Design, Development and Implementation of Standalone Transmission Control Module for Mercedes-Benz 722.6 5G-Tronic Gearbox (Draft Report)

by

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18277

Dissertation submitted in partial fulfillment of

the requirement for the

Bachelor of Engineering (Hons)

(Electical and Electronic)

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

APRIL 2017

CERTIFICATION OF ORIGINALLY

This is to certify that I am responsible for the work submitted in his project, that he original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have no been undertaken or done by unspecified sources or persons.

LEE ZHI YAN

ABSTRACT

Mercedes-Benz car owners whose cars are equipped with old Mercedes-Benz 5G-Tronic 722.6 hydraulic transmission are not offered with newer parameters of transmission updates such as manual and automatic gear shifting mode. So, these cars often suffer from high fuel consumption and slower response to acceleration compared with latest car models. The inconvenience of gear shifting problem can be overcome by design and development of standalone transmission control module specifically for Mercedes Benz 722.6 5G-Tronic gearbox which can read information from the console mounted shift lever and shift of gear can be implemented either in automatic or manual mode in order to improve gear shift quality and higher fuel efficiency. The experimental works are carried out by connecting microcontroller to LEDs which represent solenoid valve in Mercedes Benz 722.6 transmission module, 16x2 LCD display and temperature sensor. The experiment results from temperature sensor are verified as compared with expected outcomes. On the other side, the development and integration of all subsystems into one module together with verification. The observed data from LED are tested in solenoid valve to compare the real shift pattern with the transmission application chart.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Vehicles with automatic and manual gear shift transmissions are receiving growing interest in recent years because there continues to be an ever increasing demand from car enthusiasts for enhancements in automotive performance and fuel efficiency. In transmission upgrade, the Mercedes-Benz 722.6 transmission can be physically bolted to different Mercedes engines (M102, M103, M104, M119, M120, M601, M602, M603, M606, etc.) quite straightforwardly -- with some changes required in their shifters and shifter linkages. The design and development of a standalone transmission control module (STCM) algorithm which can smoothly control the change of gears at the right moment can be done through collecting information such as the engine RPM (revolution per minute), acceleration pedal position transmission temperature and acceleration.

Research done by V. Mallela and Z. Sun (2013) illustrates transmission in automobile has the function to deliver energy generated from combustion of fuel in engine block through shaft to the wheel, either moving forward or backward [1]. According to R. Rakwana and R. Katerne (2014), shifting of gear in transmission system is arranged automatically by controller. Katerne(2014) also says controller can give feedback to car transmission to maintain appropriate rev per minute(RPM) and synchronize power or torque[2].

Design of Standalone Transmission Control Module(TCM) is conceptually based on Mercedes-Benz 722.6 5G-Tronic Gearbox transmission in which gear shifting control will not interfere powertrain control module (PCM). As 722.5 5-speed transmission and most of the 4-speed 4G-Tronic transmissions (722.4, 722.3, 722.2 variants) are hydraulically adjusted, this 722.6 transmission is equipped with hydraulically operated gearbox. This standalone module will provide semi-automated change of gears which user can upshift to higher gear or downshift to lower gear when he/she engages in manual mode without crossing the redline of engine.

Design and development of automatic transmission can be done with adding more number of gears in transmission to allow vehicle operates in power band and engine stays in low rev at high speed. However, how complicated and unstable hydraulic actuation could become when the transmission should be overhauled or replaced with newer version to fit with the engine [1]. Shifting of gears is affected by engine revolution per minute(RPM), speed, temperature, throttle position and braking pedal intensity.

The control system of manumatic transmission consists of temperature sensor, accelerometer, Hall Effect Sensor, microcontroller, LED, electromagnetic relay and LCD display

Other than advantages fully automatic transmission like 722.5 transmission, M. Roger (2012) illustrates automatic transmission car has problem of longer response time, lower miles per gallon and expensive if compared with manual transmission [3].
Here are some key upgrades needed to improve on old Mercedes 722.6 transmission system.

- Offers two transmission mode: manual or automatic mode which allows responsiveness in high performance driving route by manual mode, and perform smooth shifts by automatic mode.

1.2 Problem Statement

1) With only autonomic shift gear to choose from, the driver cannot aware of the performance the car can deliver and way to control it. While driving in hilly terrain, the throttle input and torque from engine is inappropriate to the road surface condition, thus led to bad handling and instability of car. Besides that, high fuel consumption is the major issue in automatic shifting that emit higher C02 than car with manual transmission. Configuration of gear shift which is done automatically by transmission

control unit can’t determine the driving style of driver and fail to create the excitement of the drive.

2) Standalone transmission control module must be independent on analysis of car parameters such as RPM, speed of car, transmission temperature, weight of car, and accelerator pedal intensity and brake pedal intensity to control gear shifting process without interference from powertrain control module (PCM).

1.3 OBJECTIVE

The aim of study is to:

1) Design standalone transmission control module which can facilitate automatic and manual gear shifting process without interference from powertrain control module (PCM).
2) Design light indicator for representing engine rev to let user know the ideal moment to upshift or downshift gears to avoid engine from operating at rotational speed above redline.
3) Design a car information display to let user know about transmission temperature, weight of car intensity of accelerometer and brake pedal at the instant.

1.4 SCOPE OF STUDY

The project involves three parts: sensors, control and feedback unit and output. The sensors are accelerometer (acceleration), potentiometer (throttle and brake pedal intensity) and temperature sensor (transmission temperature) where the outputs are channeled into microcontroller 18F4331. In the control unit, algorithm of conversion of sensors values into standard format which is used as a determining factor for gear shift. Design of a functional block for representing different stage of gear shift is based on Mercedes 722.6 transmission chart. In the output stage, the set of output pins used to trigger the relay allow control of current flow into the solenoid valve circuits.

Timing of shift of gear will affect the shift quality and car performance so proper function blocks are designed. The characteristics of PWM signals supplied to solenoid valve are to be understood carefully. How the duty cycle can affect the opening and closing valve must be clear before construction of prototype begins.

Lab experiment will be conducted to light up set of LED as representing the transmission solenoids valve. Furthermore, the microcontroller should be able to read switch for manual mode and automatic mode. Temperature sensors will be used to monitor room temperature and all values are displayed in 16X2 LCD display.

CHAPTER 2

LITERATURE REVIEW/THEORY

Components for the transmission control module is listed in table below.

Table 1: List of electronic component and device

Component/Device	Description
Microcontroller	With offering automatic and manual mode to choose from, it performs automated control of shift control and analysis of signal from sensors.
LCD Display	Shows parameter such as transmission temperature, car weight and intensity of accelerator and brake pedal to user.
Light Emitting Diode, LED	RPM of engine can be reflected by incrementing number of light ups by LEDs. It is connected to output of microcontroller.
Solid State Relay	Act as a switch for microcontroller to deal with solenoid.
Programmer Kit	Program microcontroller with machine code.
Solenoid	To control line pressure, oil pressure, pressure to torque converter clutch and shift valve.
Temperature Sensor	Measure temperature in Celsuis.
Potentiometer	Measure the intensity of throttle and brake pedal.
Accelerometer	Measure the acceleration of vehicle

2.1 Microchip PIC 18f4331 Microcontroller with Programmable Kit

PIC18F4431 has 9 10-bit analog to digital channel,40 pins structure, 33 pins allocated for PORTA, PORTB, PORTC, PORTD and PORTE. For general use, PIC 18F4431 has standard feature such as ROM, RAM, SRAM and synchronous serial port [14]. This PIC 18f4331 microcontroller has a control of 200 Kilo sample per second(Ksps) and a maximum clock speed of 40 MHz.

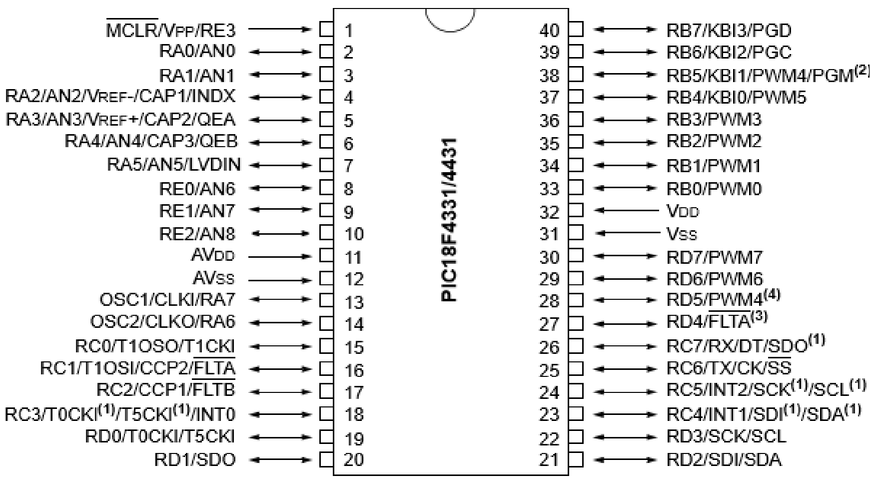
Based on R. Hasen and K. M. Salim (2013), PIC 18F4431 microcontroller has 36 input/output pins. 18F4431 microcontroller can generate up to 8 Pulse Width Modulation(PWM) by using 14-bit Pulse Width Modulation(PWM) Module (R. Hasen and K. M. Salim,2013) [12]. PWM technique is to varies pulse width in frequency to get analog results. The PWM Module is important to transfer varying clock cycle output to MOD PC, SHIFT PC and TCC solenoid. According to A. Co et al. (2002), PIC16F873, different version of microcontroller from MICROCHIP is used to control ignition trial and interval of device in passive mode, control current and power supply to lamp, voltage control and current invert signal by PIC16F873. The PIC18F4431 has a higher PWM resolution (14 bit) than PIC16F873(10 bit), means that the antecedent microcontroller maximum number of pulses that should fit into a PWM period than precedent microcontroller. Furthermore, the number of input/output pin for PIC16F873 is 12. So, it has significantly fewer input /output pins than PIC18F4431.

ADC is used for data retrieved from source. The microcontroller has a function to read analog data and converting data into digital format by using ADC. According to R. Hasen and K. M. Salim (2013), PIC18F4431 has improved flash program memory of 10 bit of A/D converter with programmable insertion of period when microcontroller is in idle state [12].

Microcontroller can be used to collect the user request from shift lever assembly (Spasojević,2013) [4]. From a research done by Blokhin (2015), he and Spasojević (2013) [5] have used microcontroller to implement an algorithm to control clutch, splitter, and main gears. The software is designed to accept interruption from sensors. Blokhin (2015) says inductive engine rotation speed, an intermediate shaft, output shaft of the main gear and amplitude of speed of gear teeth can checked continuously by microcontroller to make sure rotation speed is accurate. This microcontroller is cheap to be used in any project (R. Hasen and K. M. Salim,2013) [12].

Even though Arduino board is a complete development platform with its own standards, integrated development environment (IDE) and programming interface (API) with purported simplicity, the PIC microcontroller provide opportunity to learn about the architecture of this specific programmable integrated circuit.

Diagram 1: Illustrates pin diagram of PIC 18F4331.



2.2 Transmission Control Unit

A transmission control unit or TCU is a system which control vehicle's transmissions. A TCU evaluates values from sensors in the vehicle and engine control unit (ECU) to calculate the time instant to change gears in the vehicle to achieve good shift quality and low fuel consumption. Based on research done by A. Blokhin, multi-stage control system of mechanical transmissions of trucks and buses which is controlled by STM32F103VBT6 with the core Cortex-M3.

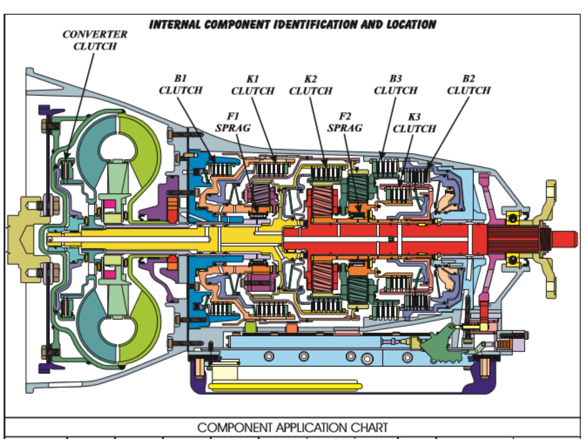
From the research, whole transmission control unit is being developed including methods for changing the distance between the discs of the friction clutch, checking on the position of the throttle pedal and the engine rotation speed, the methods of data exchange with microcontroller, the method of protecting a power supply short-circuit in the sensor circuits of the gearshift and

the control mechanism of the friction clutch, method of processing signals from inductive speed sensors and control method of pneumatic valves.
The specific microcontroller unit is suitable to use inside ruck KAMAZ-65117 only because interaction between the main modules of the program is different for every vehicle and the transmission has different sets of solenoid valve. The methods of the data exchange in transmission module must fulfill to standard SAE 1939.

The signal transportation plays a vital role in efficiency of motor control. For example, the power supply of external sensors will suffer from limiting disturbance. So, input circuits of sensors of the transmission mechanisms is designed to integrate with of the friction clutch made of high-threshold logic circuit, eliminating interference in the input circuits. This method does eliminate false information in case of disconnection(opening) or short on "weight" of external circuits of the transmission and mechanisms of the clutch control which can need to be taken care of during implementation stage.

TCU provides programmability which allows the modern automatic transmission to be used with appropriate transmission characteristics for different conditions. For a complete gear set, every automatic transmission must have forward and reverse gear. The main difference with forward gear is that there is no increment of gears we can switch to when reversing the car. The engagement of reverse gear is done by selector lever in the reverse position when the reverse clutch (RC) is being engaged (J. Deur et al.,2005) [7].

Digram 2: Illustrates the internal component of Mercedes 722.6 transmission.



2.3 LCD Display and LED Car Indicator

B. Sun et al.(2016) describe LED is always the ideal choice not only for lighting purpose in household, but also for application in automotive illumination, automotive information indicator, information display devices and even medical instrumentation [9]. The factor which makes B. Sun et al. (2016) believe that LED is better than traditional lighting devices is because it consumes less power, durable, long operating life and less environment impact whose statement is also backed by V. Kirubakaran et al.(2016) [9][10]. It provides information

Furthermore, the average lifespan of LED is very long (B. Sun et al.,2016) [13]. With what has been concluded by V. Kirubakaran et al. (2016), the result clearly shows that LED has lower harmonics than florescent lighting and the lagging power factor of LED is as low as 0.2, which means it use more current than component with higher power factor for equal transfer of useful power.

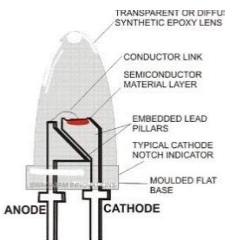
Table 2: illustrates the electrical characteristics of LED.

Maximum Forward Voltage	2.5V
Maximum Reverse Current	10A
Forward Current	20mA

16X2 LCD display can show black pixels of characters by blocking polarization with the use of polarizing filter where no voltage is applied to it. The LCD display can display 32 characters in one time. The SK40C provide extra pins for directly connecting with LCD display. The LCD display HD44780 standard requires 3 control lines and either 4 or 8 I/O lines for the data bus. For this project, an 8-bit data bus is used where the LCD will require a total of 11 data lines (3 control lines plus the 8 lines for the data bus). Study should be done on 8bits HD44780 controller Instruction and Data register before prototype starts to develop. It is important as instruction register corresponds to the register where you send commands to LCD such as LCD shift command, LCD clear, LCD address while Data register is used for storing data which is to be displayed on LCD.

Selection of LCD screen depends on quantity of car information which microcontroller can synthesize from sensor. LCD display are cheaper than LED screen as the technology is common and easier to fabricate. Research done by Spasojević [5] has proposed LED to inform user with characters about the condition of the car like gear selection after translation of signal from sensor. P. S. Babu (2015) specifies car information indicator can alert user to engage to proper gear position with implementation of microcontroller to enhance fuel efficiency [6].

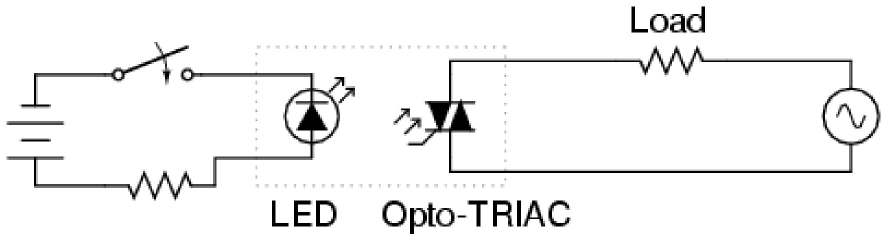
Diagram 3: Illustrates the internal structure of Light Emitting Diode.



2.4 Solid state relay

Due to low level output compared to input requirement of solenoid, current has to step up using Solid State Relay. Solid state relay is used because it installs with switches which energizes contactors by passing high current using method of capacitor discharge. The discharge of high current from solenoid can be controlled by computer input to the destination (T. K. Smitha et al., 1993) [8]. SSRs is chosen over other power switching devices as switching period faster than electromechanical relays, compact in size and silent during operation. In this experiment, electromagnetic has been used to test with air solenoid due to availability in lab but longer switching time in seconds. In the future, the SSR will replace the electromagnetic relay to match with fast response time of car solenoid.

Digram 4: Illustrates the schematic diagram of solid-state relay.



2.5 Solenoid

In general, solenoid is often demonstrated in the way that as if it twisted around a metallic core and has hollow core. It can generate uniform magnetic field when electric current is flowing in metal coil (M. A. Co et al.,2002) [14].

Solenoid is an important component in transmission as it acts as a transducer which converts electricity into physical moment. Inside transmission powertrain, electro-hydraulic solenoid is commonly used to operate a group of valve to change clutches. Inside the valve body of 722.6 transmission control unit, there are six solenoids which consist of modulated pressure control(MPC), shift pressure control(SPC), torque converter clutch(TCC) and shift control solenoid operation. Transmission control solenoids control the flow of transmission fluids into various compartments to enable the engaging or disengaging of gear sets, clutches, and brake bands. The transmission fluid is determining factor in shift quality because it carries forces and pressure to carry out shift of gear.

The electromagnet produced by solenoid can be affected by eddy current and hysteresis loss effect [16]. Eddy current is condition where unwanted current induced by varying magnetic field has reduced the main current flowing into the coil. Hysteresis loss happens when heat energy is produced in coil as power wastage.

For Shift Pressure Control (SPC) solenoid operation, it is installed in electrical conductor plate to regulates oil pressure to all clutch packs to control the pressure reduction. Other than that, it also functions as regulator for clamping force needed to prevent slipping of clutch.

Modulated pressure control(MPC) solenoid controls the main line pressure rise which is controlled by PWM signal. It also works synchronously with MPC solenoid to control clutch pressure. When exhaust pressure in solenoid is high, the line pressure is low. Solenoid will switch on for 50% of the time.

Torque converter clutch(TCC) regulates pressure in torque converter clutch through torque converter clutch control valve to aid in engaging and disengaging of clutch process.

Shift Solenoid Operation solenoid is important in regulating shift valve command pressure to corresponding shift valve. There are three types of Shift Solenoid to control first to second gear change/fourth to fifth gear change, second to third gear change, and third to fourth gear change. Only one solenoid will be activated based on gear selection by transmission control module.

As we refer to Diagram 8, The solenoid consists of a spring-loaded plunger with a looped coil of wire wrapped around. During the time when current flows into the wire, magnetic flux is generated per Right Hand Rule, and the plunger is moved against the spring force. So, a normally solenoid closes when the wire is energized, and vice-versa.

Diagram 5: Illustrates concept of how the operation of basic solenoid looks like in car transmission.

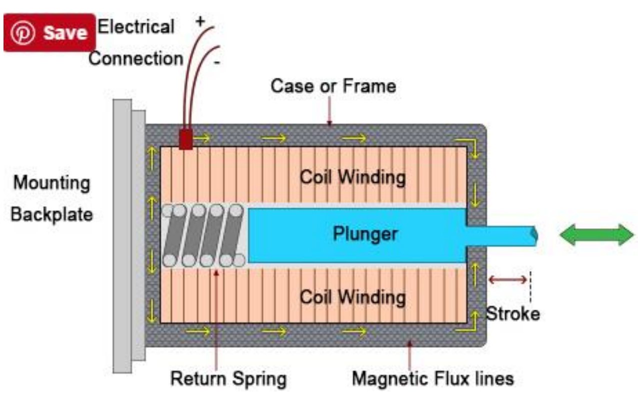
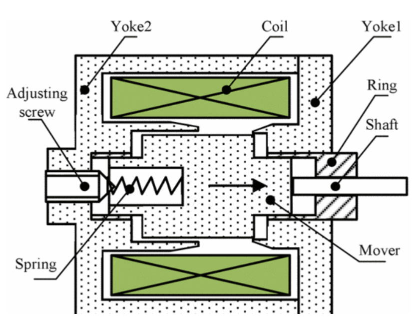


Diagram 6: Illustrates proportional solenoid based on research (F. Meng et al., 2014).



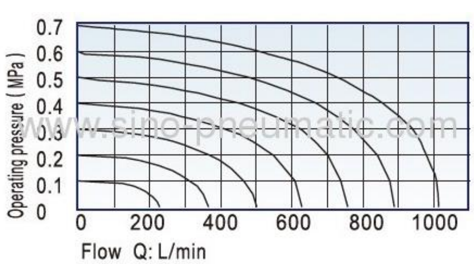
By passing an exciting current through the coil, a moving force is generated, and the mover is going toward the stator. (F. Meng et al., 2014) [17]. F. Meng et al. (2014) describe the mover is attached to the nonmagnetic shaft which thrust generated acts on the control valve. There is a valve fitted with the spring, and the spring force acts in the same direction towards the thrust of the mover.

Diagram 7: illustrates AIRTAC 4V120-06 solenoid valve that is available in the lab.

Table 3: illustrates the specification of AIRTAC 4V120-06 solenoid valve.

Fluid	Air
Operating Pressure	21-114Psi
Type	Internally piloted solenoid
Maximum frequency of operation	5cycle/sec

Diagram 8: illustrates the operating air pressure versus the flow rate of AIRTAC 4V120-06 solenoid valve.



2.6 LM35 Temperature sensor.

LM35 temperature sensor is selected to be used in this experiment because it provides output voltage linearly proportional to Celsius(Centigrade) temperature. Other than that, it does not require any steps to provide accuracy of ±¼°C at room temperature and ±¾°C over a full −55°C to +150°C temperature range. It considerably has high power efficiency which draws only 60 μA from the power supply and has an operating voltage from 4 to 30V.

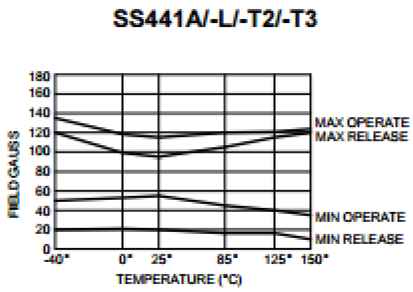
2.7 Hall Effect Sensor

Hall Effect Sensor is very sensitive in the presence of magnet.. It is used to determine the selection of gear car requires to be able to perform at highest efficiency by measuring RPM of car engine. The working principle of hall effect sensor is whenever a magnetic field applies in the direction perpendicular to the flow of current inside sensor, there will be a potential difference induced for microcontroller to detect it and synthesize useful gear shift algorithm.

There are two popular RPM sensors in measuring rotational machinery which are the electromagnetic RPM sensors and the photoelectric RPM sensors[18]. RPM calculation methods for these two kinds of RPM sensors are based on the time interval calculation of magnet. The accuracy of measurement in electromagnetic RPM sensor depends on the rotor-side mounting precision of either the permanent magnet with two or multiple poles or a ferromagnetic gear with teeth. Mechanical coupling, special magnetic coupling alignment, and magnetic shielding are the key design issues relating to such sensors. C. Rostamzadeh, K. Williams and R. KadoOutput(2014) strongly agrees that signal from hall effect sensor is clean, fast, and switches at high speed as a hall-effect switch can has 100 kHz repetition rate. [19] They also mention that it has operation temperature ranges to 150°C which can sustain harsh automotive environment.

Honeywell SS400 temperature compensated Digital Hall effect sensor is chosen for this project because it can detect RPM at wide temperature range of -40° to 150 °C which can be operated at voltage range from 3.8Vdc to 36Vdc to respond to alternating North and South poles or to a South pole only. Besides that, the interfacing with electronic circuit can be completed with digital, open collector sinking type output from this hall effect sensor. This sensor is used to represent the crankshaft position sensor. It allows the Engine Control Module to determine the orientation of the crankshaft. It is located near the flywheel or crank pulley of the engine. As the engine rotates, the teeth around the flywheel or crank pulley circumference will pass by the crank sensor. Every time one of these teeth passes the crank sensor, ECM record electrical pulse from the teeth and finally determine the length of time teeth pass the sensor as seen from each pulse.

Diagram 9 : illustrates the performance chart of hall effect sensor at temperature range from -40 to 150°C. The range of magnetic field detection becomes higher when approaching 150°C, which is similar to the temperature in engine bay.



2.8 ADXL335 3-Axis Accelerometer

It measures non-gravitational acceleration in terms of g in respond to the vibration caused by from standstill or one velocity to another. It features three-axis acceleration detection which can detect gravity acceleration which can be used to calculate the tilt angle by low-pass filtering the acceleration component of the dynamic movement of the robot from the accelerometer. Thus, the accelerometer is oriented so output will be zero g at any axis when the object travelling at the constant velocity. High power efficiency with current input of 300 μA and operating voltage of 2.5V to 6V allow it to be applicable with sk40c start-up kit. It can measure acceleration up to 10,000g at any axis, which covers the possible situation happened on a car.

2.9 Rotary Potentiometer

Pedal position sensor is located at the accelerator pedal which monitors the pressure of foot pressing upon it. To accomplish acceleration task, it will send electrical signal to the transmission control module which control the fuel system. The pedal position sensor would determine if engine response is consistent which requires sending of signal instantaneously at the moment when driver presses down the gas pedal. Moreover, engine can achieve a lower fuel consumption with pedal position sensor with throttle control stabilization. The throttle response is adjusted to minimize fluctuation and smoothen throttle signal over time. Rotary potentiometer is chosen to stimulate pedal position sensor as output signal voltage and current can be adjusted as per requirement. One method of determining a position, is to use either "distance", which could be the distance between two points such as the distance travelled or moved away from some fixed point, or by “rotation” (angular movement). For this case, we determine distance by angle of rotation. The resistance varies depending on position of slider contact on resistance track. The model of potentiometer is B10k. The potentiometer has the benefits of low price tag and compatibility to use in any electrical circuit.

Diagram 10: illustrates the construction of potentiometer at the left, graph on the right shows the relationship between position of wiper and output voltage.

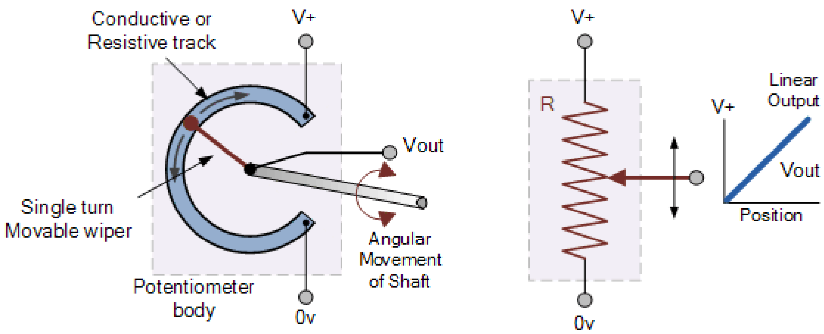


Table 4: illustrate the electrical characteristics of B10k potentiometer.

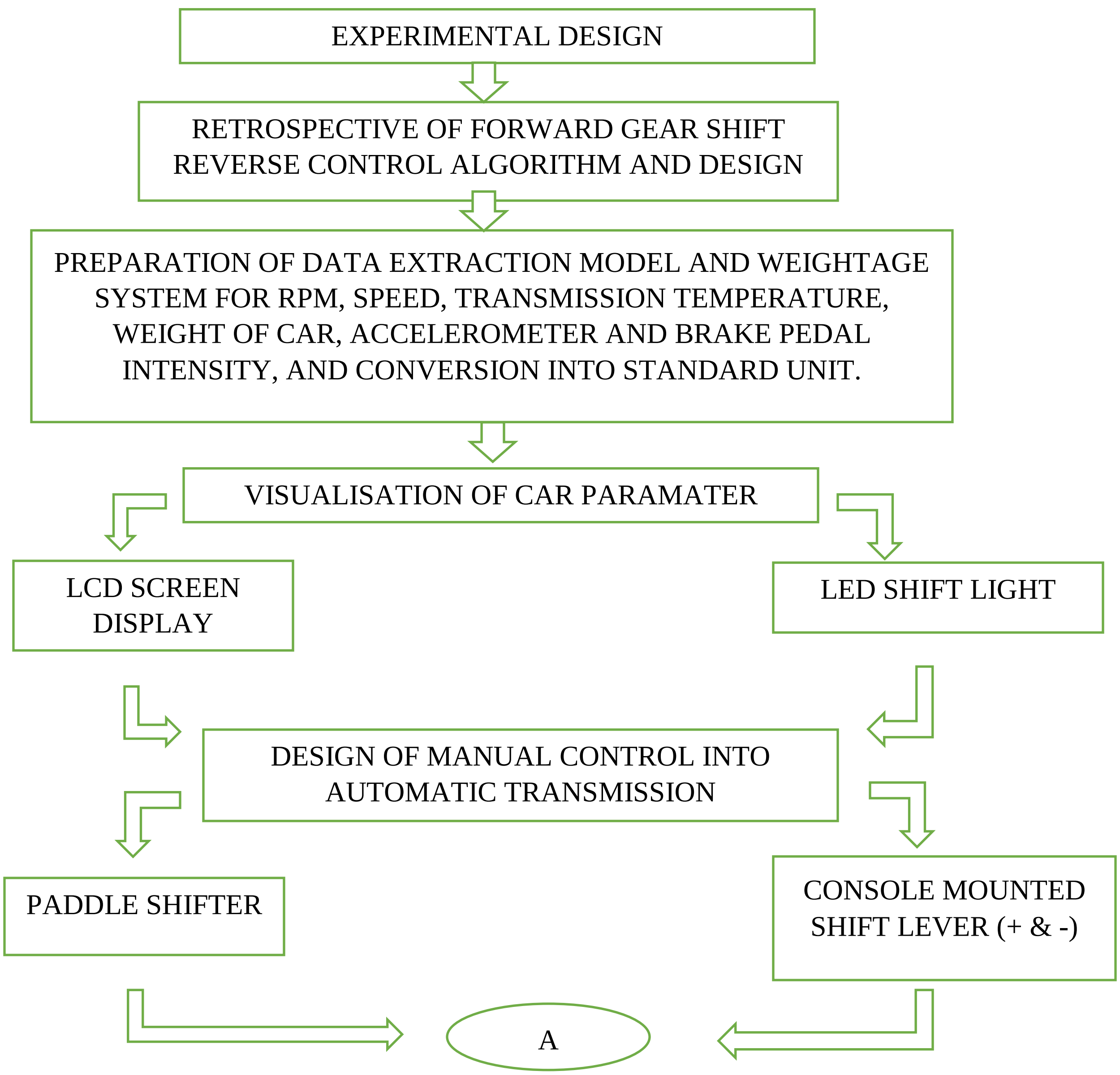
Total resistance	5k-10k Ohms
Rated Power	0.08W
Max operation voltage	150V
Rotational angle	300±10 degree

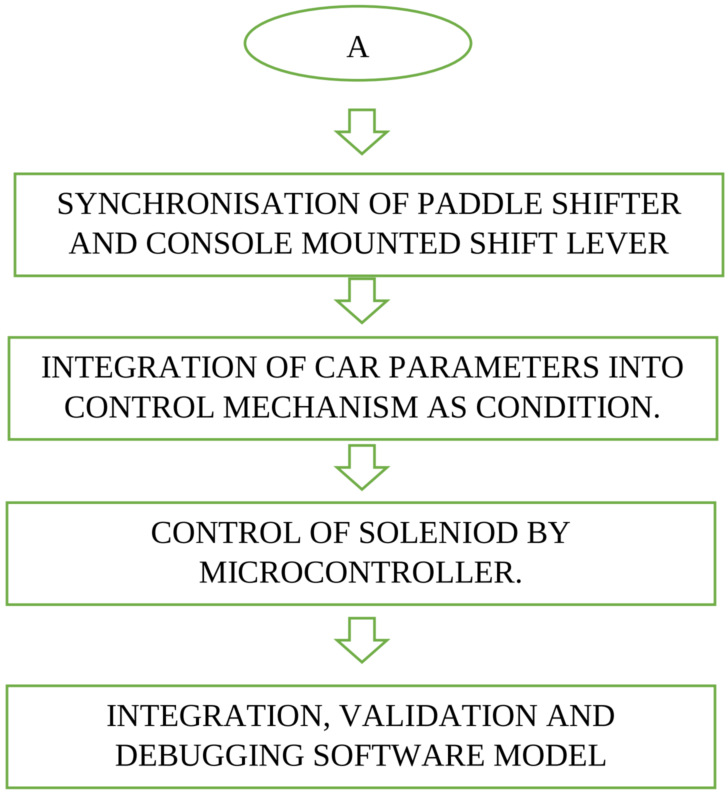
CHAPTER 3

METHODOLOGY

3.1 Research Methodology

Diagram 11: Illustrates Methodology Flowchart.





Methodology consists of 6 categories and is listed below:

1) Automatic Gear Shift Control

   -Control gear shifting mechanism electronically in terms of timing when automatic mode is engaged.

   -To activate the correct combination of solenoids during shifting phase (1-2/4-5, 2-3, 3-4, MOD Pressure Control, Shift Pressure Control, Torque Converter Clutch)

   -Allow reserve gear to propel car in backward direction.

2) Methodology for extracting RPM of engine, speed of car, temperature of transmission, accelerometer and brake pedal intensity, and car weight from the car sensor.

   -Design a function to sense car parameters above and convert into standard unit.

   -Set weightage for each car parameters in case where computation of gear decision making can fulfill shifting stability of transmission.

3) Implementation of indicator for car information

- Utilize input from temperature, weight of car, accelerator and brake paddle intensity sensors for display.

-Design light indicator which illustrates the rotation speed of the engine.

4) Implementation of automatic and manual mode for shift of gear.

- Increment and decrement by one gear done by driver using paddle shifter.

- Protection of car engine from reaching redline is covered by microcontroller with upshifting.

- integration of paddle shifter and console mounted shift lever.

5) Control of Solenoid by Microcontroller

-set up solenoid and manipulate operation by solid state relay per gear shift control requirement.

6) Subsystem integration of software, prototype calibration, debugging and validation

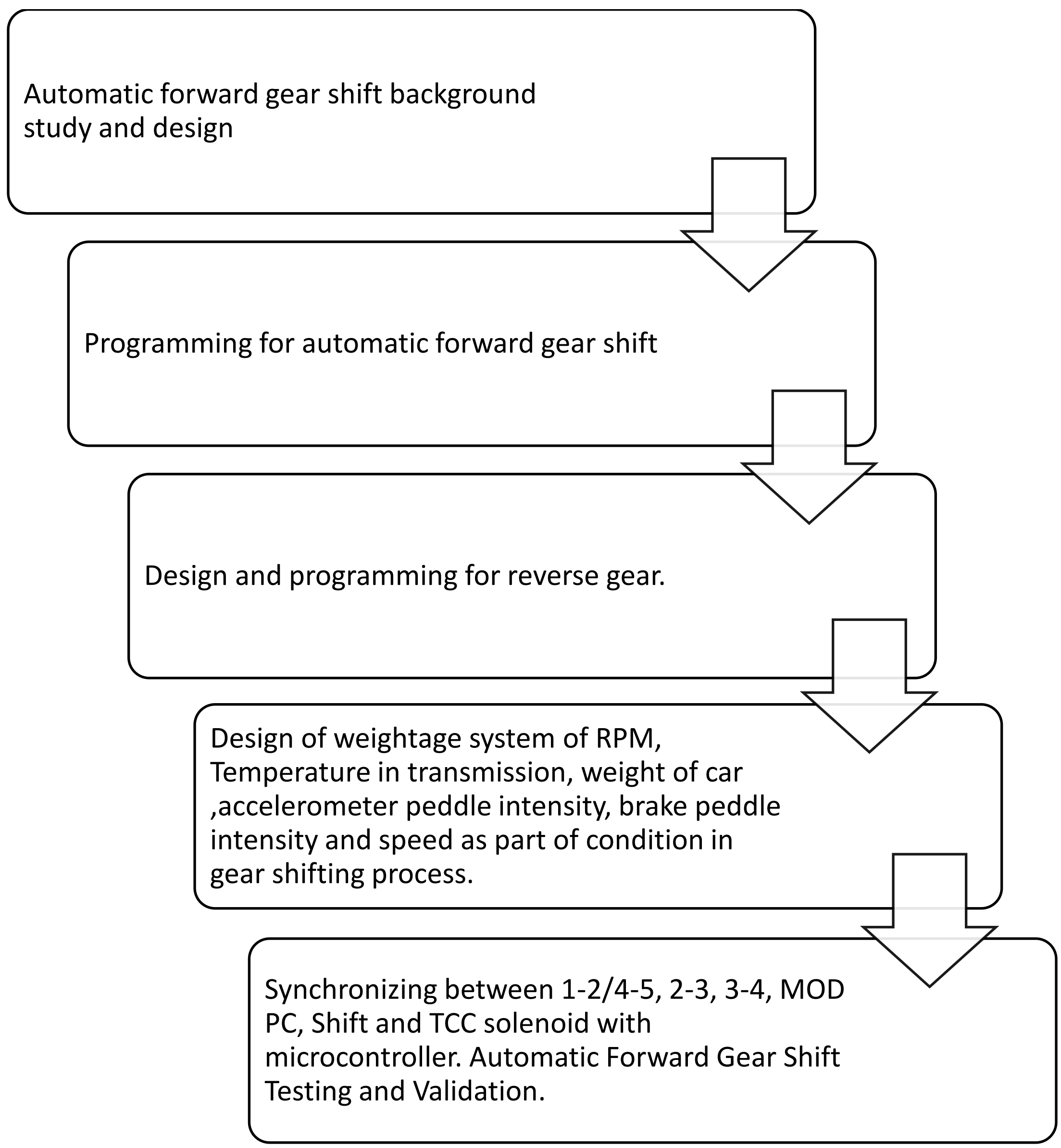
-to combine functioning blocks of gear shifting algorithm together.

-calibration of prototype in terms of gear engagement timing between hardware and software.

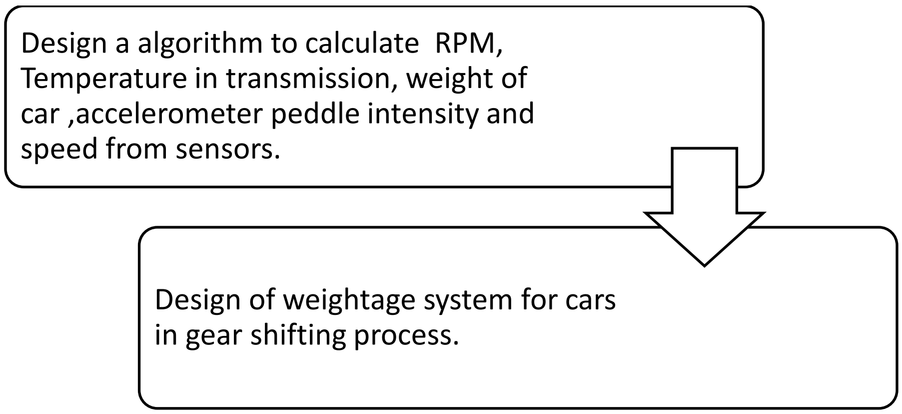
3.2 Project Activities

<u>Automatic Gear Shift Control</u>

Based on gear control module, controlling signal will be generated after true statement has been found and accessing for the functional block is granted. The signal can either be logic high/low or PWM signal. The sensor input will be continuously updated to allow car to operate in optimum power efficiency and low fuel consumption.

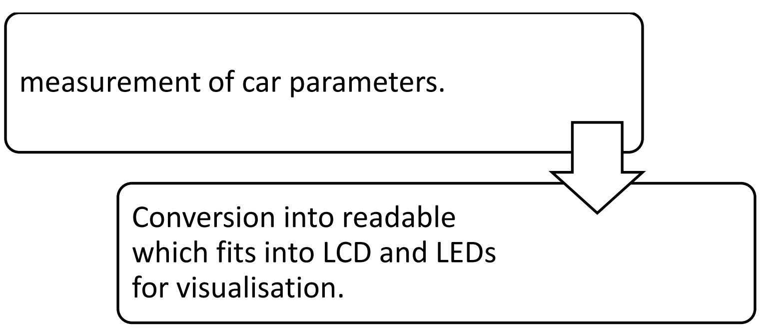


Extracting RPM of engine, speed of car, temperature of transmission, accelerometer pedal intensity, brake paddle intensity and car weight from the car sensor.



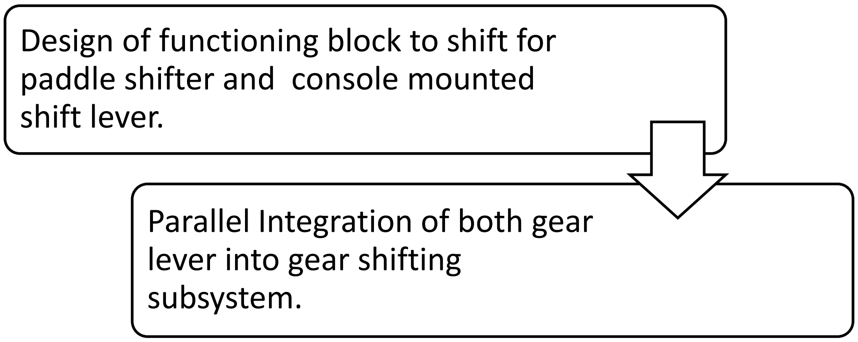
Implementation of indicator for car information

Visualization of car information about transmission temperature, weight of car, brake paddle intensity and accelerator paddle intensity for letting user updates with current car condition.



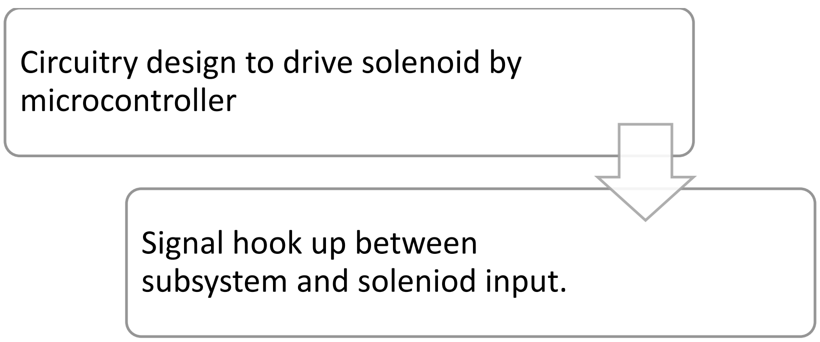
Implementation of selection between manual and auto mode gearbox

Shifting gear is controlled by microcontroller if the driver inputs no commands. Gear will be incremented and decremented one gear at one time. No breaching of rev limit and should all the gear changing commands follow shift of gear by user. Microcontroller will bypass automatic function when engine is running over the rev limit.

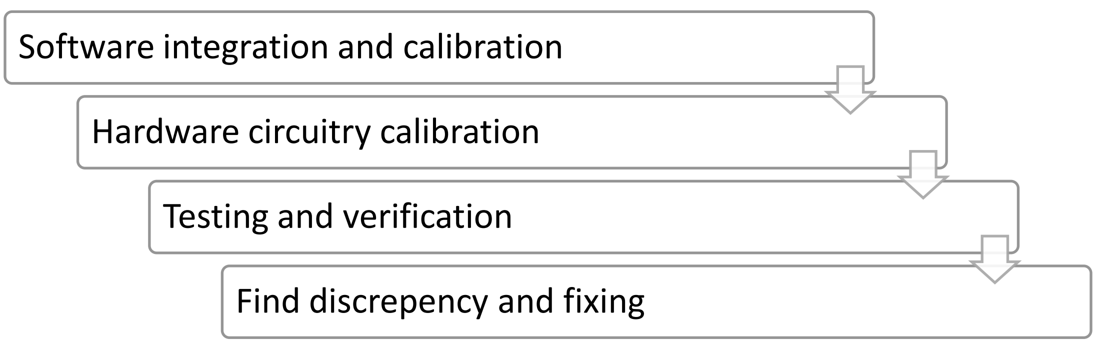


Solenoid Control

The output signal from microcontroller will be stepped up by solid state relay to control solenoid.



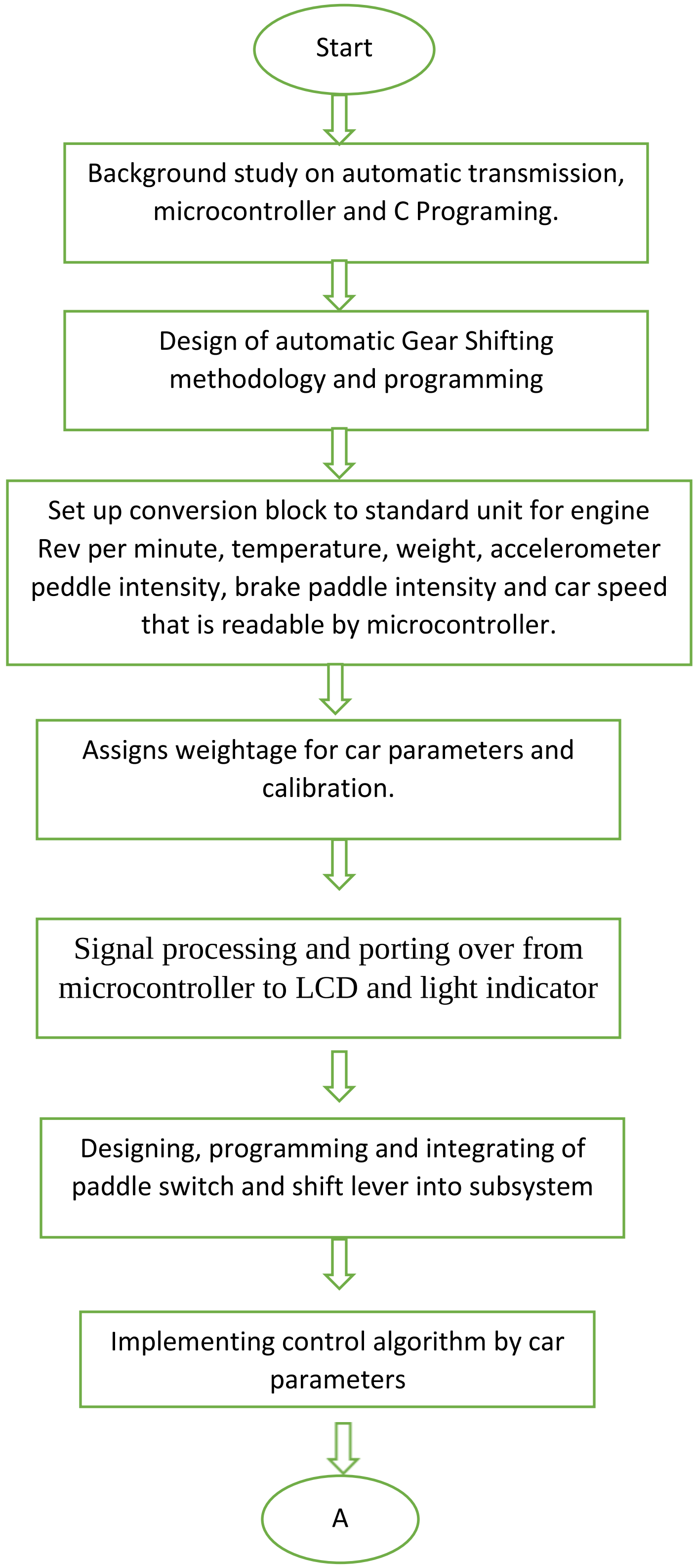
Subsystem integration of software, prototype calibration, debugging and validation

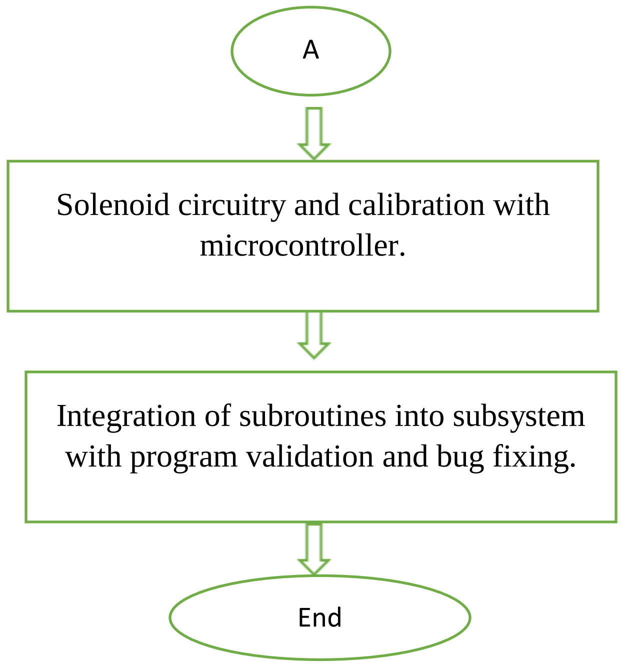


3.3 Milestone

There is a table below showing the plan for each task execution in methodology throughout final year first semester and final year final semester.

Table 3: Illustrates the plan of arranging each task into specific time frame throughout two semesters.


Start
Background study on automatic transmission, microcontroller and C Programing.
Design of automatic Gear Shifting methodology and programming
Set up conversion block to standard unit for engine Rev per minute, temperature, weight, accelerometer peddle intensity, brake paddle intensity and car speed that is readable by microcontroller.
Assigns weightage for car parameters and calibration.
Signal processing and porting over from microcontroller to LCD and light indicator
Designing, programming and integrating of paddle switch and shift lever into subsystem
Implementing control algorithm by car parameters
A



3.4 Lab Experiment

The PIC 18F4431 will be inserted into the socket that is provided by SK40C microcontroller starter start-up kit. The function of PIC is implemented by directly plugging the I/O components through programmer. After project being developed, user can upload their code using USB ICSP PIC Programmer. Later, the targeted components which has been interfacing with Microchip PIC18F4431 microcontroller are hall effect sensor, temperature sensor, potentiometer, accelerometer, LED, solenoid and electromagnetic relay. Each sensor was attached to designated pins before reading is being processed to standard values through proper conversion algorithm. All experiments are carried out in lab where environment factor doesn't change significantly. DC adaptor is connected to power socket throughout the experiment to power up whole electronics. At the end of capturing and synthesizing data, car parameters will be shown in 16x2 LCD display.

3.4.1 LED

A group of six LEDs is used to stimulate the output from the microcontroller to control transmission solenoids during gear shift. The solenoids will be replaced with LED to illustrate triggering of solenoid set during increment and decrement of shift of gear process later. LEDs are arranged in active high pattern so they will be illuminating when output pin is in LOW level. Six LEDs in a row are inserted onto the breadboard with connection to six pins (RA1, RA2, RA3, RA4, RA5 and RA6). Six output pins are instantiated in C programming and the activation pattern will follow the solenoid application chart of Mercedes Benz 722.6 transmission chart. For active high connection, LED can only be illuminated by signal "HIGH". There are four shift stages and five gear stages where they require different LED/LEDs being triggered. The shift stages are programmed where they will stick for 3 seconds before engaging into destined gear. This step is to prevent delay shifting of gear that are meant to be observable by examiner to be too long.

Next, RB0(upshift) and RB1(downshift) is used stimulate manual shift of gear. For the second part, the user will press on RB0 button for upshifting on first gear until fifth gear. It is tested again using downshift button on the start-up kit where it finally reaches 1st gear. The condition of LEDs is recorded. An assumption has been made that all parameters have been fulfilling the requirement for each shift of gear.

Table 5: illustrates Mercedes Benz 722.6 transmission solenoid application chart

GEAR SHIFTS	SOLENOID					
	1-2/4-5 ▲	2-3	3-4✱	MOD PC⌘	SHIFT PC ●	TCC ⊕
1ST	OFF	OFF	OFF	PWM	OFF	OFF
SHIFT	ON	OFF	OFF	PWM	PWM	OFF
2ND	OFF	OFF	OFF	PWM	OFF	*PWM
SHIFT	OFF	ON	OFF	PWM	PWM	*PWM
3RD	OFF	OFF	OFF	PWM	OFF	*PWM
SHIFT	OFF	OFF	ON	PWM	PWM	*PWM
4TH	OFF	OFF	OFF	PWM	OFF	*PWM
SHIFT	ON	OFF	OFF	PWM	PWM	*PWM
5TH	OFF	OFF	OFF	PWM	OFF	*PWM

Diagram 12: Connection of LED to microcontroller.

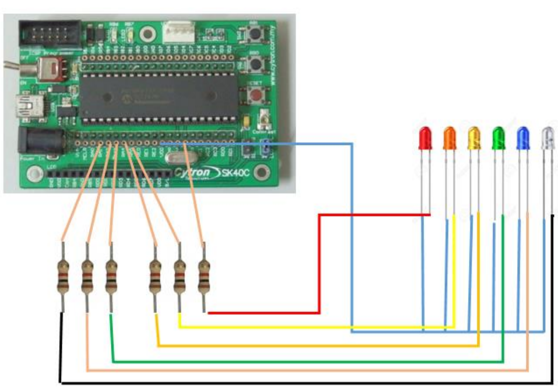


Table 6: illustrates 6 pins of microcontroller to be connected with LED which represents transmission solenoids.

PIN RA1	LED 1	1-2/4-5 Gear Solenoid
PIN RA2	LED 2	2-3 Gear Solenoid
PIN RA3	LED 3	3-4 Gear Solenoid
PIN RA4	LED 4	Modulated Pressure Control Solenoid
PIN RA5	LED 5	Shift Pressure Control Solenoid
PIN RA6	LED 6	Torque Converter Clutch Solenoid

3.4.2 Activation and Deactivation of Air Solenoid

Design of circuitry in signal output from microcontroller which require to switch solenoid valve on and off. The way on how Mercedes 722.6 solenoid valve works is based on low level activation principle of solenoid.

For this experiment, the chosen solenoid shares similarities with what found in Mercedes 722.6 transmission: AIRTEC 4V120-06 solenoid valve. Standard voltage of solenoid is DC 24V, current supply is 0.104A, the effective sectional area to control air flow is 12mm2 and allowable working air pressure is between 0.15 to 0.8MPa.

Songle SRD-05VDC-SL-C mechanical relay has been chosen because it provides medium for microcontroller to turn on/off devices which consume high voltage (24V from solenoid) at few seconds. The operating voltage is 5V where microcontroller can supply low current from output pin to charge electromagnet inside. Activation of AIRTEC 4V120-06 solenoid valve can be observed by red light inside protective cover of circuit.

Diagram 13: illustrates AIRTEC 4V120-06 solenoid valve.

Diagram 14: illustrates AIRTEC 4V120-06 solenoid valve

Vcc pin from microcontroller is directed to coil pin of relay which logic zero can activate the coil inside solenoid. Albeit that, a follow up step where the output pin should be programmed to return to high level to turn off the relay. In normally opened configuration, the electrical contacts are opened if no current inside the solenoid coil; always-open contact is closed once the LOW pin is established on coil pin.

Diagram 15: Connection between start-up kit(RA1 pin), relay and solenoid

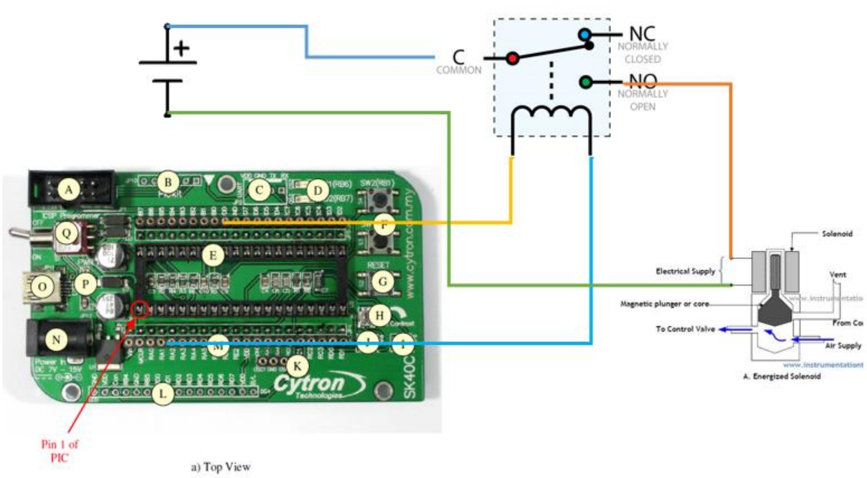


Table 7: illustrate the pins of microcontroller and relay used for operating solenoid.

Vdd(microcontroller)	Coil pin 1(relay)
Pin RA2	Coil pin 2(relay)
Common pin(relay)	Positive pin (24V power supply)
Normally opened pin(relay)	Negative pin(24V power supply)

3.4.3 Measuring temperature and displaying on 16x2 LCD

Third part of experiment is to connect temperature sensor and 16x2 LCD display. LCD HD44780U module initialization is needed before any characters can be read from the microcontroller. Most of the settings like cursor position on LCD, read for busy flag and setting entry mode are defined in LCD.c library. Temperature sensor provides analog values and it is converted into digital values with standard unit using formula[1]. From the data sheet, VOUT = 1500 mV at 150°C and VOUT = 250 mV at 25°C. The range of voltage given by LM35 is from 0 to 1V. The equation derives from taking the reading, finding what percentage of the range (8bits =1024steps) it is and dividing by ten (10mV for 1 degree Celsius).

Temp =5 (analogRead(tempPin) * 100.0) / 1024 [1]

The ADC used is 10 bit, so the digital value is divided by highest limit of 1024 steps. The original equation is derived from taking the reading, finding the percentage of the range (1024) it is, multiplying that by the range itself (aRef, or 5000 mV), and dividing by ten (10 mV per degree Celcius). As aRef is set at 1.1V, the temperature range of the LM35 is limited to 0 to 110 degrees Celcius.

As reference voltage is 1.1V over 1024, each step is separated from 1.1/1024=1.074mV apart. As 10mV equals to one degree change, every change of 10/1.074= 9.31mV in analog reading equates one degree of temperature change. The temperature value shown in the LCD display will be observed. A precautionary step has been taken where time delay is inserted after all characters have been displayed to ensure enough time for checking by observer before they are cleared off for the upcoming character display.

Diagram 16: illustrates the connection of 16x2 LCD display to start-up kit.

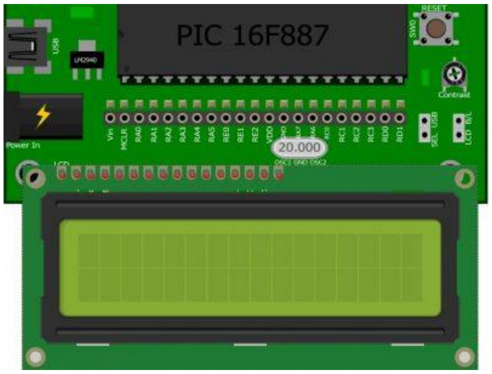


Diagram 17: illustrates the connection of temperature sensor with start-up kit.

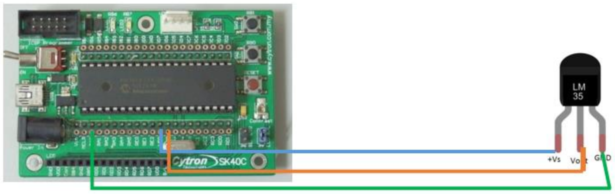


Table 8: Illustrates the pins of start-up kit to LM35 temperature sensor.

Temperature sensor	Start-up Kit
5V pin	Vdd
Ground pin	Ground
Vout	RA0

3.4.4 Measuring RPM by using HONEYWELL SS441A Hall Effect Sensor

The SS441A is non-latching hall effect sensor. The sensor will set an HIGH output voltage at the time where south pole of magnet is at the distance 10cm away from the sensor. It switches immediately to LOW output whenever magnet is allocated away from sensitive distance. Diagram 16: illustrates the circuit to connect hall effect sensor with sk40c start-up kit.

As referred to diagram below, a resistor with resistance of 10 Kilo Ohms is connected between Vcc and Vout of the sensor to pull the output signal to 5V. The interrupt function inside C programming for detecting output signal in one minute is implemented with timer 0 at 4MHz clock. Firstly, number of amplitude changes in signal is recorded throughout 1 minute when the wheel rim is turning at constant speed and blocking the magnetic field to reach sensor. When the end, the detection count is compared with the reading in tachometer.

v=πD/T [2]

where v is speed, D is diameter of wheels and T is time period to complete one full rotation. It is similar to standard formula of distance divided by time. It can be derived into formula [3] and [4].

distance =pulse count×π×D [3]

RPM = 2 * pi * radius [4]

The RPM is measured along the circumference of wheel and unit is meters per minute. This method can be improved upon using method below.

Rpm(milliseconds)=t2-t1/count *60000ms(=1min) dsa [5]

Where count is number of magnet detection, t1 is time where magnet is first detected while t2 is time where a fixed number of count is detected to trigger RPM calculation. The calculation will be done once a certain count is reached other than waiting for 1 minute.

Diagram 20: Illustrates the connection of start-up kit to hall effect sensor.

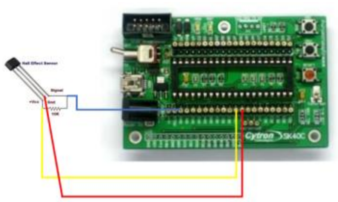


Table 20: Illustrates the pins of start-up kit to hall effect sensor.

Hall Effect Sensor	Start-up Kit
5V pin	Vdd
Ground pin	Ground
Vout(signal)	RA1

3.4.5 Measuring Forward Acceleration(z-axis) Using ADXL335 Accelerometer-Digital Form to Angle Form (90 degree to -90 degree)

Newton's second law of motion states that acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

F=ma [5]

Where F is force, m is mass of object and a is acceleration

The mass of object will affect the acceleration of car in the case where car is expected to provide same thrust in this consideration. As mass increase, acceleration will decrease and vice versa. In this case, if we assume that force and acceleration a car can provide at normal situation, mass of the car can be calculated and be fed into algorithm to determine gear that suits the car.

Power-to-weight ratio is a measurement of actual performance of any engine or power source by calculating engine's power output being divided by the weight (or mass) of the vehicle which is assumed to perform at its peak value.

Accelerometer measures acceleration in changing of velocity of an object over time. When it is in stationary position, acceleration the accelerometer is detected to be due to gravity (1g) pulling down on it. From this accelerometer, a voltage of 1.37V provided by accelerometer represents 1g acceleration. X, Y and Z pin represents the g force acting on respective axis. The analog value sent to designated port is converted to digital format by ADC. In this experiment, x and y axis pin are omitted from this experiment as only the forward acceleration will be the factor in deciding the gear selection. The digital format is then mapped to 0-255 format (8 bit resolution). The value can be converted to angular of slit by mapping the maximum and minimum ADC value to -90 to 90 format. Other than that, since 3.3V pin is not required for powering any device or sensors, it is left open circuited. The value of acceleration can be observed through LCD display.

This ADXL335 represents the -1g output as a voltage which is around 1.37V.

Read = zRead/ave; [6]

Z axis acceleration is calculated by adding measured value into total value, followed by dividing with average value. This voltage format can be converted into angle format by using formula below:

zAng = map(zRead, zMinVal, zMaxVal, -90, 90); [7]

Note that the equation requires the minimum and maximum z-axis limit that acceleration can detect. Mapping one boundary into angle format reduces the syntax error of calculation. In this case, zMinVal=281 and zMaxVal=413 which can be referred to data sheet.

Diagram 19: illustrates the circuit to connect accelerometer with sk40c start-up kit.

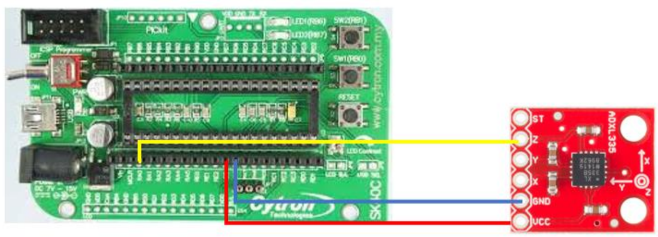


Table 10: Illustrates pins mapping between start-up kit to accelerometer.

Accelerometer pin	Start-up Kit
5V pin	Vdd
Ground pin	Ground
z direction pin	RA0

3.4.6 Measuring voltage from rotary potentiometer and displaying in 16x2 LCD display

The rotary potentiometer chosen is B10k model. It is used to represent the gas pedal position of car that can observe the driver feedback on getting desired acceleration. The output signal from potentiometer is retrieved from central wiper connection as it slides along the resistive track. The power supply is provided to SK40C via DC power Adaptor socket while program is loaded via programmer into PIC 18F4431 microcontroller. At first, the shaft is placed at left position and signal is categorized into 0 to 1023 range by Analog to digital converter. Then, printf command is used to display the voltage output at that instance. The step followed by the shaft will turn right until reaches the end of turning point to see if there are any changes detected by microcontroller. The value will be verified using multimeter to check the voltage output from potentiometer. An assumption has been made that turn of shaft to the right represents pressing of gas pedal and deceleration when shaft is turned all the way to another direction.

Diagram 20: illustrates the connection between rotary potentiometer, LCD display and sk40c board.

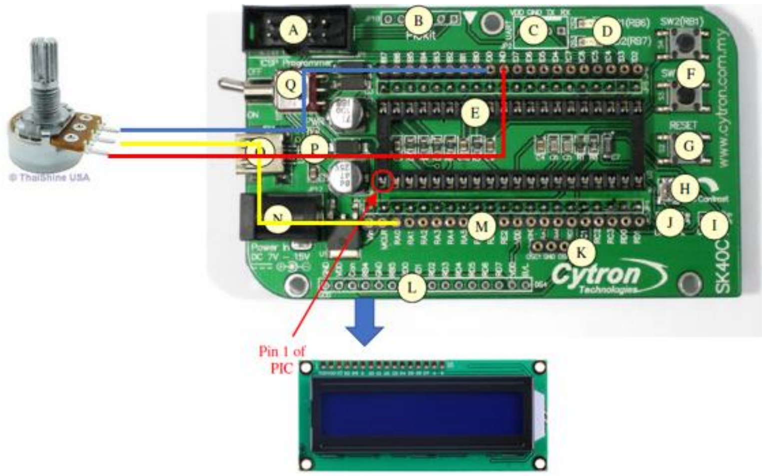


Table 11: illustrates pin mapping between rotary potentiometer and SK40C board.

Rotary Potentiometer	SK40C baord
Vref pin	Vcc pin
Ground pin	Ground pin
Signal pin	RA0 pin.

Discussion

The result obtained is then discussed with supervisor to decide the possibility of this project to finish before timeline.

3.5 Gantt Chart

Final year Semester	1								2							
Weeks	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8
Research on Automatic gear shift and design	■															
Circuitry for sensor and devices connection.		■														
Automatic gear shift code implementation -Forward and Reverse gear			■	■												
Design formulation for Rev per minute, temperature, weight, accelerometer peddle intensity, brake paddle intensity and speed.					■	■										
Study on effect of car parameters in gear shifting process and assignment of weightage.						■										
Signal adaptation from microcontroller to LCD and light indicator						■										

**Synchronizing signal between 1-2/4-5, 2-3, 3-4, MOD PC, Shift and TCC solenoid with output of microcontroller using Solid State Relay																
Manual mode design, ordering and development.																
Integrating car parameters as controlling variables in gear selection.																
Study, circuitry design and configuration of solenoid to microcontroller																
Integration of functional subroutines into one subsystem.																
Interfacing and synchronizing suitable gear shifter with the 722.6 transmission. • Hardware circuitry calibration • Software and signal calibration • Testing and verification																

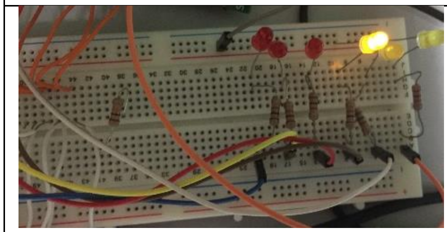
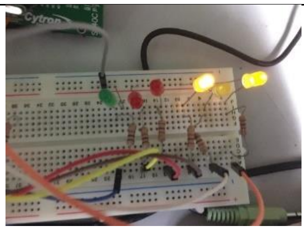
CHAPTER 5

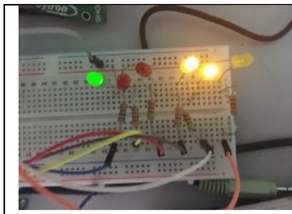
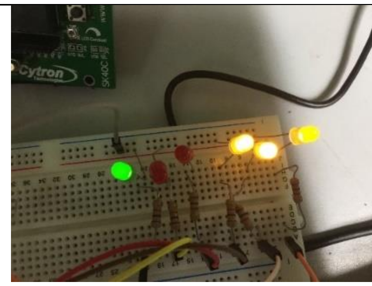
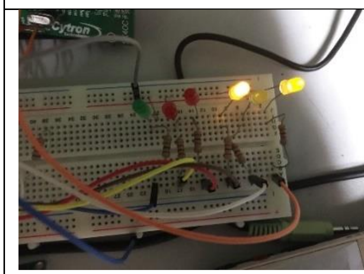
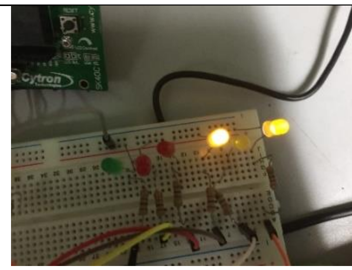
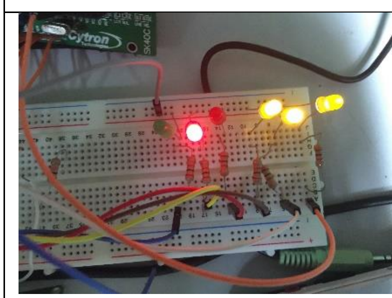
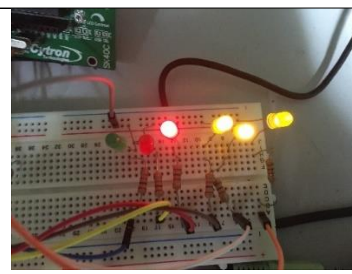
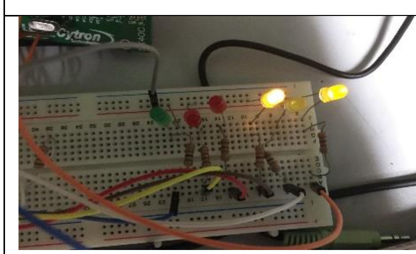
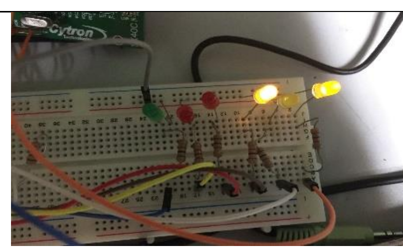
RESULTS

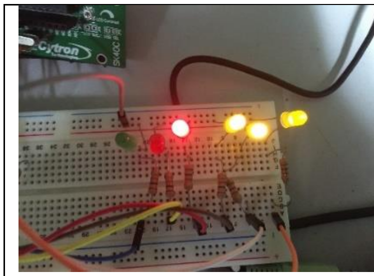
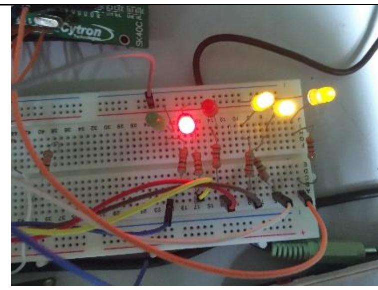
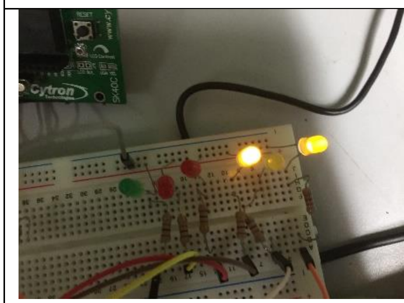
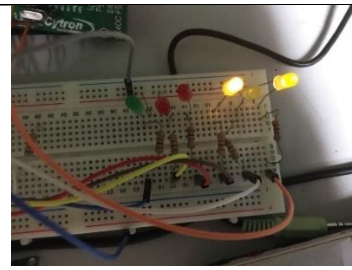
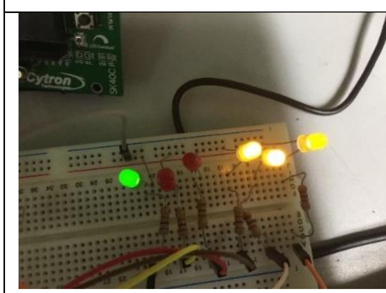
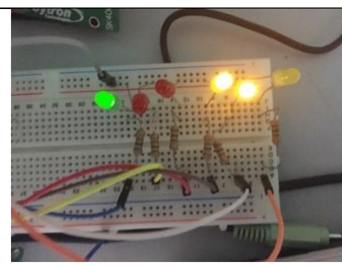
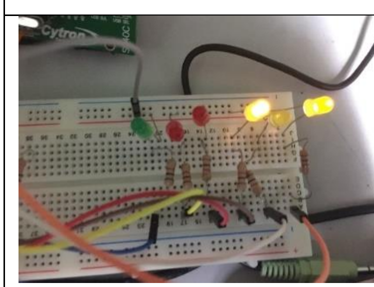
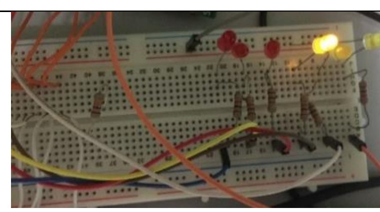
5.1 LED pattern

For manual mode, the LEDs are lighted up according to the triggering pattern of modulated pressure control (MPC)solenoid, shift pressure control (SPC) solenoid, torque converter clutch(TCC) solenoid and shift solenoid as what is listed in Mercedes Benz 722.6 transmission chart. For manual shift mode, group of LEDs starts with 1st gear and increment 1 gear at a time when RB0 is pressed. The LED stops changing at fifth gear where it already has covered solenoid triggering pattern for 5 gears. RB0 button is pressed until reaches 1st gear LED pattern. In active high configuration, the brightening up of LEDs is seen when circuit complete with current flows through LED circuit. There is a setback in this experiment when a time delay in upshift/downshift of gear introduced right after a new gear is engaged. An improvement on this timing issue could lead to a faster shift of gear but makes LED less observable.

Diagram 21: illustrates the LED light up pattern which similar to solenoid inside transmission

<table>
<tr><td>LED pattern for upshift of gear</td><td>LED pattern for downshift of gear</td></tr>
<tr><td>
1st gear</td><td>
5th gear</td></tr>
</table>

 1st to 2nd gear	 5th to 4th gear
 2nd gear	 4th gear
 2nd to 3rd gear	 4th to 3rd gear
 3rd gear	 3rd gear

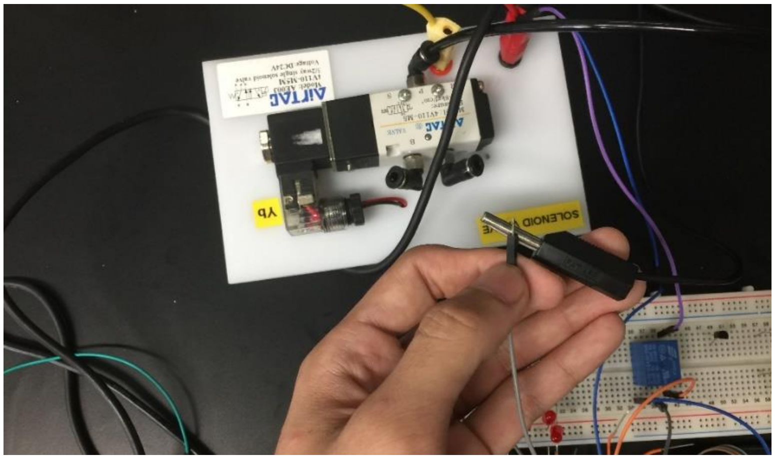
 3^{rd} to 4^{th} gear	 3^{rd} to 2^{nd} gear
 4^{th} gear	 2^{nd} gear
 4^{th} to 5^{th} gear	 2^{nd} to 1^{st} gear
 5^{th} gear	 1^{st} gear

While high level output from the automatic gear lever sends to pin B3, the upshift of gear show similar LED patterns as what is observed in manual mode. The main difference is that LED pattern continued to change by assuming all car parameters has been fulfilled to change gear. Downshift of gear can be observed when pin B3 is supplied with LOW logic. It eventually stops at solenoid triggering pattern of 1st gear.

5.2 Air solenoid results

Air can be observed coming out of always open outlet when the output pin is set to LOW level. Solenoid can be operated by using the always open pin when LOW signal is transmitted to the ground pin of relay. The opening and closing of solenoid valve can be improved using Solid State relay as car transmission requires response time close to few milliseconds.

Diagram 22: Small red light can be observed from the solenoid valve after the triggering signal sent to relay.

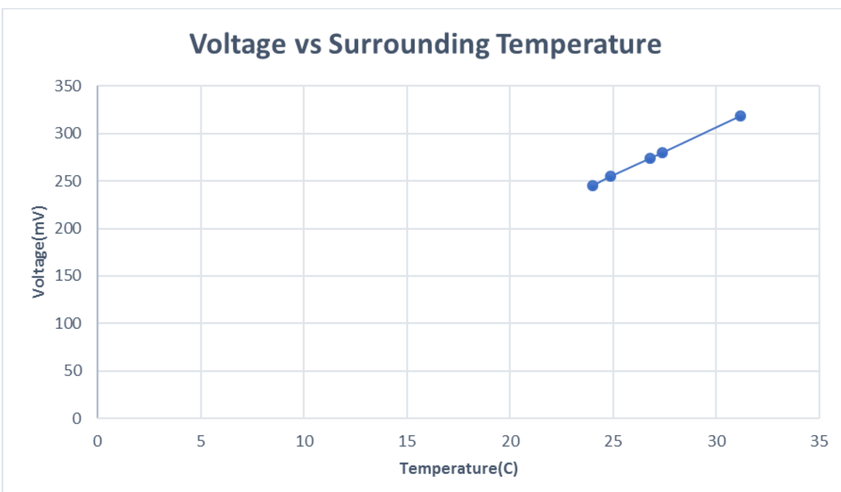


5.3 Temperature reading

From the LM35 temperature input sensor, the Analog to Digital Converter (ADC) convert digital value form temperature sensor into Degree Celsius format. The digital value of voltage is constantly updated with fixed time delay. As seen from figure below, the temperature is showing 24.9 degree Celsius during noon time. Since ADC converts temperature sensor voltage output to digital format, temperature reading is feedback to LCD for display. During the experiment, the display of characters in LCD requires configuration the LCD Driver as some LCD library in the market is customized only for specific model. The relationship between voltage and temperature is linear. The higher peak values is 319mV when surrounding temperature is 31.2V and lowest temperature ever recorded in the whole project is 245mV at 24 Degree Celsius. In the future, the sensor would be tested in engine bay for durability and sensitivity to extreme hot temperature.

Diagram 23: illustrates the room temperature and digital values converted by microcontroller.

Table 12: Relationship between voltage versus surrounding temperature



5.4 Measurement of number of magnet detection by using hall effect sensor

From the diagram below, the count for magnet detection is displayed at the LCD display which illustrates slow speed rotation detection. The sensor is sensitive enough to detect fast changes in magnetic field. The engine's pistons are connected directly to the crankshaft. When they rotate, the crankshaft will move in up and down motion. Each time the crankshaft completes a 360-degree turn, it's called a revolution. The measuring of The RPM in this experiment is targeting speed of wheel powered by DC motor. It is calculated via external time measurement method which counting is stopped by user when time reaches 1 minute.

From the diagram, it is noticed that the slope increases exponentially as power supply to DC motor increases. At the end of 8 minute, there is no increment of speed of DC motor, so RPM remains constant until experiment ends.

It is noted that the RPM can be calculated from number of magnet detection by using formula [2]. The RPM will only be known at the end of 1 minute, so any RPM change in the time interval will be missed out due to this calculation algorithm.

The focus of project later will be calculating RPM after minimum count of magnet change is collected. The time to reach the number of count at second period can be processed with first period to find out the median time in order to solve RPM in shorter period.

Diagram 24: illustrates the count of magnet detection, 147 in one minute duration.

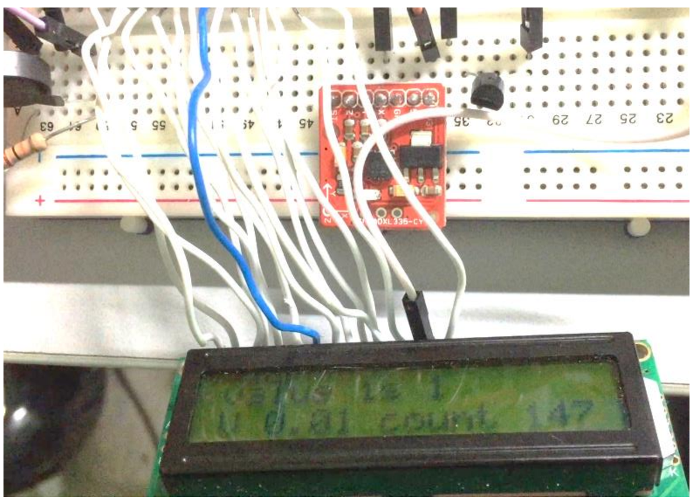
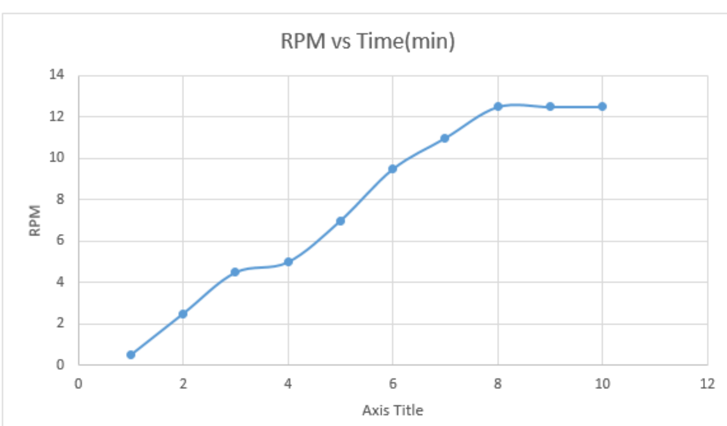


Table 13: Relationship between RPM versus time



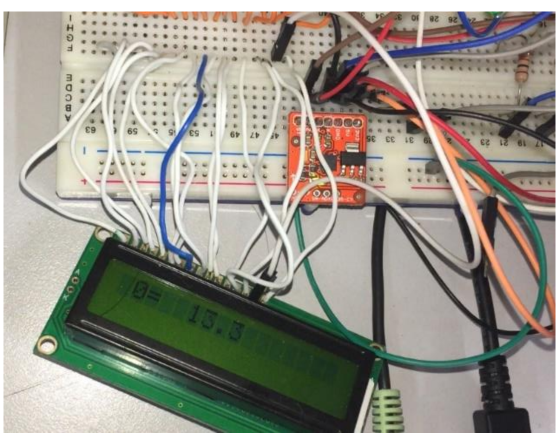
5.5 Measurement of acceleration

The output from accelerometer is measured and successfully converted into 8-bit resolution format. The largest value of tilt is 256 is displayed when the accelerometer is upturned 180 degree facing to the floor. Whereas the smallest value of tilt is 0 when it places at proper orientation as shown in diagram below. For this experiment, 1g equivalents to car accelerates from rest to 40m/s in 4s or from rest to 60m/s in 6s. As this project is designated for Mercedes Benz W124 E-class 2.0 8 valve model, it can achieve 0-100km/h in approximately 12 seconds, it can achieve the acceleration of 100km/(60minute×60second)÷12.6second÷9.81ms^(-2)=0.2248g. As this figure is the limit the car can achieve, calibration and validation process have to be carried out using 722.5 transmission to ensure appropriate gear selection.

Furthermore, car is assume to have 4000N and experience 0.2248g. So, the weight of the car can be determined by 4000/0.2248=17793.59Kg. If the dry weight of the car is 15000kg, this means the load the car carries is 2793.59Kg

Another parameter which needs to be considered in this experiment is power to weight ratio of the car. If it can produces 200Horsepower and dry weight of car is 15000Kg, the power to weight ratio of the car is 0.013. If the value retrieved is larger than this limit is consider as invalid input and assignation of other values is into light, medium and heavy weight category.

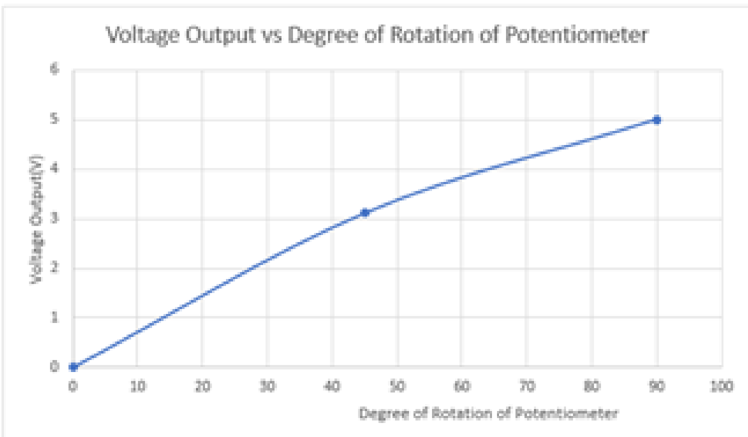
Diagram 27: illustrates the 8-bit resolution of tilt. The value of tilt is 13.3.



5.6 Rotary Potentiometer Results

As measured from multimeter, the voltage increases when potentiometer is turned along its axis to the right. This results proves that it is useful to act as gas padal position sensor which accurately alter the voltage output to the microcontroller. As gas pedal is turned 90 degrees to the right, the condition can fulfill the argument of upshift of gear and let the transmission to increment by 1 gear.

Table 14: Relationship between voltage output versus degree of rotation of potentiometer.



CHAPTER 5

CONCLUSION & RECOMMENDATION

To begin with, Although the objectives of this project were achieved, there is still further work and modifications which could improve upon the model and its performance. For extension of project in the future, I would recommend integrating the control circuit with Mercedes Benz 722.6 transmission. The data collected from different sensors could have distinctively collected in faster approach. In this research, the sensors are in room temperature to perform task which is measuring car parameters albeit being allocated different time for different area of measurement. Other than that, the scope for subjects could be broadened to include wider variety of car parameters and different kind of cars. Lastly, the fabrication of standalone control module into integrated circuit would be ideal for fulfilling the needs of car enthusiasts who owns a Mercedes Benz 722.5 transmission to upgrade their current transmission.

Secondly, a transmission control module(TCM) algorithm has been implemented by using microcontroller to control 6 solenoids which cause clutch application change. At the same time, the TCM can allow real-time tracking of car parameters and feedback to driver. The suitable gear changing algorithm can be tuned through analysis of data and user feedback. The model of gear shifter will cater for any sudden change of values and interrupt from the sensors to provide appropriate power trajectory to the car axle. To achieve the remaining outcomes above, here are the proposed ideas to achieve goals:

1) After getting input from RPM, acceleration, temperature and weight of car sensor, analyzing, validating and synthesizing gear selection algorithm.
2) Design a proper interrupt function for yielding sensors' output in which data will not be affected by one another.
3) Upcoming experiment should include outcomes where microcontroller should be able to interact with car transmission. It also requires developing data conversion functions to synthesize data from sensor inside transmission.
4) LED light indicator should reflect the correct rotational speed for letting driver knows perfect time for the optimum gearshift.

5) Microcontroller should offer reverse mode where vehicle can move in backward direction.

Sensor will record the parameter before sending into microcontroller, Then, the microcontroller will decide the best gear based on shifting algorithm written in the scripts. Thing follows with microcontroller will give signal to solid state relay before adjusting solenoid. Lastly, four standard parameters that show kind of car condition transmission control which control unit is handling. To have proper information feedback system, user will be alerted to check the car when some value is out of safety range. Recommendation for this project is to provide driver with sport mode, normal mode, fuel economy mode and rainy mode to choose from. If car is inclining up the uphill terrain or trying to overtake vehicle in front, the car powertrain should have provided more acceleration and power by holding the same gear longer than usual driving application. Albeit that, the car will require high fuel consumption and damage the transmission component to help engine maximize power output.

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Appendices

Temperature reading

```
#include <18f4431.h>
#FUSES XT,NOWDT,NOLVP,NOPROTECT
#FUSES PUT,BROWNOUT
#device  ADC=8

#use delay (clock = 20000000)
#include <flex_lcd.c >

float TempVal=0;

delay_func()
{
unsigned int16 i;
    for(i=0; i<100; i++)
    {
    }
}

void main()
{
   set_tris_a(0x01);
   set_RTCC(6);
   enable_interrupts (INT_RTCC);
   enable_interrupts (GLOBAL);
   lcd_init();
    float value, value1;
   setup_adc (ADC_CLOCK_INTERNAL);
```

```
  setup_adc_ports (PIN_A0);
  set_adc_channel (0);
  while (1)
  {
    value = read_adc ();
    TempVal=value*100/1024;
    lcd_gotoxy(1,1);
  printf(lcd_putc,"position is %f",(float)TempVal );
   }
}
```

RPM reading

```
#include <18F4431.h>
#device adc=10
#include <stdlib.h>
#include <math.h>


#fuses HS,NOWDT,NOPROTECT,PUT,NOLVP

#use delay(clock=10000000)
#use rs232(baud=9600, xmit=PIN_C6, rcv=PIN_C7, stream=PC)
#include <flex_lcd.c >
#define LED PIN_C0


main()
{
    long value1=0, value2=0;
   lcd_init();
   //output_high(LED);

   // setup to do A/D conversion
    setup_adc_ports(sAN2|VSS_VDD);
   setup_adc(ADC_CLOCK_DIV_8);

    while(1)
   {
      lcd_gotoxy(1,1);
      // read in value on AN0
```

```
      set_adc_channel(0);
      delay_ms(10);
      value1 = read_adc();

      //delay_ms(10);

      // read in value on AN1
      //set_adc_channel(1);
      //value2 = read_adc();



      delay_ms(10);

      fprintf(PC, "%ld,     ", value1);
      //fprintf(PC, "%ld\r\n", value2);
   }

} // end of main
```

LED Pattern

```
#include <18F4431.h>

#FUSES NOWDT                //No Watch Dog Timer
#FUSES XT                   //Crystal osc <= 4mhz for PCM/PCH , 3mhz to 10 mhz for PCD
//#FUSES NOPBADEN            //PORTB pins are configured as digital I/O on RESET
#FUSES NOLVP                //No low voltage prgming, B3(PIC16) or B5(PIC18) used for I/O
//#FUSES NOXINST             //Extended set extension and Indexed Addressing mode disabled (Legacy
mode)
#FUSES NODEBUG

#use delay(clock=4000000)
//#include <flex_lcd.c>
//#include "eeprom.c"
#include <stdlib.h>



#USE FAST_IO(D)
//The fast method of doing I/O will cause the compiler to perform I/O without programming of the
direction register.
//This directive takes effect until another #use xxxx_IO directive is encountered.
//The user must ensure the direction register is set correctly using set_tris_X()
//So, need to explicitly use set_trisx() command

void firstgear();
void secondgear();
void thirdgear();
void fourthgear();
void fifthgear();
```

```
void firstsecond();
void secondthird();
void thirdfourth();
void fourthfifth();
void readswitch();

int state=1;

delay_func()
{
  unsigned int16 i;
  for(i=0; i<1000; i++)
  {
  }
}

main()
{
  set_tris_b(0x0F);
  set_tris_d(0x00);
  int upshift=1;
  int downshift=1;
  int oldupshift=1;
  int olddownshift=1;
  int state=0;
  int gear=1;
  int pastgear;
  int manu_downshift;
  int manu_upshift;
  //unsigned char mode = 1;
```

```
//lcd_init();
gear=5;
while (1)
{
//firstgear();



downshift=input(PIN_B1);
upshift=input(PIN_B0);
manu_downshift=input(PIN_B2);
manu_upshift=input(PIN_B3);
pastgear=gear;

  //if(upshift==0)
  /*if((upshift==0) && (manu_upshift))
  {
    gear++;
    //secondgear();
    state=1;
  }
  */
  gear--;
  state=1;
   if(downshift==0){
  //else if(downshift==0 && (state==1)){
  gear--;
  //thirdgear();
  state=1;
  }
```

```
//gear++;
switch(gear){
    case 0: firstgear();
        gear=1;
        break;

    case 1:if(pastgear==2 && state==1){
         firstsecond();
          }
         firstgear();
    break;
    case 2:if(pastgear==1 && state==1){
         firstsecond();
        }
        if(pastgear==3 && state==1){
         secondthird();
        }
        secondgear();
        break;
    case 3:if(pastgear==2 && state==1){
         secondthird();
        }
        if(pastgear==4 && state==1){
         thirdfourth();
        }
       thirdgear();
       break;
    case 4:if(pastgear==3 && state==1){
         thirdfourth();
        }
```

```
                    if(pastgear==5 && state==1){
                     fourthfifth();
                    }
                  fourthgear();
                  break;
            case 5:if(pastgear==4 && state==1){
                     fourthfifth();
                    }

                  fifthgear();
                  break;
            case 6:fifthgear();
                  gear=5;
            break;
         }

    //delay_ms(10000);
    //lcd_gotoxy(1,1);
   // printf(lcd_putc,"gear is %d\n",gear);
   // printf(lcd_putc,"gear is %d\n",upshift);
   }

}




void firstgear()
{
   output_low(PIN_D2);
   output_low(PIN_D3);
```

```
   output_low(PIN_D4);
   output_high(PIN_D5);
   output_low(PIN_D6);
   output_low(PIN_D7);
   delay_func();
   state=0;
}

void firstsecond(){
output_high(PIN_D2);
   output_low(PIN_D3);
   output_low(PIN_D4);
   output_high(PIN_D5);
   output_high(PIN_D6);
   output_low(PIN_D7);
   delay_func();
   state=0;
}

void secondgear()
{

   output_low(PIN_D2);
   output_low(PIN_D3);
   output_low(PIN_D4);
   output_high(PIN_D5);
   output_low(PIN_D6);
   output_high(PIN_D7);
   delay_func();
   state=0;
```

```
}

void secondthird()
{
 output_low(PIN_D2);
   output_high(PIN_D3);
   output_low(PIN_D4);
   output_high(PIN_D5);
   output_high(PIN_D6);
   output_high(PIN_D7);
   delay_func();
   state=0;
}

void thirdgear()
{

   output_low(PIN_D2);
   output_low(PIN_D3);
   output_low(PIN_D4);
   output_high(PIN_D5);
   output_low(PIN_D6);
   output_high(PIN_D7);
   delay_func();
  state=0;

}

void thirdfourth()
{
```

```
  output_low(PIN_D2);
  output_low(PIN_D3);
  output_high(PIN_D4);
  output_high(PIN_D5);
  output_high(PIN_D6);
  output_high(PIN_D7);
  delay_func();
  state=0;
}

void fourthgear()
{

  output_low(PIN_D2);
  output_low(PIN_D3);
  output_low(PIN_D4);
  output_high(PIN_D5);
  output_low(PIN_D6);
  output_high(PIN_D7);
  state=0;
  delay_func();

}

void fourthfifth()
{
  output_high(PIN_D1);
  output_low(PIN_D2);
  output_low(PIN_D3);
  output_high(PIN_D4);
```

```
    output_high(PIN_D5);
    output_high(PIN_D6);
    delay_func();
    state=0;
}

void fifthgear()
{

    output_low(PIN_D2);
    output_low(PIN_D3);
    output_low(PIN_D4);
    output_high(PIN_D5);
    output_low(PIN_D6);
    output_high(PIN_D7);
    state=0;
    delay_func();

}
```

Acceleration reading

```
#include <18f4431.h>

#FUSES HS,NOWDT,NOLVP,NOPROTECT

#FUSES PUT,BROWNOUT

#device ADC=8
#INCLUDE <math.h>

#use delay (clock = 20000000)
#include <flex_lcd.c >

double map(double value, float x_min, float x_max, float y_min, float y_max);

delay_func()
{
unsigned int16 i;
    for(i=0; i<10; i++)
    {
    }
}

void main()
{
   set_tris_a(0xFF);
   set_timer1(6);
   setup_counters(RTCC_INTERNAL,RTCC_DIV_32);
   enable_interrupts (INT_RTCC);
   enable_interrupts (GLOBAL);
```

```
   lcd_init();
   enable_interrupts(GLOBAL);
   enable_interrupts(PERIPH);
   enable_interrupts(INT_EXT_H2L);
   enable_interrupts(INT_TIMER1);

   //setup_timer_1(T1_INTERNAL|T1_DIV_BY_8);

   float value, value1; //<------ changed to float from int16
   setup_adc (ADC_CLOCK_INTERNAL); // <--- i have changed here!!!
  setup_adc_ports(sAN0|sAN1|sAN2|VSS_VDD);
   //set_adc_channel ();
   float valuex,valuey,valuez;
   float VREF = 5.0;
   int xMinVal = 265;
   int xMaxVal = 398;

   int yMinVal = 259;
   int yMaxVal = 393;

   int zMinVal = 281;
   int zMaxVal = 413;

   int xAng=0, yAng=0, zAng=0;
   double RAD_TO_DEG = 57.2957795;
   double PIval = 3.14159265359;
   double xdeg=0, ydeg=0, zdeg=0;

int Mass=0, Force=0;
float Weight=0;
```

```
// double resultx,resulty,resultz;
 //int v,count=0;

 while (1)
 {
   int ave = 10;
   for(int i=0; i<ave ; i++)
   {
     set_adc_channel(0);
     valuex+=read_adc();
     set_adc_channel(1);
     valuey+=read_adc();
     set_adc_channel(2);
     valuez+=read_adc();
   }
   valuex=valuex/ave;
   valuey = valuey/ave;
   valuez = valuez/ave;
   //v = map(count, 0, 1023, 0, 5);



   xAng = map(valuex, xMinVal, xMaxVal, -90, 90);
   yAng = map(valuey, yMinVal, yMaxVal, -90, 90);
   zAng = map(valuez, zMinVal, zMaxVal, -90, 90);
   //resultx= atan2 (-yAng, -zAng);
   //resulty=atan2(-xAng, -zAng);
   //resultz=atan2(-yAng, -xAng);

   //xdeg = RAD_TO_DEG * (resultx + PIval);
   //ydeg = RAD_TO_DEG * (resulty + PIval);
```

```
//zdeg = RAD_TO_DEG * (resultz + PIval);
xdeg = RAD_TO_DEG * (atan2(-yAng, -zAng) + PI);
ydeg = RAD_TO_DEG * (atan2(-xAng, -zAng) + PI);
zdeg = RAD_TO_DEG * (atan2(-yAng, -xAng) + PI);
//set_adc_channel(0);   //read from channel 0
//delay_func();
//delay_ms(2);
//valuex=read_adc();

//delay_func();
//delay_ms(10);
//set_adc_channel(1);   //read from channel 1
//delay_func();
//delay_ms(2);
//valuey=read_adc();

//delay_func();
//delay_ms(10);
//set_adc_channel(2);  //read from channel 2
//delay_func();
//delay_ms(2);
//valuez = read_adc ();

lcd_gotoxy(1,1);
//delay_func();
//delay_ms (500);
//valuex = read_adc ();
//valuey = read_adc();
//valuez = read_adc();
//value1 =  value / 10;
```

```
  Mass=15000;//assume car is 15000kg
  Force=4000;//assume car have 4000N
  Weight=(Force/xAng)- Mass

   printf(lcd_putc," x=%6.1f", (float)xAng);
   printf(lcd_putc,"weight=%f,(float)Weight);
   //printf(lcd_putc,"\n y=%6.1f", (float)yAng);

   //lcd_gotoxy(6 ,1);
   //printf(lcd_putc,"  y=%4.1f\n",(float)valuey);
   //lcd_gotoxy(1,2);
   //printf(lcd_putc,"z=%4.1f\n",(float)valuez);
   //printf(lcd_putc,"yof\n");
   //printf(lcd_putc,"hello world");
   //lcd_putc("\\f);
   //printf(lcd_putc,"\\f");

   }
}

double map(double value, float x_min, float x_max, float y_min, float y_max)
{
    return (y_min + (((y_max - y_min)/(x_max - x_min)) * (value - x_min)));
}
```

Potentiometer Reading

```
#include <18f4431.h>

//#device adc = 8
//#use delay (clock = 20000000)
#FUSES XT,NOWDT,NOLVP,NOPROTECT

#FUSES PUT,BROWNOUT

#device ADC=8

#use delay (clock = 20000000)
#include <flex_lcd.c >
//#include "adc.h"
//#include <math.h>
//#include <stdio.h>
//#include <stdlib.h>

//#byte PORTB=0X06

float oC=0;
float TempVal=0;
int counter=122;



delay_func()
{
unsigned int16 i;
   for(i=0; i<100; i++)
   {
```

```
    }
}

void main()
{
  //delay_func();
  set_tris_b(0xF0);
  set_RTCC(6);
  setup_counters(RTCC_INTERNAL,RTCC_DIV_32);
  enable_interrupts (INT_RTCC);
  enable_interrupts (GLOBAL);
  lcd_init();
   float value, value1; //<------ changed to float from int16
  setup_adc (ADC_CLOCK_INTERNAL); // <--- i have changed here!!!
  setup_adc_ports (PIN_B6);
  set_adc_channel (0);
  while (1)
  {
    delay_ms (500);
    value = read_adc ();
    lcd_gotoxy(1,1);
  printf(lcd_putc," position is %f",(float)value );
  }
}
```