HYBRID CAR CONTROL SYSTEM

By

NAJWA SHUHAIDA OMAR

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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June 2007

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.

Najwa Shuhaida Omar

ABSTRACT

Hybrid Vehicle has been a popular topic recently due to global warming as well as increasing fuel consumption issues. Major automobile company such as Honda and Toyota started to develop hybrid vehicle in response to environmental degradation. This report analyzes the hybridization of a conventional car by adding an electric motor to drive the wheels. The study being done is based on the objectives to understand the vehicle's system and designing the hardware. The purpose of this study is, beside to study the HEV system itself, it is also to identify requirements of various control system in series HEV and apply the theoretical knowledge to design the elements of series HEV and its control system.

In this report, the researcher has divided the topic into 5 main chapters which are the introduction, literature review, methodology, results and discussion and conclusion. Introduction part will give the details about the purposes and objectives. Details about the vehicle system are included in the literature review where type of vehicle and its construction is explained in details. Based on chosen configuration, the details about parameters of the designed vehicle are explained in methodology part. Results and discussions give the overall comment on the designed vehicle and being concluded at conclusion part. Recommendations are suggested at conclusion part.

The researcher hopes that this report will gives an understanding about HEV. It is important to notice that the contents of this report are comprehensive and easily understood even by non-technical readers. The ideas are represented in proper manner and very well organized. Hopefully readers would take the advantage of sharing the researcher knowledge in completing the Final Year Project.

ACKNOWLEDGEMENTS

I would like to express my gratitude to all those who gave me the possibility to complete my final year project on Hybrid Car Control System. I am deeply indebted to my supervisor, Dr Taj M, Baloch, Senior Lecturer from Electrical and Electronic Department of University Technology PETRONAS whose help, stimulating suggestions and encouragements. He was always there to listen and give me advices upon completing my project.

I am also wanted to thank the committee of EE Final Year Project for giving me the opportunity to do a research on this topic. I am also profoundly grateful to all lecturers in EE department that spared me some time to give me continuous supports and guidance.

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LIST OF ABBREVIATIONS

AC - alternating current

DC – direct current

EV – Electric Vehicle

ICE – Internal Combustion Engine

HEV – Hybrid Electric Vehicle

SHEV – Series Hybrid Electric Vehicle

PHEV – Parallel Hybrid Electric Vehicle

PWM – Pulse Width Modulation

CHAPTER 1
INTRODUCTION

1.1 Background of study

In response to the concerns over the environmental degradation, the California Air Regularatory Board (CARB) proposed a regulation; progressively increase number of vehicle to be zero emission vehicles, beginning the year of 1998 [1]. Following this regulation, several other states representing nearly 40% of the vehicle on the road, starts considering similar regulations. At this moment, only electric vehicle can meet the requirement, but nowadays most automobile manufacturer starts to consider low emissions Hybrid Vehicle which have electric motor as second drive. Hybrid Vehicle is a vehicle that uses more than one (1) power sources for its propulsion [2] and the combination results in benefits. The hybridization can comes in various forms and types for examples hybrid cars and trucks that combine an electric motor with a gasoline engine date back to the turn of the 20th century. Recently, people and industry especially in automotive industry talk about hybridization seriously. The technologies have been developing tremendously. Why is it so?

Everybody loves vehicle especially car since it is very convenient and it help people to transport themselves from one place to another. Meaning, it really do help people making their lives easier. In the other hand, people hate pollution; it causes a lot of bad effect especially to the environment and health of living thing. Besides that, increase in price of petrol nowadays cost high standard of living for majority of people. In recent years, global warming cause greenhouse effect and exhaustion of natural resources especially petroleum have become worldwide serious issues. Remarkable increase in number of vehicles is considered to be major contribution of these problems. To cope up with these problem caused by vehicles, a study have been done on developing a vehicle that can reduce the pollutions from its emission and economically fuel consumption or better gas mileage. The automobile industry is developing a Hybrid Electric Vehicle (HEV). Any vehicle that has more than one power source can be classified as a hybrid electric vehicle (HEV) and the term is used for a vehicle that combines electric drive with heat engine using fossil-fuel energy source [3]. Present-day HEV are equipped with both Internal Combustion Engine (ICE) and electric motor as its power source. There are quite a number of hybrid cars being produced nowadays for example Lexus RX 400h hybrid, Lexus GS 450h Hybrid, Honda Civic Hybrid, Honda Accord Hybrid, Honda Insight Hybrid, Toyota Prius, 2007 Toyota Camry hybrid, Toyota Highlander, and Ford Escape Hybrid.

1.2 Problem statement

Transportation is a major source of energy consumption and airborne pollutant around the world. Energy consumed by millions of vehicle produced tons of airborne pollutants to the atmosphere each year. Due to remarkable increase in hybrid vehicle production and the force to reduce pollution to the environment, the researcher would like to do a study on this area in understanding about the vehicle and implement it in designing the prototype of the vehicle. The project will be focusing on hybrid vehicle control system. In this project, the author will establish a logical explanation on the system especially in the vehicle's control system. Research done concentrate on the vehicle's control system and identify the parameters that are important to the vehicle.

Control system of vehicle is a crucial part to be understood and design since it will control the propulsion of the vehicle. The study of HEV's and their control have been the most advance topic in research centre recently. In this project, identify all the parameters required in the system will be done based on the configuration or topology of the vehicle choose. The design parameter being discussed in this project was a system including batteries, electrical motors, a generator, and a second source of torque with its fuel source. The second source of torque is often an internal combustion engine, running on gasoline. In other cases, it may be an I.C.E. powered by hydrogen, a diesel engine, a small gas turbine/generator or a striling engine. For the prototype of the vehicle, it will cover until the electrical part of the vehicle.

Researcher hopes that this project will help reader to understand the overview of hybrid vehicle since the usage of it will be increased in a few years time.

1.3 Objectives and scope of study

Objective of this project is to understand the HEV system. In order to achieve that, the researcher needs to identify the parameters that contribute the vehicle's control system. So, the scope of study will be identifying and choosing the vehicle's control system and the end, implement them in order to come out with the hardware of the vehicle. Beside that, there are also additional scopes of study that the author has set in order to accomplish the project that are:

- Study on HEV system
- Study on various control system in hybrid car
- Designing and simulate elements of the vehicle's control circuit
- Design a prototype of a hybrid car control system

For the 1st part of Final Year Project, research has been done about the system and during the 2nd part; the researcher implemented the research done in designing the prototype of the vehicle.

CHAPTER 2
LITERATURE RIVIEW/THEORY

2.1 EV and HEV history

The HEV concept goes back to 1905. On November 23 of that year, American engineer H. Piper filed for a patent on a hybrid vehicle. Piper's design called for an electric motor to augment a gasoline engine to let the vehicle accelerate to a rip-roaring 40 kilometers (25 miles) per hour in a mere 10 seconds, instead of the usual 30. But by the time the patent was issued, three and a half years later, engines had become powerful enough to achieve this kind of performance on their own. Nevertheless, a few hybrids were built during this period; there is one from around 1912, for example, in the Ford Museum in Dearborn, Mich[3].

The more powerful gasoline engines, along with equipment that allowed them to be started without cranks, contributed to the decline of the electric vehicle and of the nascent HEV between 1910 and 1920. In the early to mid-1970s, though, a brief flurry of interest and funding, prompted by the oil crisis, led to the construction of several experimental HEVs in the U.S. and abroad. Interest in and funding for, HEVs began to wane almost as soon as oil became plentiful again.

In mid-December 1997, almost a century after the hybrid was first conceived, more than 25 years after development work began on them in earnest, and after more than $1 billion had been spent worldwide in recent years on development, Toyota began offering a hybrid automobile to the general public, the Prius.

2.2 Electric Vehicle (EV)

Electric vehicles are a promising technology for the long-range goal of energy efficiency and reduced atmospheric emissions. A well-designed electric motor drive can yield close to 90% efficiency and since the onboard systems in an electric vehicle are powered by batteries and electric motors, there are no toxic emission Using present technologies; Electric vehicles can achieve ranges of only 200-250 km before the battery is depleted. While this is sufficient for everyday use, it precludes the use of electric vehicle for long distance trips. Until an electric storage device is developed that can provide adequate range and quick recharging capabilities, the electric vehicle will have a limited role as a delivery vehicle or as a commute. Below, is the configuration of electric vehicle:

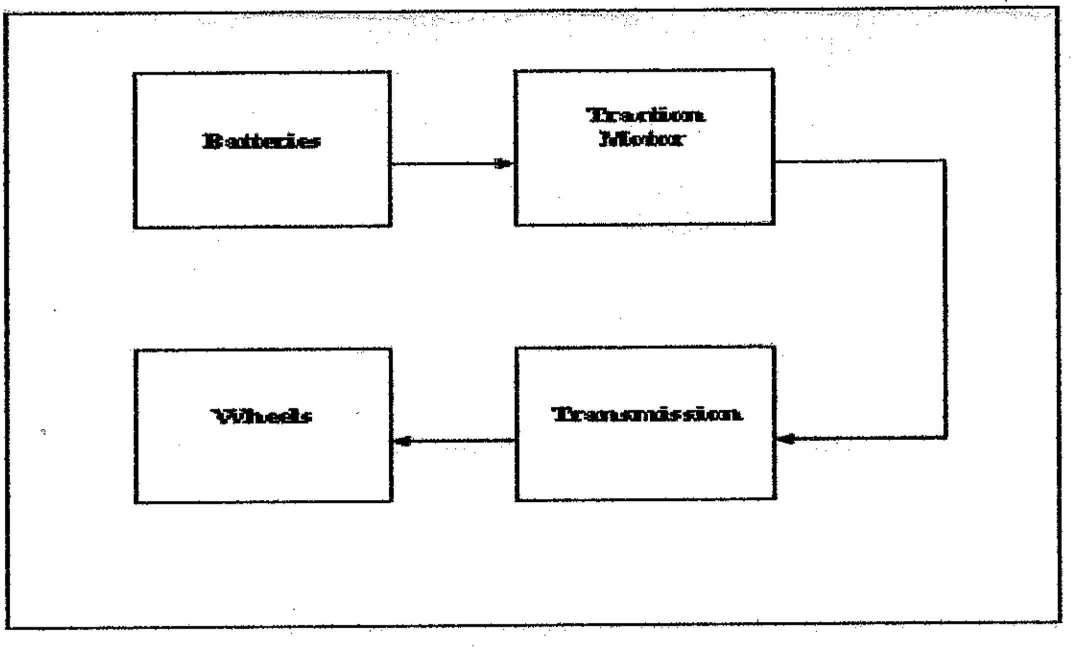


Figure 1: Configuration of EV

2.3 Hybrid Electric Vehicle (HEV)

HEV, besides offer high efficiency and reduce emission when compared to the conventional car, it can also be design to overcome limitation in the electric vehicle. In the other hand, the vehicle is an improvement of conventional car and electric vehicle. As introduced earlier, HEV utilize two (2) energy sources, electric motor and ICE to power the electrical system. Electrical motor use to improve the energy efficiency and reduce the emission while ICE provide the extended range capability.

A Hybrid Vehicle, as defined by Technical Committee 69 (Electric Road Vehicles) of International Electro Technical Commission, is one in which propulsion energy during specified operational missions is available from two or more kinds or types of energy stores, sources or converters with at least one store or converter onboard [4]. This definition is purposefully vague as energy sources also include fuel cells etc. Similarly, ultra capacitors and flywheels are examples of power sources. A more specific definition of a HEV is given as a hybrid vehicle in which at least one of the energy stores, sources or converters can deliver electric energy.

Most HEV may contain the following part:

- *Internal Combustion engine (ICE)* have slightly same engine as in conventional car. However, it has smaller size and used advanced technologies to compensate with latest requirements. It is more efficient compared to conventional cars. Its smaller size is due having electric motor to take over certain circumstances such as faster driving or accelerating
- *Fuel tank* is the energy storage device for the fuel engine)
- *Electric motor* with advanced technologies, it also can act like a generator as well. Besides functioning as traction motor, it also uses generator properties to slow down / brake and recharge the batteries
- *Generator* being used in the series HEV to produce electric power supplied to the batteries
- *Batteries* used to power the electric motor and other electronic components. It can be recharged each time the brake is pressed
- *Transmission* will turn the wheel

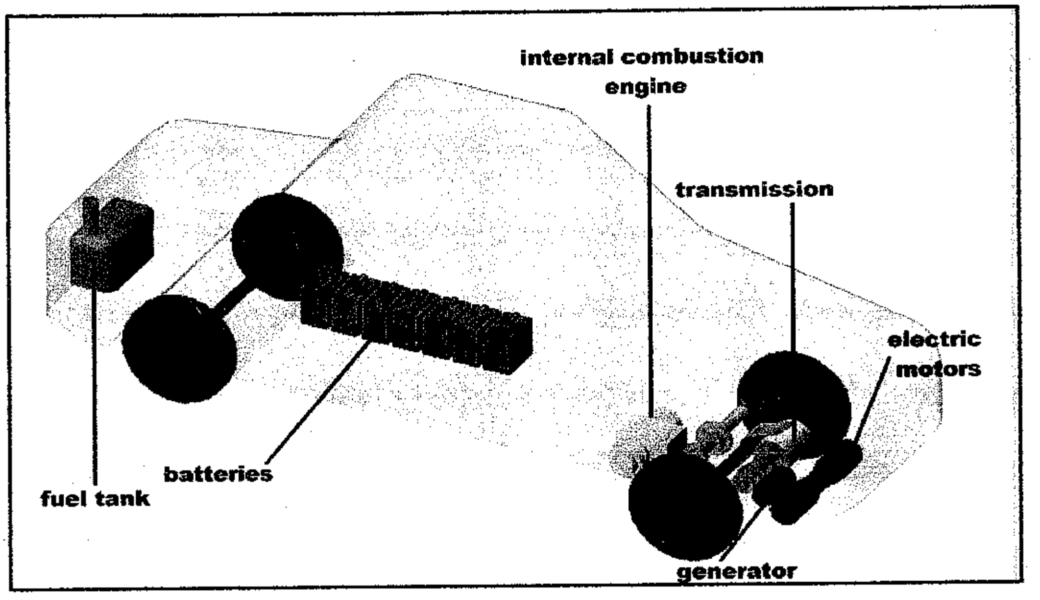


Figure 2: Common components of HEV [5]

Though many different configurations of power sources and converters are possible in a hybrid electric power plant, there are two generally accepted classifications, series and parallel.

There is a reason why hybrid vehicle not being created equal. Different type of geometry of hybrid vehicle depends on its type of usage. The systems used in the Prius, Escape, Insight and Civic hybrids are designed and engineered to perform the daily tasks of commuting to work, trips to the grocery store, taking the kids to soccer practice, or for traveling to visit friends and relatives [3]. While for heavy duty work, there is different type of hybrid geometry used. So, different type/configuration, have its own application.

2.3.1 Series HEV

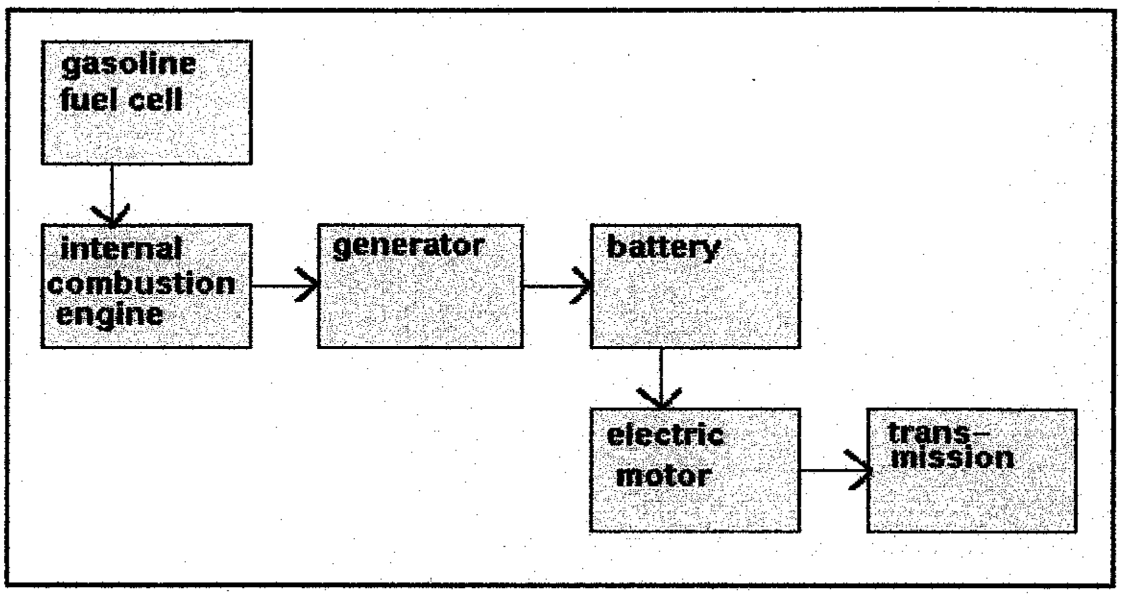


Figure 3: SHEV configuration [5]

In a series hybrid, only one energy converter provides torque to the wheels while the other is used to recharge a battery pack. The series configuration shown in figure above represents a typical design where the ICE/generator pair charges the batteries and only the motor actually provides propulsion.

Although the sizes and types of components used in a series HEV drive train vary, their functional roles remain the same. An onboard generator maintains the state of charge of an energy accumulator and the energy from this accumulator is transformed by an energy converter into torque to drive the wheels. The main design parameters in a series hybrid are the selection and sizing of the generation and storage devices. Generators can be an ICE/generator pair, a gas turbine generator, fuel cells, or a number of other technologies. Candidates for the accumulator include batteries, ultra capacitors, flywheels, and hydraulic accumulators. Typically, an electric motor is used to provide torque at the wheels. Conventional design methodology for a series hybrid consists mainly of sizing the propulsion motor to provide the desired performance and then choosing a generator and storage device to provide the required range on a specific drive cycle. As previously stated, although the devices chosen to fill those roles might be different, their function remains the same. Thus, a series power plant can be designed based almost entirely on the functional roles and then components can be selected to best meet power requirements.

2.3.2 Parallel HEV

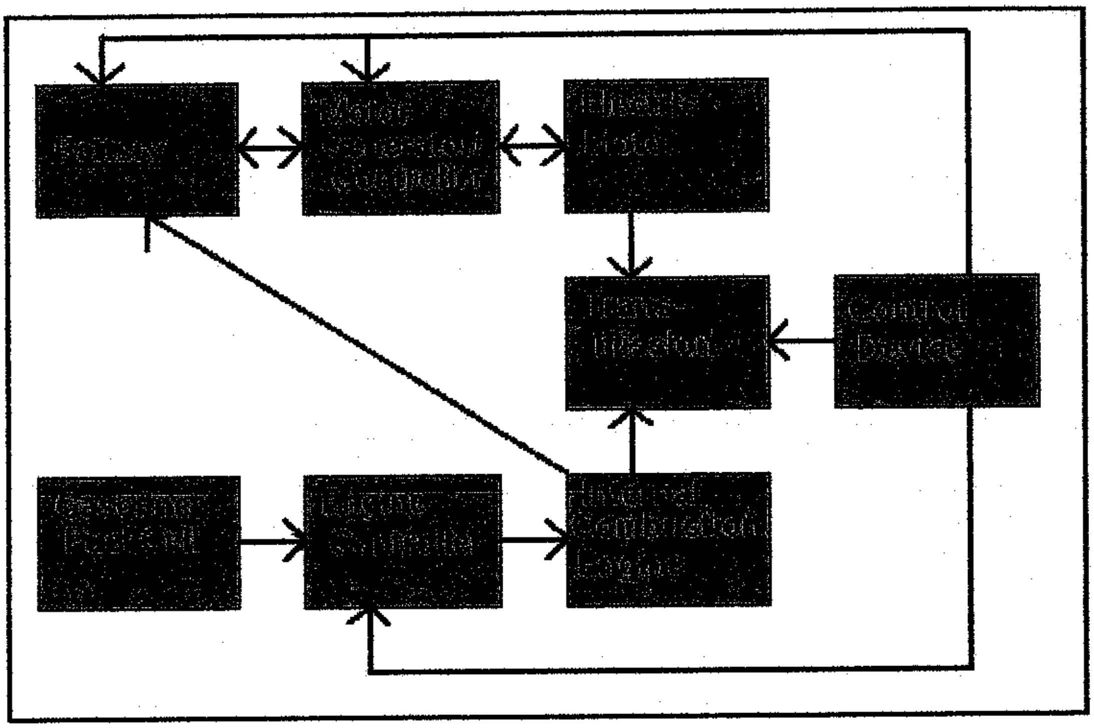


Figure 4: Parallel HEV configuration [5]

In a typical parallel design, both electric motor and ICE being connected in parallel. Either the ICE or the electric motor could be considered as the primary energy source depending on the vehicle design and energy management strategy. It is even possible to design a drive train in which the ICE and electric motor are equally responsible for propulsion or each is the prime mover at a certain time in the drive-cycle. A component's functional role might even change within the course of a drive-cycle due to battery depletion or the other vehicle requirements, an option not available in series hybrid designs. Vehicle architecture decisions, component selection and sizing, gearing, and other design parameters become considerably more complex in a parallel hybrid due to the sheer number of choices and their effects on a vehicle's performance for a particular mission.

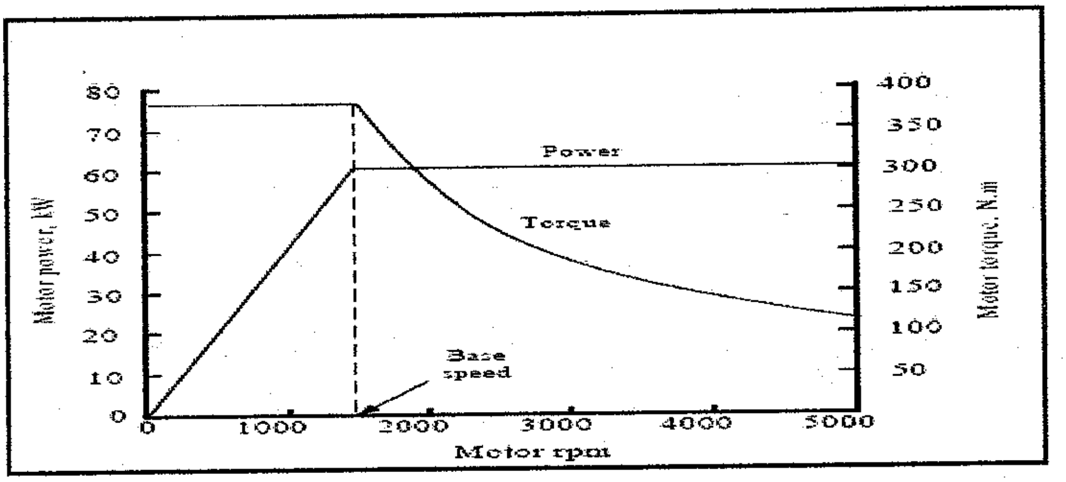
CHAPTER 3
METHODOLOGY

In this project, researcher concentrated on series HEV. This is due to simple construction and less complexity of a system. Besides, lack of time and money were also a major drawback of the design. Series HEV is an extended version of electric vehicle. Electric vehicles suffer from some serious disadvantages, mainly their limited driving range due to limited storage of energy on–board in the form of batteries, limited payload and volume capacity due to the weight and size of the batteries, and also the long time it takes for the batteries to charge. In a series hybrid, an ICE/ Electric generator system is added to the electric vehicle drive train, to charge the batteries on board, and thus increase the driving range.

3.1 Series HEV (SHEV)

Although there are many possible configurations for a series hybrid drive train, the configuration used in this project is based on figure 3. A traction motor propels the vehicle. The speed torque characteristics of an electric motor are ideally suited for traction. The motor delivers high torque at low speeds and low torque at high speeds. The motor gives a constant torque for variable speed up to the 'base speed' of the motor; beyond the base speed, the torque of the motor decreases with increase in the speed. The torque speed characteristics of the motor shown in graph 1.

The traction motor is powered by a battery pack and/or an engine generator unit. As can be seen from the figure, the engine generator unit is not directly coupled to the wheels, but supplies its power to the wheels through the electric motor.



Graph 1: Torque-speed characteristic [6]

Hence, the internal combustion engine, which is the prime mover of the electric generator, can run at a single speed, and give out torque /power is such a way that it always runs at its maximum efficiency region. The remaining power required by traction, which might be more or less than the constant power supplied by the engine/generator, is managed by the battery, using an effective control strategy. The engine/generator unit either helps the batteries to power the traction motor when load power demand is large, or charges the batteries when the load power demand is small. The motor controller is used to control the traction motor to produce the power required by the vehicle. The traction motor can be controlled both as a motor as well as a generator, either in the forward direction or reverse direction. The fuel tank is the unidirectional energy source, while the battery source is the bi-directional energy source. The drive train may need a battery charger to charge the batteries by wall plug – in from the power network. The control strategy is developed in such a fashion that the battery is always charged on board, and thus the driving distance is never limited by the life of the battery (refer to figure 5 for the common control strategy of SHEV). As mentioned previously, the life of the battery is the biggest disadvantage of the electric vehicle and by charging the batteries on board, this disadvantage is eliminated. The control strategy, which causes the engine to run at a constant torque and speed, is also supposed to ensure that the battery remains charged to a certain level at all time. Hence, the control strategy for the series hybrid and for that matter any type of hybrid is very complex.

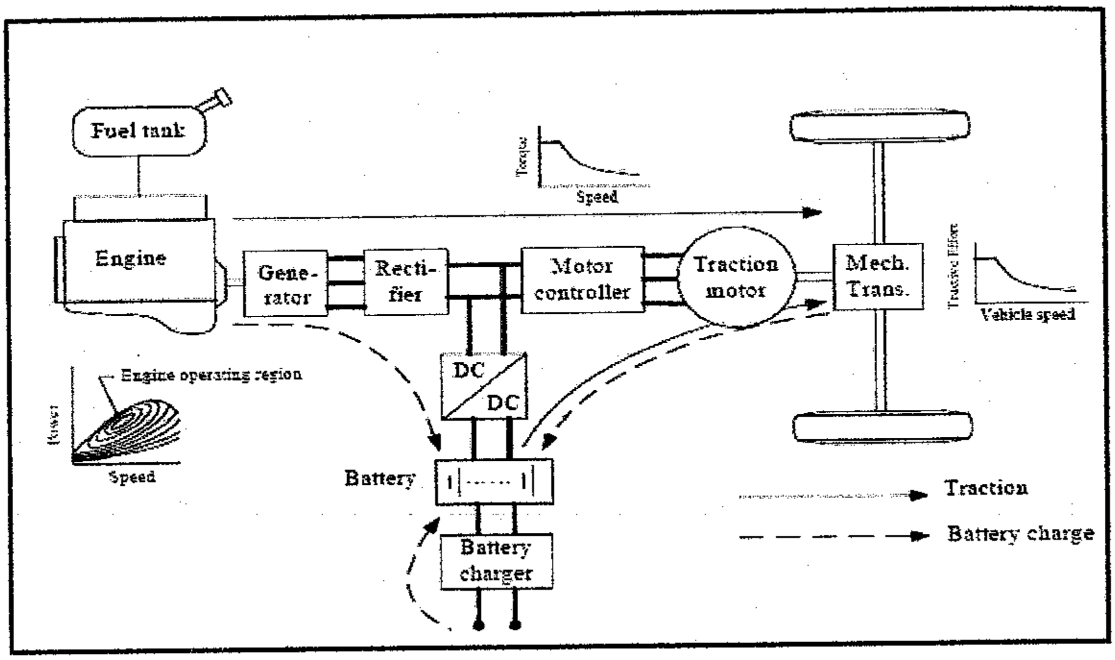


Figure 5: Control System of SHEV [7]

For the working prototype, the vehicle's systems concentrate on the electrical drive. The vehicle features:

- Start and stop
- Move forward and reverse
- Vehicle speed control
- Braking system (Regenerative Braking)
- Charge and discharge of the battery

3.2 Control strategy

The control strategy is controlled by various controllers, depending on input gives by the driver. Purpose of a good control strategy is to give optimal performances of the vehicle. In this project, the researcher concentrated on the control strategy of traction motor and battery

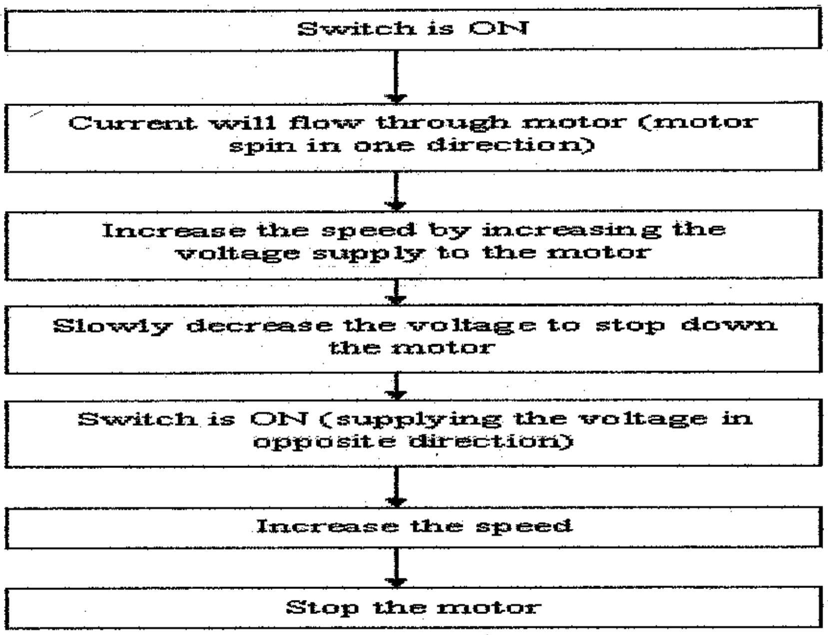
3.2.1 Traction motor

Motor used in this project is the 12V DC motor. The advantages of using DC motor:

- The power from battery is available in direct current form
- DC can be control by controlling the field and armature circuit by various way
- It is easier to supply DC source to the motor since the battery that are supplying the power source is in DC.
- Easier to control due to linearity
- It is cheaper and easier to obtained high field strength.
- The torque-speed characteristic of the motor is suitable. It has high torque at near zero speed. The torque then falls off as speed increases but the power will remain constant
- Easier to operate the motor as generator in regenerative braking.

For start and stop control, the vehicle depend on input demand of the driver. Switches on and off controlled the supply voltage being supplied to the DC motor. For forward and reverse movement, input demand by the driver will be controlled by polarity of supply voltage. By reversing the polarity, the motor can move in opposite direction. In controlling speed of the motor, variable resistor being insert into the circuit to control the armature voltage supply to the motor. Speed of the vehicle being controlled by varying armature voltage of the motor.

The flowchart of motor control system is as follow:

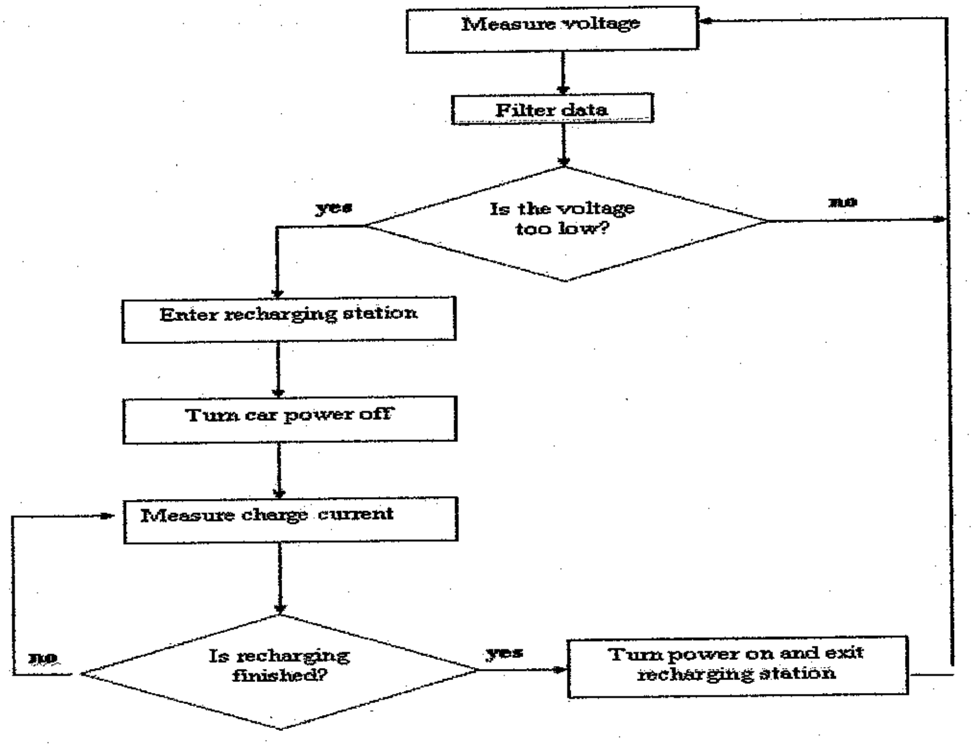


3.2.2 Battery

Battery used in providing power to the vehicle is a rechargeable sealed lead acid battery, 12V, 1.3Ah. Choice made was due to the ability of the battery to recharge, which is one of the features of the vehicle.

The battery is the oldest type of galvanize battery. Even though the battery is the second lowest energy-to-weight ratio, but corresponding to their low energy-to-volume ratio, the battery has the ability to supply high surge currents so that the cells maintain a relatively large power-to-weight ratio. Besides their low cost, it is also ideal for use the battery in cars, as they aptly provide the high current required by automobile starter motors.

The flowchart of battery control system is as follow:



For this project, the choice was made due to:

1. Inexpensive and simple to manufacture.
2. Mature, reliable and well-understood technology - when used correctly, lead-acid is durable and provides dependable service.
3. The self-discharge is among the lowest of rechargeable battery systems.
4. Low maintenance requirements - no memory; no electrolyte to fill on sealed version.
5. Capable of high discharge rates.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Motor controller circuit

Motor controller circuits will be as follows:

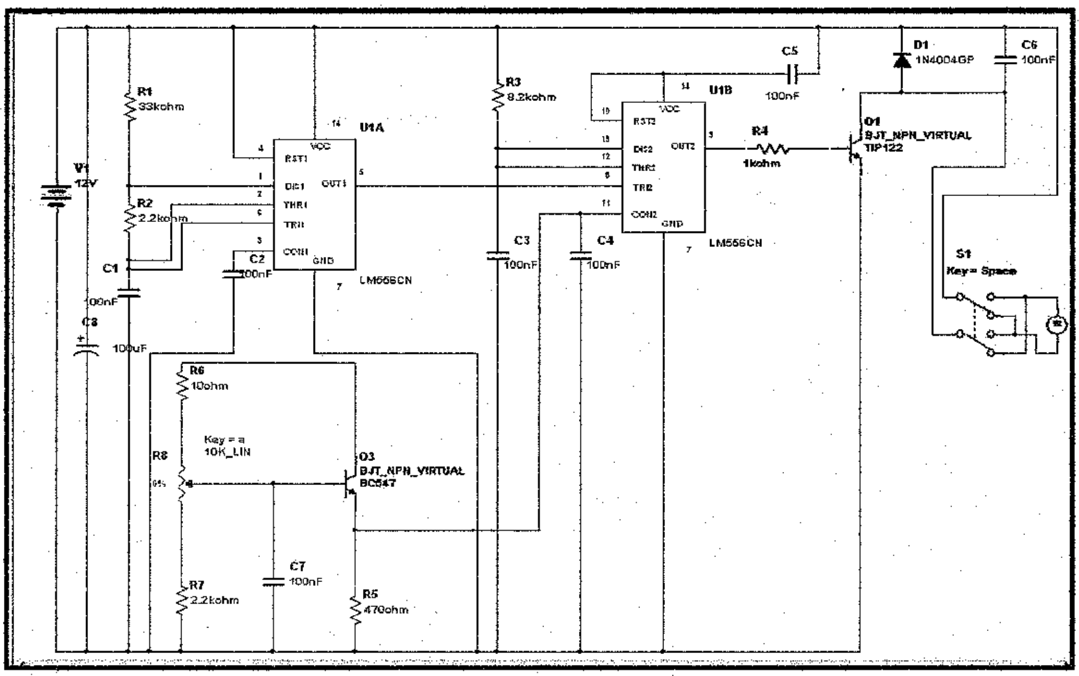


Figure 6: Motor controller circuit

The circuit uses two timer/oscillators connected as a Pulse Width Modulator. The chip used is an nmos dual timer/oscillator, NE556. This IC has two 555 timers in one 14-pin IC package. One 555 (IC1:B) is configured as an astable oscillator. The output frequency of the trigger pulses is given by:

$$f = 1.44 / ((R3 + 2R4) C2), \text{ or about } 410Hz.$$

The time period for the high output is given by

T_{HIGH} = 0.69 (R3 + R4) C2 seconds.

The low output by TLOW = 0.69R4C2 seconds.

The second 555 (IC1: A) is configured for Pulse Width Modulation. It is setup in monostable mode.

It is triggered with the continuous pulse train from the first 555. However, by also applying a DC voltage to pin 3 the comparator reference levels will be changed from their nominal levels of one-third & two-thirds of the supply voltage. This has the effect of modulating the pulse width as the control voltage varies. The control voltage is supplied via transistor Q1, which is configured as an emitter-follower.

The output from the timer is a continuous stream of pulses whose width is controlled by the voltage level applied to the control voltage input. This modulated output drives a power Darlington transistor, Q2, which is used to switch the voltage to the DC motor.

The maximum ON time of the output pulse, and therefore maximum motor speed, can be set by changing the value of resistor R1. Increasing the value lowers the maximum motor speed. The end stop resistor R1 may be replaced by a link if desired.

To change the rotation of the motor in forward or reverse position, just by changing the toggle switch. Before changing the direction, it is important to make sure that the supply voltage is zero to the motor in order to prevent overheat of the motor's winding. The value of voltage can be set to zero by varying the rv1 (potentiometer to the 0%).

After constructing the circuit, the researcher observed that the circuit manages to perform start/stop and forward/reverse feature. The dual directional toggle switch able to rotate the traction motor in opposite direction. But, there also a problem with a supply voltage to the motor where the voltages supply was insufficient enough to turn the motor in even in low speed. The researcher found out that there was a voltages drop being measured at S1 was 0.342V where the operating voltage of the motor in the other hand was 12V. This showed there was a large drop at the Q1.

4.2 Battery monitoring circuit

In order to evaluate condition of the battery, the researcher has included a battery monitoring circuit. The purpose of this circuit is to monitor battery condition as well as remind the user to charge the battery. It is quite a crucial part since the propulsion system is depending on the electric motor and the electric motor is powered up by the battery. So, a proper system for monitoring the battery is needed. Figure below shows the LED battery monitor for 12V system implemented in the project.

Figure below shows the LED battery monitor for 12V system implemented in the project:

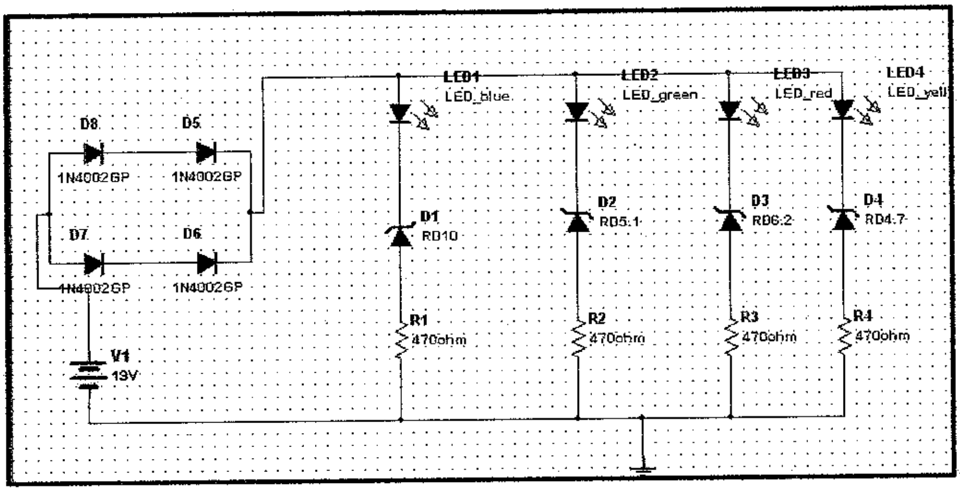


Figure 7: Battery monitoring circuit

The circuit function is to monitor the battery condition. It consists of 4 1N4002 diode connected in such ways to prevent the risk of damaging battery if connected with incorrect polarity. 4 different type of LED color used to indicate the value of voltages stored in the battery. The LED is connected in series with zener diode and 470 ohm zener diode and parallel with different diode color. D1-D4 zener diode is a zener voltage diode. It has different value of voltage that used to limit the voltage value in each line.

The circuit will work as follows:

1. D4 light up = 9V (poor battery condition)
2. D1 & D2 = 11V (doubtful value)
3. D1, D2, &D3 = 13V (fine)
4. D4 flashing = Over voltage value

4.3 Battery charging circuit

Since battery is the power source for vehicle propulsion, the researcher needs to consider the charging circuit for battery. The charger should be portable.

Figure below shows the charging circuit for 12V battery. The researcher did not manage to simulate the circuit due to lack of components.

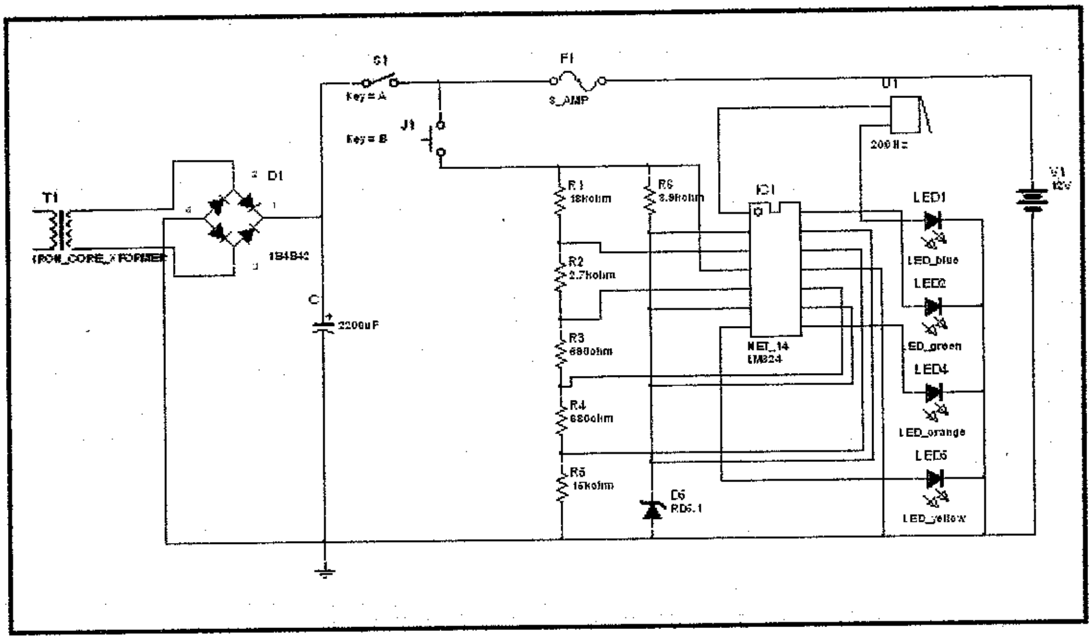


Figure 8: Battery charging circuit

The circuit constructed can replenish the charge in 8-9 hours. It also has a voltage analyzer circuit to analyze the performance of the battery before start of charging. The voltage analyzer gives audio-visual indication of the battery voltage level and also warns about the critical voltage level at which the battery requires immediate charging.

The charger circuit consists of standard step down 12V transformer and bridge rectifier to convert the ac supply to dc supply.

The battery analyzer circuit comprising the LM324 that has 4 separate op-amps with differential inputs. The op-amp acts as a comparator.

S2 is a pushbutton, which is pressed momentarily to check the battery voltage before charging the battery. When the circuit is connected to the battery and push switch S2 is pressed (with S1 open), the battery voltage is sampled by the analyzer circuit. The results give as follows:

Battery Voltage	LEDs status				Comments
	RED	GREEN	YELLOW	ORANGE	
<9.8V	Off	Off	Off	Off	Buzzer off
>9.8V	On	Off	Off	Off	Danger level
11.5V	On	On	Off	off	Low level
12.0V	On	On	On	Off	Normal level
12.5V	On	On	On	On	High level

Table 1: Condition of the battery

The overall vehicle layout is given as follows:

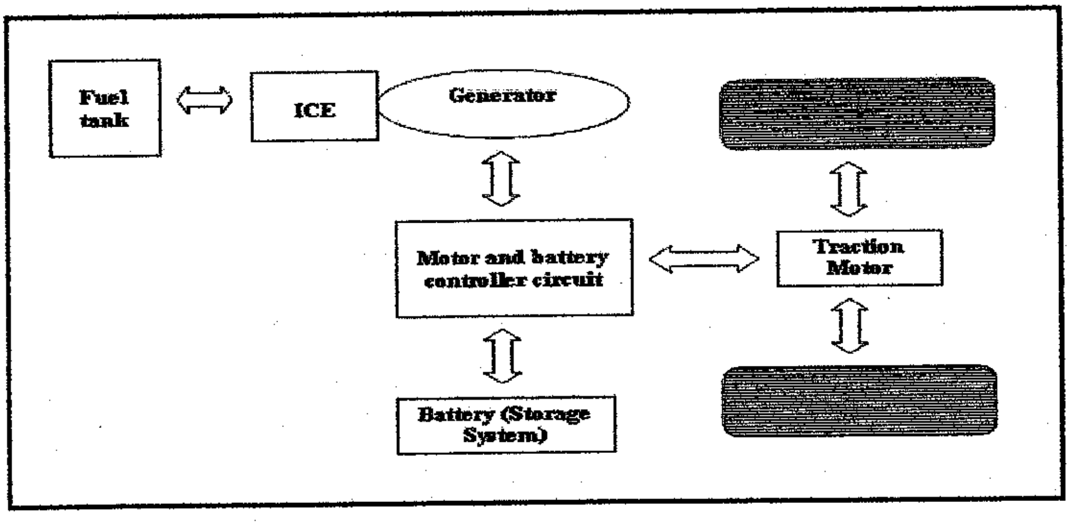


Figure 9: Overall vehicle layout [8]

The concentrated part was motor and battery controller circuit. Traction motor used is 12V DC motor and battery used was 12V sealed lead acid battery. For the second power source (ICE and generator), the researcher did not manage to finish it since lack of time and money.

There are other control element available and can be designed in this project such as indicating devices for movement indication devices by using LED or pilot lamp. There are also available various DC motor speed control such as power switching regulator IC, controller using PIC, and many more.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

There were three (3) objectives of this project, to understand Hybrid Electric Vehicle (HEV), determining the parameters and designing the hardware. When understanding about the HEV system, initial chapter explained the system in detailed. Then, when choosing the system to be implemented, the researcher chooses to design series HEV. The system actually is a complex system, having more components compared to conventional and electric vehicle.

During identifying and designing the parameters, it involved deciding how the vehicle's control system to be performs. Due to lack of time and budget, the researcher only concentrates on the electrical part only, that was electric traction motor and storage system (in this project, it was battery).

In designing the vehicle, motor used was 12V DC motor and battery implemented was 12V sealed lead acid battery. For the traction motor, the parameters being controlled were the supply voltage to the motor (armature voltage) in order to control start, stop and movement of the vehicle (either in forward or reverse direction) and also the speed of the vehicle.

Overall, in series HEV, there are 2 propulsion system used, the traction motor and ICE. During operation, only traction motor being used to propel the vehicle. ICE is used to provide electricity to be stored in the battery storage system. All the system already explained in details.

5.2 Recommendations

As explained in previous chapter, there are various ways to design the system. In this project, the researcher managed to touch on electrical part only. For the future works, here some recommendations can be made:

- Include the regenerative braking to the system. This is one of important features the vehicle have. Due to lack of components, budget and time, this feature did not include.
- In order to optimize the energy used by the vehicle, energy management system can be included to this present design.
- For future works also, in order to complete the system, the ICE and generator part should be include. Then the system will works as being stated.
- The design can have additional sets of equations that can be used for optimization reasons, like optimization of cost, power density amongst other things

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APPENDICES

Gantt chart for Final Year Project 1 (Semester July 2006)

tailed / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
pic assignment/propose	■	■												
liminary research works			■	■										
roduction about the topic				■	■									
ntifying the requirements of various control tem of the vehicle					■	■								
stem modeling						■	■							
nulation/Laboratory work								■	■	■				
afting Interim report									■	■	■	■		
al presentation													■	
omission Interim Report														■

APPENDIX 2-1

Milestone for the First Semester of 2 Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■													
	-Propose Topic														
	-Topic assigned to students														
2	Preliminary Research Work		■	■											
	-Introduction														
	-Objective														
	-List of references/literature														
	-Project planning														
3	Submission of Preliminary Report			●											
4	Project Work				■	■	■	■							
	-Reference/Literature														
	-Practical/Laboratory Work														
5	Submission of Progress Report								●						
6	Project work continue								■	■	■	■			
	-Practical/Laboratory Work														
7	Submission of Interim Report Final Draft												●		
8	Oral Presentation													●	
9	Submission of Interim Report														●

● Suggested milestone

■ Process

FAIRCHILD
SEMICONDUCTOR™

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LM556/NE556

Dual Timer

Features

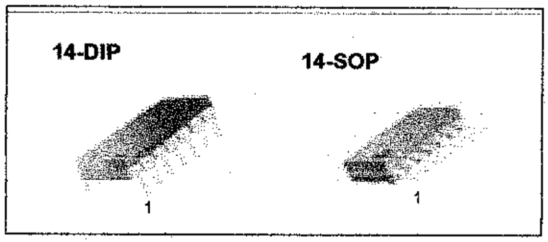
- Replaces Two LM555/NE556 Timers
- Operates in Both Astable And Monostable Modes
- High Output Current
- TTL Compatible
- Timing From Microsecond To Hours
- Adjustable Duty Cycle
- Temperature Stability Of 0.005% Per °C

Applications

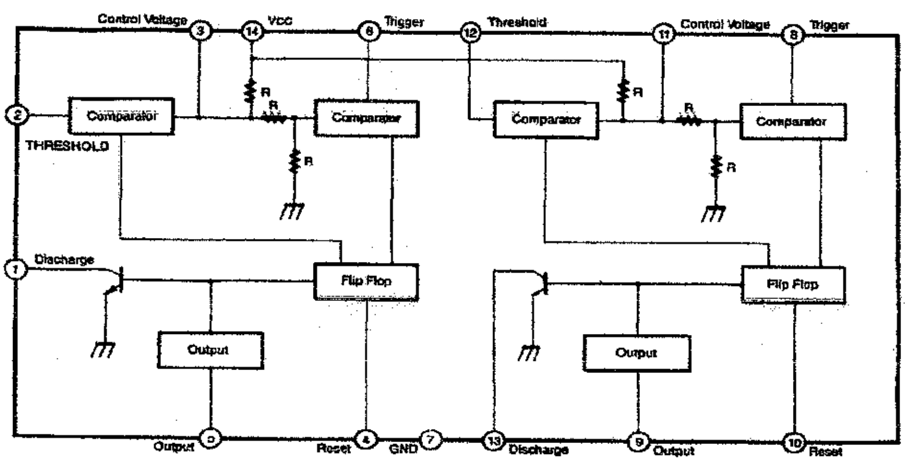
- Precision Timing
- Pulse Shaping
- Pulse Width Modulation
- Frequency Division
- Traffic Light Control
- Sequential Timing
- Pulse Generator
- Time Delay Generator
- Touch Tone Encoder
- Tone Burst Generator

Description

The LM556/NE556 series dual monolithic timing circuits are a highly stable controller capable of producing accurate time delays or oscillation. The LM556/NE556 is a dual LM555. Timing is provided an external resistor and capacitor for each timing function. The two timers operate independently of each other, sharing only V_{CC} and ground. The circuits may be triggered and reset on falling waveforms. The output structures may sink or source 200mA.



Internal Block Diagram



Rev. 1.0.0

Absolute Maximum Ratings (T_A = 25°C)

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC}	16	V
Lead Temperature (soldering 10sec)	T_{LEAD}	300	°C
Power Dissipation	P_D	600	mW
Operating Temperature Range LM556/NE556	T_{OPR}	0 ~ + 70	°C
Storage Temperature Range	T_{STG}	- 65 ~ + 150	°C

Electrical Characteristics

(T_A = 25°C, V_{CC} = 5 ~ 15V, unless otherwise specified)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Supply Voltage	V_{CC}	-	4.5	-	16	V
Supply Current *1(two timers) (low state)	I_{CC}	V_{CC} = 5V, R_L = ∞ V_{CC} = 15V, R_L = ∞	-	5 16	12 30	mA mA
Timing Error *2(monostable) Initial Accuracy Drift with Temperature Drift with Supply Voltage	 ACCUR Δt/ΔT Δt/ΔV_{CC}	 R_A = 2KΩ to 100KΩ C = 0.1μF T = 1.1RC	-	 0.75 50 0.1	-	 % ppm/°C %/V
Control Voltage	V_C	V_{CC} = 15V	9.0	10.0	11.0	V
		V_{CC} = 5V	2.6	3.33	4.0	V
Threshold Voltage	V_{TH}	V_{CC} = 15V	8.8	10.0	11.2	V
		V_{CC} = 5V	2.4	3.33	4.2	V
Threshold Current*3	I_{TH}	-	-	30	250	nA
Trigger Voltage	V_{TR}	V_{CC} = 15V	4.5	5.0	5.6	V
		V_{CC} = 5V	1.1	1.6	2.2	V
Trigger Current	I_{TR}	V_{TR} = 0V	-	0.01	2.0	μA
Reset Voltage*5	V_{RST}	-	0.4	0.6	1.0	V
Reset Current	I_{RST}	-	-	0.03	0.6	mA
Low Output Voltage	V_{OL}	V_{CC} = 15V I_{SINK} = 10mA I_{SINK} = 50mA I_{SINK} = 100mA I_{SINK} = 200mA V_{CC} = 5V I_{SINK} = 8mA I_{SINK} = 5mA	-	 0.1 0.4 2.0 2.5 0.25 0.15	 0.25 0.75 3.2 0.35 0.25	V V
High Output Voltage	V_{OH}	V_{CC} = 15V I_{SOURCE} = 200mA I_{SOURCE} = 100mA	 12.75	 12.5 13.3	-	V
		V_{CC} = 5V I_{SOURCE} = 100mA	 2.75	 3.3	-	V
Rise Time of Output	t_R	-	-	100	300	ns
Fall Time of Output	t_F	-	-	100	300	ns
Discharge Leakage Current	I_{LKG}	-	-	10	100	nA
Matching Characteristics*4 Initial Accuracy Drift with Temperature Drfit with Supply Voltage	 ACCUR Δt/ΔT Δt/ΔV_{CC}	-	-	 1.0 10 0.2	 2.0 0.5	 % ppm/°C %/V
Timing Error (astable)*2 Initial Accuracy Drift with Temperature Drift with Supply Voltage	 ACCUR Δt/ΔT Δt/ΔVcc	 V_{CC} = 15V R_A,R_B = 1KΩ to 100KΩ C = 0.1μF	-	 2.25 150 0.3	-	 % ppm/°C %/V

Notes:

*1. Supply current when output is high is typically 1.0mA less at V_{CC} = 5V

*2. Tested at V_{CC} = 5V and V_{CC} = 15V

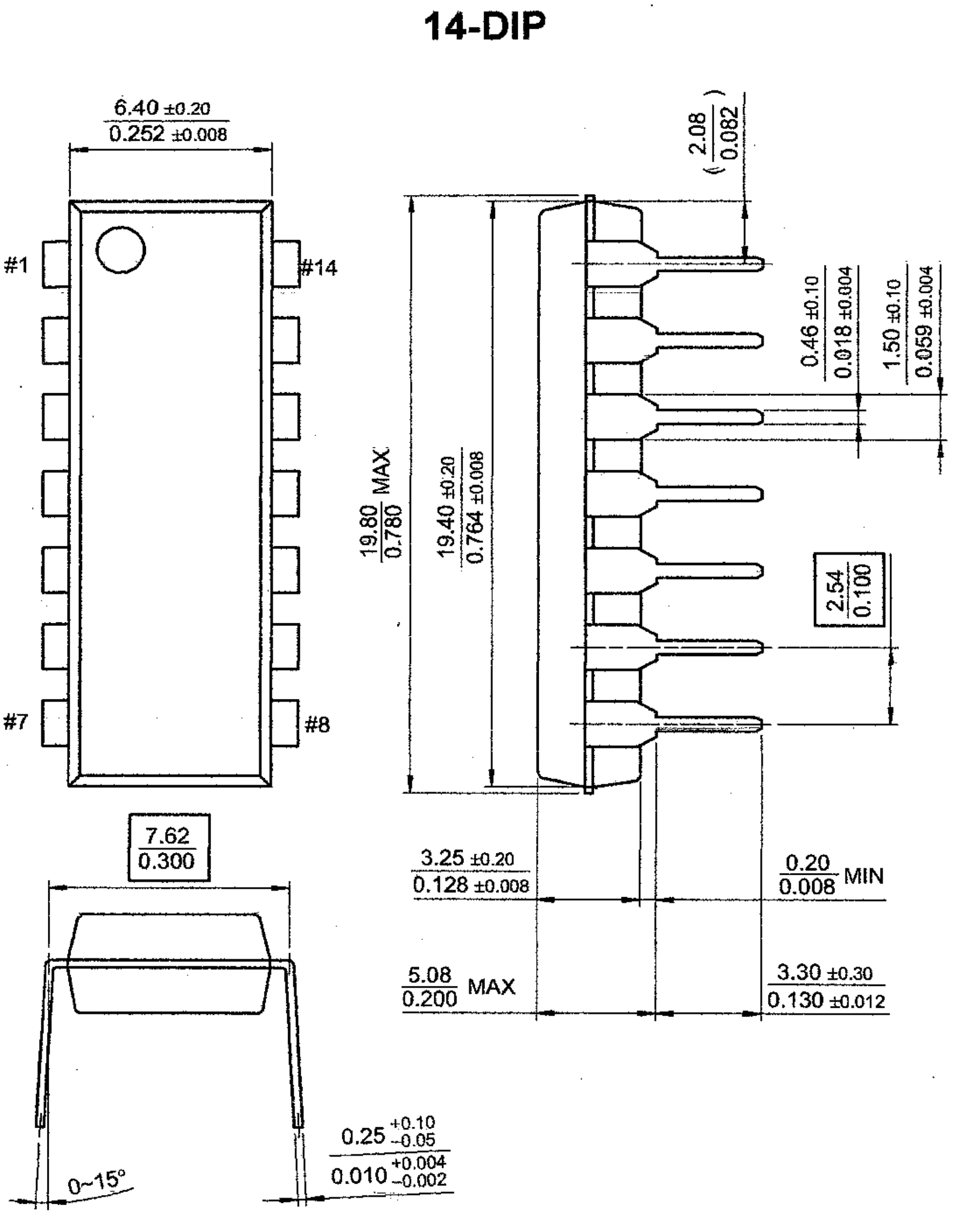
*3. This will determine the maximum value of R_A + R_B for 15V operation.
The maximum total R = 20MΩ, and for 5V operation the maximum total R = 6.6MΩ.

*4. Matching characteristics refer to the difference between performance characteristics of each timer section in the monostable mode.

*5. As reset voltage lowers, timing is inhibited and then the output goes low.

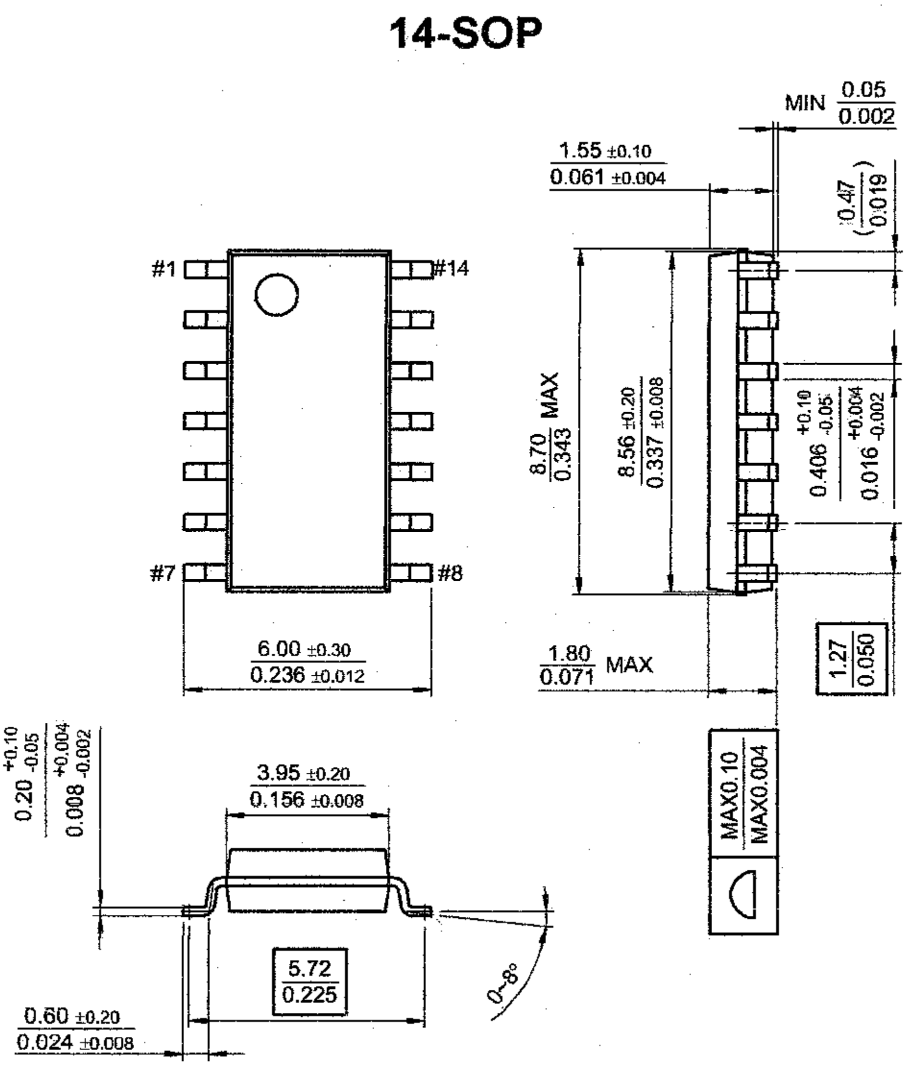
Mechanical Dimensions

Package



Mechanical Dimensions (Continued)

Package



Ordering Information

Product Number	Package	Operating Temperature
LM556CN	14-DIP	0 ~ + 70°C
LM556CM	14-SOP	
NE556	14-DIP	
NE556D	14-SOP	

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2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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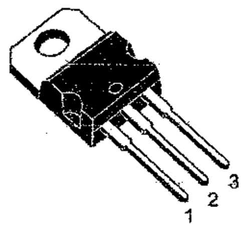
TIP120/121/122
TIP125/126/127

COMPLEMENTARY SILICON POWER DARLINGTON TRANSISTORS

- STMicroelectronics PREFERRED SALESTYPES

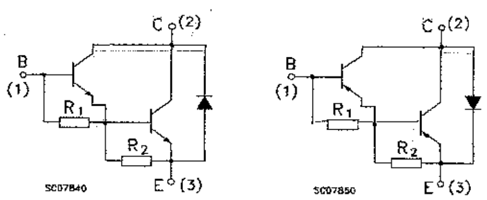
DESCRIPTION

The TIP120, TIP121 and TIP122 are silicon Epitaxial-Base NPN power transistors in monolithic Darlington configuration mounted in Jedec TO-220 plastic package. They are intented for use in power linear and switching applications. The complementary PNP types are TIP125, TIP126 and TIP127, respectively.



TO-220

INTERNAL SCHEMATIC DIAGRAM



R_1 Typ. = 5 KΩ R_2 Typ. = 150 Ω

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter		Value			Unit
		NPN	TIP120	TIP121	TIP122	
		PNP	TIP125	TIP126	TIP127	
V_{CBO}	Collector-Base Voltage ($I_E = 0$)		60	80	100	V
V_{CEO}	Collector-Emitter Voltage ($I_B = 0$)		60	80	100	V
V_{EBO}	Emitter-Base Voltage ($I_C = 0$)		5			V
I_C	Collector Current		5			A
I_{CM}	Collector Peak Current		8			A
I_B	Base Current		0.1			A
P_{tot}	Total Dissipation at $T_{case} \leq 25$ °C $T_{amb} \leq 25$ °C		65 2			W W
T_{stg}	Storage Temperature		-65 to 150			°C
T_j	Max. Operating Junction Temperature		150			°C

* For PNP types voltage and current values are negative.

THERMAL DATA

$R_{thj-case}$	Thermal Resistance Junction-case	Max	1.92	°C/W
$R_{thj-amb}$	Thermal Resistance Junction-ambient	Max	62.5	°C/W

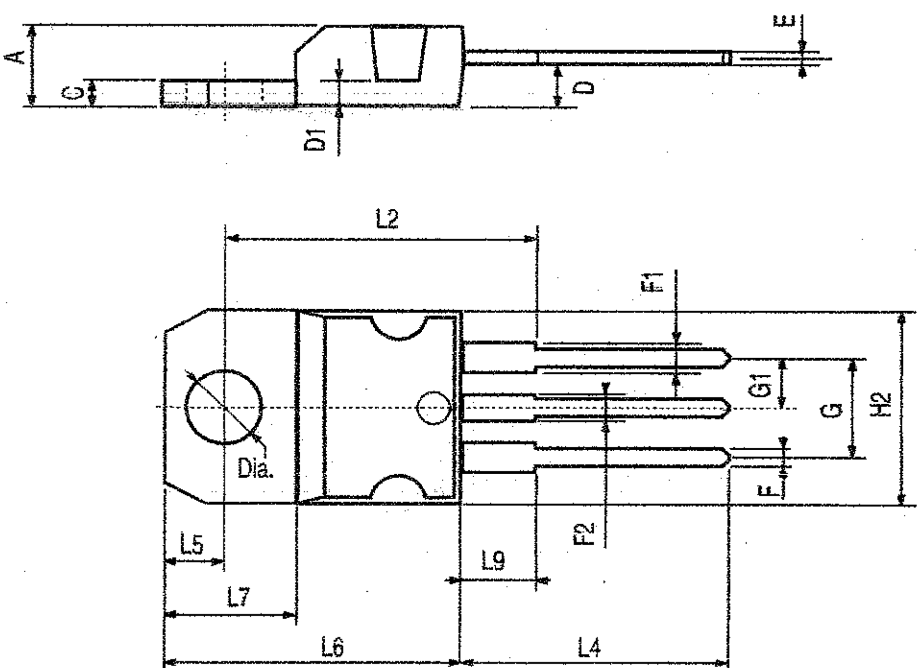
ELECTRICAL CHARACTERISTICS (T_{case} = 25 °C unless otherwise specified)

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
I_{CEO}	Collector Cut-off Current (I_B = 0)	for **TIP120/125** for **TIP121/126** for **TIP122/127**	V_{CE} = 30 V V_{CE} = 40 V V_{CE} = 50 V			0.5 0.5 0.5	mA mA mA
I_{CBO}	Collector Cut-off Current (I_B = 0)	for **TIP120/125** for **TIP121/126** for **TIP122/127**	V_{CB} = 60 V V_{CB} = 80 V V_{CB} = 100 V			0.2 0.2 0.2	mA mA mA
I_{EBO}	Emitter Cut-off Current (I_C = 0)	V_{EB} = 5 V				2	mA
$V_{CEO(sus)}$*	Collector-Emitter Sustaining Voltage (I_B = 0)	I_C = 30 mA for **TIP120/125** for **TIP121/126** for **TIP122/127**		 60 80 100			 V V V
$V_{CE(sat)}$*	Collector-Emitter Saturation Voltage	I_C = 3 A I_C = 5 A	I_B = 12 mA I_B = 20 mA			2 4	V V
$V_{BE(on)}$*	Base-Emitter Voltage	I_C = 3 A	V_{CE} = 3 V			2.5	V
h_{FE}*	DC Current Gain	I_C = 0.5 A I_C = 3 A	V_{CE} = 3 V V_{CE} = 3 V	1000 1000			

* Pulsed: Pulse duration = 300 μs, duty cycle < 2 %
For PNP types voltage and current values are negative.

TO-220 MECHANICAL DATA

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	4.40		4.60	0.173		0.181
C	1.23		1.32	0.048		0.051
D	2.40		2.72	0.094		0.107
D1		1.27			0.050	
E	0.49		0.70	0.019		0.027
F	0.61		0.88	0.024		0.034
F1	1.14		1.70	0.044		0.067
F2	1.14		1.70	0.044		0.067
G	4.95		5.15	0.194		0.203
G1	2.4		2.7	0.094		0.106
H2	10.0		10.40	0.393		0.409
L2		16.4			0.645	
L4	13.0		14.0	0.511		0.551
L5	2.65		2.95	0.104		0.116
L6	15.25		15.75	0.600		0.620
L7	6.2		6.6	0.244		0.260
L9	3.5		3.93	0.137		0.154
DIA.	3.75		3.85	0.147		0.151



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