Mobile Robot (Structure, Sensor Unit and Motor Drive)

by

Mohd Azrin Bin Ishak (3367)

Dissertation report submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

DECEMBER 2006

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Mobile Robot (Structure, Sensor Unit and Motor Drive)

by

Mohd Azrin Bin Ishak (3367)

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL & ELECTRONICS ENGINEERING)

Approved by,

____
(ASSOC PROF DR MOHD NOH B KARSITI)
Project Supervisor
Head Programme
Electrical and Electronics Engineering

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR
31750 TRONOH, PERAK

DECEMBER 2006

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.

MOHD AZRIN BIN ISHAK

ACKNOWLEDGEMENT

In the name of Allah, the Merciful.

Most gratitude to my supervisor of this project, Dr. Mohd Noh Karsiti for allowing me to do a Final Year project under his supervision. He has managed to support and gives meaningful and useful advices which are the keys factor of finishing the project within the specific timeframe even with a tight time schedule. I believe the project will not have been finished without his effort to guide and supervise me.

Also my special thanks to Ms Nasreen, the coordinator of Final Year project and also her committee. Without their management and coordination, the flow of this project might not be as expected.

I would like to give my appreciation and thank to Ms Siti Hawa who has given me technical support as a lab technician. She has been helpful to lend me the apparatus of electrical and electronics parts like power supply, oscilloscope and digital multimeter which are very meaningful for me to complete the project within the timeframe.

Very special thank to Mr. Isnani for giving his permission to use the laboratory to complete the structure of this project. Also he was the man that helps me in producing Printed Circuit Board (PCB).

Lastly, my utmost gratitude to my father Mr. Ishak Mohamed Tahar and my mother Mrs. Azlina Mustafa who has help me in many ways. Only God may repay them. Also my special thank to my partner, Mr. Wan Mohd Ariff Wan Nordin who also helped me in doing some part that I faced problem. Not to forget also to all my friends and others who have help in the project directly or indirectly.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

A Mobile Robot is developed to detect and avoid obstacles during its navigation from one point to another point. The Mobile Robot system is composed of 5 (five) main parts, which is structure / mechanical part, to do the mechanical part of the robot; sensor unit part, to detect and send the received signal to the controller part; motor drive part, to navigate the robot; controller part, acts as a brain of the robot to control all action taken by the robot; and power supply part, which is used to power up the entire system of the robot. This project has been assigned to two students so that the scope of works can be divided into hardware and software implementation. This report will concentrate on the hardware implementation part including all the circuits used for the system of the robot. The methods used in this project are literature review, research via the internet and books, simulation by using certain software and testing the robot system. The model then is built and its motive is to find its own path and avoid collision in the designed maze.

CHAPTER 1
INTRODUCTION

1.1 Background of the Project

Mobile robot can be defined as a robot that can autonomously self move or navigate from one location to another location, whether it is physically small or large. In order to complete the robot system successfully, the basic knowledge of programming and hardware implementation experience are important. Besides, the study about the new knowledge which is artificial intelligent, fuzzy logic, neural networks, research about ultrasonic, H Bridge circuit and components needed in the circuits are also leading to successfully of the project.

The robot consists of 5 (five) major parts as follows:

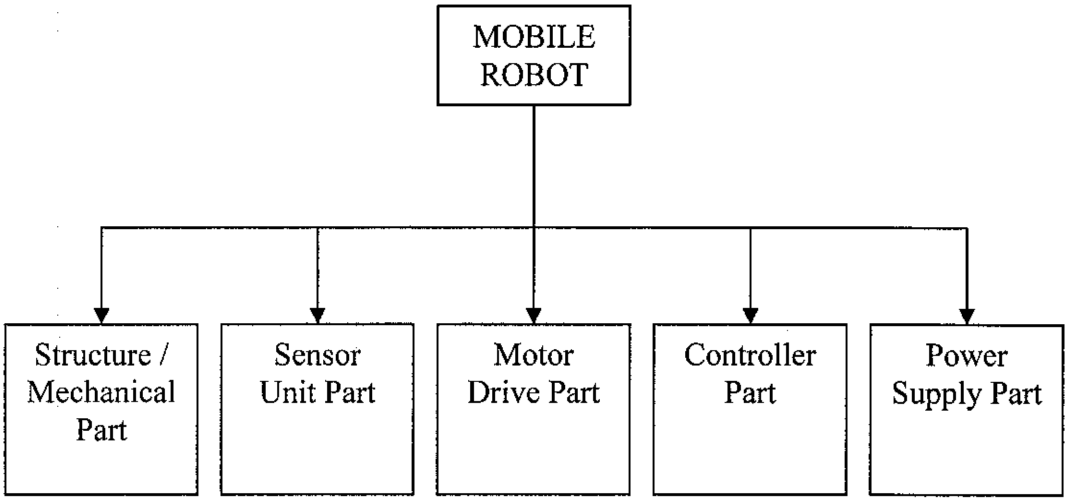


Figure 1: Mobile Robot Major Parts

The structure / mechanical part generally is functioning to give a good structure or platform for the robot so that the robot is in stable condition. The mechanical part will be dealing with how the robot is connected between the tires and the DC Motors used in order to make the robot can navigate. The shaped and the material used for the structure also will make sense to make the robot can navigate from one point to another point.

The sensor unit part is function as a detector, which is to detect or sense any obstacles that it may face and send its detection signal to the Controller part. The controller will instruct the DC Motors the necessary action based on its program depending on which sensor is triggered. The amount of sensors also needs to be taken into consideration to make the robot responses successfully to its surrounding. The type of sensors used for the robot need to be determined whether to use ultrasonic or infra red sensor.

The motor drive part is function to drive the DC Motors used so that the robot could navigate from one point to another point. The movement of the robot, weather to move forward, to move backward, to turn right, or to turn left will be controlled by the function of H Bridge. The controller will give the input to the H Bridge based on the sensor triggered so that the H Bridge can do the necessary action weather to move forward, to move backward or even stop the robot from moving.

The controller part is the brain of the robot. All the action taken by the robot will be controlled by this controller. The controller will take input from the sensors, process it and produce the output to the DC Motors so that the robot will response based on what is told by the controller. There are many controllers available in the market and the microcontroller should be chosen based on cost, speed of operation and easy to use.

The power supply part functioned to power up the entire system of the robot. All the circuits need to be power ON so that all the systems integrated in the robot should function properly. This can be done by using Sealed Lead Acid (SLA) battery or 9 V batteries. The 5 V voltage regulators also are needed due to all the digital values need 5 V to be operated.

1.2 Problem Statement

Nowadays there are many robots are implemented. The development of robotics field has grown very fast in past 10 years and they are implemented to do certain job based on their condition. For example, the robot could be used for transportation. In Europe, the mobile robot has been used as transportation in the factory to move small part of components of the big machine. The robot also can be used for surveillance in a certain area.

Besides, the robot also can be used for special task. This could be used for rescue activities. For example, the robot could be used at the war zone to know the situation there weather it is safe or still in the unsafe condition. The robot also can be used at disaster area. For example, after earthquake disaster, there are plenty of people trapped under the fallen building and this robot can be sent to that area to monitor weather there is still life person or not.

1.3 Significant of the Project

In order to complete the mobile robot, there are many new things and new knowledge will be dealt with especially the fuzzy logic, neural networks, and sensory system. Indirectly, this project acts as the research for the future development of making a new mobile robot with more efficient and innovative.

There are a lot of other universities that is doing research on robotics. Having an in house design robot will lead to detail understanding of the robot mechanism itself. This study will lead to further detail development and also application on the in house robots. The university can use the research material to compete in robotics competition around the world.

1.4 Objective and Scope of the Study

The Mobile Robot is expected to be autonomously self navigate from one point to another point. The robot should have an artificial intelligence that enables it to response to the environment it faces, detect and avoid any obstacle in its path. The robot also needs to find its own path when it is put in a designed maze. It should plan its own path when it is put in the designed maze and avoid collision during its navigation to its final point.

The scope of study for this project will be discussed as followed:

1.4.1 Structure / Mechanical part

The Mobile Robot will need a structure or a platform for its stability and to place any components of the circuit on it. The challenge is to design a platform that is tough so that it can hold heavy load but the material itself is not too much heavy. Heavy weight for the body will lead to more power consumption and heavier on the design for the motor and gearing. The effect maybe come from the shaft of the tires, means that it will cause bend shaft if the load is too much heavy.

1.4.2. Sensor Unit part

Sensors are transducers that can be used to measure some parameters of the surrounding. This information will be then fed to the controller to be executed to check for some event that will trigger another event. This is a way for the robot to see its surrounding. There are many type of sensors but the common one is ultrasonic and infra red sensors. The difference of these types of sensors is the medium that it used to propagate, weather it used sound wave to propagate or it used infra red to propagate. Both of them are still using the same frequency, let say 40 kHz.

1.4.3. Motor Drive part

The design will be concentrating on the robot which navigates by using DC Motors and tires. The specifications of the DC Motor depend largely on the type of load that the robot will carry. Besides, the speed of the DC Motor also need to be taken into consideration because if the DC Motor is too fast, the controller cannot take necessary action and the speed need to be controlled by using encoder. These will be the major constraints besides the availability of the component locally. The drive circuit also is needed to control the current and voltage supplied to the DC Motor and to determine the rotation of the DC Motor.

1.4.4. Controller part

Controller acts as the brain of the robot. This will be the component that will decide what to do in conjunction of some event detected by the sensors. The controller will be able to make some minor decision which eventually will control the movement of the robot based on its surrounding.

1.4.5. Power Supply part

The power that is being supplied to the all parts of the robot needs to be regulated at a certain value. This will lead to some design on the power system for the robot. As the size of the robot is relatively large a fail save mechanism will be implemented to avoid any hazards to its surrounding. The example of fail safe is the application of fuses.

CHAPTER 2
LITERATURE REVIEW

The research of the robot has been done part by part of the sub component for the robot such as structure or mechanical, sensor unit, motor drive, controller and power supply part. This section will cover all these parts in briefly.

2.1 Structure / Mechanical Part

In term of this project, structure can be defined as a platform that can be a place to put all the components of the circuit. Without this structure, the shape of the robot can not be built. There are many shapes and sizes for the structure. The design will depend on the application or the task the robot will do. For example the robot that will be needed to put into disaster area, it needs to be able to withstand the environment, tough enough and also light. The shape can be round or circle which is good for tight spaces. This also is important for the robot to avoid stuck at maybe at a corner so that it can still navigate. The shapes and sizes do not matter as long as the drive motor is sufficient to carry the load. Many robot designers would prefer to use light weight material which is easy to be shaped into the desired shape. Many of the design uses rounded shape as it will give better movement in tight space. Method of connecting these parts will be screw method.

The mechanical part will be dealing with the components connected between tires and DC Motors. These parts could be gear, bearing, coupler and others. Basically gear is needed to slow down or speed up the rotation of the tires when they were connected with the DC Motors. The coupler usually is used to join in two different or same sizes of shafts for example to join in shaft of DC Motor with the shaft of tire.

2.2 Sensor Unit Part

Sensors are transducers which are capable of changing one state of energy to another. This transducer will give output in current or voltage variation. Thus this output can be sent to the other part of the robot so that this information can be used in order to manipulate the movement of the robot.

Ultrasonic sensor is common sensor used in robotics. This type of sensors used high frequency sound burst which is generated at certain frequency. Ultrasonic is sound with a frequency greater than the upper limit of human hearing (upper than 20 kHz). [8] For communication, usually the value of frequency that the ultrasonic used is 40 kHz. That is why many types of transducer used 40 kHz as medium of frequency. Actually the working principle of the ultrasonic is simple. There are two transducers. The first one is used for transmitting the signal and the second one is used for receiving the signal. The transmitter will transmit the signal at certain frequency (ultrasonic sound frequency). This signal will be bounced back if it hit an object. The bounced echo will be then picked up by ultrasonic receiver which will give the signal to a set of amplifiers and finally converted to digital signal by means of comparator or other method. The output from the ultrasonic can be use as simple to detect obstacle or to be used as ranging module. In order to use the ultrasonic as a ranging module the output of the receiver needs to be connected to an analogue to digital converter which is fed to controller. The controller can then determine the range based on the voltage value on its input.

The advantage of using sound is that it is not sensitive to objects of different colour and light reflective properties. Keep in mind, however that some material reflect sound better than others. On the other hand, there is a material absorb sound completely. In the long run or time, I think detection by sound is more fool proof way to go. [1]

2.3 Motor Drive Part

DC motor drives act as an interface between a controller and the motor. The drive must match the control signals (voltage and power levels) and signal type (analogue or digital). The drive produces power conversion, amplification, and sequencing of waveform signals. The types of DC motor drives include adjustable or variable speed control, servo control, and integral motion control. Some drives are capable of delivering adjustable or variable speed control. Important specifications to consider when searching for DC motor drives include considering whether or not a brushless DC motor drive or amplifier is needed.

Important operating specifications to consider when searching for DC motor drives include maximum speed, continuous power, continuous output voltage, maximum continuous output current, and peak output current. The maximum device speed is the speed when the drive is burdened with no external forces, such as weight. The continuous power is the maximum amount of power the device can output continuously. The continuous output voltage is the maximum voltage the device can output continuously. The maximum continuous output current is the maximum current the device can output continuously. Maximum current value may require additional cooling. The peak output current is the peak current the device can output. [9]

Other important features to consider when specifying DC motor drives include PWM switching. PWM or switching drives have an output that is pulse width modulated or switching. An important environmental parameter to consider for DC motor drives is the operating temperature.

The motor must have sufficient torque in order to move the load. This has been the great challenge. The numbers of tires also make senses in determining the required torque for the robot. As to ease of giving mobility, three (3) tires will be used, and two (2) of them will be coupled with dc motors and another one will be let free as a support. These combinations have been tested and prove to be workable.

2.4 Controller Part

There are several controllers that can be used to control a robot. There are many types of microcontroller available in the market such as PIC from Microchip, 68HC11 from Motorola, 8051 from Intel and many more. The difference is in the architecture and the language used. The basic and common controller is PIC. There are a few benefits or advantages by using the PIC microcontroller. They are:

1. Faster speed

   -will run faster depending upon the instructions used

2. Lower cost

   -save cost compared to the other microcontroller

3. PIC Programming Overview

   -simple three step process: write the code, compile the code, and upload the code into the microcontroller.

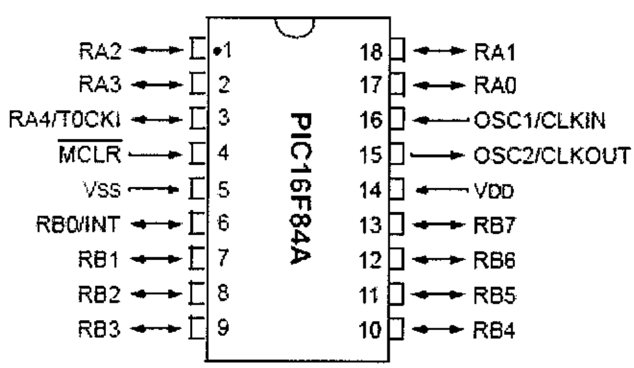


Figure 2 : PIC 16F84 Pin Configurations from Microchip

2.5 Power Supply Part

In many large scale robots, the power of the robot will be supplied by rechargeable batteries. There are many types of batteries which is suitable for robotics. The different is with the material that is used for the batteries and also the value of current that the battery can supply in a specific numbers of periods. The higher value of the current per hour the longer it can supply power to the robot. The drawback is that the batteries will need special care such as a specific way of charging and discharging and also the price is relatively high.

Fail safe is important in robots as it uses a lot of expensive and sensitive components that might get destroy due to surges or short circuit. Fail safe circuit such as circuit breaker needs to be put in place to overcome this. Normally the fail safe feature will be implemented with the voltage and regulator circuit. The circuit will detect any abnormality and decide to break the connection or do some other preventive measure. [2]

Due to the size of the robot is relatively big, another fail safe will be put in place such as remote off. This can avoid any unwanted accident due to the robot malfunction or breakdown. The remote can automatically turn off the robot from a certain distance. [2]

CHAPTER 3

METHODOLOGY

The methodology of the Mobile Robot project is shown in the flow chart below.

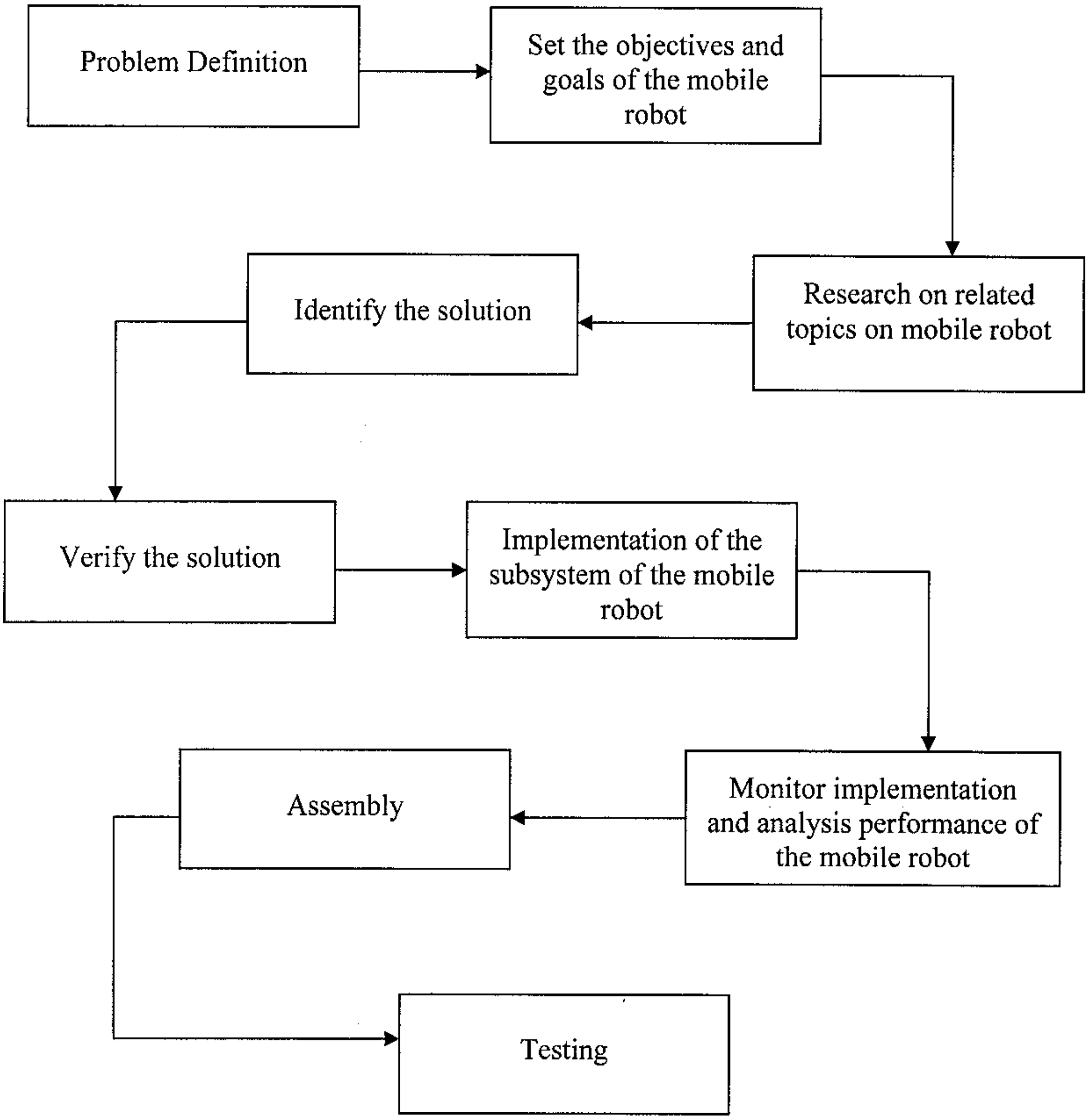


Figure 3 : The Methodology of the Mobile Robot Project

3.1 Tool and Equipment

There are several hardware and software that were used throughout the project accomplishment. Some of the main components are listed as below:

Hardware

- PIC 16F84 and 16F877
- 2 DC Motors
- Ultrasonic sensors
- Power Supply (Sealed Lead Acid)
- Perspex (for platform of the robot)
- Mechanical Components (Tires, gear and bearing)
- Electronic Components (Resistor, capacitor, voltage regulator, etc)

Software

- MPLAB
- Visual Basic
- PSPICE
- MultiSim

3.2 Project Work

The project was done in 5 phase which represented as in Figure 4 below. In order to built a complete mobile robot, there are 5 major tasks was focused on. Under each tasks there are subtasks that was completed before all of them can be attached together.

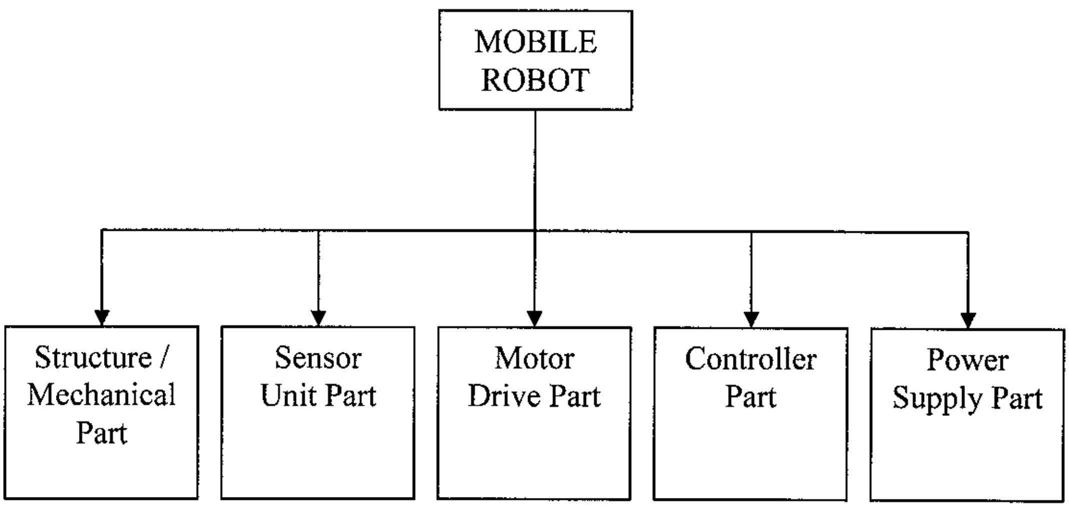


Figure 4 : Subdivision Of Mobile Robot Project

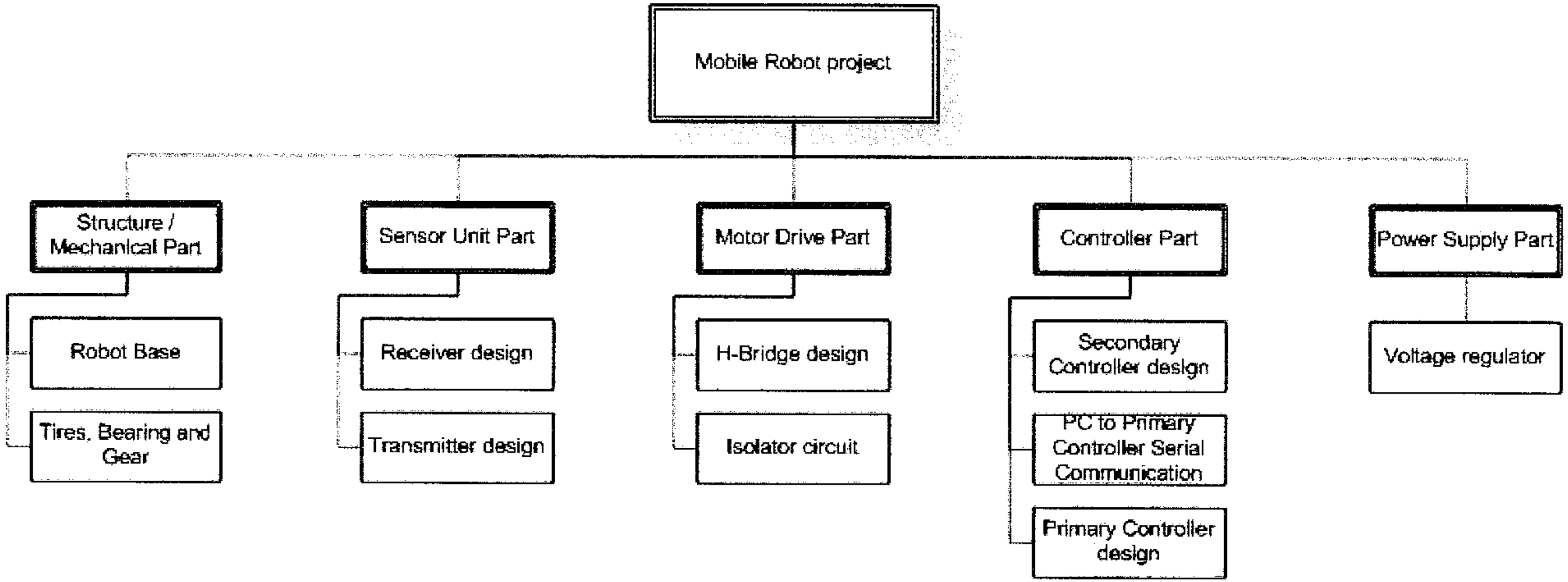


Figure 5 : Work Breakdown Structure for Mobile Robot Project

3.2.1 Structure / Mechanical Part

The structure or platform for the robot is chosen from the material that is not too heavy but can hold heavy load. This is due to the load of the robot is approximately 5 kilogram. So the plastic Perspex is chosen as a material to build a robot platform.

It is good for the Perspex to be thick enough so that it can hold the heavy load caused by the robot. For this constraint, 6 mm thickness of Perspex is chosen and this size is proved workable to hold the load caused by the robot. The shape of the platform itself also had been decided. The shape should be in round or circle so that if this robot suddenly touched the obstacle it faces during its navigation, it still can move and avoid sticking at the obstacle or object. This is due to smooth shaped surface of the Perspex.

The size of the round shaped is chosen to be 140 mm in radius. There are three (3) tires used, two (2) are used at the front of the robot and one (1) is used at the back of the robot. The back tire is used for supporting factor and it can be free move. The caster wheel is used at the back so that it can freely move. The methods used for connecting all components connected to the platform are nuts, screw and thread.

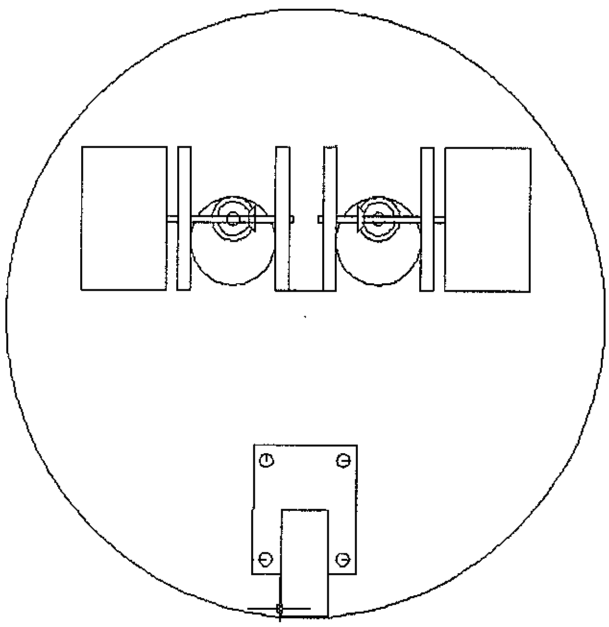


Figure 6 : Top view of the Robot

As shown in the Figure 5 above, the two (2) DC Motors are placed from up to bottom of the platform. Usually the DC Motors are placed in parallel with the platform so that they can be easily connected to the tires. But for this design, the placement of the DC Motors should be in that manner due to too lengthy size of the DC Motors itself, which is around 110 mm. If we want to proceed with the idea of placing DC Motors in parallel with the platform, we need to increase the size of the platform. If the platform is too big, it will cause a problem maybe from the weight of the robot, and also from the power supply. So that is why we put the DC Motors in that position (from up to bottom).

But for this design, we will face problem on how to connect the DC Motors with the tires. So we came out with the idea of using Bevel gear to connect the DC Motor with the tire.

3.2.2 Sensor Unit Part

For the sensor unit part, ultrasonic is chosen as a method to detect the obstacle faced by the robot. The amount of the ultrasonic sensors needed is four (4) and they are placed at the four side of the platform of the robot. The placement of the sensors are positioned at the front, back, right and left of the robot.

As shown in the figure below, there are two methods that have been implemented in the sensor unit part for this robot. The first one is based on amplitude sensitive and the other one is based on frequency sensitive. Amplitude sensitive showed the increased in voltage when the sensor detect or face an object a few centimetres in front of it. The frequency sensitive only received the same value of frequency that it had transmitted. So this is how the sensors detect the object they face and send the signal to the controller.

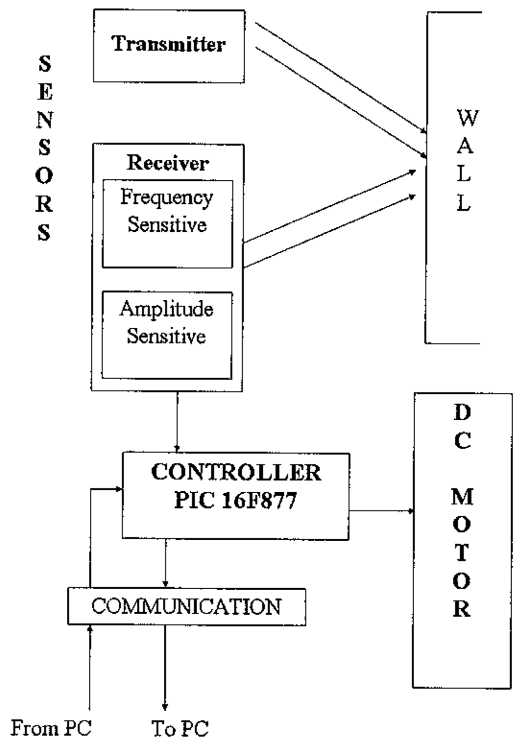


Figure 7 : Block Diagram How the Sensor React

We had decided to use four different frequencies, which are 37 kHz, 39 kHz, 41 kHz and 43 kHz. Thus each sensor only can detect the frequency that it already transmitted. By doing this, we can specifically know which part of obstacle we faced, weather it is coming from front, from back, from left or from right.

3.2.3 Motor Drive Part

Motor drive part consists of DC Motors, tires, gears and bearings. The DC Motor that is used for this project had speed at around 100 rpm. This speed is good for the robot because it is not too fast so that the speed can be controlled by the controller if the controller wants to do necessary action during the navigation. This DC Motor also has high torque so that it can start to move at heavy load.

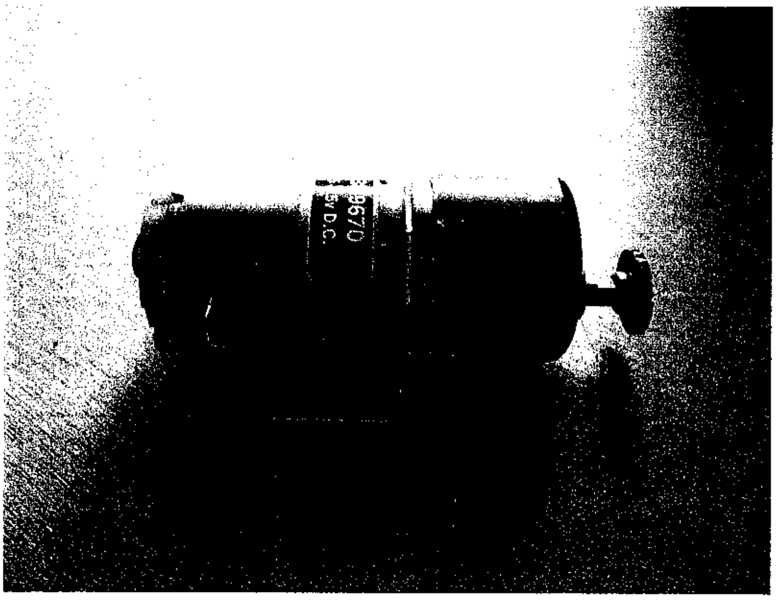


Figure 8 : DC Motor used for the Robot

To connect between shaft of the DC Motor with the shaft of the tire, the Bevel gear is used. This is due to the position of the DC Motor and the tire, which is perpendicular to the each other. The reason why we used this type of gear is due to not same size of shafts, meaning that the size of shaft for DC Motor is not same as the size of shaft of tire. Of course the speed will be slow down because the teeth of the gear is not the same.

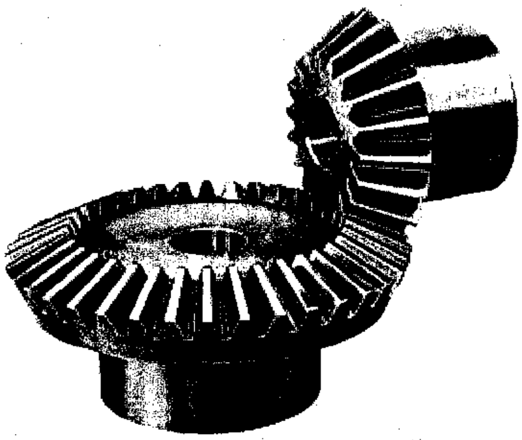


Figure 9 : Bevel Gear

3.2.4 Controller Part

For this controller part, there are two types of controller we used. The first one is PIC16F877, which is a primary controller. This controller is used for controlling the rotation of the DC Motor, weather to go forward, to go backward, to turn left or to turn right. But there is another one controller that we used for this project. We used PIC16F84 as our secondary controller. This controller is used for controlling the transmitted time of the sensors.

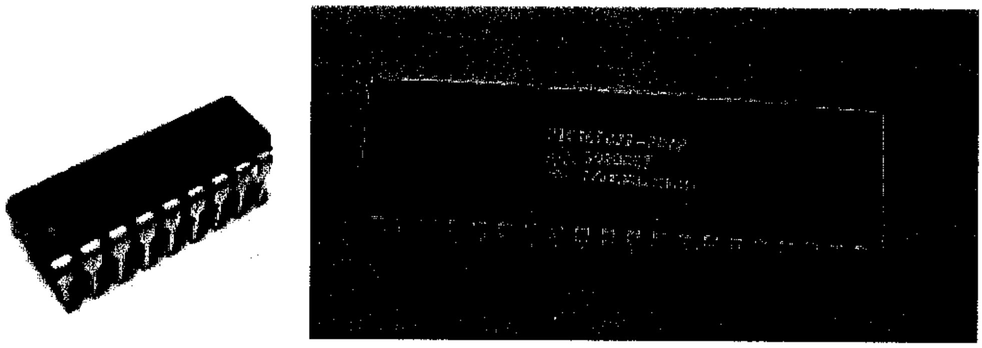


Figure 10 : PIC 16F84 and PIC 16F877

3.2.5 Power Supply Part

Power supply part consists of sealed lead acid (SLA) which is available in the market. This is needed for a project that needs to move or navigate from one location to another location. There are many types of SLA, and it depends on the value of voltage and current. Besides, we also need to use voltage regulator so that we can regulate the specific voltage that needed by the certain circuit. This is due to many circuits in implementing robot project.

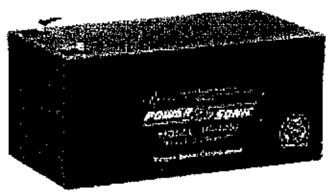


Figure 11 : Sealed Lead Acid (SLA)

3.3 Robot System

Actually this robot will find its own path, starting from one location and ended at one location in a designed maze. The user just needs to select the location where it starts and the location where it stops in a Personal Computer (PC). So the robot will find its own path based on easy to go and short distance. [3]

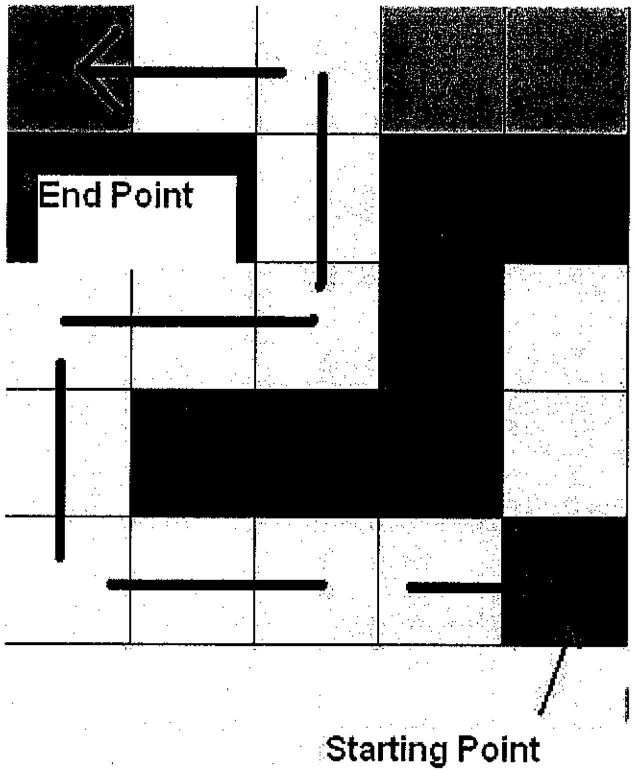


Figure 12 : Robot as a whole

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Structure / Mechanical Part

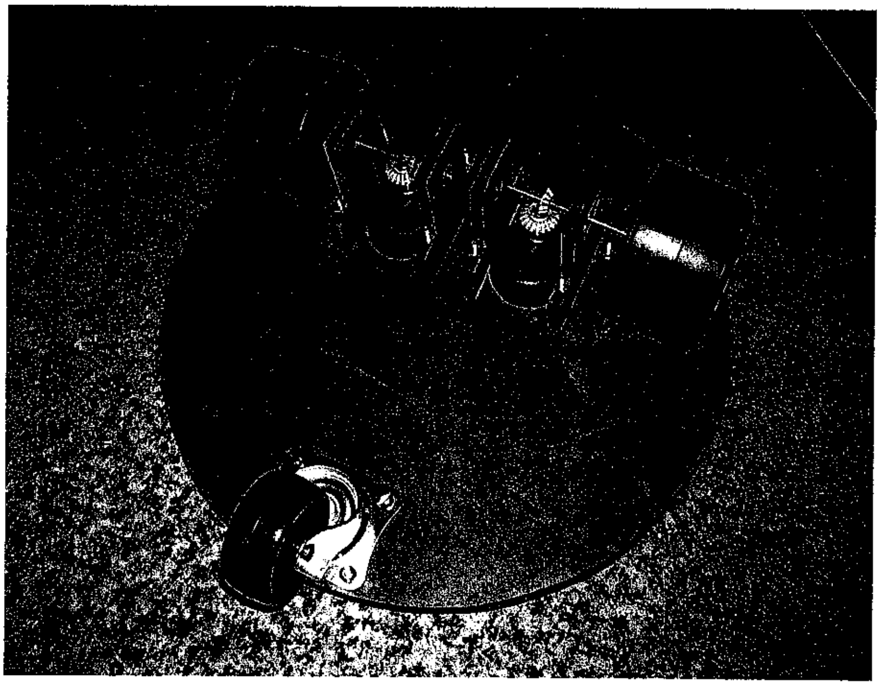


Figure 13 : From Bottom view of the Robot

From the figure above, the shape of the structure itself is round. There is a reason why the structure platform was shaped in round or circle. The reason is the robot still can move and does not stuck if it hit the wall or obstacle in front of it. The size of the round shaped is about 140mm in radius and it is made from 6 mm thickness of plastic Perspex.

The amount of tires of the robot is 3 (three). The two tires at the front of the robot are connected to the DC Motor. These two motors actually functioned as the navigation system for the robot. The direction of the DC motors whether clockwise or anticlockwise will determine the direction of navigation of the robot. By controlling the direction of the DC Motors, the robot will move whether in the move forward, move backward, to turn right or to turn left.

At the back of the robot is the location of the caster wheel. This caster wheel functioned as a supporting wheel.

The platform of the robot also needs to be in stable condition, means that it should be in parallel with the earth surface. This is to ensure that the things that we put onto the platform do not fall down during its static or its navigation.

4.2 Sensor Unit Part

The sensor is reliable to detect an object at a minimum distance of half a meter a way from the robot. Once triggered, the circuit will latch the relay to create a high to low transition which is then detected by the controller. The original circuit needs the circuit to be powered from a 9 dc volt power supply.

4.2.1 Transmitter Section

For this section, the Timer 555 is used in order to generate sound wave at four (4) different frequencies. This is due to all the four sensors that are placed at the four sides of the robot need four different frequencies. The frequency selected for all the four sensors were determined and we decided to use 43 kHz for in front sensor, 41 kHz for left sensor, 39 kHz for right sensor and 37 kHz for back sensor. Actually there is range of the selected frequencies used by the all four (4) sensors. We used:

- In front sensor – 42.1 kHz until 44.0 kHz
- Left sensor - 40.1 kHz until 42.0 kHz
- Right sensor - 38.1 kHz until 40.1 kHz
- Back sensor - 36.1 kHz until 38.0 kHz

Before the selected frequencies are chosen, we need to know the range of frequency that the transducer is capable of. After testing in the laboratory, the range of the frequency that is capable of the transducer to carry on is in the range between 36 kHz and 45 kHz.

The components needed for this section is Timer 555 and a few other components like resistor and capacitor. The voltage supply needed is around 9 V. The components needed are shown as followed.

1. Timer 555
2. Variable Resistor (1 k Ohm)
3. Resistor (1.5 k Ohm)
4. Capacitor (10 nF)
5. Transmitter transducer
6. Voltage regulator (9 V)

The circuit diagram is shown as followed:

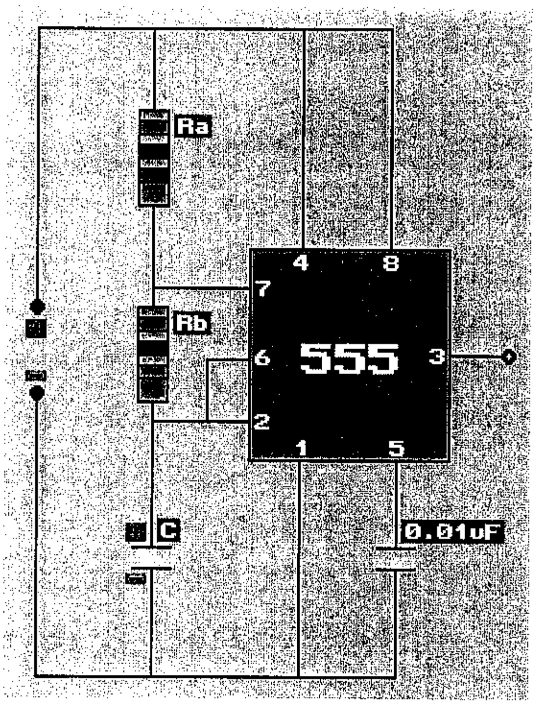


Figure 14 : Circuit Diagram for Transmitter Section
(Taken from 555-timer.clarkson.uk.com)

Based on the circuit diagram showed above, the value of the frequency that we wanted can be done by varying the value of variable resistor. By referring to the datasheet provided for the Timer 555 [4], there is an equation to use if we want to get specific value of frequency. The equation of getting the frequency is shown as followed:

$$\mathbf{Fc = 1.44 / (Ra + 2Rb)\, C}$$

where Fc = Cut off Frequency

Ra = Variable resistor (1 k Ohm)

Rb = Resistor (1.5 k Ohm)

C = Capacitor (10 nF)

Another important thing in this section is the duty cycle, D. The duty cycle is the proportion of time during which a component, device, or system is operated (see Figure 15). The duty cycle can be expressed as a ratio or as a percentage. The duty cycle is given by the ratio between time on and time taken in one cycle or period. The equation of duty cycle for this transmitter section is given as followed:

$$\mathbf{D = Rb / (Ra + 2Rb)}$$

where D = Duty cycle

Ra = Variable resistor (1 k Ohm)

Rb = Resistor (1.5 k Ohm)

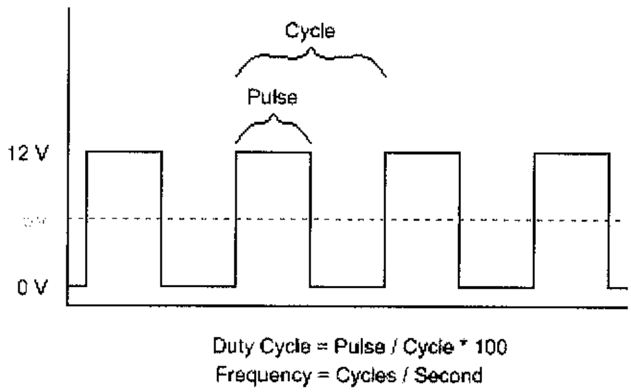


Figure 15 : Duty Cycle
(Taken from www.acroname.com)

During the testing at the laboratory, all the four (4) frequencies that we want to generate is obtained and is shown in the Table 1 below.

Table 1 : The Value of Frequency Generated

Location of Sensors	**Desired Frequency**	**Actual Frequency**	**Duty Cycle**
In Front	43 kHz (42.1 kHz to 44 kHz)	44.0 kHz	0.4615
Left	41 kHz (40.1 kHz to 42 kHz)	40.9 kHz	0.4286
Right	39 kHz (38.1 kHz to 40 kHz)	38.7 kHz	0.4032
Back	37 kHz (36.1 kHz to 38 kHz)	36.7 kHz	0.3856

4.2.2 Receiver Section

For the receiver section, the decision has been made to use both amplitude sensitive and frequency sensitive. Then, the output from these two parts will be ORed by using OR gate before it is sent to the input of the controller (PIC16F84). This section is showing us a good result and we decided to use this circuit as our receiver section for sensor unit system for the robot. When it detects the output will give 0 digital values and will be sent to the controller. When it will not, the output will give 1 digital value.

For the amplitude sensitive, actually there are three parts which are amplifier, rectification and switching network. The components needed for this amplitude sensitive are as followed:

1. 741 Operational Amplifier
2. NPN 3904 Transistor
3. Capacitors
4. Resistors
5. 4001 Diodes

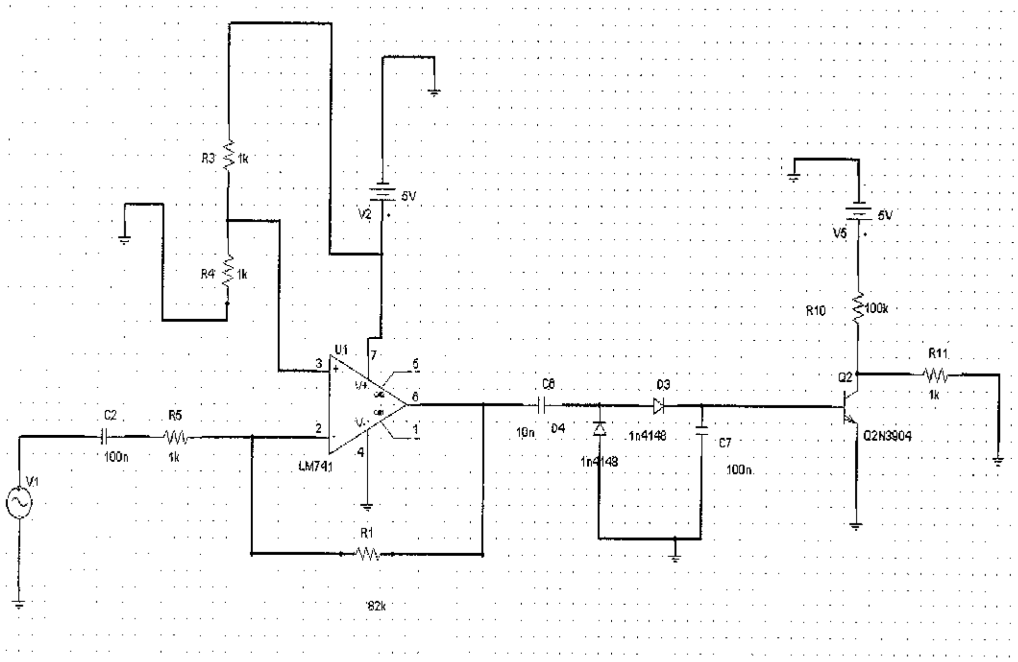


Figure 16 : Amplitude Sensitive Circuit Diagram

When the signal is received at the receiver, usually the signal is weak and need to be amplified first. The signal will be amplified first at the amplifier part. This amplifier part consists of Operational Amplifier 741. At the end of this part, the signal, which is in AC signal, will be amplified by the determined gain. The gain at the amplifier part can be done by selected the value of resistors based on the equation.

Then, the signal that already amplified will pass to the rectifier part. This rectifier part consists of diodes and capacitors. The function of this part is to get a DC value so that it will be useful to switch the BJT Switching at the next part. The BJT Switching is used to switch the value of voltage weather zero or digital voltage (Vcc) value. This value, which is in digital value, then is sent to the controller part.

Figure 17 : Parts in Receiver Section

The ultrasonic signal transmitted to the free space will be reflected if there is an obstacle in front of the transducers. The reflected wave can be detected by the transducer at the receiver. From the experiment, the reflected signal has certain amplitude for some distance of the obstacle as shown in the Table 2 below.

Table 2 : Reflected voltage level for different obstacle's distance

Distance between transducers and obstacle (m)	Reflected Signal (mV)
> 5	50
1	100
0.5	300
0.3	450

From the observation, it is found that if there is no obstacle detected in front of the transducers, the reflected signal has amplitude of 50 mV.

For the frequency sensitive, the main part of the component is Tone Decoder, LM 567. This component actually acts as a band pass filter. The frequency that it will be filtered out can be design by using certain formula, and this can be done by manipulating the value of resistor and capacitor in the circuit. The formula that is used to have a cut off frequency is as followed:

$$\mathbf{Fo = 1/ [1.1\ R1.C1]}$$

where Fo = Cut off frequency

R1 = Resistor

C1 = Capacitor

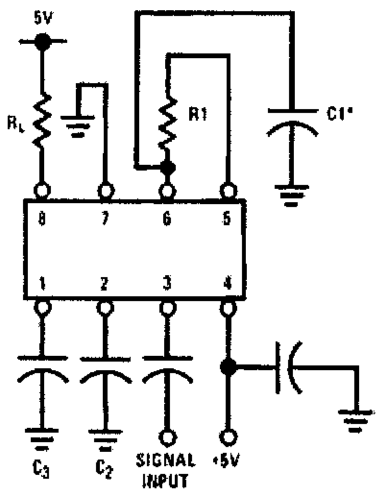


Figure 18 : Frequency Sensitive Circuit Diagram
(Taken from LM 567 Tone Decoder Datasheet)

The LM 567 needed for this section is four (4) because it needs to detect the frequency at the value of 37 kHz, 39 kHz, 41 kHz and 43 kHz which was transmitted at the transmitter part just now.

At the receiver part, especially at the frequency sensitive section, the four (4) frequencies can be detected at the output of the Tone Decoder, LM 567. The experiment has been done at the laboratory by applying pure wave frequency provided by Function Generator to detect the frequencies at the output of the Tone Decoder, LM 567 [5]. The result is shown in the Table 3 below.

Table 3 : Frequencies Detected at the tone Decoder, LM 567

Frequency Applied	Output at the LM 567
43 kHz	43 kHz
41 kHz	41 kHz
39 kHz	39 kHz
37 kHz	37 kHz

After testing at the laboratory, it will give output zero if the selected frequency is bounced back and will remain output high if anything except the selected frequency is bounced back.

Then, both the output from amplitude sensitive part and frequency sensitive part will be combined at OR gate, and the output from OR gate off course will be patched to the controller, or PIC 16F84. [7]

Both the output from Amplitude Sensitive and Frequency Sensitive will give value 0V (0 in binary value) if the signal of obstacle has been detected and will produce value 5V (1 binary value) if the signal is not detected. The result is shown in the Table 4 below.

Table 4 : Output being sent to the Controller part if obstacle detected

Frequency (for example)	**Output at Amplitude Sensitive**	**Output at Frequency Sensitive**	**Output send to Controller part (Binary Value)**
42 kHz	0	1	1
41 kHz	1	1	1
32 kHz	0	0	0
38 kHz	0	1	1

4.3 Motor Drive Part

In order to navigate from one point to another point, the direction of the DC motors will determine whether the robot will move forward, stop, turn right or turn left. The directions of the DC motors are controlled by the H Bridge circuit. The Dual Full Bridge Driver (LM 298) has been used as H Bridge circuit.

The amount of current varies depending on the load of the motor. The more the weight to the motor the higher the current will be needed to maintain the same speed. This has been the challenge as the maximum of the rating current design with no load will be around 100 mA. If the load is taken into consideration, the value of current will be up to 1 A. However, at this circuit, there are two current sensing resistors that valued of 10 ohm that will protect the circuit by limits the current flows through the circuit. Besides, there are 8 (eight) fast recovery diodes that connected between the DC Motors, functioned as to reduce the spike occurred during the reverse flow of the current when the motors are rotating.

The Figure 19 below shows the pin configuration of the chip.

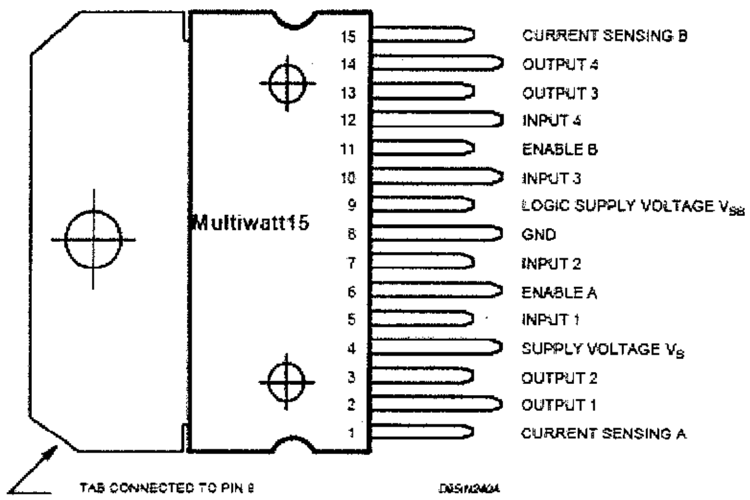


Figure 19 : LM 298 pins configuration
(Taken from LM 298 Dual Full Bridge Driver Datasheet)

This chip is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. There are two enable inputs that are used to enable or disable the device independently from the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage. [6]

Basically there are many other advantages of this LM 298. They are as follows:

1. Total DC current up to 4 A
2. Low saturation voltage
3. Over temperature protection
4. Logical 0 input voltage up to 1.5 V (high noise immunity)

The connections between the LM 298 with the other components are shown in the figure below.

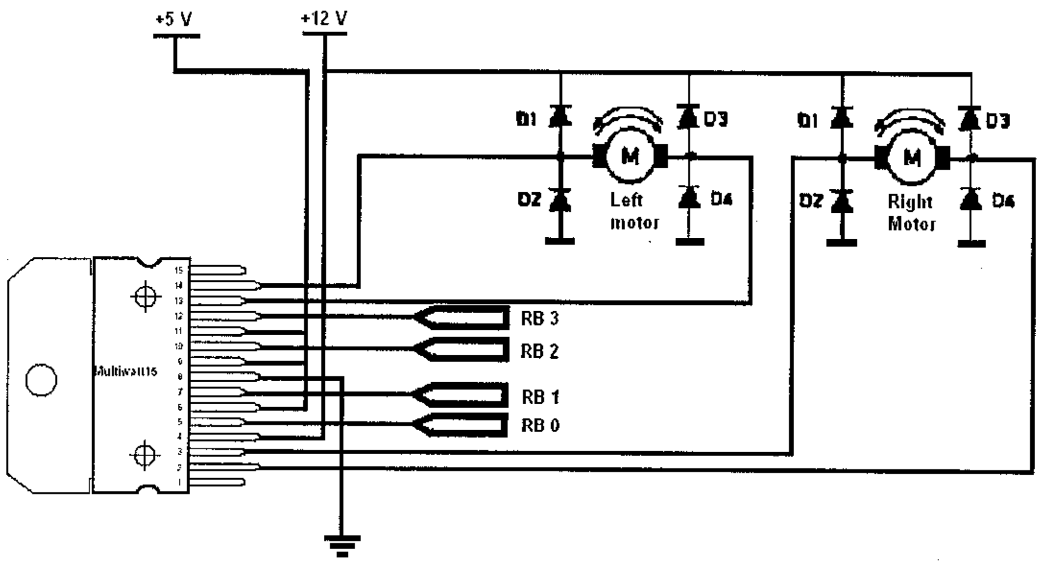


Figure 20 : Left and Right DC Motor with LM 298 Dual Full Bridge Driver

The H Bridge was design to be able to allow maximum of 4A of current to be supplied to the DC motors. The amount of current varies depending on the load of the motor. The more the weight to the motor the higher the current will be needed to maintain the same speed. This has been the challenge as the maximum of the rating current design will be around 4A. If the current that is being drawn is more than 4A the current will give smoke signals.

The operation of the DC Motors is summarized from the Table 5 below.

Table 5 : The operation of DC Motors, pins number based on LM 298 pins

Robot move forward direction			
Pin Number	Voltage (V)	DC Motor Left	DC Motor Right
5 (input 1)	5	forward	
7 (input 2)	0		
10 (input 3)	5		forward
12 (input 4)	0		
Robot move left direction			
5 (input 1)	5	reverse	
7 (input 2)	0		
10 (input 3)	0		forward
12 (input 4)	5		
Robot move right direction			
5 (input 1)	0	forward	
7 (input 2)	5		
10 (input 3)	5		reverse
12 (input 4)	0		
Robot stop			
5 (input 1)	5	stop	
7 (input 2)	5		
10 (input 3)	5		stop
12 (input 4)	5		

The external bridge of diodes is made by four fast recovery elements that must be chosen as low as possible at the worst case of the load current. These diodes fast recoveries are connected at the DC Motors. Besides, the non inductive capacitors, usually 100 nF were highly recommended to be connected between Vs (pin 4), Vss (pin 9) to ground.

During the testing at the laboratory, the DC Motor is moving as we want when we applied the binary value as showed in the Table 5.

4.4 Controller Part

The discussion of this part will be done by my partner, Mr. Wan Mohd Ariff Wan Nordin, because he is man in charge that handling software part for this Mobile Robot project, especially in Controller part.

4.5 Power Supply Part

In order to power up the Mobile Robot, supposed the Seal Lead Acid batteries will be used as the power supply. The 12V that be supplied will be connected to the H Bridge board (deliver power to the motor) and also to the regulator board which will supply a regulated 5V to the H Bridge board. The 9V also will be used as a power unit for sensor unit part. The receiver and transmitter need 9V to operate the circuit.

The voltage regulator is a built in device which is capable of stepping down DC voltage to the desired voltage. Internally the circuit consists of transistor which will open and close in process to regulate the output voltage. If the voltage at the output is less the transistor will open more thus giving more voltage at the output. In order to ensure the voltage regulator works at its operating point, a heat sink is attached to the power regulator package.

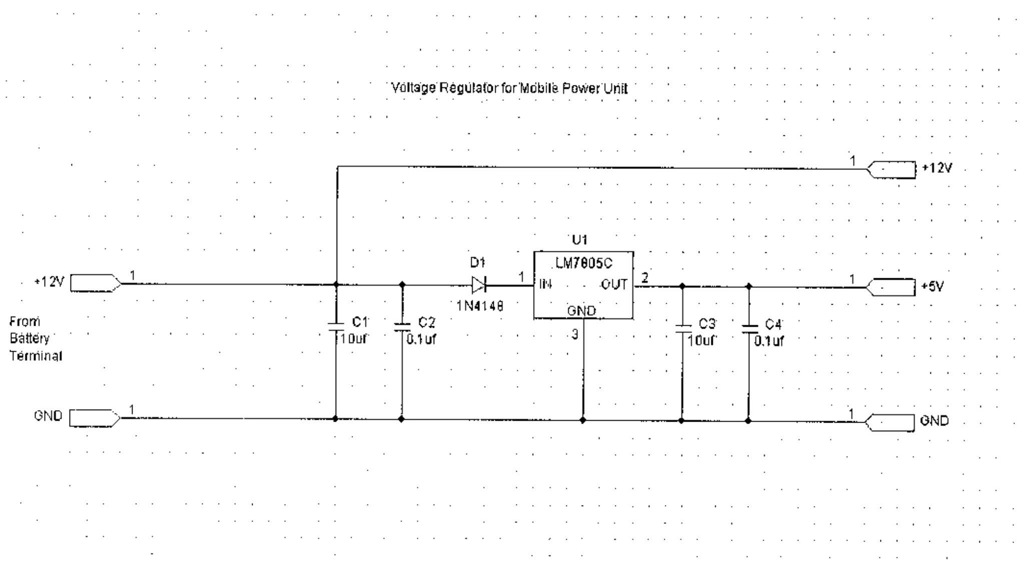


Figure 21 : Voltage Regulator

4.6 Robot System

When all the part has been assembled, the testing of the robot will be done. During the testing, the robot can navigate from one location to the other location in a designed maze. The robot can move forward, stop, turn right and turn left. The movement of the robot is smooth enough and sometimes it still hit the wall in the designed maze.

CHAPTER 5
CONCLUSION AND RECCOMENDATION

5.1 Conclusion

The implementation of mobile robot system should incorporate several parts; controller implementation for positioning and navigation, sensory systems, mechanical unit part and mobile power unit part. The basic knowledge of programming, hardware implementation experience and able to capture new knowledge is important to complete the project successfully.

The material of the structure platform is made is not too heavy and stable, meaning that it can hold the overall weight of robot up to 10 kg. Besides the round shaped of the platform gives advantage for the robot if it hit the wall during it navigation thus still can move. The H Bridge design using LM 298 Dual Full Bridge Driver is good enough and the problem expected coming from the high current drawn if the load is too heavy. The ultrasonic is the sensor that used for this robot. The challenging part comes from the sensors itself because the sensor is too sensitive. The circuit of the ultrasonic has been implemented for both Amplitude and Frequency Sensitive.

5.2 Recommendations

For the future work, the improvement of the mobile robot design can be done by including some additional feature so that the design would be more robust and efficient. The recommendations are suggested as followed:

Structure / Mechanical

For the mechanical structure, it is recommended to use at least a pair of bearing for both left and right motor so that the effect of shaft loading will not damaged the shaft coupler and the DC motor's shaft. The robot also should have a cover so that the internal electronic part can be protected from its environment.

Sensors

The robot currently used the ultrasonic sensor, but one of the difficulties in utilizing this type of sensor is to get the consistent output from the sensor, another alternative sensor that can be consider into the design is the infrared sensor. Infrared sensor can be use as the secondary sensor system if the ultrasonic failed to perform its task.

Motor Drive Part

Instead of the using of bevel gear as a connector between the DC Motor and tire, the using of coupler also makes sense as a connection between them. This coupler can be designed at the mechanical laboratory by using aluminium block or other metal block.

Controller

As the algorithm for the path planning to be implemented, the controller with higher processing capability must be used, then the controller PIC 16F877 will be used to have a process as more complex algorithm. PIC 16F877 contain more memory space, more input and output ports, and other special features. Many applications can be done to this controller.

Power Supply

The mobile power supply also can be including with a short circuit protection in case when the faulty occurs at the load the battery will not be damaged. The electronic component must also be protected if the power supply accidentally connected in reverse position. So it is necessary for the mobile power system to have a reverse polarity protection. Since the power is supplied from a battery, the robot should also monitor the condition of the input power, so that it can indicate a signal before it is running out of power.

REFERENCES

[1] Gordon Mccomb, TAB Books, Robot Builder's Bonanza 99 Inexpensive Robotics Projects.

[2] Mohd Shahriman M Sharif, Universiti Teknologi PETRONAS, 2004, Mobile Robot: Obstacle Avoidance and Manuvering.

[3] Wan Mohd Ariff Wan Nordin, Universiti Teknologi PETRONAS, 2006, Mobile Robot : Obstacle Avoidance and Path Planning.

[4] Timer 555 Datasheet

[5] Tone Decoder LM 567 Datasheet

[6] Dual Full Bridge Driver L 298 Datasheet

[7] PIC 16F84 and PIC 16F8XX Datasheet

[8] Ultrasonic Sensor
www.wikipedia.org/wiki/Ultrasonic

[9] DC Motor Drive
www.globalspec.com/LearnMore/DC_Motor_Drives

APPENDICES

1) Timer 555 Datasheet

2) Tone Decoder LM 567 Datasheet

3) Dual Full Bridge Driver L 298 Datasheet

4) PIC 16F84 and PIC 16F8XX Datasheet

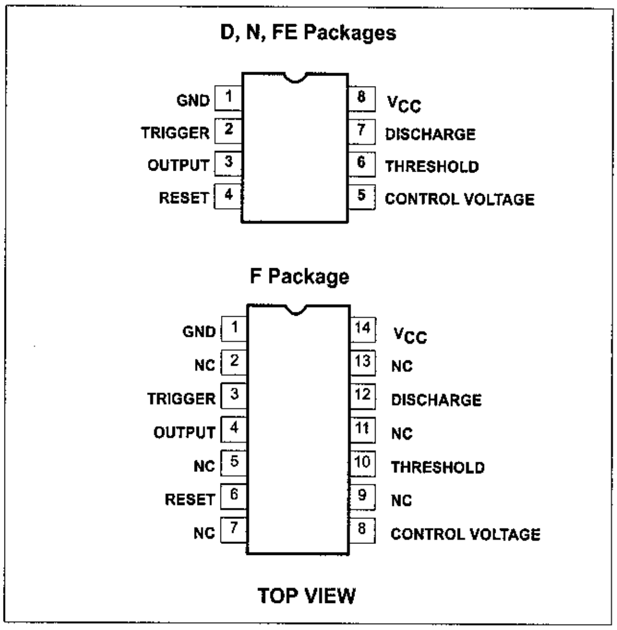
mer

NE/SA/SE555/SE555C

CRIPTION

55 monolithic timing circuit is a highly stable controller capable ducing accurate time delays, or oscillation. In the time delay of operation, the time is precisely controlled by one external or and capacitor. For a stable operation as an oscillator, the inning frequency and the duty cycle are both accurately lled with two external resistors and one capacitor. The circuit e triggered and reset on falling waveforms, and the output ure can source or sink up to 200mA.

PIN CONFIGURATIONS



TURES

- 1-off time less than 2µs
- :. operating frequency greater than 500kHz
- ng from microseconds to hours
- rates in both astable and monostable modes
- 1 output current
- stable duty cycle
- compatible
- perature stability of 0.005% per °C

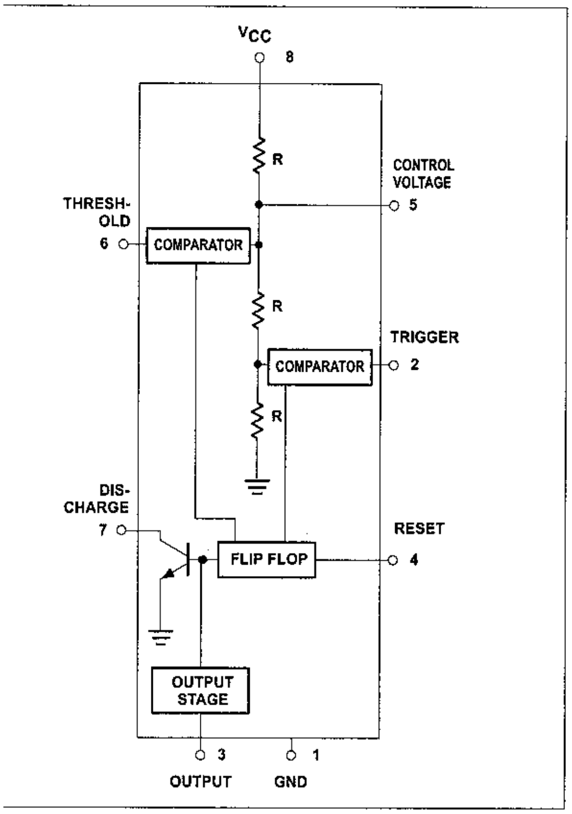
LICATIONS

- ision timing
- e generation
- uential timing
- e delay generation
- e width modulation

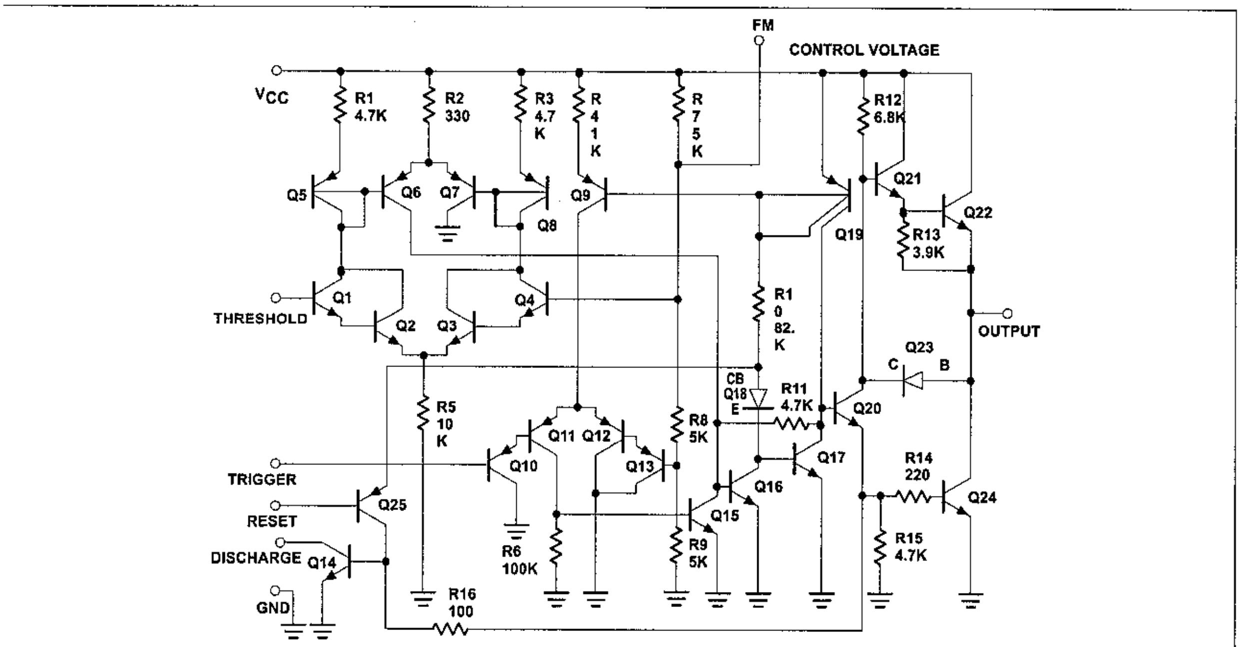
ERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	DWG #
Plastic Small Outline (SO) Package	0 to +70°C	NE555D	0174C
Plastic Dual In-Line Package (DIP)	0 to +70°C	NE555N	0404B
Plastic Dual In-Line Package (DIP)	-40°C to +85°C	SA555N	0404B
Plastic Small Outline (SO) Package	-40°C to +85°C	SA555D	0174C
Hermetic Ceramic Dual In-Line Package (CERDIP)	-55°C to +125°C	SE555CFE	
Plastic Dual In-Line Package (DIP)	-55°C to +125°C	SE555CN	0404B
n Plastic Dual In-Line Package (DIP)	-55°C to +125°C	SE555N	0405B
Hermetic Cerdip	-55°C to +125°C	SE555FE	
n Ceramic Dual In-Line Package (CERDIP)	0 to +70°C	NE555F	0581B
n Ceramic Dual In-Line Package (CERDIP)	-55°C to +125°C	SE555F	0581B
n Ceramic Dual In-Line Package (CERDIP)	-55°C to +125°C	SE555CF	0581B

ƆCK DIAGRAM



ᒍIVALENT SCHEMATIC



TE: Pin numbers are for 8-Pin package

ƷOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNIT
:	Supply voltage SE555 NE555, SE555C, SA555	 +18 +16	 V V
	Maximum allowable power dissipation[1]	600	mW
	Operating ambient temperature range NE555 SA555 SE555, SE555C	 0 to +70 -40 to +85 -55 to +125	 °C °C °C
ɜ	Storage temperature range	-65 to +150	°C
LD	Lead soldering temperature (10sec max)	+300	°C

ΞS:
ıe junction temperature must be kept below 125°C for the D package and below 150°C for the FE, N and F packages. At ambient tempera- res above 25°C, where this limit would be derated by the following factors:
D package 160°C/W
FE package 150°C/W
N package 100°C/W
F package 105°C/W

AND AC ELECTRICAL CHARACTERISTICS

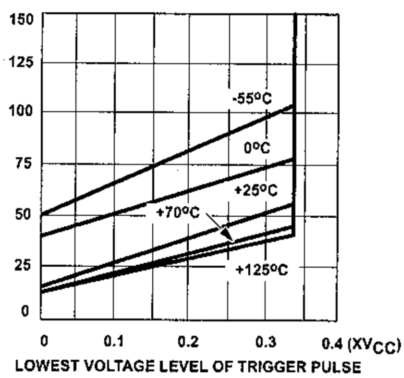
25°C, V_{CC} = +5V to +15 unless otherwise specified.

YMBOL	PARAMETER	TEST CONDITIONS	SE555			NE555/SE555C			UNIT
			Min	Typ	Max	Min	Typ	Max	
:	Supply voltage		4.5		18	4.5		16	V
	Supply current (low state)[1]	V_{CC}=5V, R_L=∞		3	5		3	6	mA
		V_{CC}=15V, R_L=∞		10	12		10	15	mA
	Timing error (monostable)	R_A=2kΩ to 100kΩ							
	Initial accuracy[2]	C=0.1μF		0.5	2.0		1.0	3.0	%
'ΔT	Drift with temperature			30	100		50	150	ppm/°C
'ΔV_S	Drift with supply voltage			0.05	0.2		0.1	0.5	%/V
	Timing error (astable)	R_A, R_B=1kΩ to 100kΩ							
	Initial accuracy[2]	C=0.1μF		4	6		5	13	%
ΔT	Drift with temperature	V_{CC}=15V			500			500	ppm/°C
ΔV_S	Drift with supply voltage			0.15	0.6		0.3	1	%/V
	Control voltage level	V_{CC}=15V	9.6	10.0	10.4	9.0	10.0	11.0	V
		V_{CC}=5V	2.9	3.33	3.8	2.6	3.33	4.0	V
	Threshold voltage	V_{CC}=15V	9.4	10.0	10.6	8.8	10.0	11.2	V
		V_{CC}=5V	2.7	3.33	4.0	2.4	3.33	4.2	V
	Threshold current[3]			0.1	0.25		0.1	0.25	μA
IG	Trigger voltage	V_{CC}=15V	4.8	5.0	5.2	4.5	5.0	5.6	V
		V_{CC}=5V	1.45	1.67	1.9	1.1	1.67	2.2	V
3	Trigger current	V_{TRIG}=0V		0.5	0.9		0.5	2.0	μA
SET	Reset voltage[4]	V_{CC}=15V, V_{TH}=10.5V	0.3		1.0	0.3		1.0	V
;ET	Reset current	V_{RESET}=0.4V		0.1	0.4		0.1	0.4	mA
	Reset current	V_{RESET}=0V		0.4	1.0		0.4	1.5	mA
	Output voltage (low)	V_{CC}=15V							
		I_{SINK}=10mA		0.1	0.15		0.1	0.25	V
		I_{SINK}=50mA		0.4	0.5		0.4	0.75	V
		I_{SINK}=100mA		2.0	2.2		2.0	2.5	V
		I_{SINK}=200mA		2.5			2.5		V
		V_{CC}=5V							
		I_{SINK}=8mA		0.1	0.25		0.3	0.4	V
		I_{SINK}=5mA		0.05	0.2		0.25	0.35	V
	Output voltage (high)	V_{CC}=15V							
		I_{SOURCE}=200mA		12.5			12.5		V
		I_{SOURCE}=100mA	13.0	13.3		12.75	13.3		V
		V_{CC}=5V							
		I_{SOURCE}=100mA	3.0	3.3		2.75	3.3		V
:	Turn-off time[5]	V_{RESET}=V_{CC}		0.5	2.0		0.5	2.0	μs
	Rise time of output			100	200		100	300	ns
	Fall time of output			100	200		100	300	ns
	Discharge leakage current			20	100		20	100	nA

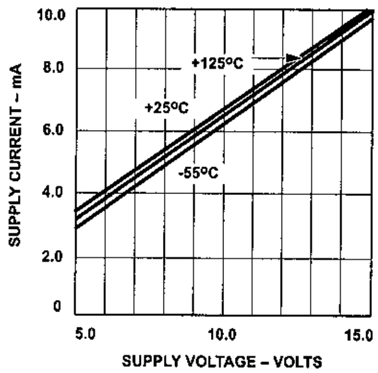
ES:
upply current when output high typically 1mA less.
›sted at V_{CC}=5V and V_{CC}=15V.
ʼis will determine the max value of R_A+R_B, for 15V operation, the max total R=10MΩ, and for 5V operation, the max. total R=3.4MΩ.
pecified with trigger input high.
me measured from a positive going input pulse from 0 to 0.8×V_{CC} into the threshold to the drop from high to low of the output. Trigger is ›d to threshold.

·ICAL PERFORMANCE CHARACTERISTICS

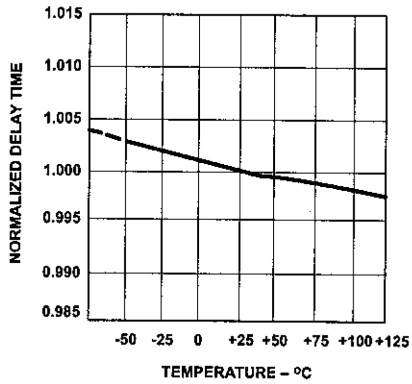
Minimum Pulse Width Required for Triggering



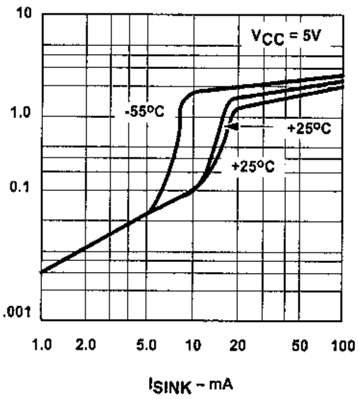
Supply Current vs Supply Voltage



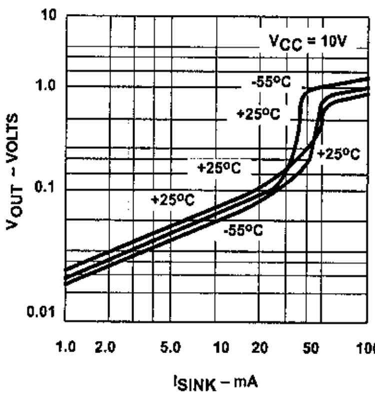
Delay Time vs Temperature



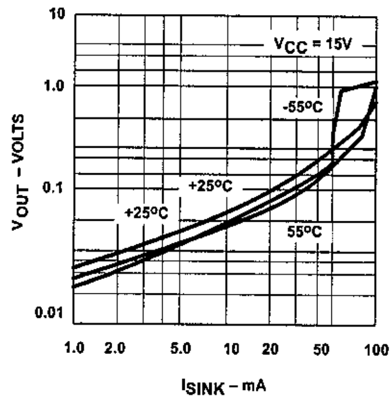
Low Output Voltage vs Output Sink Current



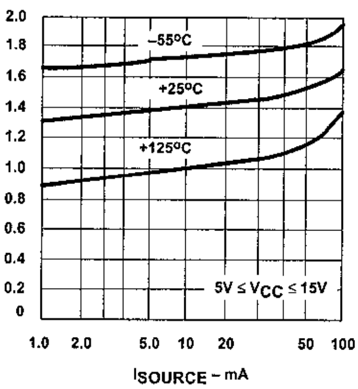
Low Output Voltage vs Output Sink Current



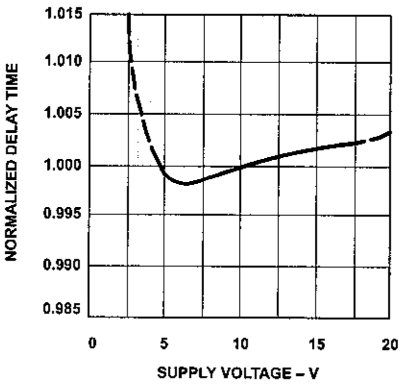
Low Output Voltage vs Output Sink Current



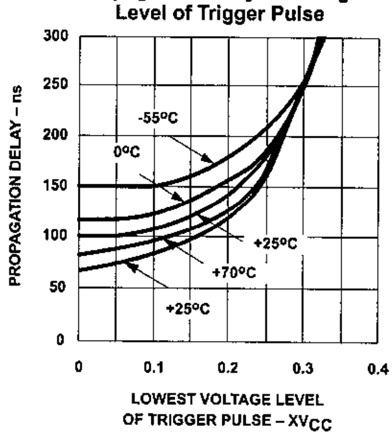
High Output Voltage Drop vs Output Source Current



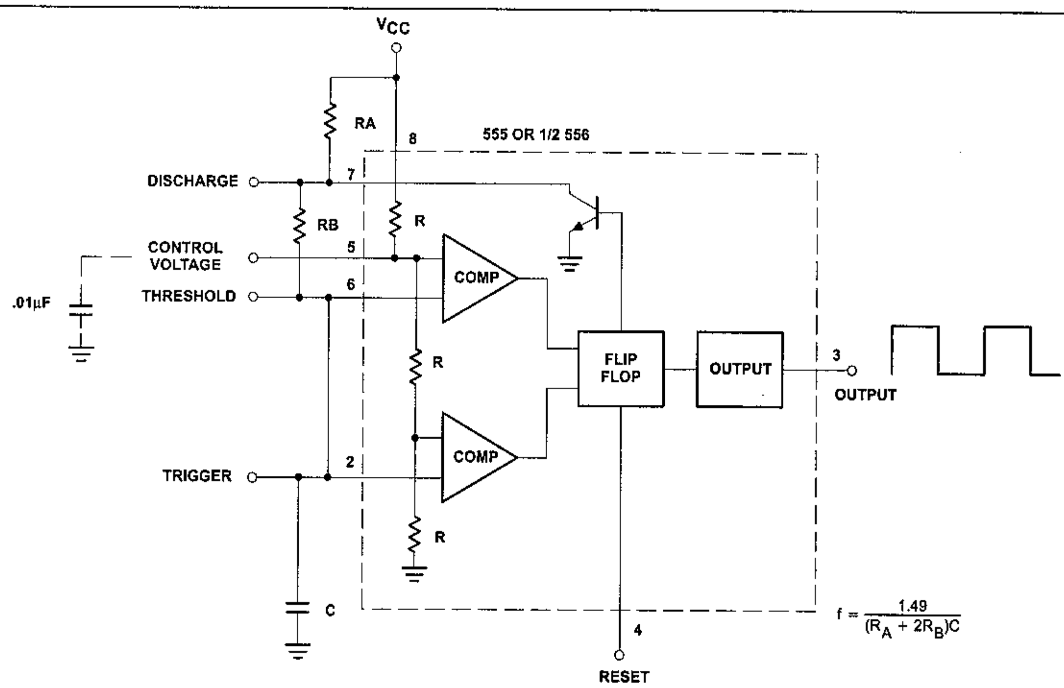
Delay Time vs Supply Voltage



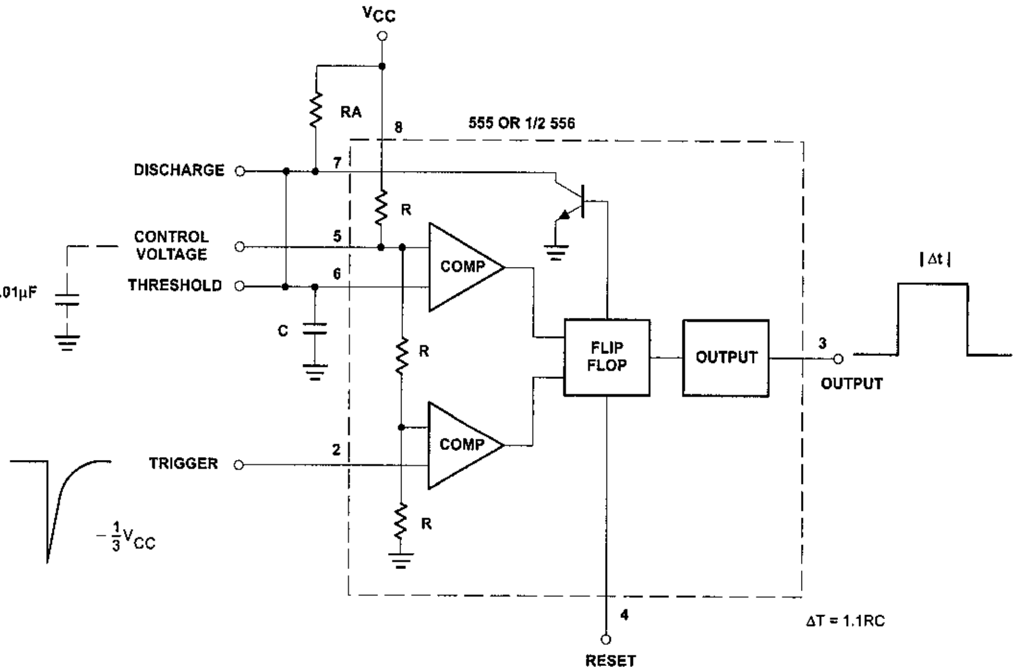
Propagation Delay vs Voltage Level of Trigger Pulse



'ICAL APPLICATIONS

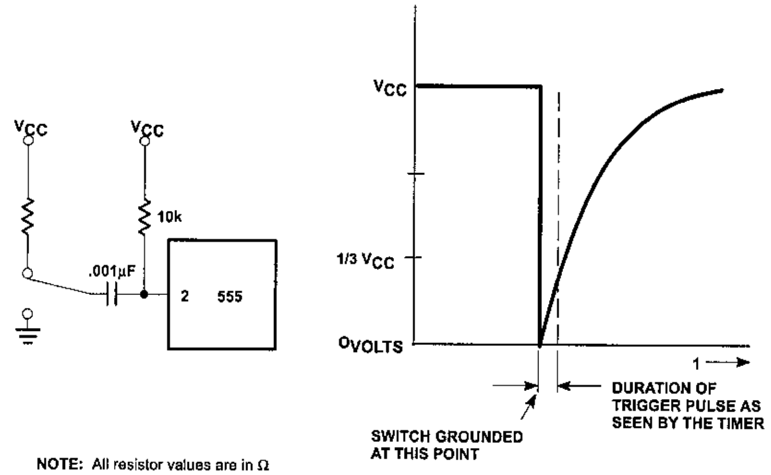


Astable Operation



Monostable Operation

ICAL APPLICATIONS



NOTE: All resistor values are in Ω

Figure 1. AC Coupling of the Trigger Pulse

ger Pulse Width Requirements and Time ıys

o the nature of the trigger circuitry, the timer will trigger on the :ive going edge of the input pulse. For the device to time out :rly, it is necessary that the trigger voltage level be returned to voltage greater than one third of the supply before the time out 1. This can be achieved by making either the trigger pulse iently short or by AC coupling into the trigger. By AC coupling gger, see Figure 1, a short negative going pulse is achieved the trigger signal goes to ground. AC coupling is most ɜntly used in conjunction with a switch or a signal that goes to ıd which initiates the timing cycle. Should the trigger be held /ithout AC coupling, for a longer duration than the timing cycle ɹtput will remain in a high state for the duration of the low r signal, without regard to the threshold comparator state. This › to the predominance of Q_{15} on the base of Q_{16}, controlling ate of the bi-stable flip-flop. When the trigger signal then ıs to a high level, the output will fall immediately. Thus, the t signal will follow the trigger signal in this case.

Another consideration is the "turn-off time". This is the measurement of the amount of time required after the threshold reaches 2/3 V_{CC} to turn the output low. To explain further, Q_1 at the threshold input turns on after reaching 2/3 V_{CC}, which then turns on Q_5, which turns on Q_6. Current from Q_6 turns on Q_{16} which turns Q_{17} off. This allows current from Q_{19} to turn on Q_{20} and Q_{24} to given an output low. These steps cause the 2μs max. delay as stated in the data sheet.

Also, a delay comparable to the turn-off time is the trigger release time. When the trigger is low, Q_{10} is on and turns on Q_{11} which turns on Q_{15}. Q_{15} turns off Q_{16} and allows Q_{17} to turn on. This turns off current to Q_{20} and Q_{24}, which results in output high. When the trigger is released, Q_{10} and Q_{11} shut off, Q_{15} turns off, Q_{16} turns on and the circuit then follows the same path and time delay explained as "turn off time". This trigger release time is very important in designing the trigger pulse width so as not to interfere with the output signal as explained previously.

National Semiconductor

February 1995

LM567/LM567C Tone Decoder

General Description

The LM567 and LM567C are general purpose tone decoders designed to provide a saturated transistor switch to ground when an input signal is present within the passband. The circuit consists of an I and Q detector driven by a voltage controlled oscillator which determines the center frequency of the decoder. External components are used to independently set center frequency, bandwidth and output delay.

Features

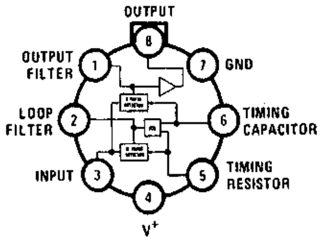
- 20 to 1 frequency range with an external resistor
- Logic compatible output with 100 mA current sinking capability
- Bandwidth adjustable from 0 to 14%
- High rejection of out of band signals and noise
- Immunity to false signals
- Highly stable center frequency
- Center frequency adjustable from 0.01 Hz to 500 kHz

Applications

- Touch tone decoding
- Precision oscillator
- Frequency monitoring and control
- Wide band FSK demodulation
- Ultrasonic controls
- Carrier current remote controls
- Communications paging decoders

Connection Diagrams

Metal Can Package

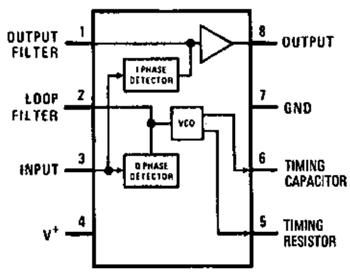


TL/H/6975–1

Top View

Order Number LM567H or LM567CH
See NS Package Number H08C

Dual-In-Line and Small Outline Packages



TL/H/6975–2

Top View

Order Number LM567CM
See NS Package Number M08A
Order Number LM567CN
See NS Package Number N08E

RRD-B30M115/Printed in U. S. A.

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage Pin	9V
Power Dissipation (Note 1)	1100 mW
V_8	15V
V_3	−10V
V_3	V_4 + 0.5V
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	
LM567H	−55°C to +125°C
LM567CH, LM567CM, LM567CN	0°C to +70°C

Soldering Information	
Dual-In-Line Package	
Soldering (10 sec.)	260°C
Small Outline Package	
Vapor Phase (60 sec.)	215°C
Infrared (15 sec.)	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

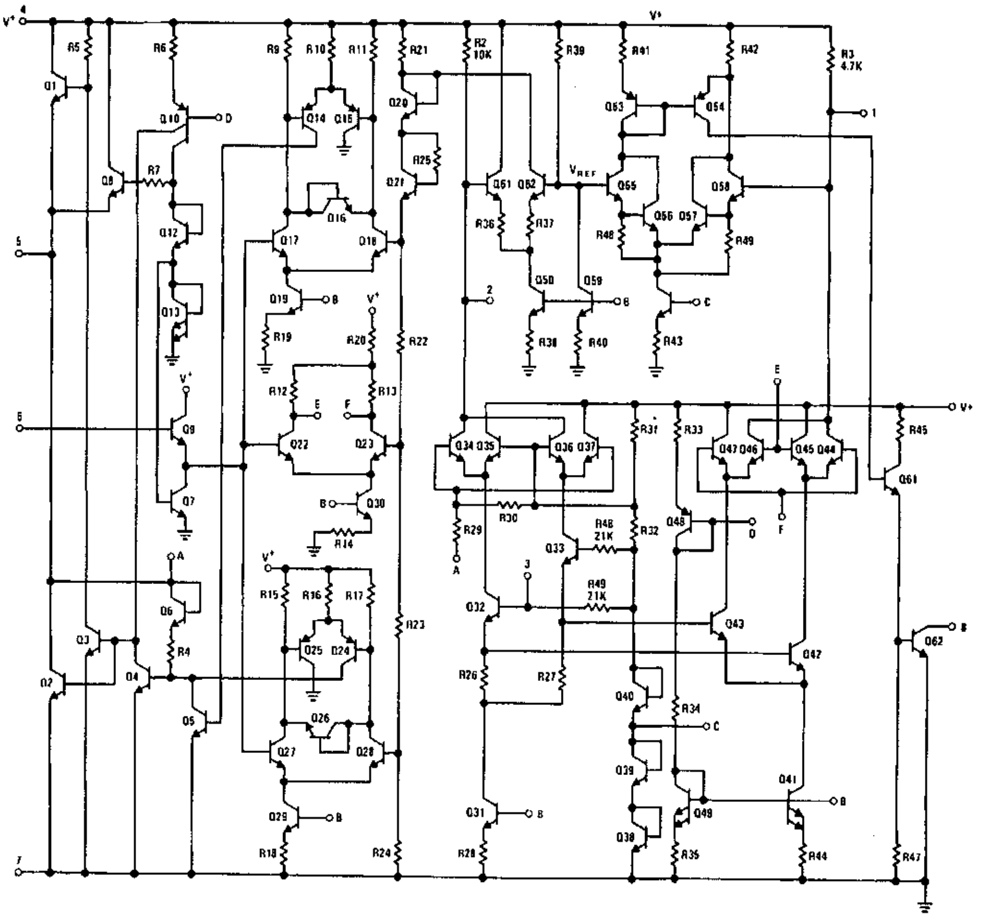
Electrical Characteristics AC Test Circuit, T_A = 25°C, V+ = 5V

Parameters	Conditions	LM567			LM567C/LM567CM			Units
		Min	Typ	Max	Min	Typ	Max	
'ower Supply Voltage Range		4.75	5.0	9.0	4.75	5.0	9.0	V
'ower Supply Current)uiescent	R_L = 20k		6	8		7	10	mA
'ower Supply Current ıctivated	R_L = 20k		11	13		12	15	mA
ıput Resistance		18	20		15	20		kΩ
;mallest Detectable Input Voltage	I_L = 100 mA, $f_i = f_o$		20	25		20	25	mVrms
.argest No Output Input Voltage	I_C = 100 mA, $f_i = f_o$	10	15		10	15		mVrms
.argest Simultaneous Outband Signal to ıband Signal Ratio			6			6		dB
/linimum Input Signal to Wideband loise Ratio	B_n = 140 kHz		−6			−6		dB
.argest Detection Bandwidth		12	14	16	10	14	18	% of f_o
.argest Detection Bandwidth Skew			1	2		2	3	% of f_o
.argest Detection Bandwidth Variation with 'emperature			±0.1			±0.1		%/°C
.argest Detection Bandwidth Variation with ;upply Voltage	4.75 − 6.75V		±1	±2		±1	±5	%V
lighest Center Frequency		100	500		100	500		kHz
:enter Frequency Stability (4.75–5.75V)	$0 < T_A < 70$ $-55 < T_A < +125$		35 ± 60 35 ± 140			35 ±60 35 ± 140		ppm/°C ppm/°C
:enter Frequency Shift with Supply Voltage	4.75V − 6.75V 4.75V − 9V		0.5	1.0 2.0		0.4	2.0 2.0	%/V %/V
'astest ON-OFF Cycling Rate			f_o/20			f_o/20		
)utput Leakage Current	V_8 = 15V		0.01	25		0.01	25	µA
)utput Saturation Voltage	e_i = 25 mV, I_8 = 30 mA e_i = 25 mV, I_8 = 100 mA		0.2 0.6	0.4 1.0		0.2 0.6	0.4 1.0	V
)utput Fall Time			30			30		ns
)utput Rise Time			150			150		ns

Note 1: The maximum junction temperature of the LM567 and LM567C is 150°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient or 45°C/W, junction to case. For the DIP the device must be derated based on a thermal resistance of 110°C/W, junction to ambient. For the Small Outline package, the device must be derated based on a thermal resistance of 160°C/W, junction to ambient.

Note 2: Refer to RETS567X drawing for specifications of military LM567H version.

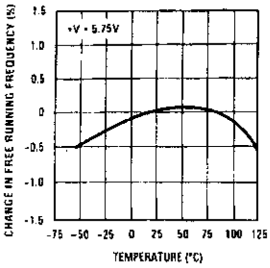
Schematic Diagram



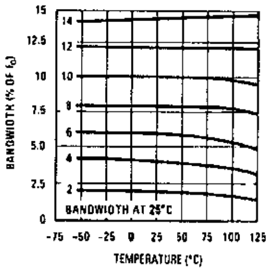
TL/H/6975-3

Typical Performance Characteristics

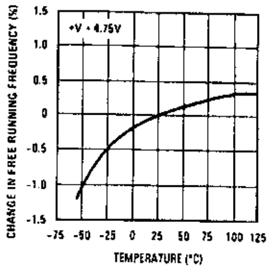
Typical Frequency Drift



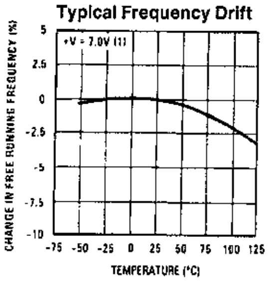
Typical Bandwidth Variation



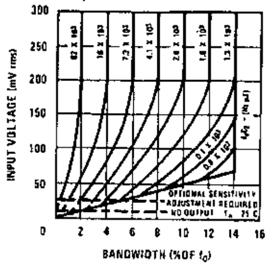
Typical Frequency Drift



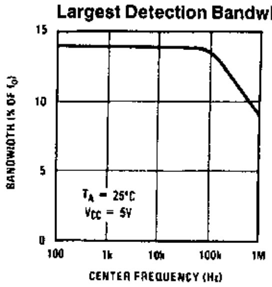
Typical Frequency Drift



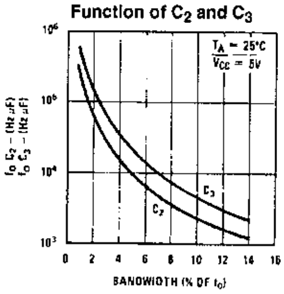
Bandwidth vs Input Signal Amplitude



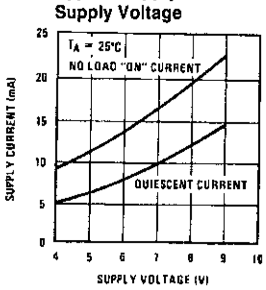
Largest Detection Bandwidth



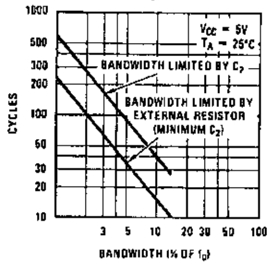
Detection Bandwidth as a Function of C_2 and C_3



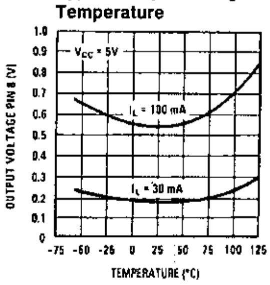
Typical Supply Current vs Supply Voltage



Greatest Number of Cycles Before Output



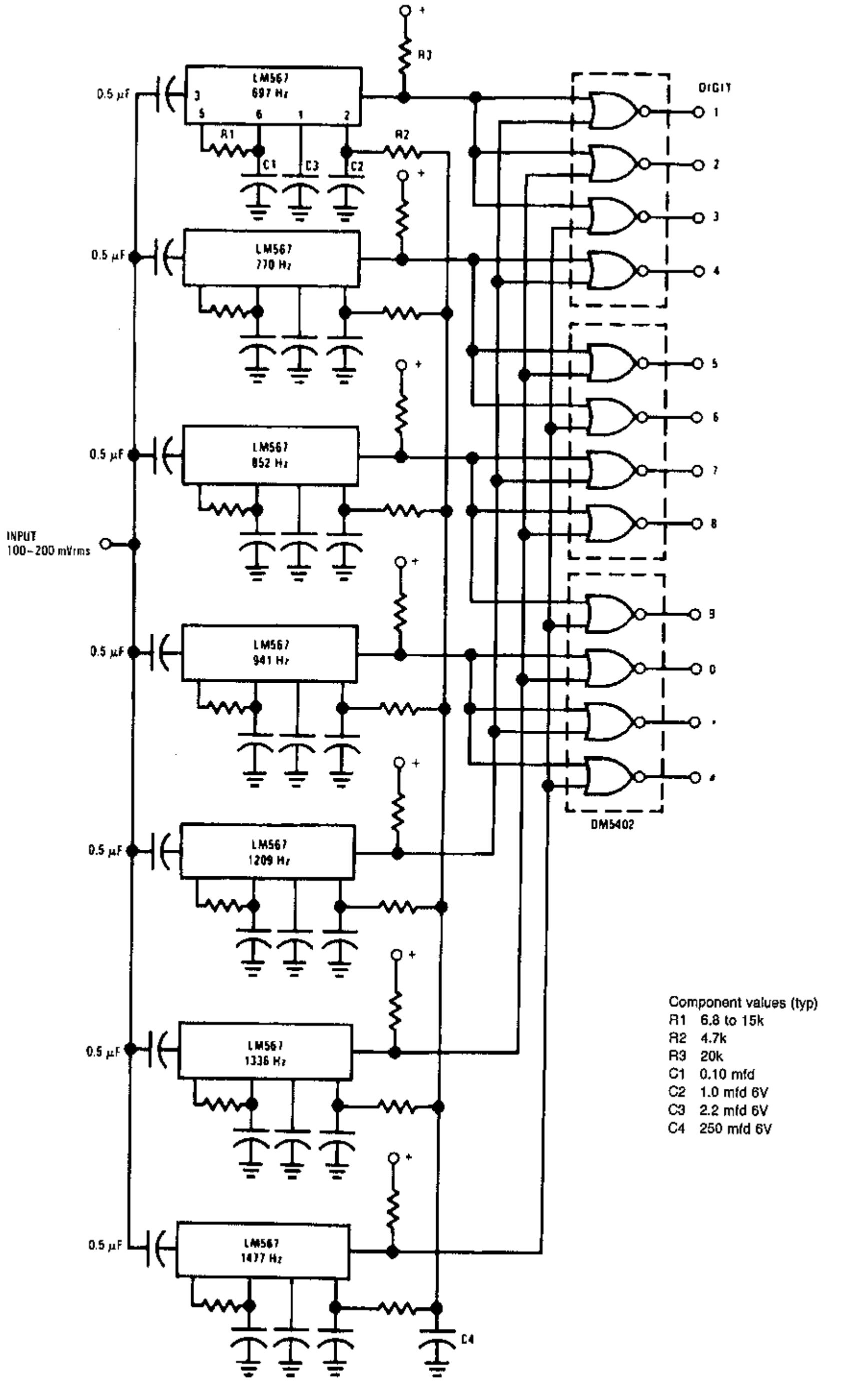
Typical Output Voltage vs Temperature



TL/H/6975–4

Typical Applications

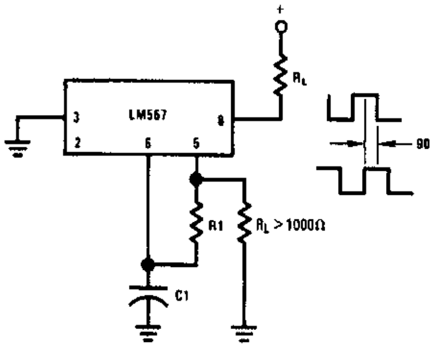
Touch-Tone Decoder



TL/H/6975–5

Typical Applications (Continued)

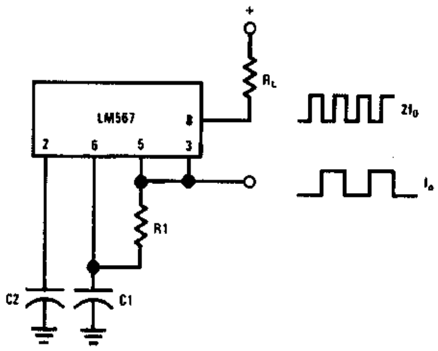
Oscillator with Quadrature Output



Connect Pin 3 to 2.8V to Invert Output

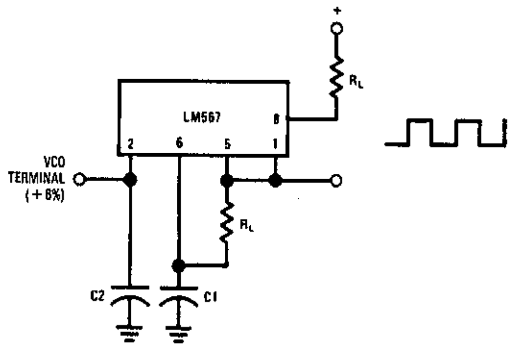
TL/H/6975-6

Oscillator with Double Frequency Output



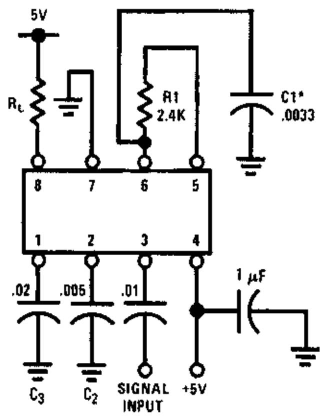
TL/H/6975-7

Precision Oscillator Drive 100 mA Loads



TL/H/6975-8

AC Test Circuit



TL/H/6975-9

f_i = 100 kHz + 5V

*Note: Adjust for f_o = 100 kHz.

Applications Information

The center frequency of the tone decoder is equal to the free running frequency of the VCO. This is given by

$$f_o \cong \frac{1}{1.1\,R_1C_1}$$

The bandwidth of the filter may be found from the approximation

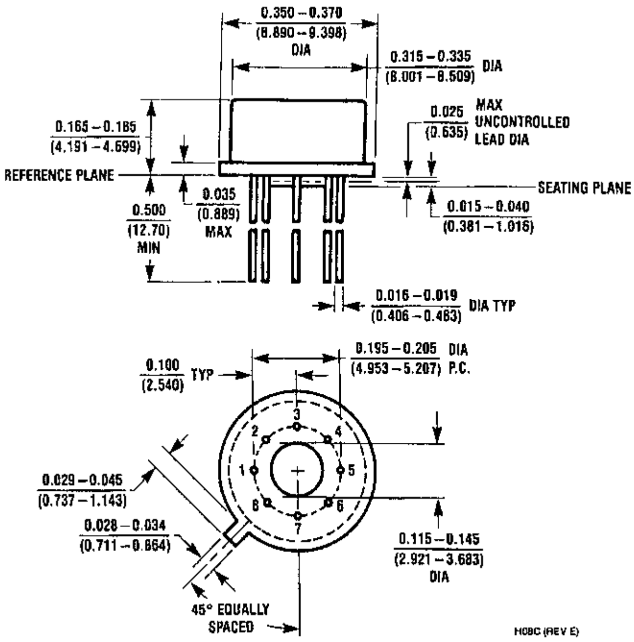
$$BW = 1070\sqrt{\frac{V_i}{f_oC_2}} \text{ in \% of } f_o$$

Where:

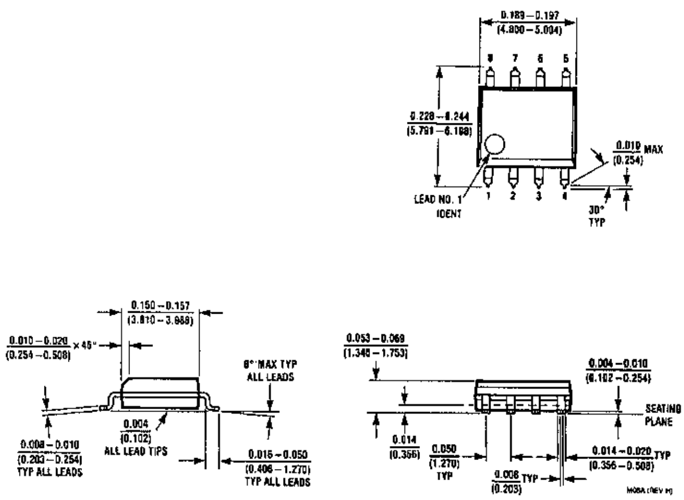
V_i = Input voltage (volts rms), $V_i \leq 200$ mV

C_2 = Capacitance at Pin 2 (µF)

Physical Dimensions inches (millimeters)

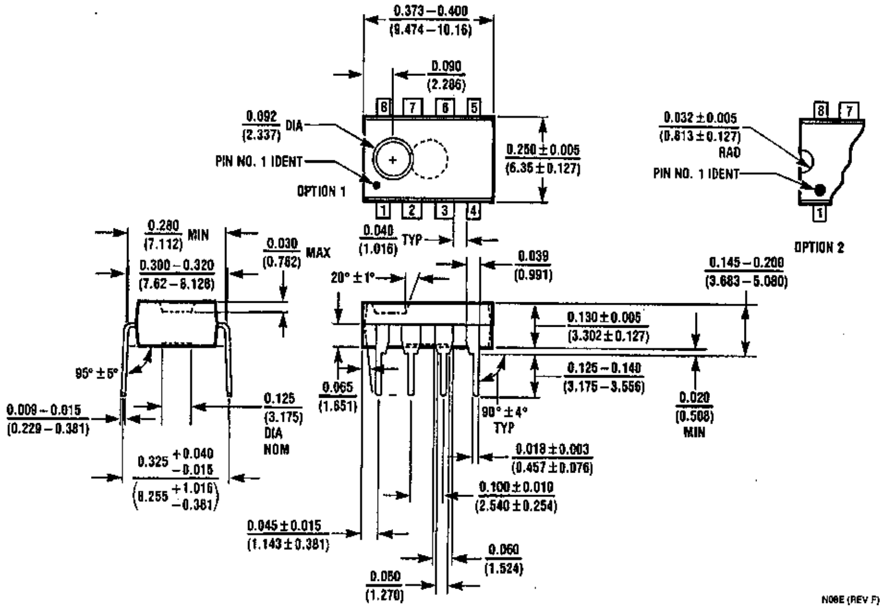


Metal Can Package (H)
Order Number LM567H or LM567CH
NS Package Number H08C



Small Outline Package (M)
Order Number LM567CM
NS Package Number M08A

Physical Dimensions inches (millimeters) (Continued)



Molded Dual-In-Line Package (N)
Order Number LM567CN
NS Package Number N08E

National Semiconductor Corporation
1111 West Bardin Road
Arlington, TX 76017
Tel: 1(800) 272-9959
Fax: 1(800) 737-7018

National Semiconductor Europe
Fax: (+49) 0-180-530 85 86
Email: cnjwge@tevm2.nsc.com
Deutsch Tel: (+49) 0-180-530 85 85
English Tel: (+49) 0-180-532 78 32
Français Tel: (+49) 0-180-532 93 58
Italiano Tel: (+49) 0-180-534 16 80

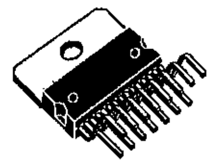
National Semiconductor Hong Kong Ltd.
13th Floor, Straight Block,
Ocean Centre, 5 Canton Rd.
Tsimshatsui, Kowloon
Hong Kong
Tel: (852) 2737-1600
Fax: (852) 2736-9960

National Semiconductor Japan Ltd.
Tel: 81-043-299-2309
Fax: 81-043-299-2408

L298

DUAL FULL-BRIDGE DRIVER

- OPERATING SUPPLY VOLTAGE UP TO 46 V
- TOTAL DC CURRENT UP TO 4 A
- LOW SATURATION VOLTAGE
- OVERTEMPERATURE PROTECTION
- LOGICAL "0" INPUT VOLTAGE UP TO 1.5 V (HIGH NOISE IMMUNITY)



Multiwatt15

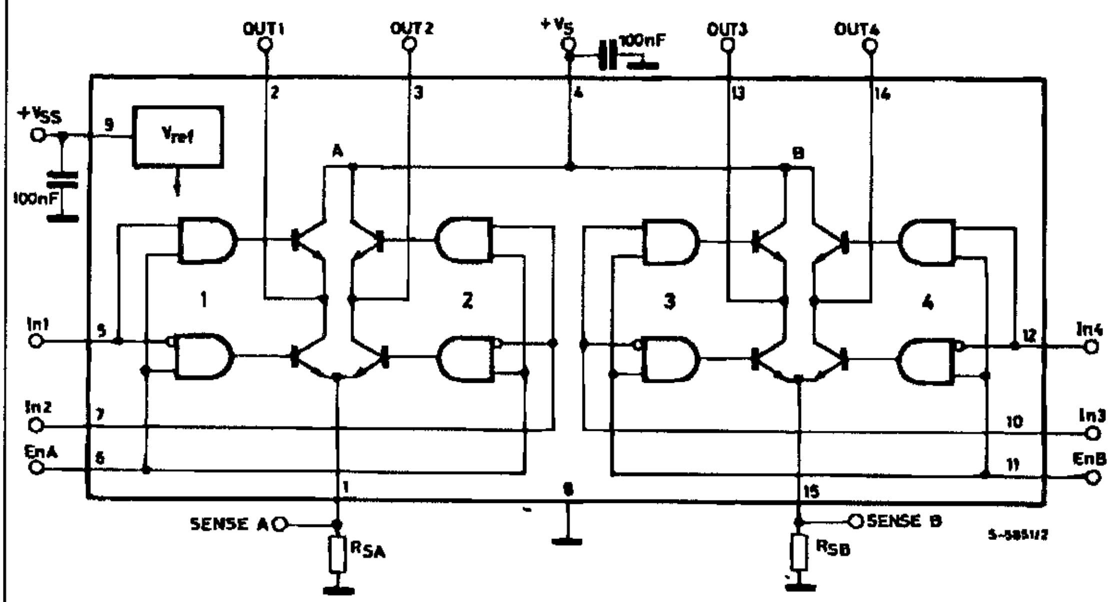
PowerSO20

ORDERING NUMBERS : L298N (Multiwatt Vert.)
L298HN (Multiwatt Horiz.)
L298P (PowerSO20)

DESCRIPTION

The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

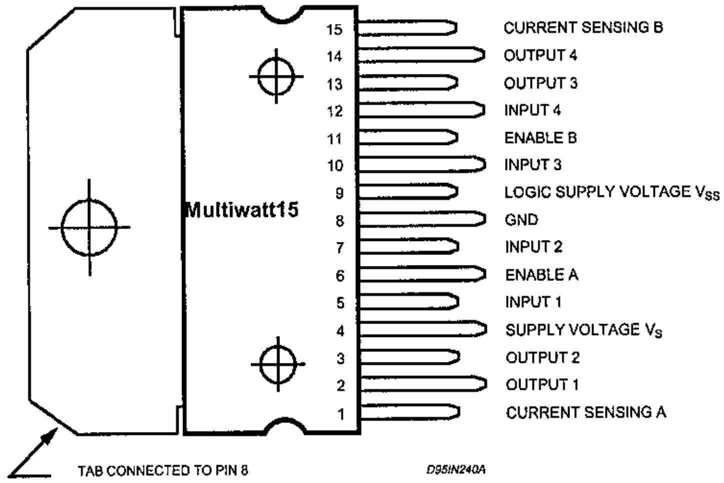
BLOCK DIAGRAM

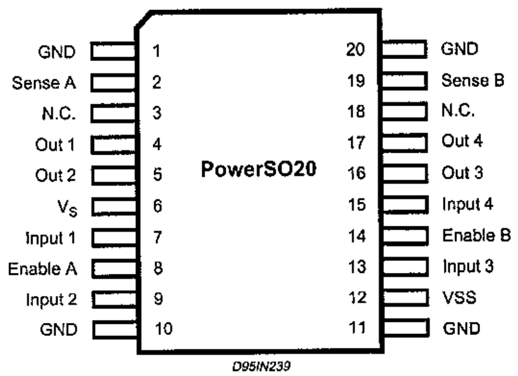


ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_S	Power Supply	50	V
V_{SS}	Logic Supply Voltage	7	V
V_I,V_{en}	Input and Enable Voltage	–0.3 to 7	V
I_O	Peak Output Current (each Channel) – Non Repetitive (t = 100μs) –Repetitive (80% on –20% off; t_{on} = 10ms) –DC Operation	 3 2.5 2	 A A A
V_{sens}	Sensing Voltage	–1 to 2.3	V
P_{tot}	Total Power Dissipation (T_{case} = 75°C)	25	W
T_{op}	Junction Operating Temperature	–25 to 130	°C
T_{stg}, T_j	Storage and Junction Temperature	–40 to 150	°C

PIN CONNECTIONS (top view)





THERMAL DATA

Symbol	Parameter		PowerSO20	Multiwatt15	Unit
$R_{th\ j\text{-}case}$	Thermal Resistance Junction-case	Max.	–	3	°C/W
$R_{th\ j\text{-}amb}$	Thermal Resistance Junction-ambient	Max.	13 (*)	35	°C/W

(*) Mounted on aluminum substrate

PIN FUNCTIONS (refer to the block diagram)

MW.15	PowerSO	Name	Function
1;15	2;19	Sense A; Sense B	Between this pin and ground is connected the sense resistor to control the current of the load.
2;3	4;5	Out 1; Out 2	Outputs of the Bridge A; the current that flows through the load connected between these two pins is monitored at pin 1.
4	6	V_S	Supply Voltage for the Power Output Stages. A non-inductive 100nF capacitor must be connected between this pin and ground.
5;7	7;9	Input 1; Input 2	TTL Compatible Inputs of the Bridge A.
6;11	8;14	Enable A; Enable B	TTL Compatible Enable Input: the L state disables the bridge A (enable A) and/or the bridge B (enable B).
8	1,10,11,20	GND	Ground.
9	12	VSS	Supply Voltage for the Logic Blocks. A100nF capacitor must be connected between this pin and ground.
10; 12	13;15	Input 3; Input 4	TTL Compatible Inputs of the Bridge B.
13; 14	16;17	Out 3; Out 4	Outputs of the Bridge B. The current that flows through the load connected between these two pins is monitored at pin 15.
–	3;18	N.C.	Not Connected

ELECTRICAL CHARACTERISTICS (V_S = 42V; V_{SS} = 5V, T_j = 25°C; unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V_S	Supply Voltage (pin 4)	Operative Condition	V_{IH} +2.5		46	V
V_{SS}	Logic Supply Voltage (pin 9)		4.5	5	7	V
I_S	Quiescent Supply Current (pin 4)	V_{en} = H; I_L = 0 V_i = L V_i = H		13 50	22 70	mA mA
		V_{en} = L V_i = X			4	mA
I_{SS}	Quiescent Current from V_{SS} (pin 9)	V_{en} = H; I_L = 0 V_i = L V_i = H		24 7	36 12	mA mA
		V_{en} = L V_i = X			6	mA
V_{iL}	Input Low Voltage (pins 5, 7, 10, 12)		–0.3		1.5	V
V_{iH}	Input High Voltage (pins 5, 7, 10, 12)		2.3		VSS	V
I_{iL}	Low Voltage Input Current (pins 5, 7, 10, 12)	V_i = L			–10	μA
I_{iH}	High Voltage Input Current (pins 5, 7, 10, 12)	Vi = H ≤ V_{SS} –0.6V		30	100	μA
V_{en} = L	Enable Low Voltage (pins 6, 11)		–0.3		1.5	V
V_{en} = H	Enable High Voltage (pins 6, 11)		2.3		V_{SS}	V
I_{en} = L	Low Voltage Enable Current (pins 6, 11)	V_{en} = L			–10	μA
I_{en} = H	High Voltage Enable Current (pins 6, 11)	V_{en} = H ≤ V_{SS} –0.6V		30	100	μA
$V_{CEsat(H)}$	Source Saturation Voltage	I_L = 1A I_L = 2A	0.95	1.35 2	1.7 2.7	V V
$V_{CEsat(L)}$	Sink Saturation Voltage	I_L = 1A (5) I_L = 2A (5)	0.85	1.2 1.7	1.6 2.3	V V
V_{CEsat}	Total Drop	I_L = 1A (5) I_L = 2A (5)	1.80		3.2 4.9	V V
V_{sens}	Sensing Voltage (pins 1, 15)		–1 (1)		2	V

ELECTRICAL CHARACTERISTICS (continued)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
T_1 (V_i)	Source Current Turn-off Delay	0.5 V_i to 0.9 I_L (2); (4)		1.5		μs
T_2 (V_i)	Source Current Fall Time	0.9 I_L to 0.1 I_L (2); (4)		0.2		μs
T_3 (V_i)	Source Current Turn-on Delay	0.5 V_i to 0.1 I_L (2); (4)		2		μs
T_4 (V_i)	Source Current Rise Time	0.1 I_L to 0.9 I_L (2); (4)		0.7		μs
T_5 (V_i)	Sink Current Turn-off Delay	0.5 V_i to 0.9 I_L (3); (4)		0.7		μs
T_6 (V_i)	Sink Current Fall Time	0.9 I_L to 0.1 I_L (3); (4)		0.25		μs
T_7 (V_i)	Sink Current Turn-on Delay	0.5 V_i to 0.9 I_L (3); (4)		1.6		μs
T_8 (V_i)	Sink Current Rise Time	0.1 I_L to 0.9 I_L (3); (4)		0.2		μs
fc (V_i)	Commutation Frequency	I_L = 2A		25	40	KHz
T_1 (V_{en})	Source Current Turn-off Delay	0.5 V_{en} to 0.9 I_L (2); (4)		3		μs
T_2 (V_{en})	Source Current Fall Time	0.9 I_L to 0.1 I_L (2); (4)		1		μs
T_3 (V_{en})	Source Current Turn-on Delay	0.5 V_{en} to 0.1 I_L (2); (4)		0.3		μs
T_4 (V_{en})	Source Current Rise Time	0.1 I_L to 0.9 I_L (2); (4)		0.4		μs
T_5 (V_{en})	Sink Current Turn-off Delay	0.5 V_{en} to 0.9 I_L (3); (4)		2.2		μs
T_6 (V_{en})	Sink Current Fall Time	0.9 I_L to 0.1 I_L (3); (4)		0.35		μs
T_7 (V_{en})	Sink Current Turn-on Delay	0.5 V_{en} to 0.9 I_L (3); (4)		0.25		μs
T_8 (V_{en})	Sink Current Rise Time	0.1 I_L to 0.9 I_L (3); (4)		0.1		μs

1) 1)Sensing voltage can be –1 V for t ≤ 50 μsec; in steady state V_{sens} min ≥ –0.5 V.
2) See fig. 2.
3) See fig. 4.
4) The load must be a pure resistor.

Figure 1 : Typical Saturation Voltage vs. Output Current.

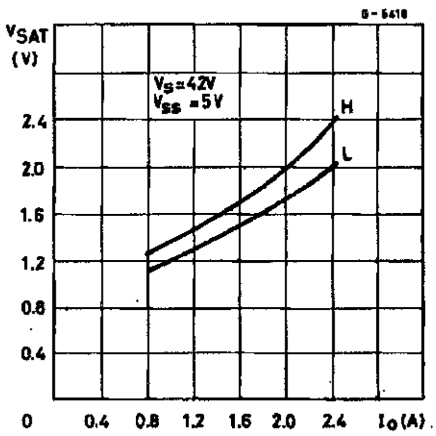
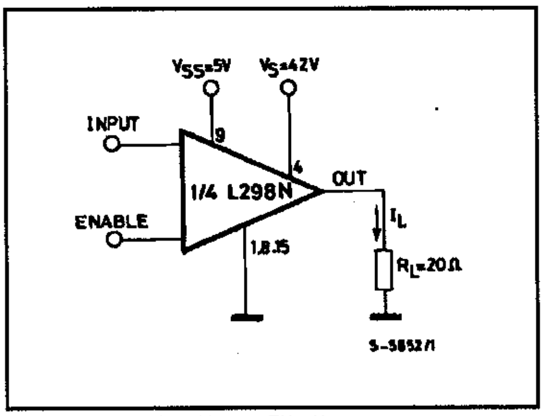


Figure 2 : Switching Times Test Circuits.



Note : For INPUT Switching, set EN = H
For ENABLE Switching, set IN = H

Figure 3 : Source Current Delay Times vs. Input or Enable Switching.

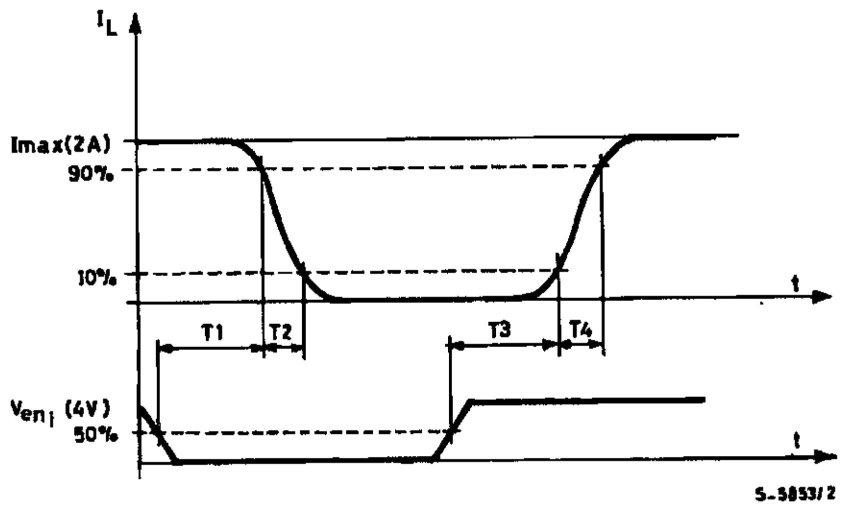
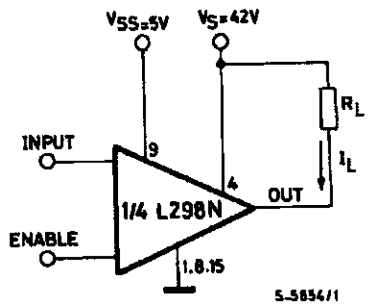


Figure 4 : Switching Times Test Circuits.



Note : For INPUT Switching, set EN = H
For ENABLE Switching, set IN = L

Figure 5 : Sink Current Delay Times vs. Input 0 V Enable Switching.

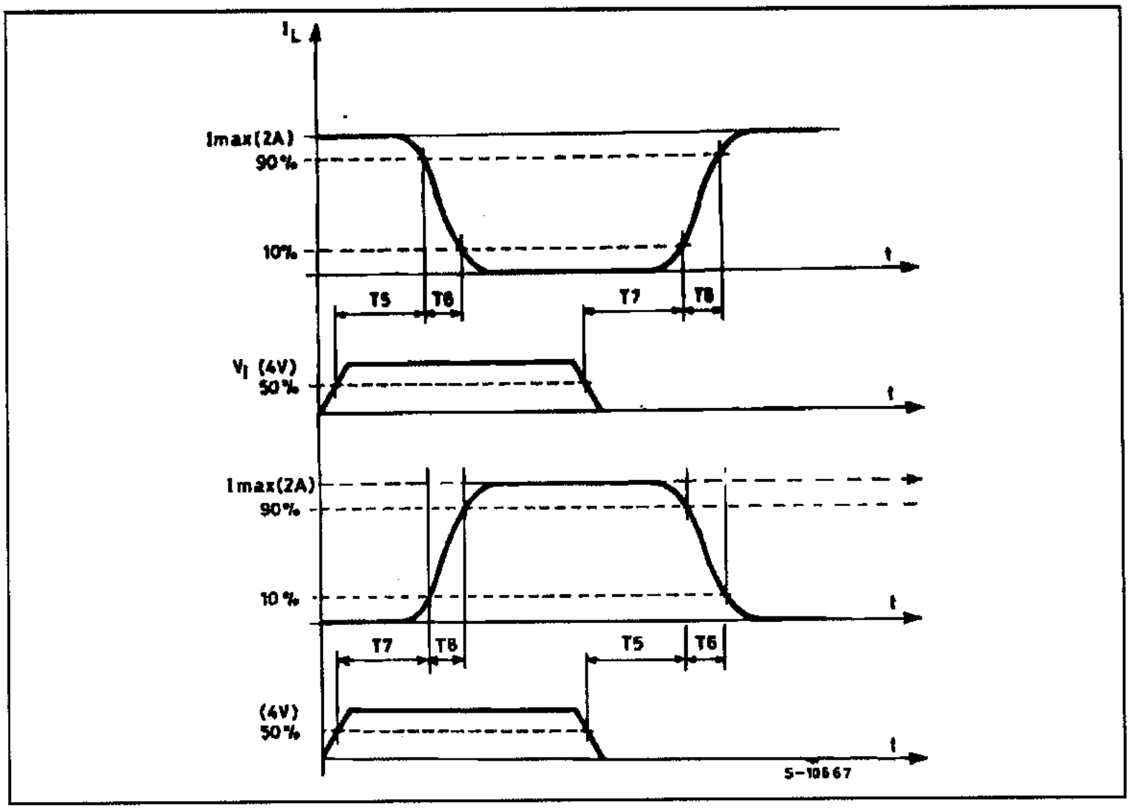
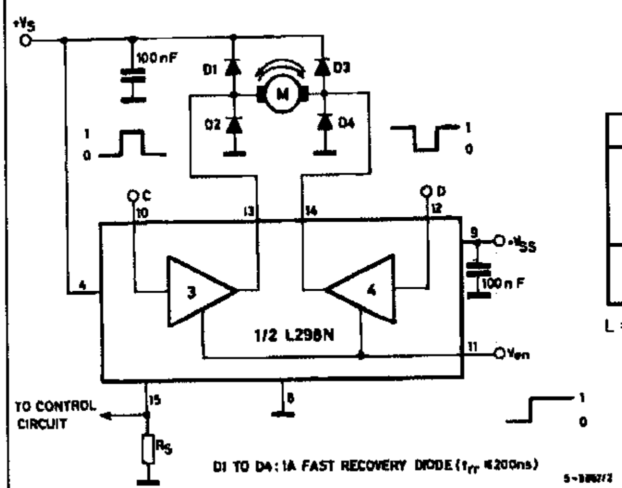


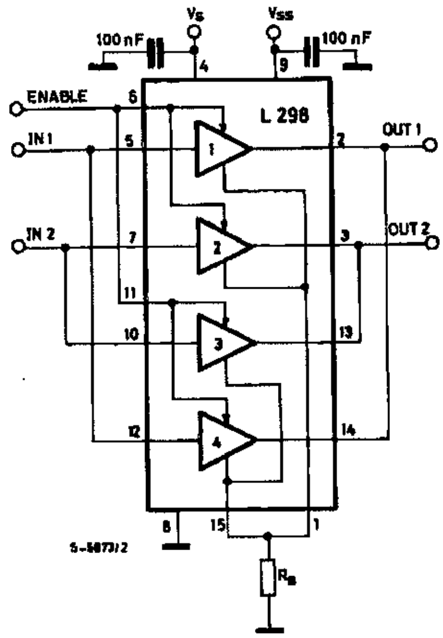
Figure 6 : Bidirectional DC Motor Control.



Inputs		Function
V_{en} = H	C = H ; D = L	Forward
	C = L ; D = H	Reverse
	C = D	Fast Motor Stop
V_{en} = L	C = X ; D = X	Free Running Motor Stop

L = Low H = High X = Don't care

Figure 7 : For higher currents, outputs can be paralleled. Take care to parallel channel 1 with channel 4 and channel 2 with channel 3.



APPLICATION INFORMATION (Refer to the block diagram)

1.1. POWER OUTPUT STAGE

The L298 integrates two power output stages (A ; B). The power output stage is a bridge configuration and its outputs can drive an inductive load in common or differenzial mode, depending on the state of the inputs. The current that flows through the load comes out from the bridge at the sense output : an external resistor (R_{SA} ; R_{SB}.) allows to detect the intensity of this current.

1.2. INPUT STAGE

Each bridge is driven by means of four gates the input of which are In1 ; In2 ; EnA and In3 ; In4 ; EnB. The In inputs set the bridge state when The En input is high ; a low state of the En input inhibits the bridge. All the inputs are TTL compatible.

2. SUGGESTIONS

A non inductive capacitor, usually of 100 nF, must be foreseen between both Vs and Vss, to ground, as near as possible to GND pin. When the large capacitor of the power supply is too far from the IC, a second smaller one must be foreseen near the L298.

The sense resistor, not of a wire wound type, must be grounded near the negative pole of Vs that must be near the GND pin of the I.C.

Each input must be connected to the source of the driving signals by means of a very short path.

Turn-On and Turn-Off : Before to Turn-ON the Supply Voltage and before to Turn it OFF, the Enable input must be driven to the Low state.

3. APPLICATIONS

Fig 6 shows a bidirectional DC motor control Schematic Diagram for which only one bridge is needed. The external bridge of diodes D1 to D4 is made by four fast recovery elements ($t_{rr} \leq 200$ nsec) that must be chosen of a V_F as low as possible at the worst case of the load current.

The sense output voltage can be used to control the current amplitude by chopping the inputs, or to provide overcurrent protection by switching low the enable input.

The brake function (Fast motor stop) requires that the Absolute Maximum Rating of 2 Amps must never be overcome.

When the repetitive peak current needed from the load is higher than 2 Amps, a paralleled configuration can be chosen (See Fig.7).

An external bridge of diodes are required when inductive loads are driven and when the inputs of the IC are chopped ; Shottky diodes would be preferred.

This solution can drive until 3 Amps In DC operation and until 3.5 Amps of a repetitive peak current.

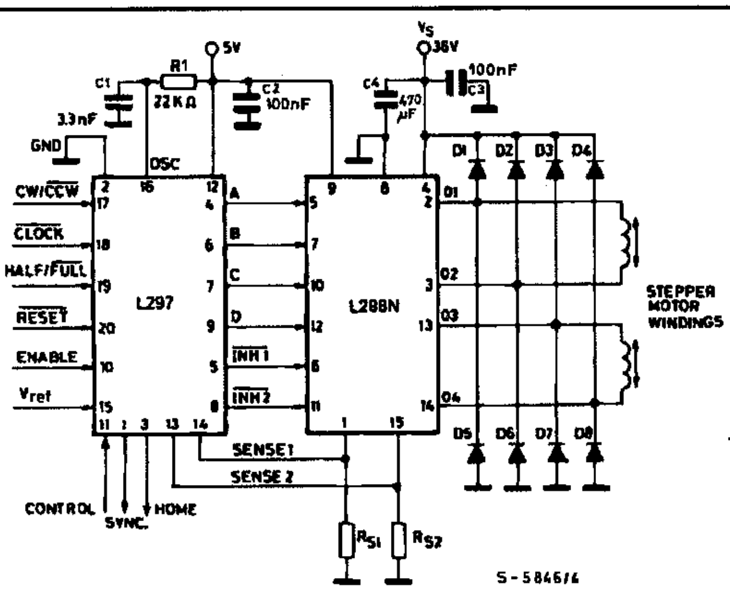
On Fig 8 it is shown the driving of a two phase bipolar stepper motor ; the needed signals to drive the inputs of the L298 are generated, in this example, from the IC L297.

Fig 9 shows an example of P.C.B. designed for the application of Fig 8.

Fig 10 shows a second two phase bipolar stepper motor control circuit where the current is controlled by the I.C. L6506.

Figure 8 : Two Phase Bipolar Stepper Motor Circuit.

This circuit drives bipolar stepper motors with winding currents up to 2 A. The diodes are fast 2 A types.



$R_{S1} = R_{S2} = 0.5\,\Omega$

D1 to D8 = 2 A Fast diodes { $V_F \leq 1.2$ V @ I = 2 A; trr ≤ 200 ns

Figure 9 : Suggested Printed Circuit Board Layout for the Circuit of fig. 8 (1:1 scale).

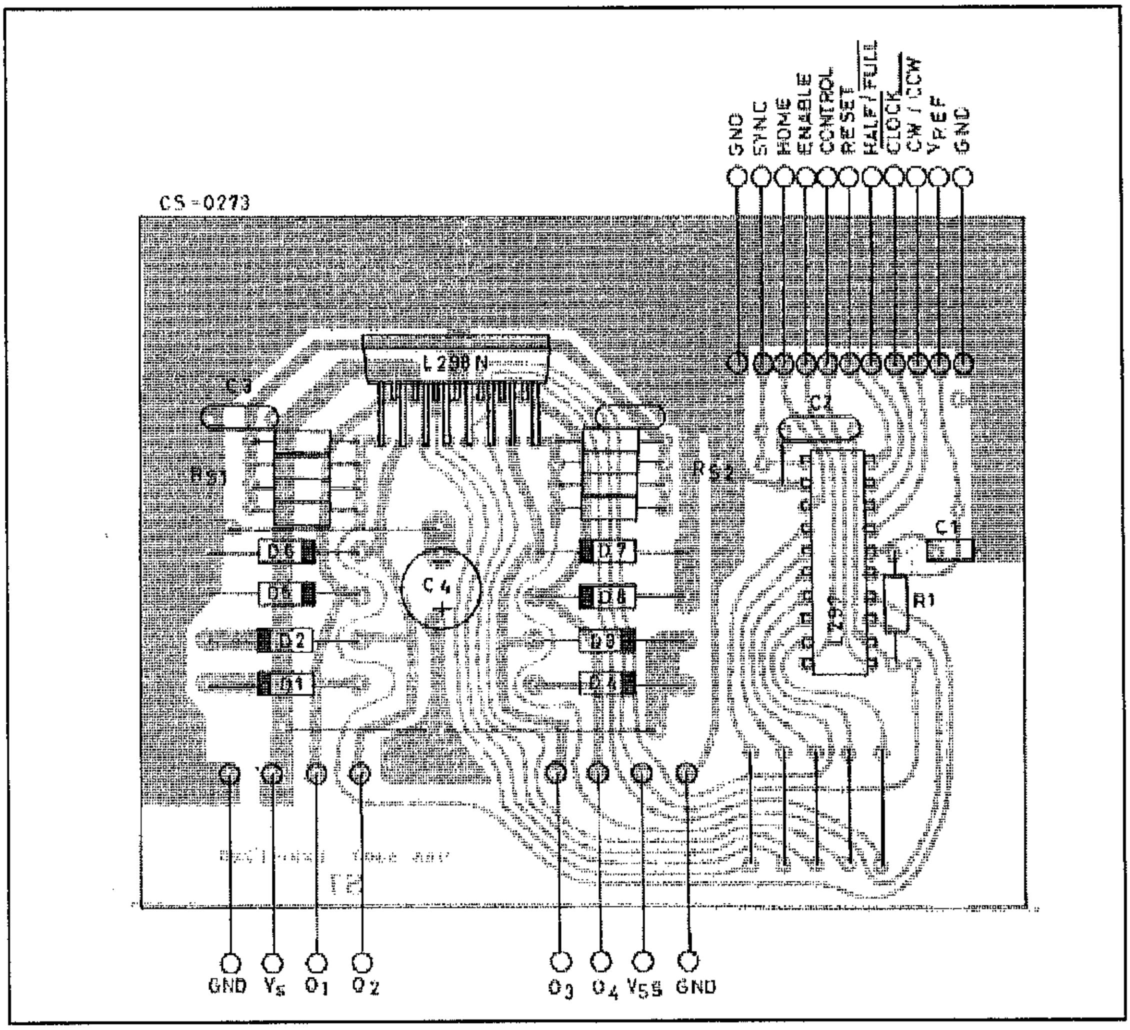
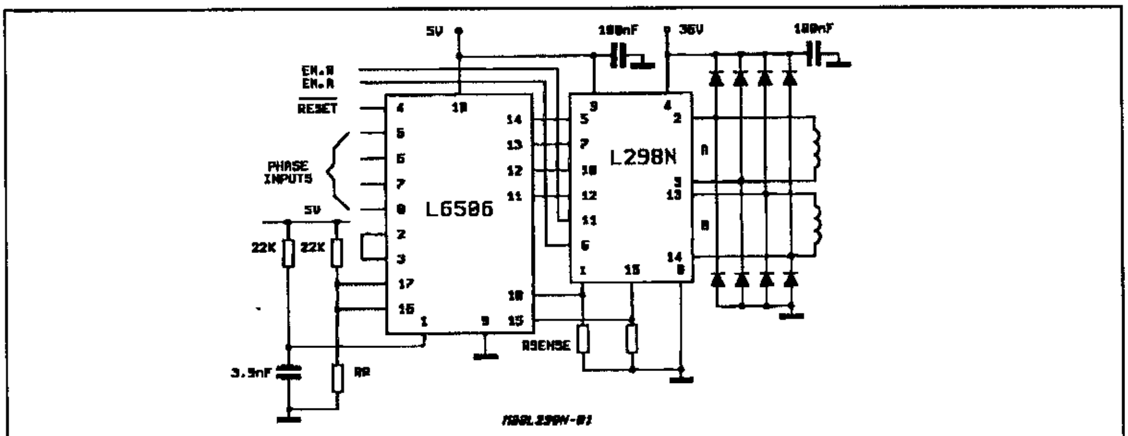


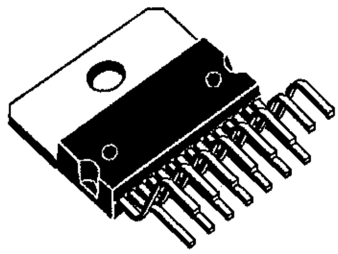
Figure 10 : Two Phase Bipolar Stepper Motor Control Circuit by Using the Current Controller L6506.



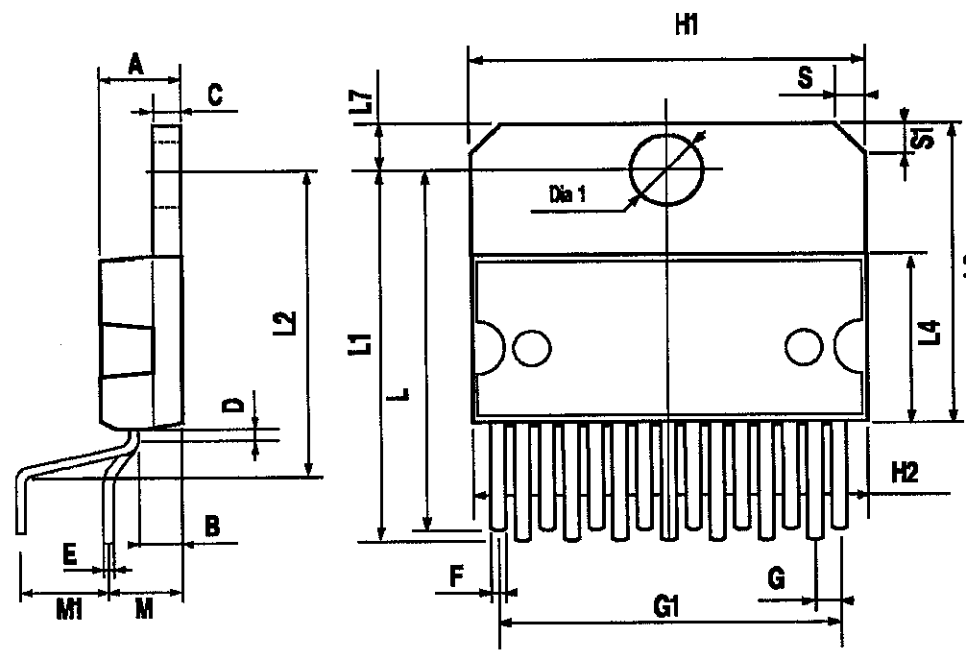
RR and Rsense depend from the load current

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			5			0.197
B			2.65			0.104
C			1.6			0.063
D		1			0.039	
E	0.49		0.55	0.019		0.022
F	0.66		0.75	0.026		0.030
G	1.02	1.27	1.52	0.040	0.050	0.060
G1	17.53	17.78	18.03	0.690	0.700	0.710
H1	19.6			0.772		
H2			20.2			0.795
L	21.9	22.2	22.5	0.862	0.874	0.886
L1	21.7	22.1	22.5	0.854	0.870	0.886
L2	17.65		18.1	0.695		0.713
L3	17.25	17.5	17.75	0.679	0.689	0.699
L4	10.3	10.7	10.9	0.406	0.421	0.429
L7	2.65		2.9	0.104		0.114
M	4.25	4.55	4.85	0.167	0.179	0.191
M1	4.63	5.08	5.53	0.182	0.200	0.218
S	1.9		2.6	0.075		0.102
S1	1.9		2.6	0.075		0.102
Dia1	3.65		3.85	0.144		0.152

OUTLINE AND MECHANICAL DATA

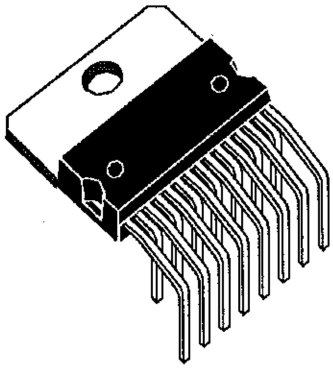


Multiwatt15 V

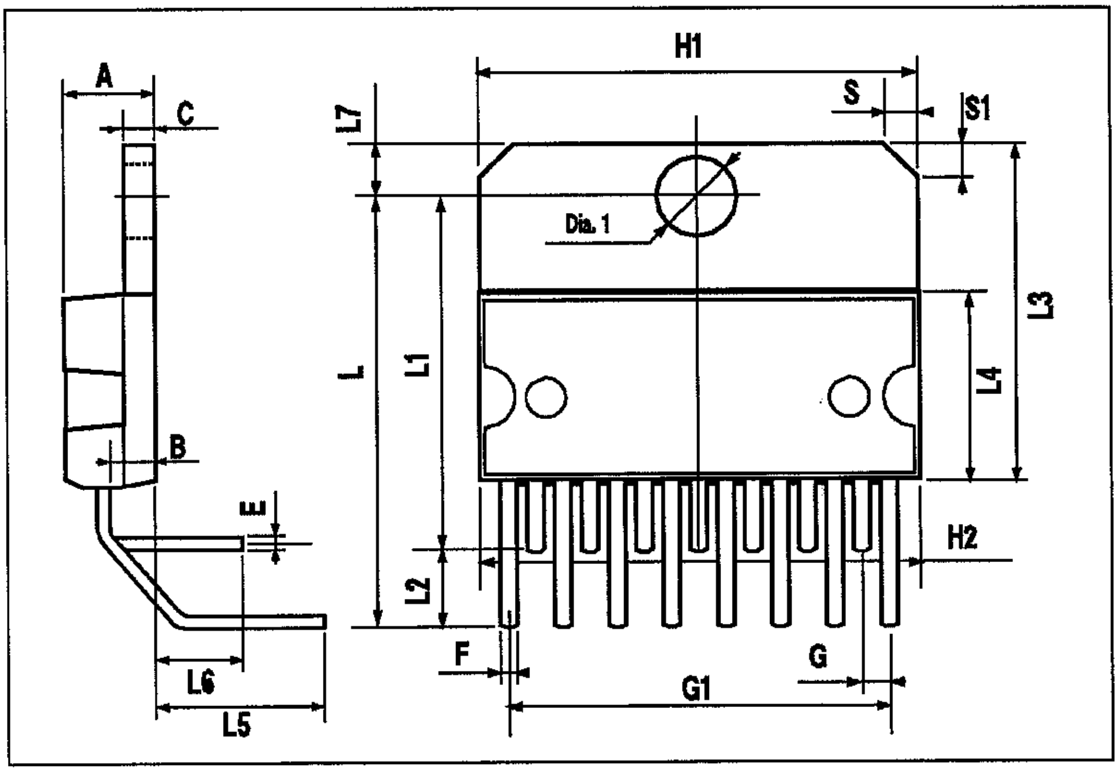


DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			5			0.197
B			2.65			0.104
C			1.6			0.063
E	0.49		0.55	0.019		0.022
F	0.66		0.75	0.026		0.030
G	1.14	1.27	1.4	0.045	0.050	0.055
G1	17.57	17.78	17.91	0.692	0.700	0.705
H1	19.6			0.772		
H2			20.2			0.795
L		20.57			0.810	
L1		18.03			0.710	
L2		2.54			0.100	
L3	17.25	17.5	17.75	0.679	0.689	0.699
L4	10.3	10.7	10.9	0.406	0.421	0.429
L5		5.28			0.208	
L6		2.38			0.094	
L7	2.65		2.9	0.104		0.114
S	1.9		2.6	0.075		0.102
S1	1.9		2.6	0.075		0.102
Dia1	3.65		3.85	0.144		0.152

OUTLINE AND MECHANICAL DATA

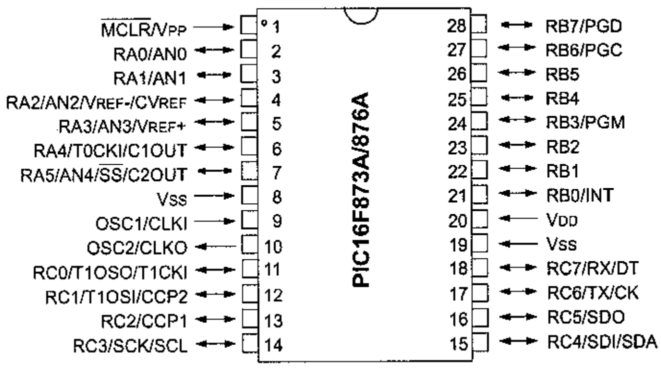


Multiwatt15 H

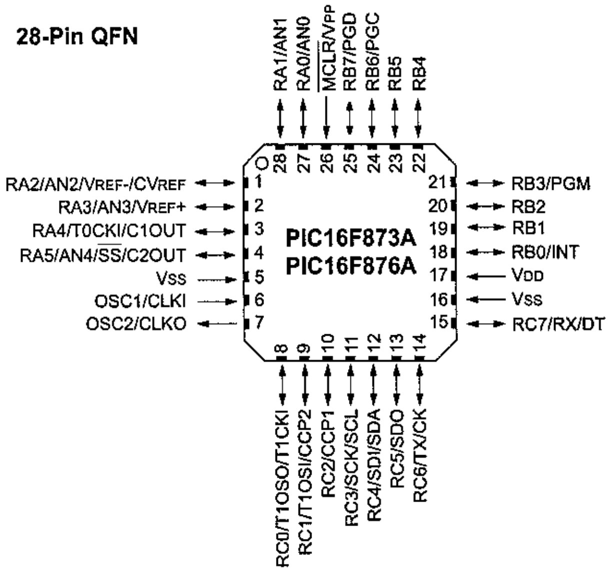


n Diagrams

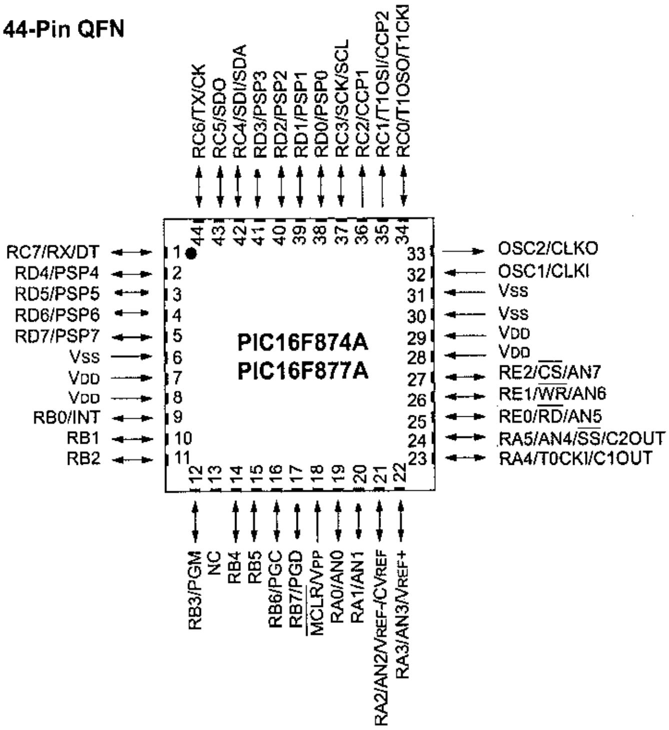
28-Pin PDIP, SOIC, SSOP



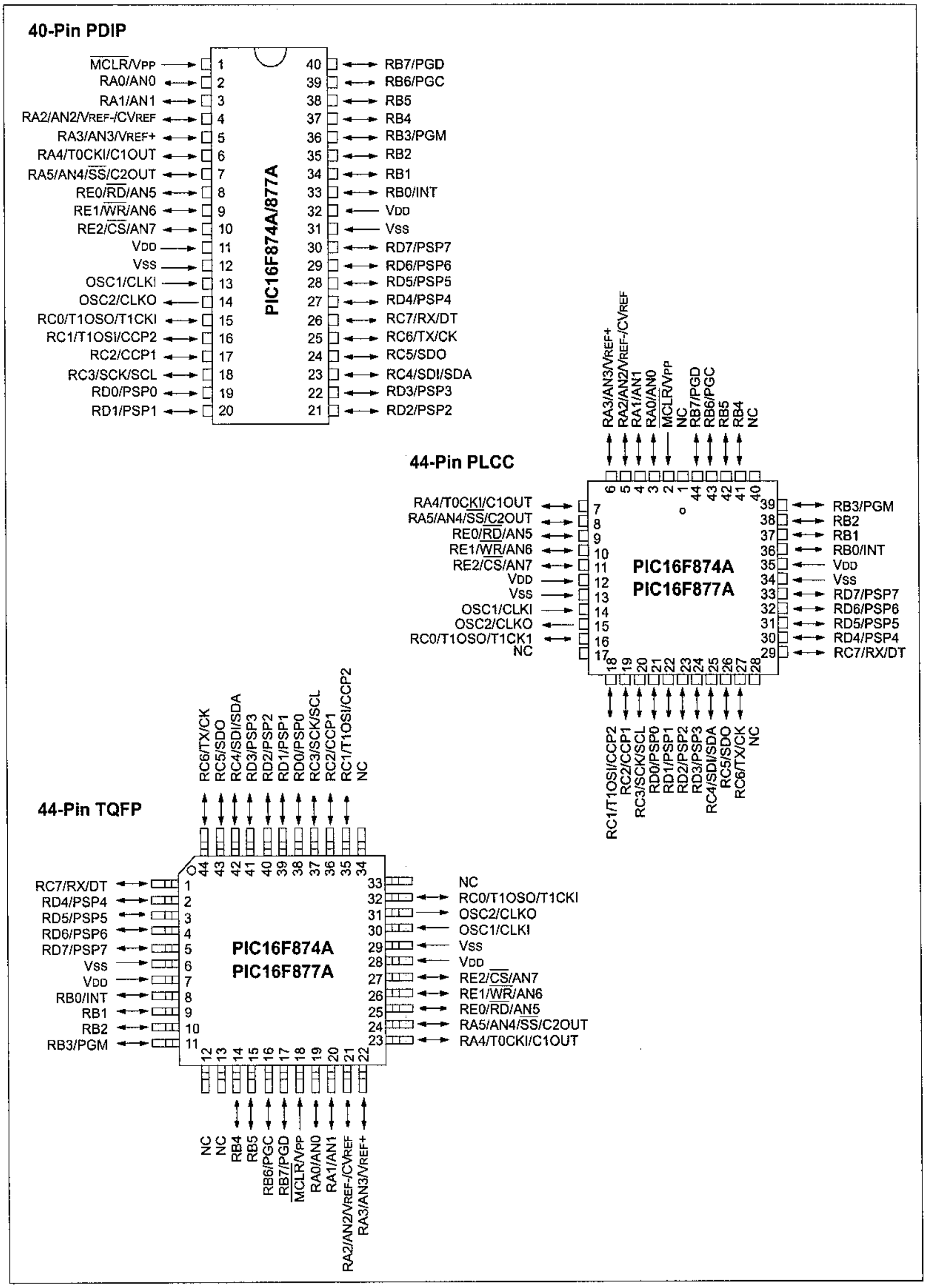
28-Pin QFN



44-Pin QFN



Pin Diagrams (Continued)



able of Contents

TO OUR VALUED CUSTOMERS

It is our intention to provide our valued customers with the best documentation possible to ensure successful use of your Microchip products. To this end, we will continue to improve our publications to better suit your needs. Our publications will be refined and enhanced as new volumes and updates are introduced.

If you have any questions or comments regarding this publication, please contact the Marketing Communications Department via E-mail at **docerrors@mail.microchip.com** or fax the **Reader Response Form** in the back of this data sheet to (480) 792-4150. We welcome your feedback.

Most Current Data Sheet

To obtain the most up-to-date version of this data sheet, please register at our Worldwide Web site at:

http://www.microchip.com

You can determine the version of a data sheet by examining its literature number found on the bottom outside corner of any page. The last character of the literature number is the version number, (e.g., DS30000A is version A of document DS30000).

Errata

An errata sheet, describing minor operational differences from the data sheet and recommended workarounds, may exist for current devices. As device/documentation issues become known to us, we will publish an errata sheet. The errata will specify the revision of silicon and revision of document to which it applies.

To determine if an errata sheet exists for a particular device, please check with one of the following:

- Microchip's Worldwide Web site; http://www.microchip.com
- Your local Microchip sales office (see last page)
- The Microchip Corporate Literature Center; U.S. FAX: (480) 792-7277

When contacting a sales office or the literature center, please specify which device, revision of silicon and data sheet (include literature number) you are using.

Customer Notification System

Register on our Web site at **www.microchip.com/cn** to receive the most current information on all of our products.

1.0 DEVICE OVERVIEW

This document contains device specific information about the following devices:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

PIC16F873A/876A devices are available only in 28-pin packages, while PIC16F874A/877A devices are available in 40-pin and 44-pin packages. All devices in the PIC16F87XA family share common architecture with the following differences:

- The PIC16F873A and PIC16F874A have one-half of the total on-chip memory of the PIC16F876A and PIC16F877A
- The 28-pin devices have three I/O ports, while the 40/44-pin devices have five
- The 28-pin devices have fourteen interrupts, while the 40/44-pin devices have fifteen
- The 28-pin devices have five A/D input channels, while the 40/44-pin devices have eight
- The Parallel Slave Port is implemented only on the 40/44-pin devices

The available features are summarized in Table 1-1. Block diagrams of the PIC16F873A/876A and PIC16F874A/877A devices are provided in Figure 1-1 and Figure 1-2, respectively. The pinouts for these device families are listed in Table 1-2 and Table 1-3.

Additional information may be found in the PICmicro® Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip web site. The Reference Manual should be considered a complementary document to this data sheet and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

TABLE 1-1: PIC16F87XA DEVICE FEATURES

Key Features	PIC16F873A	PIC16F874A	PIC16F876A	PIC16F877A
Operating Frequency	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory (bytes)	128	128	256	256
Interrupts	14	15	14	15
I/O Ports	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C	Ports A, B, C, D, E
Timers	3	3	3	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Analog Comparators	2	2	2	2
Instruction Set	35 Instructions	35 Instructions	35 Instructions	35 Instructions
Packages	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN