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JUDUL: __MODELLING MAGNETIC LEVITATION (MAGLEV) TRAIN__

SESI PENGAJIAN: 2011/2012

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MODELLING MAGNETIC LEVITATION (MAGLEV) TRAIN

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This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electrical and Electronics Engineering

Faculty of Electrical & Electronics Engineering
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Dedicated, in thankful appreciation for support, encouragement and understandings to my beloved mother and father
And those people who have guided and inspired me throughout my journey of education.

Thanks for everything…

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ABSTRACT

‘Maglev’ represents magnetic levitation. The magnetically levitated train has no wheels, but floats on an electromagnetic wave. Maglev is trains that run on magnets in a certain way so that they are equally levitated. Maglev trains prove to be a promising technology in the future. The transrapid system uses servo mechanism to pull the train up from underneath the track and maintains a constant gap while travelling at high speed. Magnetically levitated trains may be the transportation of the future because of their advantages on modern transportation use today. As the train floats on the track, there is no contact with ground and need no moving parts, making the train a low maintenance affair. Their maintenance is less expensive than the conventional trains. Furthermore, there is no possibility of any parts wearing out and there is less noise because no steels wheels running on steel tracks. However, noise still occurred by air resistance. They are a lot better than the trains we used today and run almost as fast as an airplane. Also, these trains run on magnets, and therefore do not produce pollution, making them much more environmentally safe.

ABSTRAK

'Maglev'(Magnetic Levitation) mewakili pengapungan atau pengangkatan magnet. Kereta api Maglev tidak mempunyai roda dan bergerak dengan terapung di atas gelombang elektromagnet. Maglev adalah kereta api yang bergerak di atas magnet dengan cara tertentu supaya terapung sepenuhnya. Kereta api Maglev terbukti menjadi satu teknologi yang canggih di masa hadapan. Sistem Transrapid menggunakan mekanisma servo dengan menarik kereta api dari bawah trek dan mengekalkan jurang semasa pergerakan pada kelajuan yang sangat tinggi. Kereta api Maglev menjadi pengangkutan yang akan digunakan pada masa hadapan kerana kelebihan mereka pada penggunaan pengangkutan moden hari ini. Ia terapung di atas landasannya, tidak bersentuh dengan tanah dan tidak memerlukan bahagian yang bergerak, menyebabkan kos penyelenggaraan yang rendah. Penyelenggaraan mereka adalah kurang mahal daripada kereta api konvensional. Tambahan pula, tidak ada kemungkinan mana-mana bahagian akan tercabut dan mengeluarkan bunyi bising kerana tiada penggunaan roda keluli di trek. Walaubagaimanapun, bunyi bising masih terhasil oleh rintangan udara. Banyak kelebihan terdapat pada kereta api Maglev berbanding daripada kereta api yang kita gunakan hari ini dan ia bergerak hampir laju dengan kelajuan kapal terbang. Akhir sekali, kereta api Maglev tidak menghasilkan pencemaran udara, menjadikan mereka teknologi yang lebih mesra alam.

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LIST OF ABBREVIATION

V	Voltage
LED	Light Emitting Diode
LM298	Dual Full Bridge Motor Driver
LM7805	Voltage Regulator
DC	Direct Current
PIC	Peripheral Interface Controller
IC	Integrated Circuit
VDD	Supply Voltage
VSS	Ground
RPM	Revolution Per Minute
IR	Infrared
RF	Radio Frequency

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Maglev

The idea of Maglev transportation has been around since the early 1900s. The benefit of eliminating the wheel/rail friction to obtain higher speeds and lower maintenance costs has great appeal. The basic idea of a Maglev Train is to levitate it with magnetic fields so there is no physical contact between the train and the rails (guide ways). There are three primary functions basic to maglev technology: levitation or suspension, propulsion and guidance. Figure 1.1 shows the three main concepts about Maglev Train: propulsion, levitation and guidance.

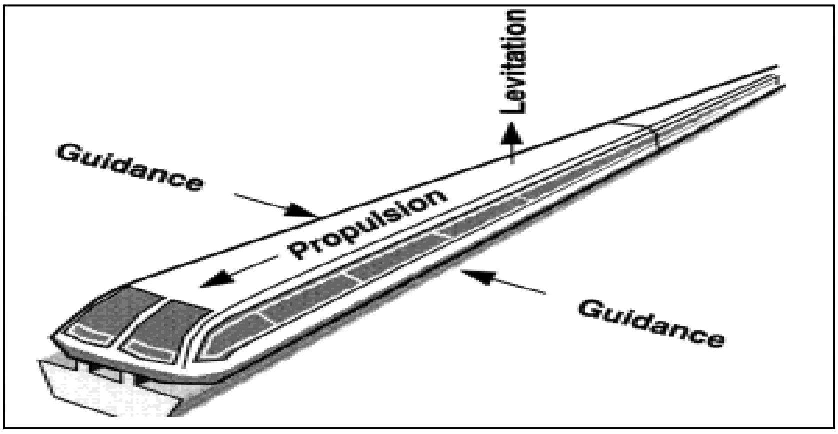

Figure 1.1: Three main concepts about Maglev Train

1.11 Suspension Systems

German engineers had developed Electromagnetic Suspension (EMS) while Japanese engineers had developed Electrodynamic Suspension (EDS), the newest EDS technology is the Inductrack. There are three basic different concepts of magnetic suspension have evolved.

1) The attractive Electromagnetic Suspension (EMS) uses electromagnets on the train body which are attracted to the iron rails. The vehicle magnets wrap around the iron guideways.
2) The Electrodynamic Suspension (EDS) levitates the train by repulsive forces from the induced currents in the conductive guideways. Electrmagnets on the guideway levitates the train.
3) The Inductrack concept that is permanent magnets levitates over passive coils.

In magnetic levitation, basic principles is used to suspend vehicles weighing 40 tons or more by generating a controlled magnetic force. Figure 1.1 shows the image of levitation techniques that is Electrodynamic, Electromagnetic and Inductrack.

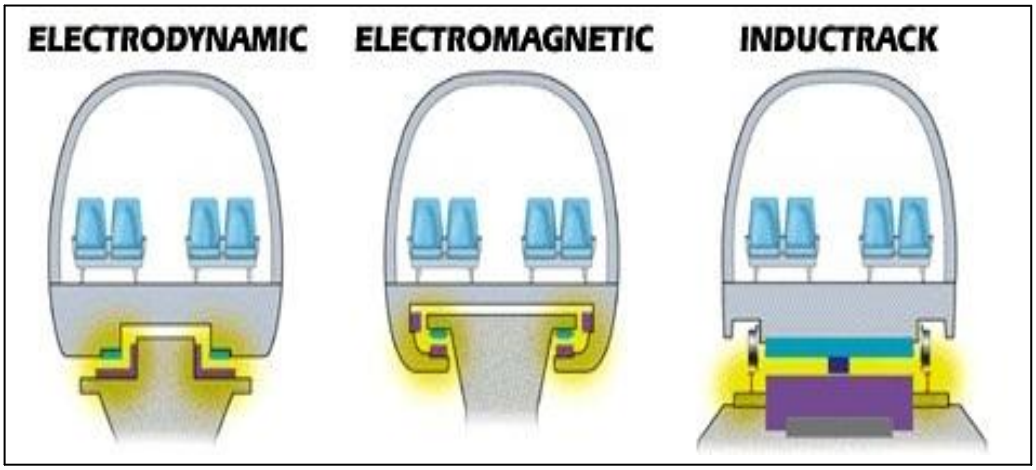

Figure 1.2: The types of Levitation for Maglev Train

However, there is a fundamental difference between these two systems. In the EMS system, the air gap between the guide ways and train magnets is very small (~1/2 inch), whereas the air gap in the EDS system may be as large as 8-10 inches. The small air gap of the EMS system implies much more stringent controls to maintain this small gap. The superconducting magnets that have been used in these MAGLEV systems have been of the low temperature variety. Because these must be operated below liquid helium temperature (4.2 K) these are expensive and complex systems [1].

Magnetic levitation is a process by which a magnet over a piece of a metal causes electrical current to flow in the metal that, in turn, produce forces that push the magnet upward. If the force is large enough, the moving magnet can levitated. Magnetic levitation is used in a new generation of train that will have cruising speeds of up to three hundred miles per hour [1].

1.12 Propulsion Systems

Long-stator propulsion using an electrically powered linear synchronous motor (LSM) winding in the guide way appears to be the best known option for high-speed maglev systems. It is also considered the more expensive option because of perceived higher guide way construction costs. Short-stator propulsion uses a linear induction motor (LIM) winding on board and a passive guide way. While short-stator propulsion typically reduces guide way costs, the LIM is heavy and reduces vehicle payload capacity, resulting in higher operating costs and lower revenue potential compared to the long-stator propulsion. A third alternative is a nonmagnetic energy source (gas turbine or turboprop) but this show results in a heavy vehicle and reduced operating efficiency [2].

A maglev train system has three basic components: a large electrical power source, metal coils lining the walls and the track, and large guidance magnets which are attached to the bottom of the train. The power source is then able to create a magnetic field in the electrified coils along the track.

Then, the magnetic field along the track repels the train so that it levitates above the ground while the magnetic field in the walls attracts and repels the train to move it along the designated path [2]. Figure 1.2 shows how the maglev train moves along the track.

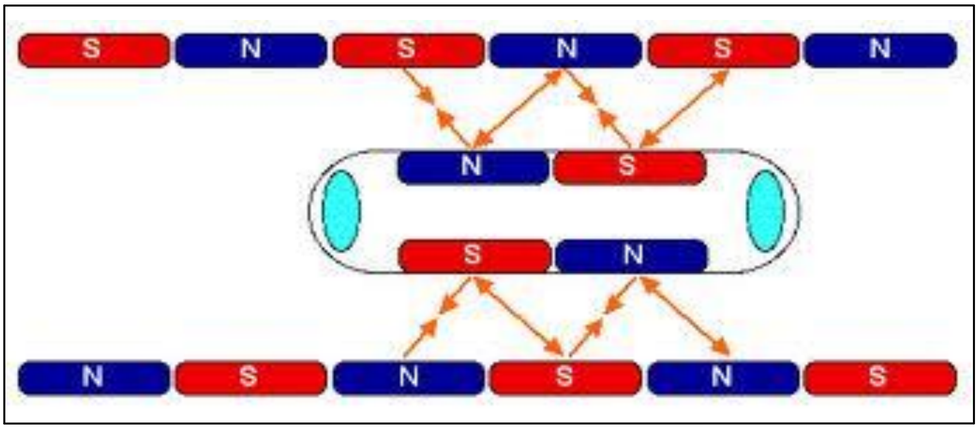

Figure 1.3: Magnetic field that move the train forwards.

The big difference between a maglev train and a conventional train is that maglev trains do not have an engine. The engine for maglev trains is rather inconspicuous. Instead of using fossil fuels, the magnetic field created by the electrified coils in the guide way walls and the track combine to propel the train [3].

The entire maglev system is control by operation control system. Operational control system is the fundamental guarantee for the normal operation of the whole maglev system. It includes all the equipment to be used in security guarantee control, execution and plan and also includes the equipment to be used in communication among the equipment. Operation control system consists of operation control center, communication system and on-board control system [3].

1.13 Guidance system

Guidance or steering refers to the sideward forces that are required to make the vehicle follow the guide way. The necessary forces are supplied in an exactly analogous fashion to the suspension forces, either attractive or repulsive. The same magnets on board the vehicle, which supply lift, can be used for guidance or separate guidance magnets. Figure 1.3 shows the magnets to guide the maglev train at guide ways [4].

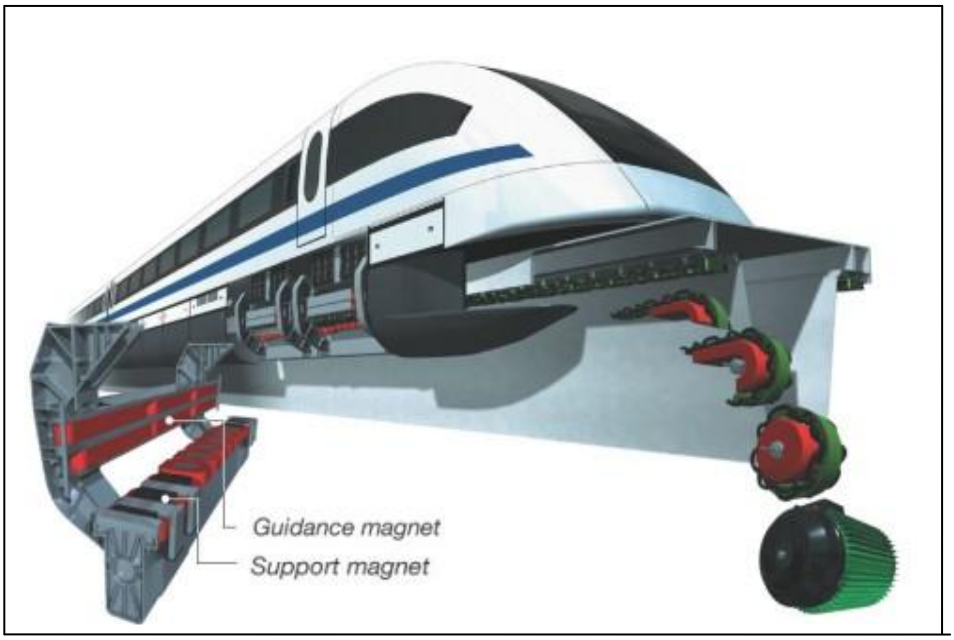

Figure 1.4: Magnets for Maglev Train guidance

1.2 Problem Statement

The material to do the model of Maglev Train is high as the costs for magnets are expensive. Magnetic force of the magnet must strong enough to levitate the model train. The cost of modeling maglev system using superconducting is very high because of superconductor itself is very expensive.

Also, to control the speed of train, a controller is needed. There must have a controller that is connected to the maglev system.

Large current through the motor is also needed in order to create enough thrust force and drag force to propel the model train forward. If the current is not enough, the train will not propel along the track.

1.3 Objectives

The objectives of this project are

I. To create a less expensive model of Maglev Train

II. To control the speed of the Maglev Train by using PIC (Microcontroller)

III. To study the difference between superconducting maglev and electromagnetic maglev.

1.4 Scopes of Project

The speed of the model maglev train is controlled by PIC that indicates three different speeds. First speed is slow, second speed is fast, and third speed is very fast..

Next, the PIC only controls the speed of DC motor and cannot control the direction of the DC motor.

Lastly, the model of Maglev Train can't be applied in real life. For modelling Maglev, inside of the body of train it's self are created including putting some magnet. However, if it applied to the real maglev, those materials that are made of magnets and have different pole at surrounding or inside the train will attract to the body of the train.

1.5 Outline of Thesis

This modelling of Maglev Train final thesis consists of five chapters including this chapter. The content of each chapter are outlined as follows:

1- Introduction	Introducing the overview of project including the background, objectives, problem statement, and scope of the project.
2-Literature Review	Before starting the project, the background and literature review about modeling of maglev train has been studied in order to understand more about the operation and principle of this project.
3-Methodology	This chapter will explain how the project was organized and the flow of system designed. Before developing the prototype, the simulation has been done

to make sure that the circuit would be working properly.

4-Result and Discussion The result will be analyzed and discussed in this chapter. It will shows the result achieved by doing this project. The results are categorized into three parts; hardware, software and analysis of the system.

5-Conclusion The overall conclusion of this project that has been addressed in this chapter including future work of the project. The future works are recommendation and suggestions made for the project to be improved in near future.

1.6 Gantt Chart

Gantt chart and the details for this project that had been implemented for the first and second semester are shows in APPENDIX. Gantt chart for semester one is APPENDIX D whereas semester two is APPENDIX E.

CHAPTER 2

LITERATURE REVIEW

2.1 Modeling of Maglev system

2.11 Control of Magnetic Levitation System Using Fuzzy Logic Control

In this study, it has been observed that the basic design of Maglev's is an arrangement of electromagnets placed on top of the plant and makes the ball levitated in the air. The modeling system is simulated using MATLAB Simulink. This paper presents the comparison output for both PID Controller and Fuzzy controller to control the ball levitate on the air. The focus of this study is to design the controller that can cope with Maglev's which highly nonlinear and inherently unstable [5].

2.12 Modeling of a flexible rotor maglev system

The modelling takes into account the three main behavioural characteristics of such magnetically-levitated rotor: the rigid dynamics, the flexible dynamics and the rotating unbalanced motion.

Using this model, a stabilizing controller has been successfully designed for the system and a complete experimental analysis of its performance is carried out [6].

2.13 Propulsion control of superconducting linear synchronous motor vehicle

In this journal, it stated that the armature current of a superconducting Linear Synchronous Motor (LSM) for a maglev vehicle is controlled to produce a suitable propulsion force so that the vehicle follows the reference speed signal sent from a control station. Besides that, the power is supplied from some inverters to the LSM armature sections where the vehicle exists. This paper shows an exact mathematical modelling of the propulsion control system to treat the system analytically, which is used for designing controllers and performance computer simulations. The calculated results include the simulations when the vehicle goes through power feeder section borders and tunnels that have a large aerodynamic drag force with taking account of an inverter failure [7].

2.14 Maglev Train (Superconducting Maglev)

It introduces superconductors and their usage in the modern world, as well as to the Meissner's Effect and the idea of magnetic levitation. It is a mesmerizing demonstration that can be kept and used indefinitely, as long as more liquid nitrogen is supplied. The Maglev Train achieves levitation through the phenomenon of superconductivity. Superconductivity occurs in special materials when they reach their critical temperature, which in this case is 107 K (-166 ºC). The main feature of superconductivity is the absence of resistance to an electrical current, called a zero-resistance state. In regular materials, the movement of electrons is restricted and an electric potential must be applied in order to create moving charge. Superconductors in the zero resistance-state allow electrons in the material to move free of impedance. Since current is moving charge (electrons), superconductors are able to carry current with almost infinite conductivity [8].

2.15 A maglev system: modeling and controller design

In this paper, the nonlinear mathematical model with five DOFs (degrees-of-freedom) of a magnetic levitation system is developed and analyzed. Then a second order sliding mode controller is proposed to regulate the levitation to a desired position, stabilize the other four DOFs in the nonlinear system and compensate the unknown increments on the load. Simulation results are presented to show the effectiveness of the proposed controller. The transport of material or products is a major problem in the manufacturing automation industry. As it currently stands transport specifications can be so variable from process within a single plant that each operation might require its own transport. Using magnetic levitation (maglev), a carrier can be partially or totally levitated or suspended by magnetic fields generated along the guiding tracks. This allows the carrier to move with little or no contact to the guiding tracks, thus greatly minimizing the problems of environmental contamination. Of course, such contact-free levitation has to be enforced for all DOFs of the rigid body [9].

2.2 PIC controller

2.21 Development of Motor Controller Based on PIC

This paper presents a motor controller based on PIC. Deferent from the traditional regular control pattern, the motor controller adopts changeable control pattern that enables a robot to use the different control mode according to the different external environment. The hardware, software architecture, algorithm of motion control, calibration, position limit, and communication are described. The experiments of position, velocity and current control are given, and the application of the motor controller is introduced [10].

CHAPTER 3

METHODOLOGY

3.1 Overview Maglev System

There are two main things for this modelling of Maglev Train which are model of the train and model of the track. Budget on doing these model are the lowest as possible. The train are controlled by PIC microcontroller to adjust the speed of DC motor. Small fan is attached to the DC motor and act just like the fan of airplane. Then, the maglev track is made by using thin plywood and lots of high magnetic strength magnet. The shape of the track is oblong shape. Suspension magnet is attached under the model of the train. The arrangement and ordering of the guidance magnet at track and train must be at same polarity. This is because of same pole of magnet will repels both of magnets and caused the model train to float (levitates) at the model track.

3.2 Hardware development

The simulation part should be running before doing the hardware part in order to make sure that the circuit can operate correctly and achieve the purpose of the project. This part is important because by doing simulation, the fault on the circuit can be safely determine without use the real components. If the prototype is developed without doing the simulation, any failure of the circuit will cause the damage on the components. Therefore, more budgets needed to buy new components. By doing this simulation, the budget of the project can be minimized and components damage can be avoided. Figure 3.1 shows the process of hardware development.

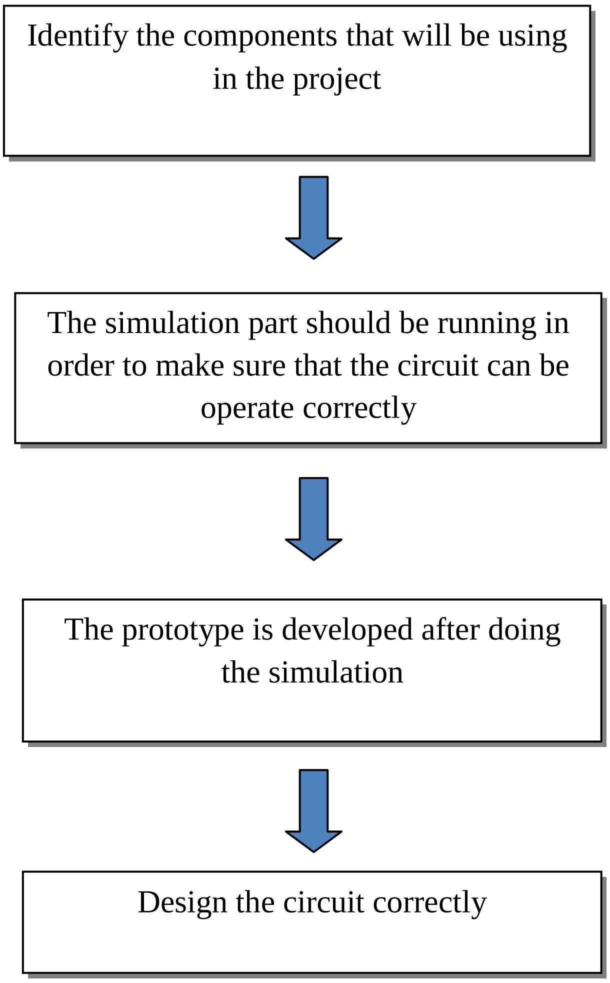

Figure 3.1: Process of Hardware Development

For this project, the software that has been used is:

i. Proteus – ISIS
ii. PIC KIT Controller
iii. PIC C Compiler

3.2.1 Track Modelling

The model of the track is made by plywood and a lot of magnets. Base of the track is 120cm x 70cm plywood. Area of the track for maglev train to propel is 100cm x 50cm. The shape is oblong shape. Magnets are arranged along the track and around two hundred magnets are used. AUTOCAD Software is used to design the model track. Figure 3.2 shows the plywood after been glued with strong gum (Dunlop General Purpose Contact Adhesive gum).

Figure 3.2: Oblong shape of maglev track model

3.2.2 Train Modelling

The model of the train is made of simulation circuit that attached to plywood as the base of the train. Magnets are glued at the bottom of the plywood. It will levitate at track because of same polarity with the magnets arranged at model track. Figure 3.3 shows the circuit of model train.

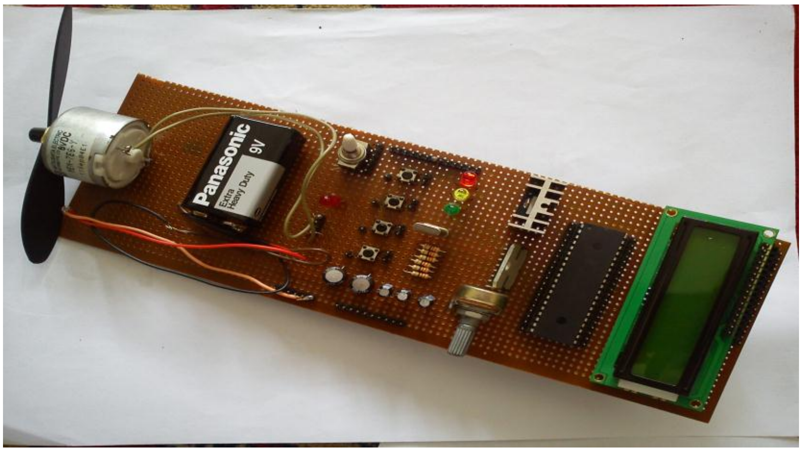

Figure 3.3: Circuit of the model train

3.2.2.1 Simulation Using ISIS Proteus Software

PROTEUS software is used to do the simulation of PIC microcontroller. The model of PIC is PIC18F4550. Figure 3.4 shows the simulation. The programming is attached in Appendix A.

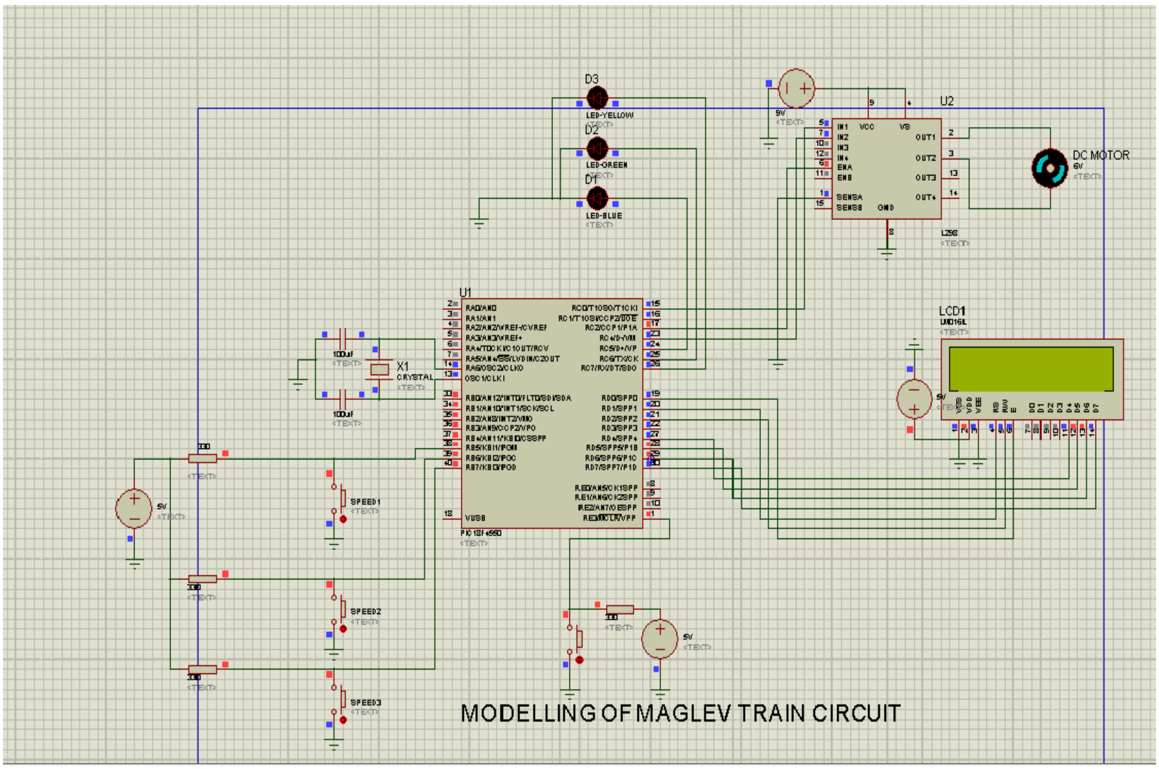

Figure 3.4: Simulation of motor speed control using Proteus Software

3.2.2.2 PIC Microcontroller

In this project, PIC18F4550 (40 pins) is used. The Hex file of the simulation at Proteus Software must be done first. The Hex file is taken from PIC C COMPILER in C language. The software PIC KIT was installed in computer according to the instruction. PIC was put at the PIC KIT and it will automatically detect the PIC. Lastly, burn the PIC according to the Hex file by clicking 'WRITE' button. Figure 3.5 shows the PIC KIT USB Programmer.

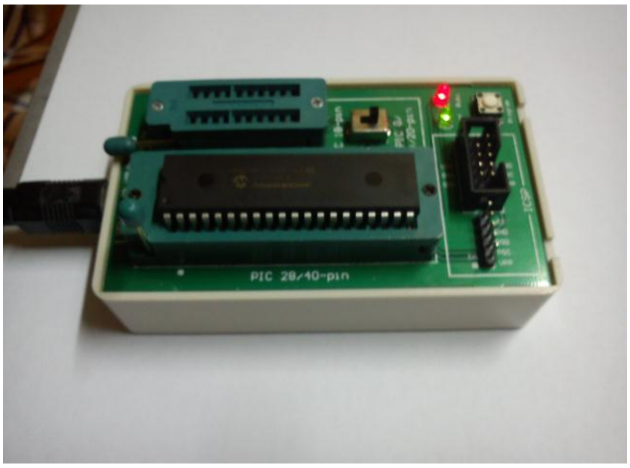

Figure 3.5: PIC KIT USB Programmer

3.2.2.3 Hardware Testing Circuit

Before assemble train circuit at Doughnut board, Breadboard was used as a testing circuit. Voltage regulator was the first to install at the hardware and it will give fixed output of 5V. LCD display and PIC18F4550 must be supplied by 5V input. Therefore, the controller power circuit is designed to supply this voltage to the controller circuit. A LM7805 voltage regulator is used. Two capacitors are added at the output of the regulator as bypassing capacitors as recommended by the microcontroller chip manufacture. Both these capacitors need to be placed physically close to the microcontroller.

Therefore, this power circuit is designed to be on the same board with the controller circuit. Figure 3.6 shows the output voltage after install voltage regulator to the circuit.

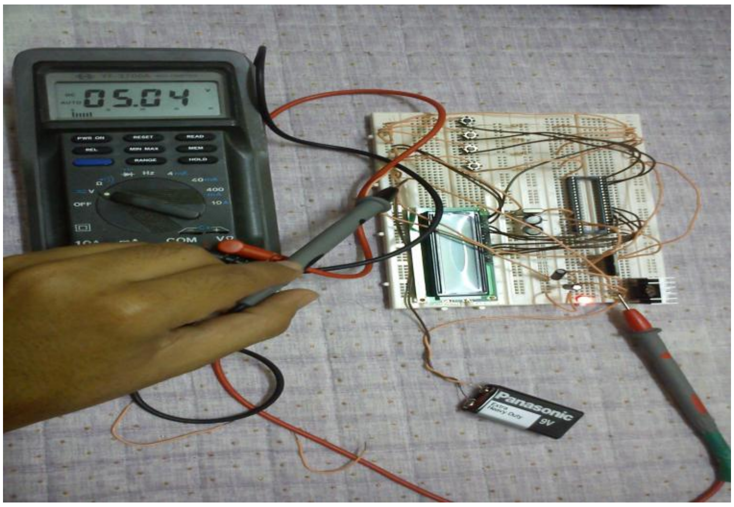

Figure 3.6: Output voltage of the circuit after installing Voltage Regulator

3.2.2.4 Magnets

The amount magnets that used are around two hundred units. The dimension of magnets is 17mm diameter and 0.06mm width. Figure 3.7 shows the magnets used for train modelling and track modelling.

Figure 3.7: Magnets used for model train and model track

A magnet has a polarity, in that one end is the north and the other is the south. Opposite poles attract but same poles repel each other. The magnetic force surrounding a magnet is not uniform. There is a great concentration of force exist at each end of the magnet and a very weak force at the center. Figure 3.8 shows how model train can levitates or float above model track by insert same pole of magnet and arrange it between them. Repulsive force exists between arrangement of same pole of magnet.

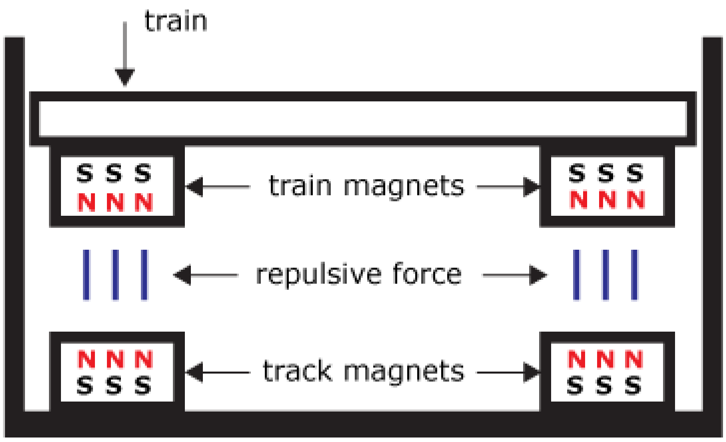

Figure 3.8: Model train levitates above model track.

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

This chapter discusses on the results and analysis data that are encountered throughout the completion of this project. After the development and completion of this project, it will be evaluated in order to measure the effectiveness and to ensure that it had met the outlined objectives successfully. Figure 4.1 shows the flow chart of the whole result to establish this project.

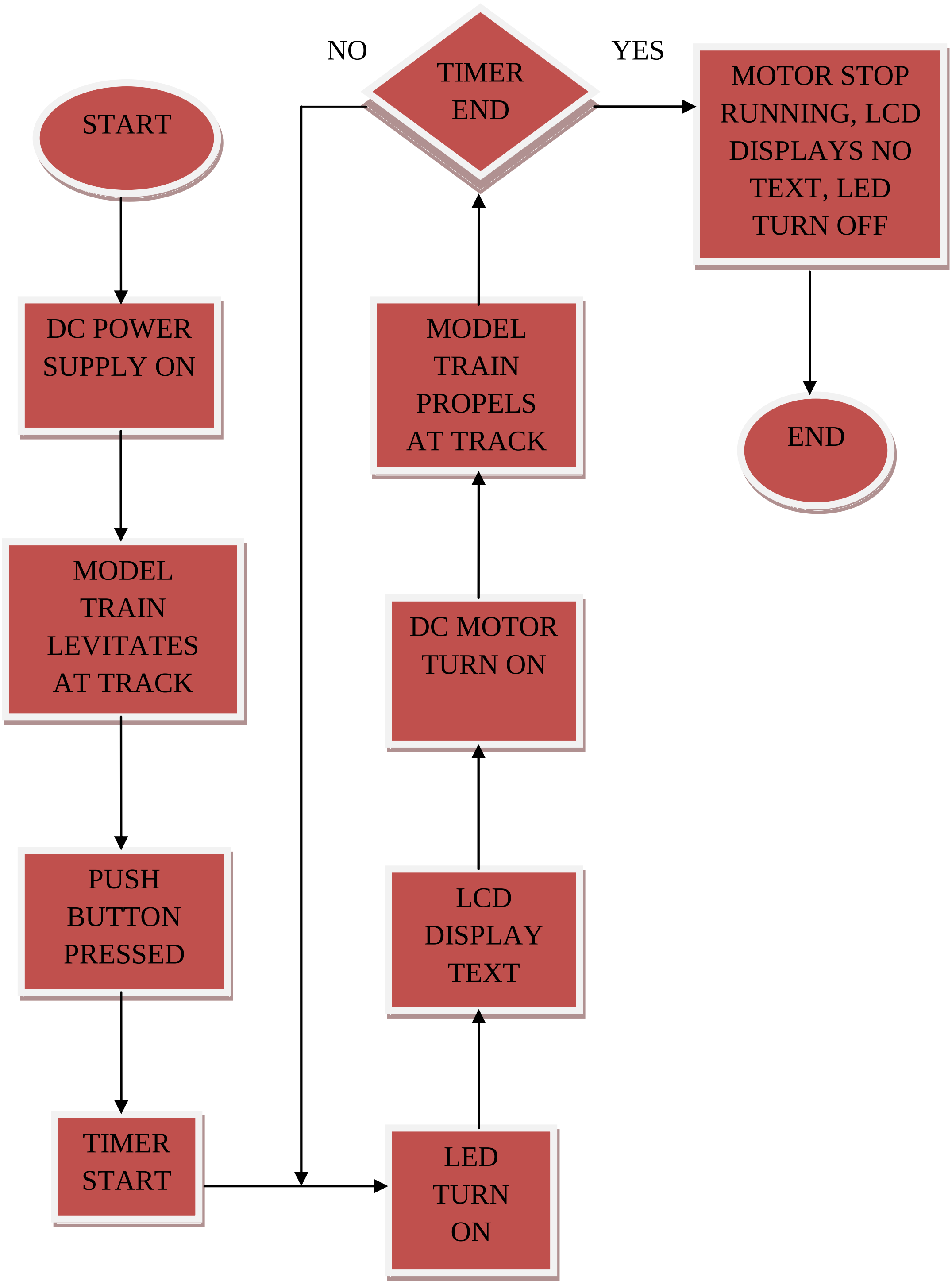

Figure 4.1: Flow chart of the whole step of functioning modeling of Maglev Train.

4.1 Software Analysis

In this section, result and discussion about PIC power supply circuit, simulation circuit and speed of DC motor will be discussed.

4.1.1 PIC Power supply circuit

Figure 4.2 shows the power supply circuit 9 Volt to 5 Volt for running the PIC microcontroller. It consists of LM7805 to produces voltage to 5 Volt at the output. The LED is used for indicator to make sure the circuit progress completely. Voltmeter at the input display 9 Volt and 5 Volt at the output of the circuit, shows that the circuit running successfully.

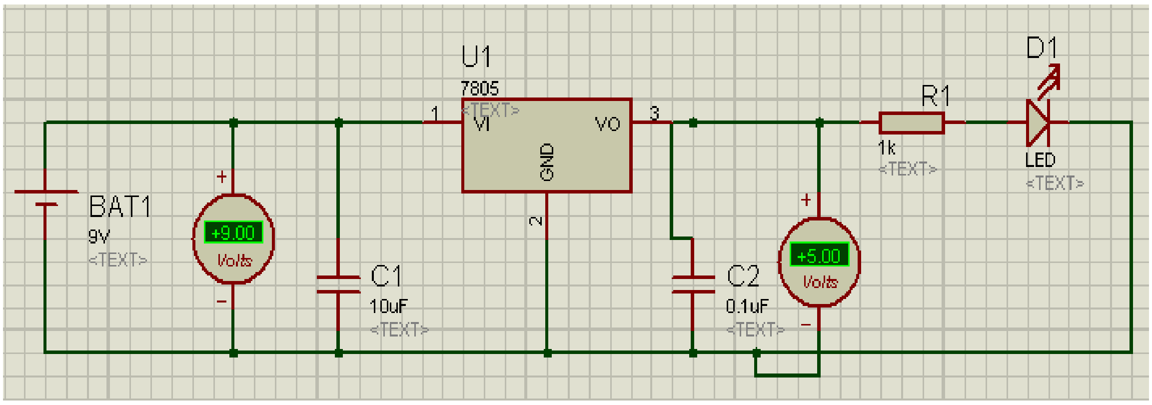

Figure 4.2: Simulation for power supply circuit

4.1.2 Software Simulation using PIC18F4550

Figure 4.3 shows the simulation circuit using ISIS Proteus software. This simulation used PIC18F4550 microcontroller to display the texts at LCD Display, turn on LED and run the 6V DC motor with different speed or RPM.

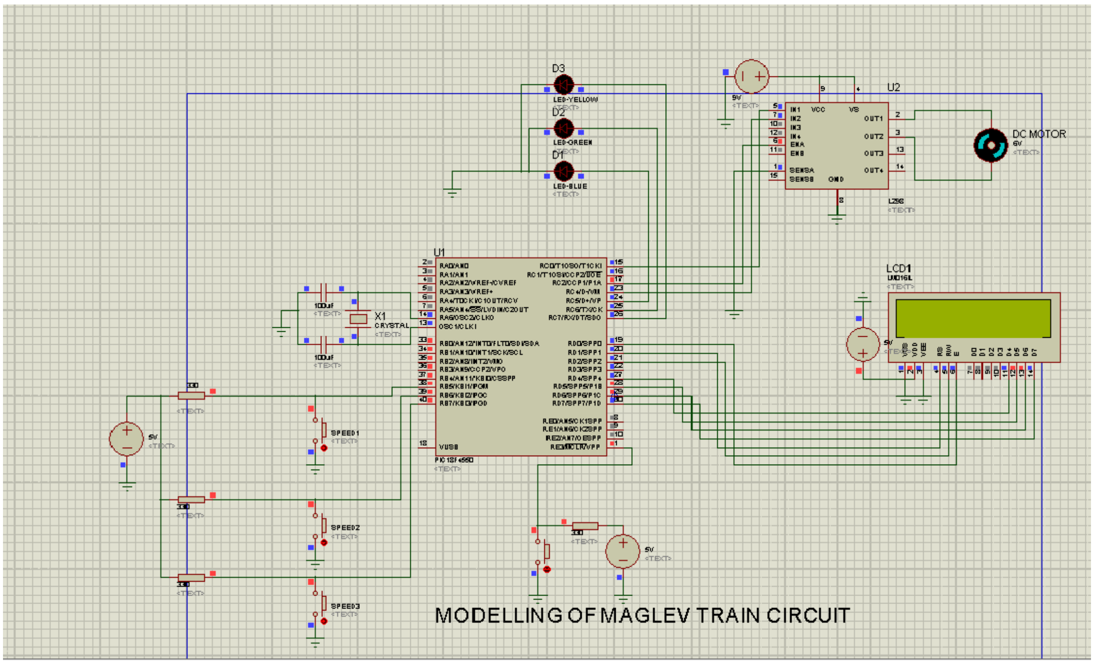

Figure 4.3: Simulation circuit of Modeling Maglev Train

There are three push buttons to indicate three different outputs at the simulation. Table 4.1 concludes the output when push button 1 is pressed.

Table 4.1: Input and output of the first option of simulation test

INPUT	OUTPUT
Push button 1 pressed	Blue LED turn on
	LCD Display displays text ‘SPEED 1 - SLOW’
	DC Motor runs slow

Figure 4.4 shows certain part at simulation circuit that indicates first option of simulation test.

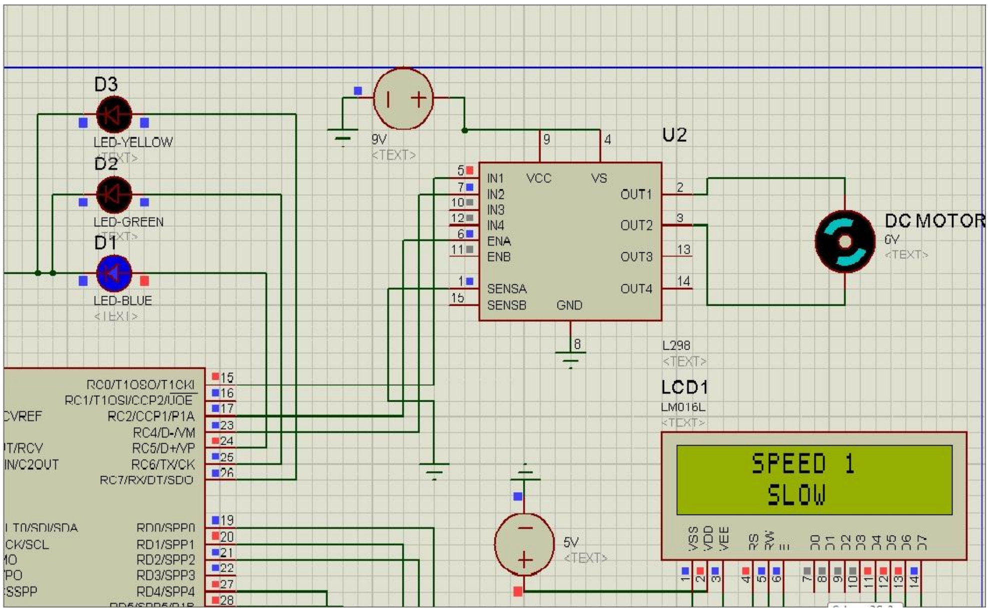

Figure 4.4: Output of the simulation when push button 1 is pressed

After that, Table 4.2 concludes the input and output when Push Button 2 is pressed.

Table 4.2: Input and output of the second option of simulation test

INPUT	OUTPUT
Push Button 2 pressed	Green LED turn on
	LCD Display displays text ‘SPEED 2 - FAST’
	DC Motor runs fast

Figure 4.5 shows certain part at simulation circuit that indicates second option of simulation test.

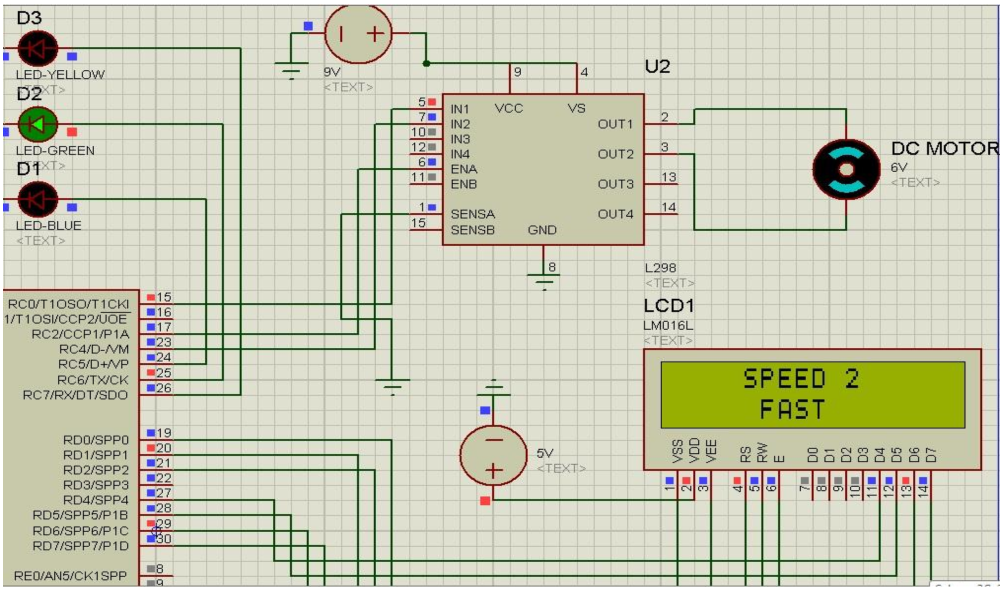

Figure 4.5: Output of the simulation when push button 2 is pressed

Lastly, the input and output of the simulation circuit are concluded at Table 4.3.

Table 4.3: Input and Output of third option of simulation test.

INPUT	OUTPUT
Push Button 3 pressed	Red LED turn on
	LCD Display displays text ‘SPEED 3 – VERY FAST’
	DC Motor runs very fast

Figure 4.6 shows certain part at simulation circuit that indicates third option of simulation test.

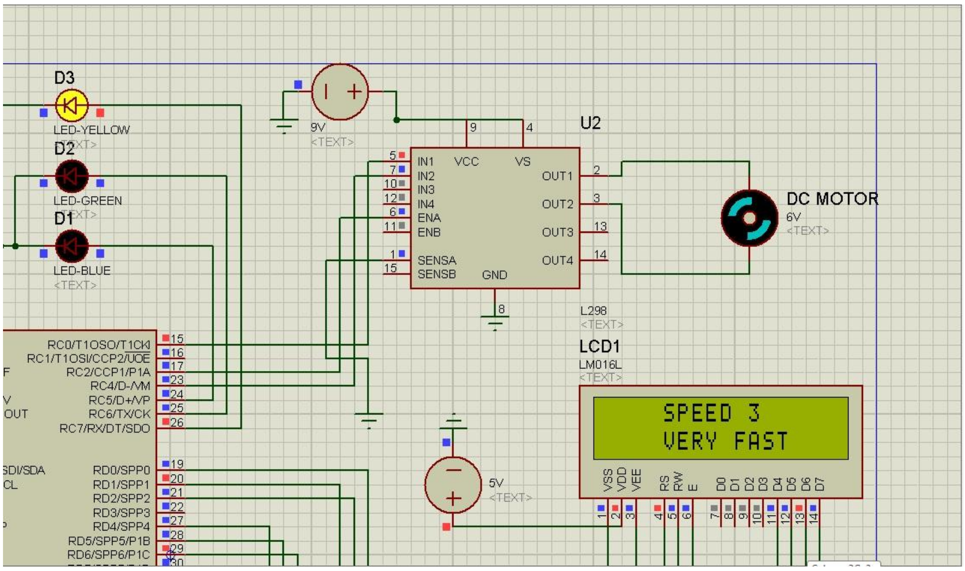

Figure 4.6: Output of the simulation when push button 3 is pressed

4.2 Hardware analysis

In this section, result and discussion about model train levitates, propels at model track and type of magnet will be discuss.

4.2.1 Model train Levitation

The model of the train is created from the circuit of simulation and plywood with magnets attached at the bottom at the plywood. To make the model train levitates at the model track, the arrangement of magnets at the train model must has same polarity with the magnets at model track. Same polarity of magnets will repels each other. Figure 4.7 shows the model train that levitates at the track.

Figure 4.7: Model train levitates at the track

4.2.2 Model train propulsion

By using the 9V DC motor, and three kind of speed as output, the model train will propels along the track according to the speed of DC motor. Figure 4.8 shows the small fan attached to the DC motor and drive the model train to move along the track.

Figure 4.8: Model train propels along the track

CHAPTER 5

CONCLUSIONS

5.0 Conclusions

At the end of this project, the project is successfully completed with the objectives stated. Model train has been created by using plywood and circuit of simulation. Model track also has been created also by using plywood and lot of magnets. The model train levitates and propels with three option of speed.

5.1 Future Recommendation

This project is the prototype of the real maglev train. The problem in this project is to control the DC motor to stop at time that needed. As mention at methodology, timer is added to the programming of PIC at model train. However, to improve on this design in the future, efficiency should be optimized by using RF (radio frequency) system to control start and stop of the circuit. Next to improve the circuit, also possibly using sensors. A Sensor can send signal to PIC Microcontroller whether want to run or stop the DC Motor.

At future projects, these features could add to the train. However the most important thing is must be made to this project is reduce the costs. Unfortunately, permanent magnets are very expensive, and building a maglev track system requires a lot of magnets. If an actual maglev train were to be built, the costs would be much too high for it to be reasonably implemented. The design in this project was not intended to minimize cost. However, for maglev trains to be implemented, the technology would need to become must more cost-effective.

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APPENDIX A

(SOURCE CODE FOR SIMULATION)

```
#include <18F4550.h>

#fuses XT,NOWDT,NOLVP,NOPROTECT

#use delay (clock=8M)

#include <lcd.c>


#define BUTTON1     PIN_B5

#define BUTTON2     PIN_B6

#define BUTTON3     PIN_B7


#define LED1        PIN_C5

#define LED2        PIN_C6

#define LED3        PIN_C7


#define PWM_MOTOR   PIN_C2


#define MOTOR_FOR   PIN_C0


#define LCD_E  PIN_D0

#define LCD_RS PIN_D3

#define LCD_RW PIN_D2

#define LCD_D4 PIN_D4

#define LCD_D5 PIN_D5

#define LCD_D6 PIN_D6

#define LCD_D7 PIN_D7


void main()

{
```

```
set_tris_b(0xFF);
set_tris_d(0x00);
set_tris_c(0x00);

output_b(0xFF);
output_d(0x00);
output_c(0x00);

setup_timer_2(T2_DIV_BY_4,254,1);
setup_ccp1(ccp_pwm);

lcd_init();

while(TRUE)

{

if (!input(BUTTON1))

{
output_high(LED1);
output_low(LED2);
output_low(LED3);

output_high(MOTOR_FOR);
```

```
set_pwm1_duty(100);



lcd_putc("\f");
lcd_gotoxy(5,1);
lcd_putc("SPEED 1");
lcd_gotoxy(6,2);
lcd_putc("SLOW");



}

else if (!input(BUTTON2))

{
output_high(LED2);
output_low(LED3);
output_low(LED1);

output_high(MOTOR_FOR);

set_pwm1_duty(800);

lcd_putc("\f");
lcd_gotoxy(5,1);
lcd_putc("SPEED 2");
```

```
lcd_gotoxy(6,2);
lcd_putc("FAST");

}


else if (!input(BUTTON3))

{
output_high(LED3);
output_low(LED2);
output_low(LED1);

output_high(MOTOR_FOR);

set_pwm1_duty(2000);



lcd_putc("\f");
lcd_gotoxy(5,1);
lcd_putc("SPEED 3");
lcd_gotoxy(5,2);
lcd_putc("VERY FAST");

}
}
```

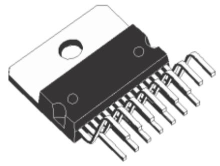
APPENDIX B

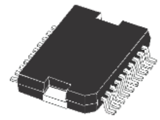
(DUAL FULL BRIDGE DRIVER)

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

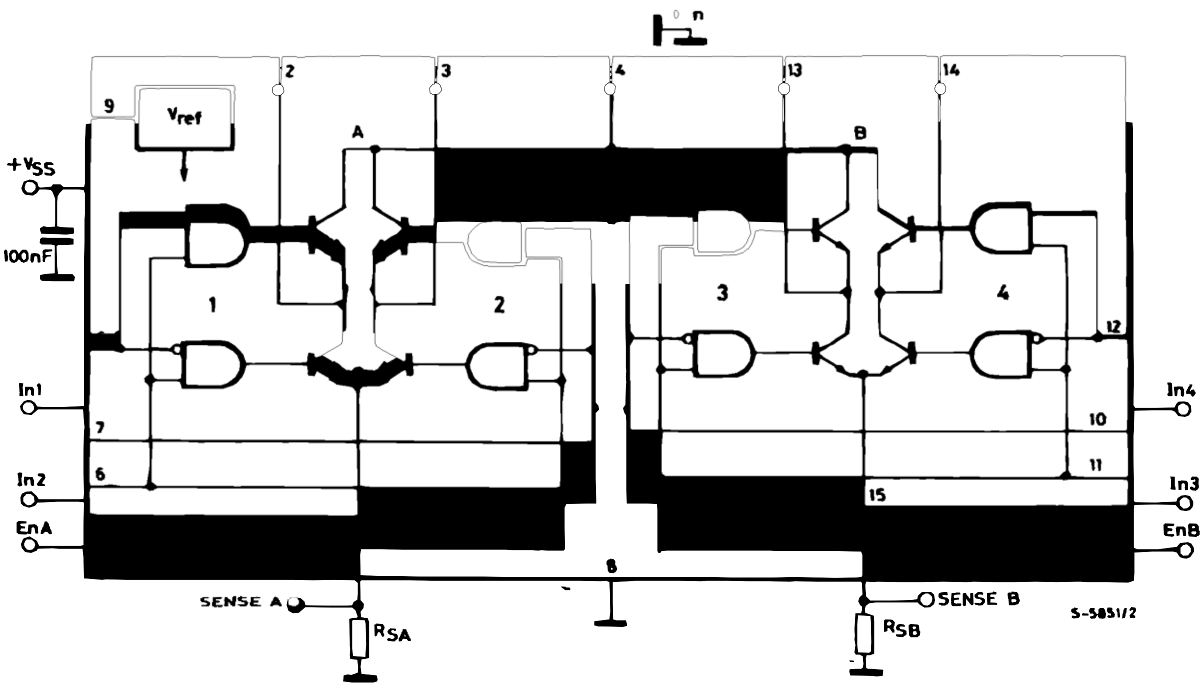

PowerSO20

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.

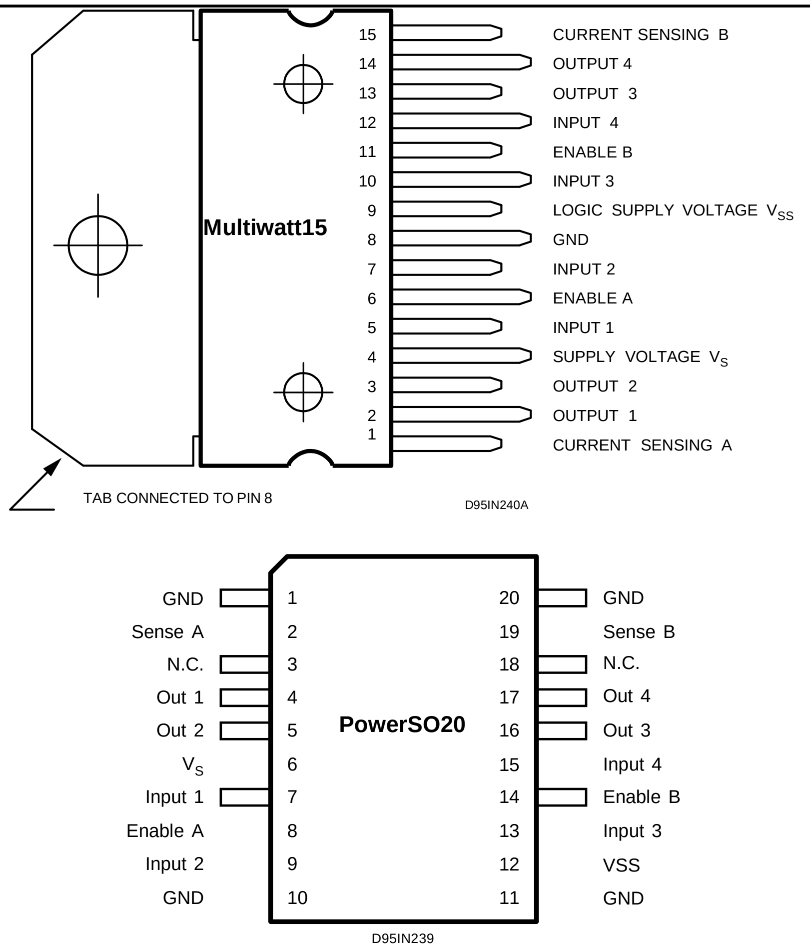
BLOCK DIAGRAM



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 = 100 s) –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	A
I_{iH}	High Voltage Input Current (pins 5, 7, 10, 12)	Vi = H V_{SS} –0.6V		30	100	A
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	A
I_{en} = H	High Voltage Enable Current (pins 6, 11)	V_{en} = H V_{SS} –0.6V		30	100	A
$V_{CEsat (H)}$	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		s
T_2 (V_i)	Source Current Fall Time	0.9 I_L to 0.1 I_L (2); (4)		0.2		s
T_3 (V_i)	Source Current Turn-on Delay	0.5 V_i to 0.1 I_L (2); (4)		2		s
T_4 (V_i)	Source Current Rise Time	0.1 I_L to 0.9 I_L (2); (4)		0.7		s
T_5 (V_i)	Sink Current Turn-off Delay	0.5 V_i to 0.9 I_L (3); (4)		0.7		s
T_6 (V_i)	Sink Current Fall Time	0.9 I_L to 0.1 I_L (3); (4)		0.25		s
T_7 (V_i)	Sink Current Turn-on Delay	0.5 V_i to 0.9 I_L (3); (4)		1.6		s
T_8 (V_i)	Sink Current Rise Time	0.1 I_L to 0.9 I_L (3); (4)		0.2		s
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		s
T_2 (V_{en})	Source Current Fall Time	0.9 I_L to 0.1 I_L (2); (4)		1		s
T_3 (V_{en})	Source Current Turn-on Delay	0.5 V_{en} to 0.1 I_L (2); (4)		0.3		s
T_4 (V_{en})	Source Current Rise Time	0.1 I_L to 0.9 I_L (2); (4)		0.4		s
T_5 (V_{en})	Sink Current Turn-off Delay	0.5 V_{en} to 0.9 I_L (3); (4)		2.2		s
T_6 (V_{en})	Sink Current Fall Time	0.9 I_L to 0.1 I_L (3); (4)		0.35		s
T_7 (V_{en})	Sink Current Turn-on Delay	0.5 V_{en} to 0.9 I_L (3); (4)		0.25		s
T_8 (V_{en})	Sink Current Rise Time	0.1 I_L to 0.9 I_L (3); (4)		0.1		s

1) 1)Sensing voltage can be –1 V for t 50 sec; 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.

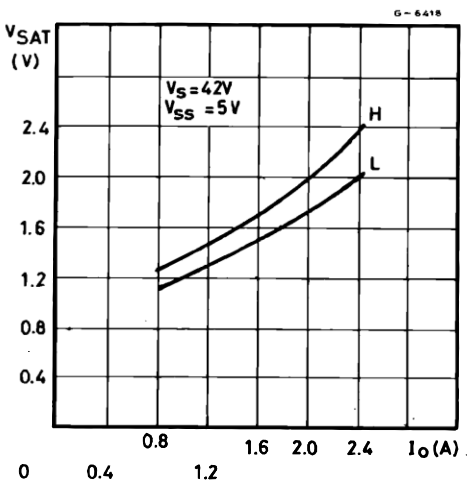
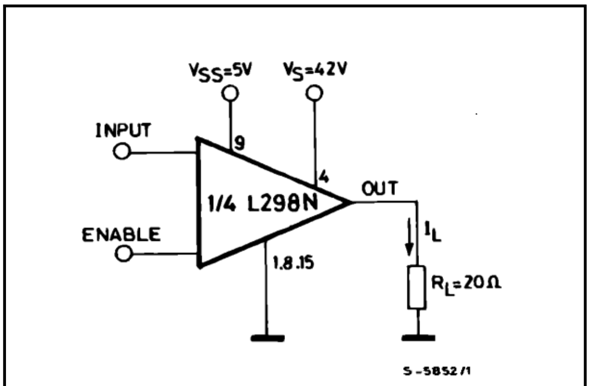
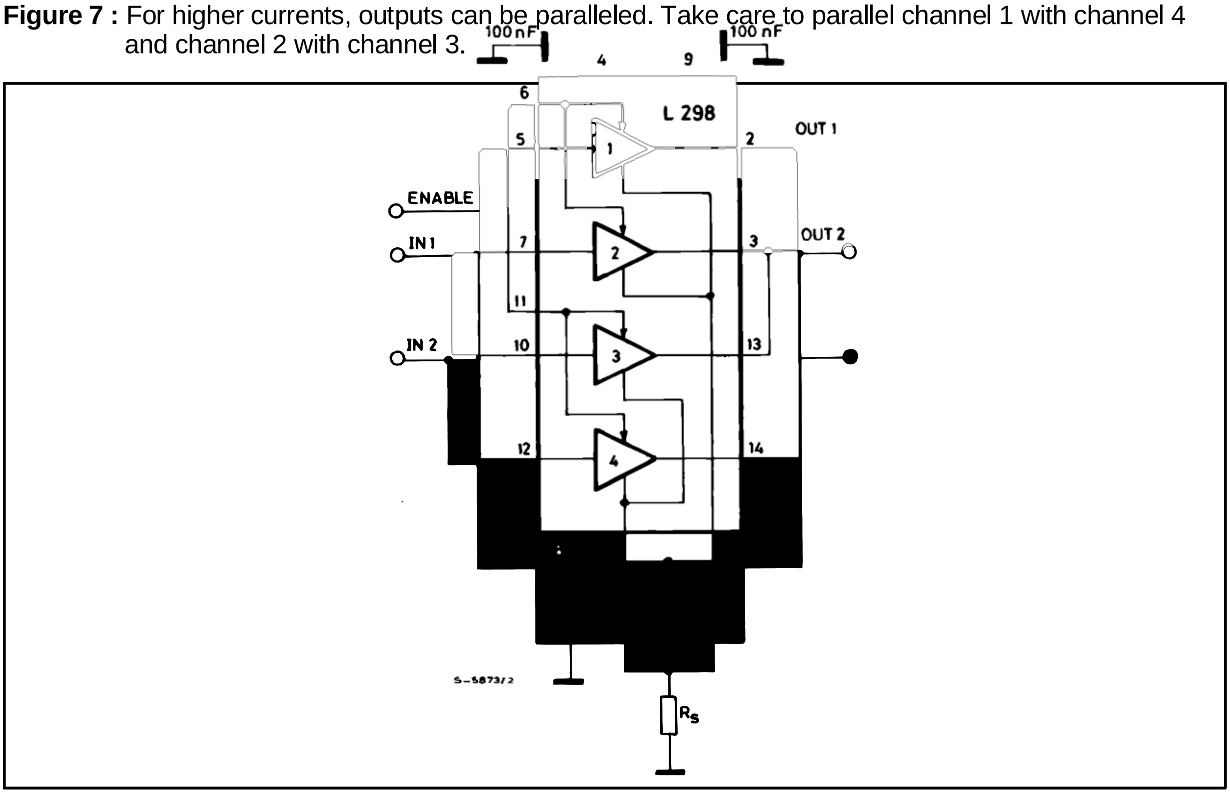


Figure 2 : Switching Times Test Circuits.



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

Figure 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} 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.

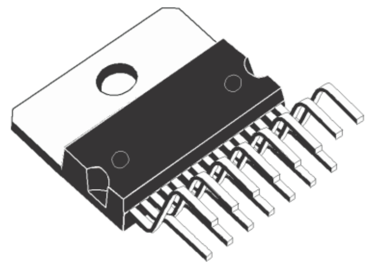
The brake function (Fast motor stop) requires that the Absolute Maximum Rating of 2 Amps must never be overcome.

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

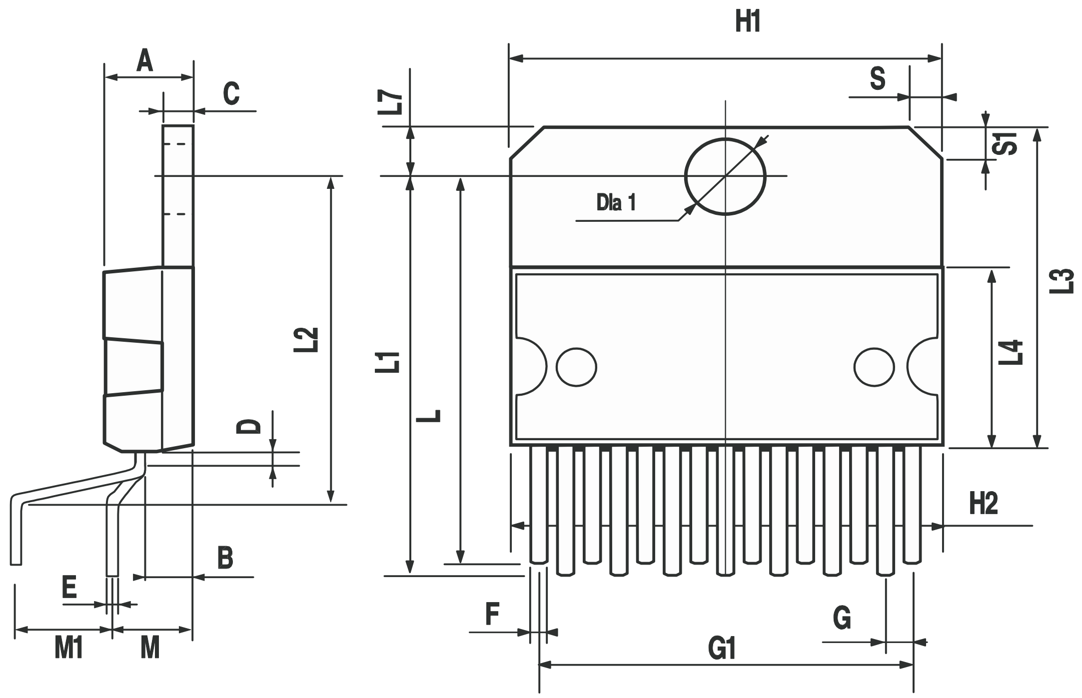
An external bridge of diodes are required when inductive loads are driven and when the inputs of the IC are chopped ; Shottky diodes would be preferred.

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



APPENDIX C

(PIC18F4550 datasheet)

PIC18F2455/2550/4455/4550

28/40/44-Pin High-Performance, Enhanced Flash USB Microcontrollers with nanoWatt Technology

Universal Serial Bus Features:

- USB V2.0 Compliant SIE
- Low-speed (1.5 Mb/s) and full-speed (12 Mb/s)
- Supports control, interrupt, isochronous and bulk transfers
- Supports up to 32 endpoints (16 bidirectional)
- 1-Kbyte dual access RAM for USB
- On-board USB transceiver with on-chip voltage regulator
- Interface for off-chip USB transceiver
- Streaming Parallel Port (SPP) for USB streaming transfers (40/44-pin devices only)

Power Managed Modes:

- Run: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 5.8 µA typical
- Sleep current down to 0.1 µA typical
- Timer1 oscillator: 1.1 µA typical, 32 kHz, 2V
- Watchdog Timer: 2.1 µA typical
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:

- Five Crystal modes, including High-Precision PLL for USB
- Two External RC modes, up to 4 MHz
- Two External Clock modes, up to 40 MHz
- Internal oscillator block:
  - 8 user selectable frequencies, from 31 kHz to 8 MHz
  - User tunable to compensate for frequency drift
- Secondary oscillator using Timer1 @ 32 kHz
- Fail-Safe Clock Monitor
  - Allows for safe shutdown if any clock stops

Peripheral Highlights:

- High current sink/source: 25 mA/25 mA
- Three external interrupts
- Four Timer modules (Timer0 to Timer3)
- Up to 2 Capture/Compare/PWM (CCP) modules:
  - Capture is 16-bit, max. resolution 6.25 ns ($T_{CY}/16$)
  - Compare is 16-bit, max. resolution 100 ns (T_{CY})
  - PWM output: PWM resolution is 1 to 10-bit
- Enhanced Capture/Compare/PWM (ECCP) module:
  - Multiple output modes
  - Selectable polarity
  - Programmable dead-time
  - Auto-Shutdown and Auto-Restart
- Addressable USART module:
  - LIN bus support
- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI™ (all 4 modes) and I²C™ Master and Slave modes
- 10-bit, up to 13-channels Analog-to-Digital Converter module (A/D) with programmable acquisition time
- Dual analog comparators with input multiplexing

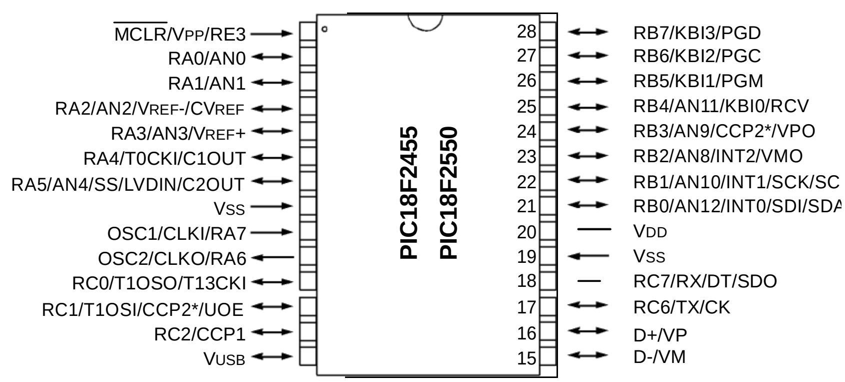
Special Microcontroller Features:

- C compiler optimized architecture with optional extended instruction set
- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle data EEPROM memory typical
- Flash/data EEPROM retention: > 40 years
- Self-programmable under software control
- Priority levels for interrupts
- 8 x 8 Single Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Programmable Code Protection
- Single-supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Wide operating voltage range (2.0V to 5.5V)

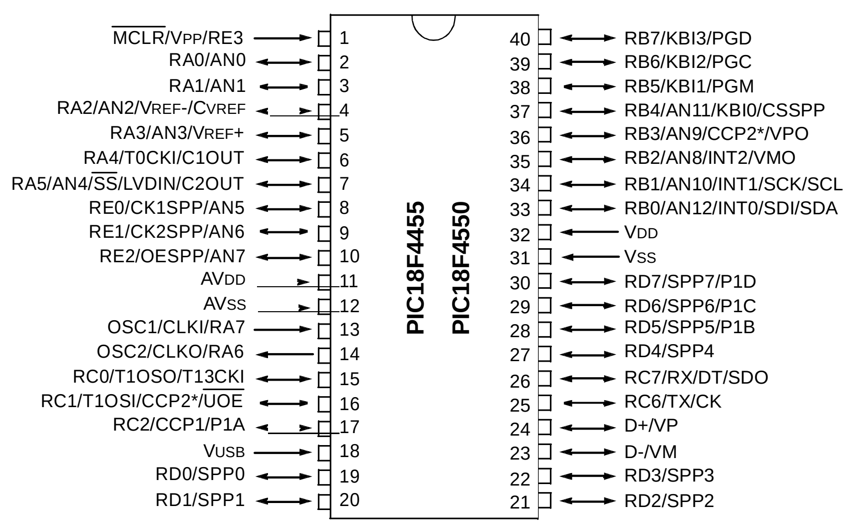
Device	Program Memory		Data Memory		I/O	10-bit A/D (ch)	CCP/ ECCP (PWM)	SPP	MSSP		EAUSART	Comparators	Timers 8/16-bit
	FLASH (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI	Master I²C			
PIC18F2455	24K	12288	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F2550	32K	16384	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F4455	24K	12288	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3
PIC18F4550	32K	16384	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3

Pin Diagrams

28-Pin SDIP, SOIC



40-Pin PDIP

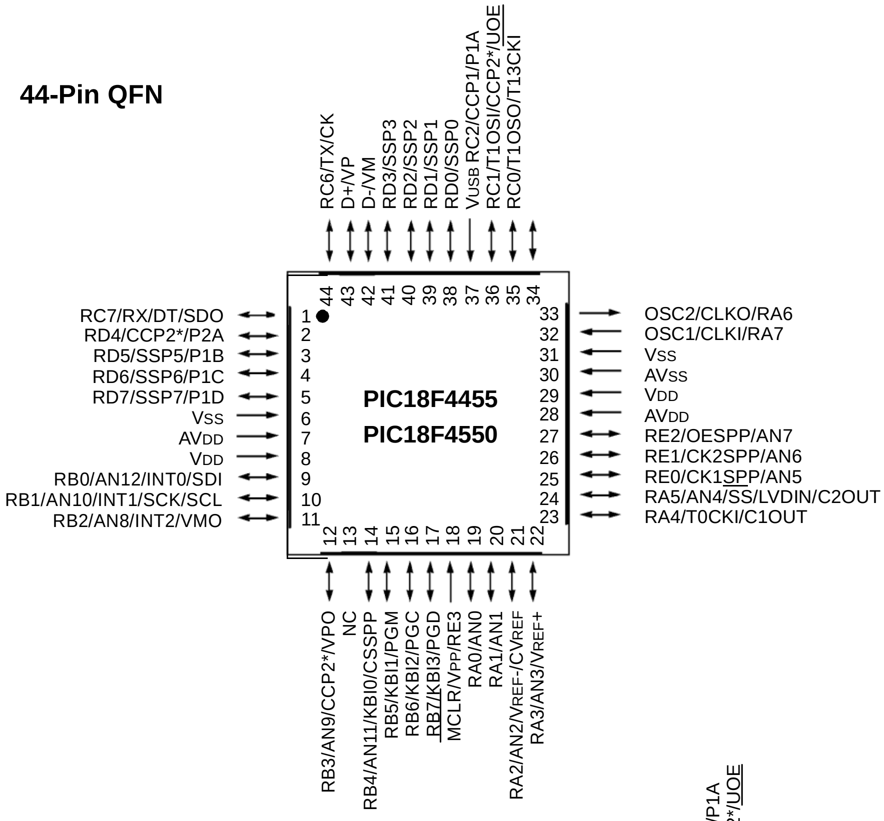


Note: Pinouts are subject to change.

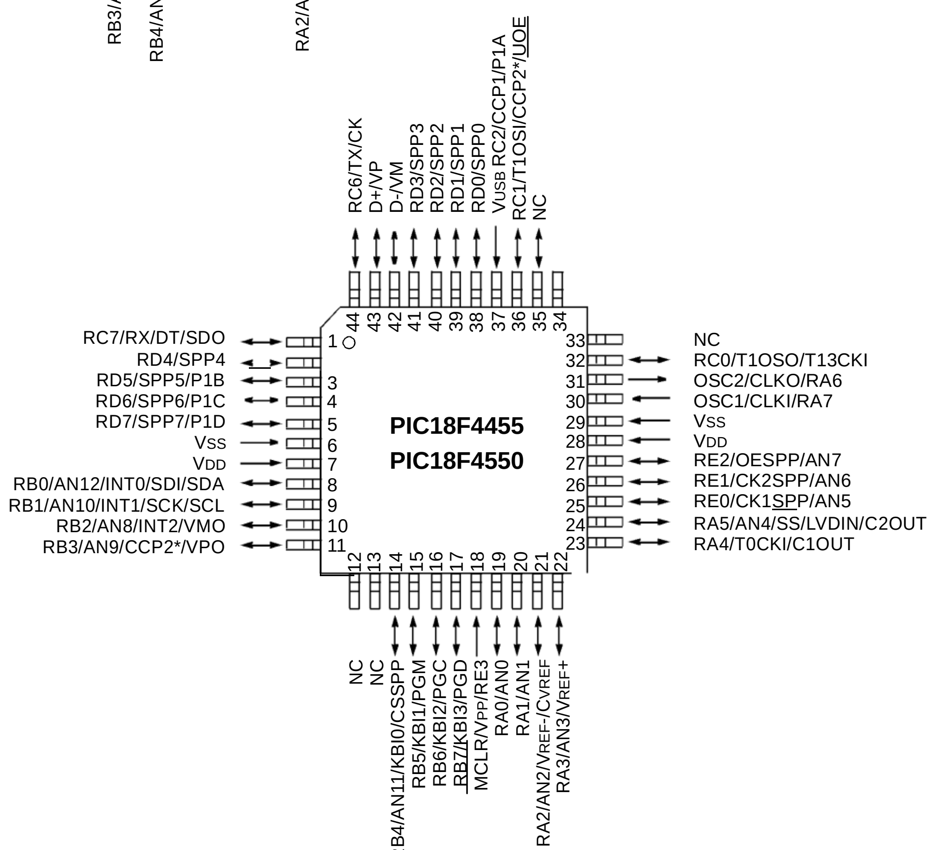
* Assignment of this feature is dependent on device configuration.

Pin Diagrams (Continued)

44-Pin QFN



44-Pin TQFP



* Assignment of this feature is dependent on device configuration.

PIC18F2455/2550/4455/4550

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
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APPENDIX E

(Gantt chart for Semester Two)

GANTT CHART (PSM 1)

Work Progress	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PSM 1 Briefing Session														
Find Supervisor and Project title														
Brief idea														
Register Title and Submit Abstract														
Literature review														
Hardware design / Simulation circuit														
Discussion & Meeting with Supervisor														
Submit proposal + Presentation Slide + Evaluation form														
Presentation / Seminar PSM 1														
Submit Report + Log Book + Evaluation form.														

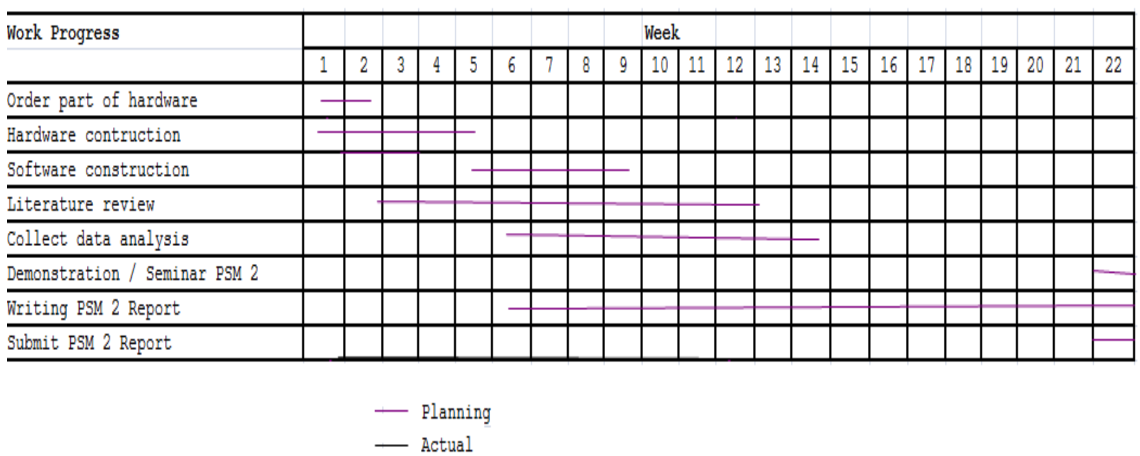
Planning

Actual

APPENDIX E

(Gantt chart for Semester Two)

GANTT CHART (PSM 2)



APPENDIX E

(6V DC Motor Datasheet)