue = 0;  // the value returned from the analog sensor
int analogPin = 0;    // the analog pin that the sensor's on

void setup() {
 pinMode(servoPin, OUTPUT);  // Set servo pin as an output pin
 pulse = minPulse;           // Set the motor position value to the minimum
 Serial.begin(9600);
}

void loop() {
 analogValue = analogRead(analogPin);      // read the analog input
 pulse = map(analogValue,0,1120,minPulse,maxPulse);    // convert the analog
value
                                          // to a range between minPulse
                                          // and maxPulse.

 // pulse the servo again if rhe refresh time (20 ms) have passed:
 if (millis() - lastPulse >= refreshTime) {
   digitalWrite(servoPin, HIGH);   // Turn the motor on
   delayMicroseconds(pulse);       // Length of the pulse sets the motor position
   digitalWrite(servoPin, LOW);    // Turn the motor off
   lastPulse = millis();           // save the time of the last pulse
 }
}
```

APPENDIX II

Engine Control Unit Pin out

1	ECU
Label	NO LABEL
Component	AS 6 18-35 SN (Deutsch)
Acc #1	N/A
Acc #2	N/A
Acc #3	N/A
Tool	N/A

1	24		30 - 1	IGN1	Cylinder 1 (Ignition Output 1)
2	24		47 - 3		8V Auxiliary Sensor and CAN
3		N/C			8V Engine Sensor Supply
4	24		30 - 5	IGN4	Cylinder 4 (Ignition Output 3)
5	24		30 - 4	IGN3	Cylinder 3 (Ignition Output 2)
6	24		11 - 2	MAP	Analog Voltage Input 3
7	24		10 - A	MAP2	Analog Voltage Input 4
8	24		5 - E	TPOS CON2	Auxiliary Output 2
9	24		5 - H	TPOS CON1	Auxiliary Output 1
10	24		30 - 2	IGN2	Cylinder 2 (Ignition Output 4)
11	22	24	12 - A	WATERT	0V Auxiliary Sensor Supply
		24	13 - A	BOOSTT	Boost Temperature
		24	14 - A	OILT	Oil Temperature
		24	15 - A	OIL P SW	Oil Pressure Switch
		24	16 - 3		Lambda 1 0V
		24	17 - 3		Lambda 2 0V
		24	21 - 1	BOOSTP	Boost Pressure Sensor
12	24		6 - 4	PEDAL	Analog Voltage Input 5
14	24	18	26		Battery Negative (Also pin 15 &
15	24				Battery Negative (Also pin 14 & 19)
19	24				Battery Negative (Also pin 14 & 15)
16	22	24	5 - D	ETC	5V Engine Sensor Supply
		22	6 - 1	PEDAL	Pedal Assembly
		24	10 - B	MAP_AT	MAP & MAT
		24	11 - 3	MAP	MAP
		24	7 - C	CRANK	
		24	8 - C	CAM1	
		24	9 - C	CAM2	
17	22		16 - 4	L1H	Lambda 1 Heater (Ignition
18	24		5 - C	TPOS2	Analog Voltage Input 2
20		N/C			Not Used
21		N/C			Not Used
22		N/C			Not Used
23	24	18	3	SR	Battery Positive (Also pin 32 & 41)
32	24				Battery Positive (Also pin 23 & 41)
41	24				Battery Positive (Also pin 23 & 32)
24		N/C			Injector Output 5
25	22		17 - 4	L2H	Lambda 2 Heater (Ignition Output 6)
26	24		5 - B	TPOS1	Analog Voltage Input 1
27	22	24	7 - B	CRANK	GND
		24	8 - B	CAM1	GND
		24	9 - B	CAM2	GND
		24	5 - A	ETC	GND
		22	6 - 3	PEDAL	GND
		24	10 - D	MAP_AT	GND
		24	11 - 1	MAP	GND
		24	20 - 3	OILP	GND
28	24		10 - C	MAT2	Analog Temperature Input 1

29		N/C			Analog Temperature Input 5
30	24		14 - B	OILT	*Analog Temperature Input 3*
31		N/C			RS232 Receive Data
33	24		35 - 2	INJ1	*Cylinder 1 (Injector Output 1)*
34	22	24	20 - 1	OILP	*5V Auxiliary Sensor Supply*
		24	21 - 3	BOOSTP	*Boost Pressure Sensor*
35	24		21 - 2	BOOSTP	*Analog Voltage Input 7*
36	24		6 - 6	PEDAL	*Analog Voltage Input 6*
37		N/C			Analog Temperature Input 6
38	24		13 - B	BOOSTT	*Analog Temperature Input 2*
39	24		12 - B	WATERT	*Analog Temperature Input 4*
40		N/C			RS232 Transmit Data
42		N/C			Injector Output 6
43	24		18 - 2	VVT INT	*Intake VVT (Auxiliary Output 3)*
44	24		20 - 2	OILP	*Oil Pressure (Analog Voltage*
45	24		15 - B	OIL P SW	*Digital Input 2*
46	24		9 - A	CAM2	*Digital Input 1*
47	24		47 - 4	CAN-	*Can Bus Low*
48	24		47 - 5	CAN+	*Can Bus High*
13	24		47 - 1		*0V Comms*
		SCRN	SCRN		
49	24		7 - A	CRANK	*Crank Reference Timing Input*
50	24		37 - 2	INJ3	*Cylinder 3 (Injector Output 2)*
51	24		19 - 2	VVT EXH	*Exhaust VVT (Auxiliary Output*
52	24		46 - 1	AIRCOND	*Digital Input 3*
53		N/C			Digital Input 4
54	24		16 - 2	L1	*Lambda 1 Sense Voltage*
55	24		17 - 2	L2	*Lambda 2 Sense Voltage*
56	24		8 - A	CAM1	*Cam Sync Timing Input*
57		N/C			Injector Output 7
58	24		22 -2	CAN PURGE	*Auxiliary Output 7*
59	24		4 - -X2	FUELPUMP	*Auxiliary Output 5*
60	24		16 -1	L1	*Lambda 1 Pump Current*
61	24		17 - 1	L2	*Lambda 2 Pump Current*
62		N/C			Injector Output 8
63	24		38 - 2	INJ4	*Cylinder 4 (Injector Output 3)*
64	24		23 - 2	TRBBOOST	*Auxiliary Output 8*
65	24		24 - -X2	ENG FAN	*Auxiliary Output 6*
66	24		36 - 2	INJ2	*Cylinder 2 (Injector Output 4)*

APPENDIX III

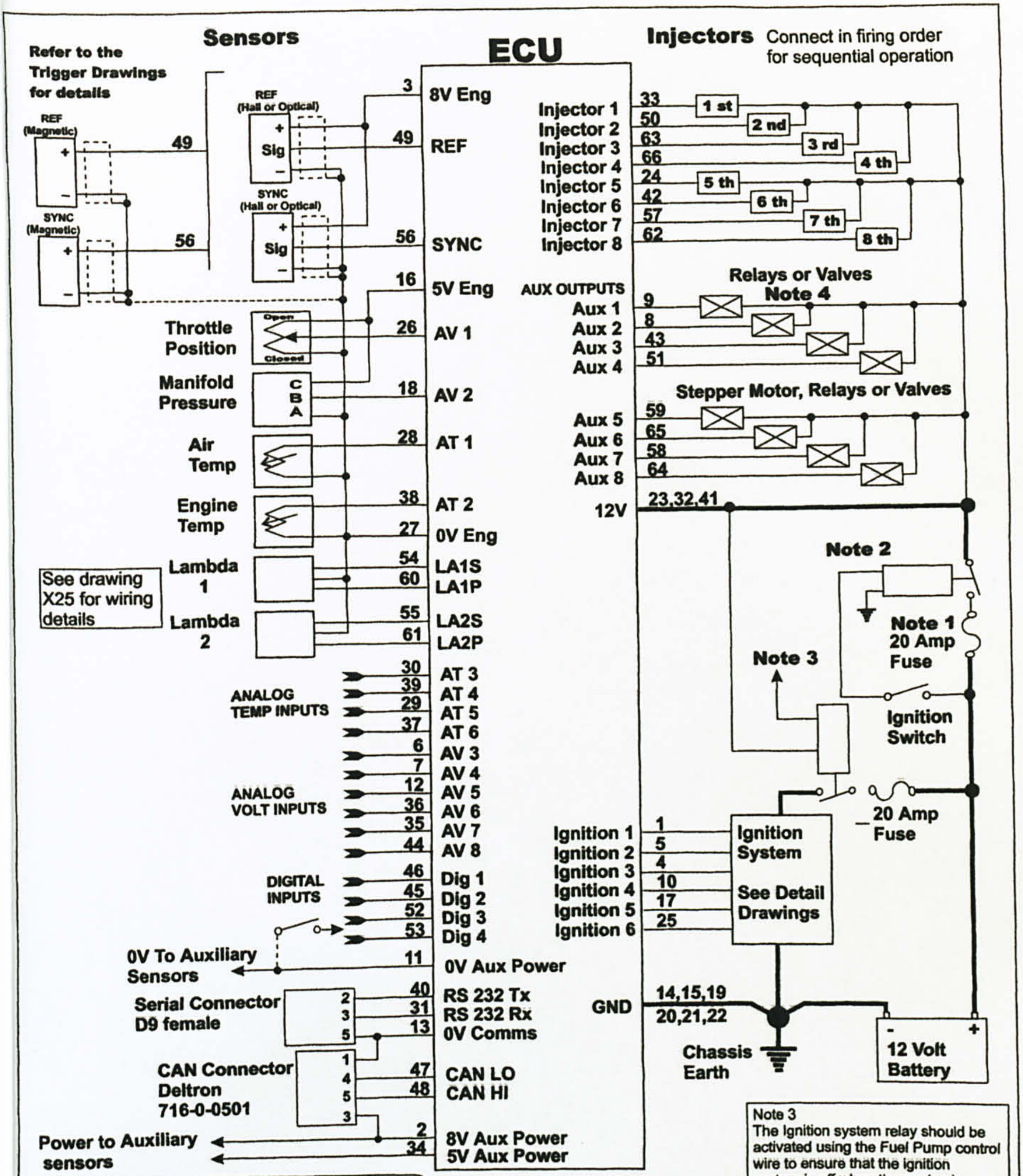
Electronic Throttle Control Pin out

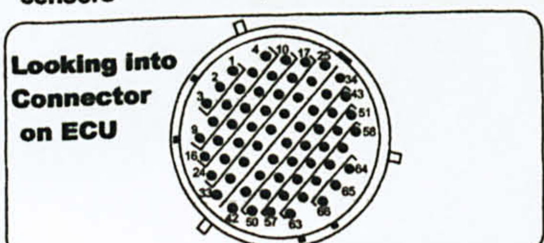
2	
	ELECTRONIC THROTTLE CONTROL
Label	ETC
Component	N/A
Acc #1	N/A
Acc #2	N/A
Acc #3	N/A
Tool	N/A

A	24		1 - 27	GND	*GND*
B	24		1 - 26	TPOS1	*TPOS1*
C	24		1 - 18	TPOS2	*TPOS2*
D	24		1 - 16	+5V	*+5V*
E	24		1 - 8	TPOS	*Motor -*
F		N/C			
G		N/C			
H	24		1 - 9	TPOS CON 1	*Motor +*

APPENDIX IV

ECU Wiring Diagram





Note 3
The Ignition system relay should be activated using the Fuel Pump control wire to ensure that the ignition system is off when the engine is stopped. Or use the Fuel Pump Relay to power the Ignition System. This also provides reverse battery protection to the ignition system.

Note 1
The Fuse is essential to ensure that the ECU is not damaged by reversed battery polarity

Note 2
To avoid the fuse blowing due to reverse battery polarity use a diode activated relay eg. Bosch 0332 014 112

Note 4
Aux 1,2, 5-8 can also drive grounded loads.
Aux 1 and 2 are High current.

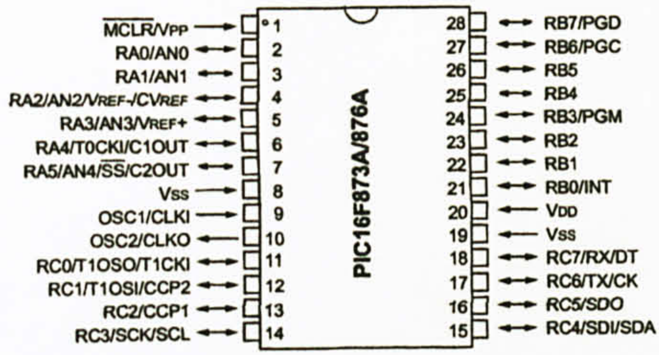
MoTeC	Title M880 ECU Wiring	Sheet No	Drawing No
	Date 22/08/2002 · Drawn ST · App AD · Products ECU	M880	ECU

APPENDIX V

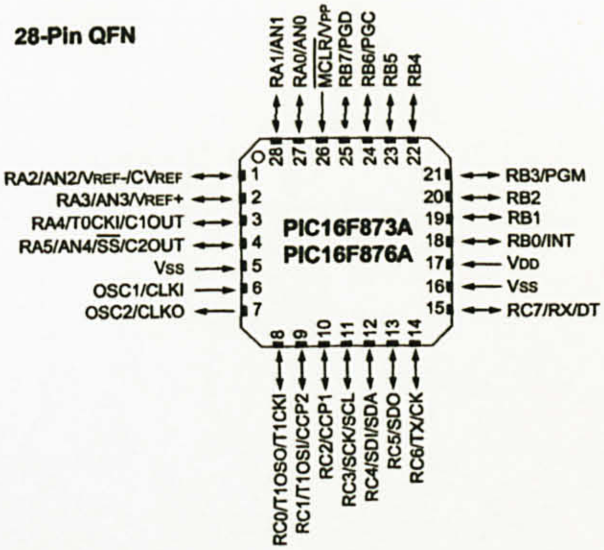
Microcontroller PIC 16F877A Data Sheet

Pin Diagrams

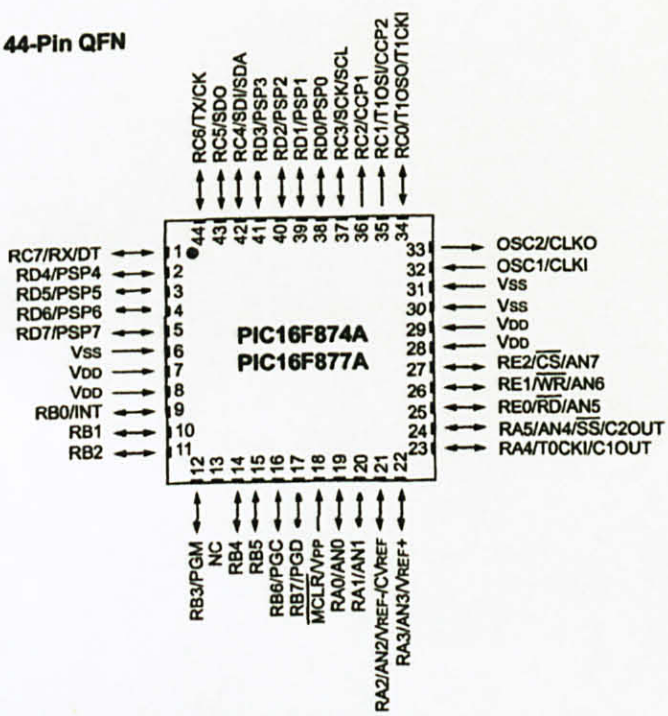
28-Pin PDIP, SOIC, SSOP



28-Pin QFN

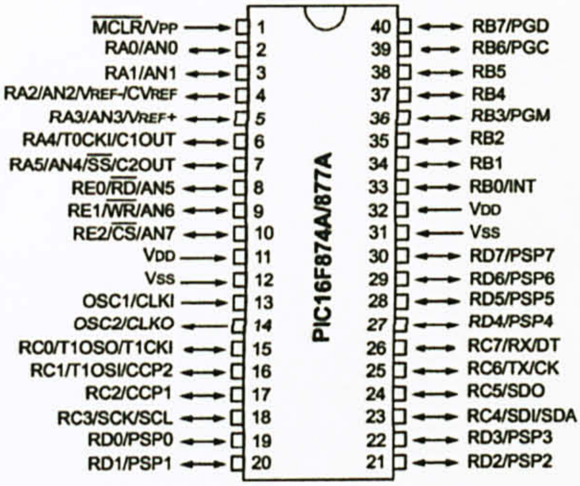


44-Pin QFN

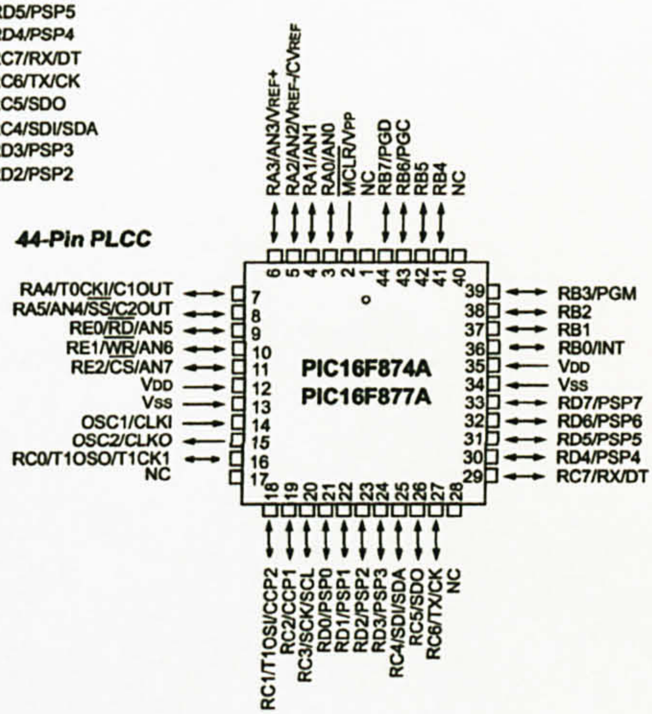


Pin Diagrams (Continued)

40-Pin PDIP



44-Pin PLCC



44-Pin TQFP