Line following robot using MC68HC11

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ABSTRACT

In the industry, carriers are required to carry products from one manufacturing plant to another which are usually in different buildings or separate blocks. Conventionally, carts or trucks were used with human drivers. Unreliability and inefficiency in this part of the assembly line formed the weakest link. The project is to automate this sector, using carts to follow a line instead of laying railway tracks which are both costly and an inconvenience. This project using MC68HC11 as a main component to build a line following robot that can follow a single line which is can solve that entire problem. Motor control was performing with servo-motor and all the wiring was done using wire wrap. Line following robot can be easily design by using concept on and off but this type of design will make robot follow a line smoothly and sometimes robot tends to move out of track. To overcome this problem we try to using more sensors to get an accuracy input.

ABSTRAK

Dalam pekerjaan industri, produk perlu dibawa dari suatu kilang pembuatan kepada yang lain dan biasanya merupakan blok-blok bangunan yg berlainan ataupun bilik yang berlainan. Secara konvensional, kereta-kereta atau trak-trak digunakan bersama dengan pemandu. Sikap tidak boleh dipercayai dan tidak cekap dalam bahagian ini dalam barisan pemasangan akan mengakibatkan terbentuknya hubungan paling lemah. Projek itu adalah bagi mengautomasikan sektor, menggunakan kereta-kereta untuk mengikut satu garisan daripada landasan kereta api di mana harga kedua-duanya adalah mahal dan tidak berpatutan. Projek ini menggunakan MC68HC11 sebagai komponen utama untuk membina satu ‘following line robot’ yang boleh mengikuti satu garisan dan sekaligus dapat menyelesaikan keseluruhan masalah tersebut. Kawalan motor beroperasi menggunakan motor servo dan semua pendawaian telah dibuat menggunakan balutan dawai. ‘Line following robot’ boleh direka dengan mudah menggunakan konsep ‘buka & tutup’ tetapi reka bentuk jenis ini membuat robot tersebut tidak mengikuti garisan dengan lancar dan kadangkala robot cenderung beralih daripada trek asal. Untuk mengatasi untuk mengatasi masalah ini kita cuba untuk menggunakan lebih pengesan untuk mendapat satu input yang lebih tepat.

ACKNOWLEDGEMENT

Alhamdulillah, a lot of praise and ‘syukur’ to Allah. I would like to give my sincere gratitude and appreciation to Mr. Hazizulden Bin Abdul Aziz as my supervisor for encouragement, guidance and motivation throughout this project. Without his guidance, this project would never be done.

Special thanks to all of my friends who always give me courage and continuously supporting me to finish this project. Without them, I might not be able to complete the entire task given. The moral support and help provided by them are very useful in completing this project.

Last but not least, I would like to say thank you to my beloved parents, Jahrani Bin Sadri and Saripah Bte Mukri for their help in financial support to finish this project. Finally, I would like to express my appreciation to my classmates for their support in leading me to solve several problems that occurred throughout this project.

Thank you very much

Assalamualaikum.

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Electronics)"

Signature : __________________________________

Name : MR.HAZIZULDEN BIN ABDUL AZIZ

Date : 12 MAY 2009

APPENDIX A

Source Code

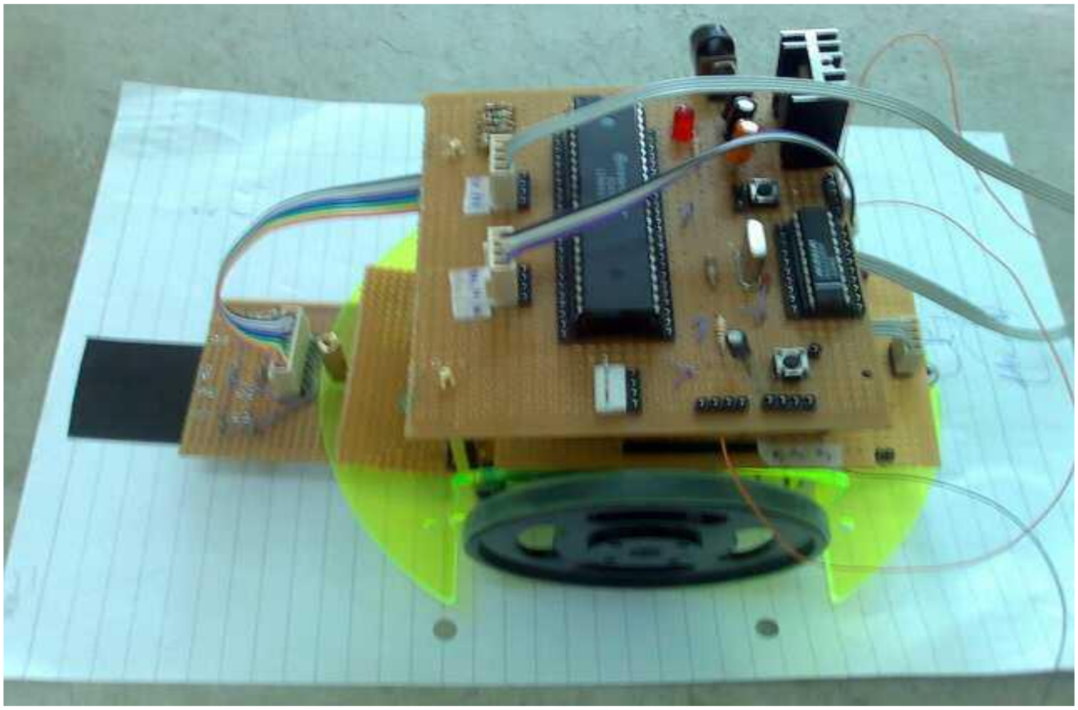
```
REGS            EQU  $1000
PORTE           EQU  $10
portB     equu  $4
ADCTL           EQU  $30
OPTION          EQU  $39
ADD1            EQU  $31
ADD2            EQU  $32
ADD3            EQU  $33


          org   $b600
main      jsr   init
          jsr   sensor
          jsr   main


init      LDX   #REGS
          LDAA       #$80
          STAA       OPTION,X ;      turn A/D on
          LDY   #30        ;      delay for 105 microseconds for
stabilize
          JSR   DELAY105a
```

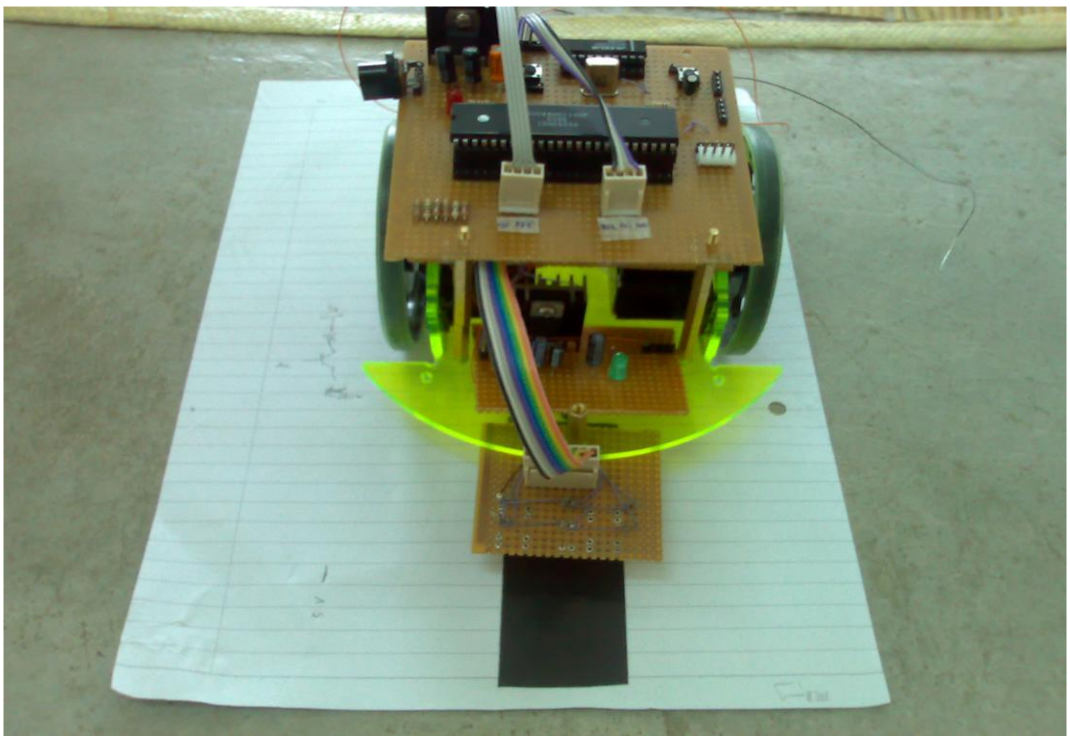
```
        LDAA    #$30        ;    select PE0,MULTI channel
        STAA    ADCTL,X     ;    setup A/D
        RTS

sensor      LDX     #REGS
        LDAB        ADD1,x
        CMPB        #$FF
        BGE     output
        LDAB        ADD2,x
        CMPB        #$FF
        BGE     output
        LDAB        ADD3,x
        CMPB        #$FF
        BGE     output
        jsr     DELAY105a

        CMPA        #$31
        BLS     not
        RTS

output      ldaa    #3
        staa    portB,x
```

```
            jsr         DELAYFAN
            rts
DELAYFAN    PSHY
            PSHX
            LDY         #$E4
REPEATA     LDX         #$3FFC
REPEATB     DEX
            BNE         REPEATB
            DEY
            BNE         REPEATA
            PULX
            PULY
            RTS


not         bra         main


DELAY105a   DEY
            BNE         DELAY105a
            RTS
```

APPENDIX B

Picture of Robot





APPENDIX C

Datasheets MC68HC11

MOTOROLA
SEMICONDUCTOR
TECHNICAL DATA

Order this document
by MC68HC11A8TS/D

MC68HC11A8
MC68HC11A1
MC68HC11A0

Technical Summary

8-Bit Microcontrollers

1 Introduction

The MC68HC11A8, MC68HC11A1, and MC68HC11A0 high-performance microcontroller units (MCUs) are based on the M68HC11 Family. These high speed, low power consumption chips have multiplexed buses and a fully static design. The chips can operate at frequencies from 3 MHz to dc. The three MCUs are created from the same masks; the only differences are the value stored in the CONFIG register, and whether or not the ROM or EEPROM is tested and guaranteed.

For detailed information about specific characteristics of these MCUs, refer to the *M68HC11 Reference Manual* (M68HC11RM/AD).

1.1 Features

- M68HC11 CPU
- Power Saving STOP and WAIT Modes
- 8 Kbytes ROM
- 512 Bytes of On-Chip EEPROM
- 256 Bytes of On-Chip RAM (All Saved During Standby)
- 16-Bit Timer System
  - 3 Input Capture Channels
  - 5 Output Compare Channels
- 8-Bit Pulse Accumulator
- Real-Time Interrupt Circuit
- Computer Operating Properly (COP) Watchdog System
- Synchronous Serial Peripheral Interface (SPI)
- Asynchronous Nonreturn to Zero (NRZ) Serial Communications Interface (SCI)
- 8-Channel, 8-Bit Analog-to-Digital (A/D) Converter
- 38 General-Purpose Input/Output (I/O) Pins
  - 15 Bidirectional I/O Pins
  - 11 Input-Only Pins and 12 Output-Only Pins (Eight Output-Only Pins in 48-Pin Package)
- Available in 48-Pin Dual In-Line Package (DIP) or 52-Pin Plastic Leaded Chip Carrier (PLCC)

Table 1 MC68HC11Ax Family Members

Device Number	ROM	EEPROM	RAM	CONFIG*	Comments
MC68HC11A8	8K	512	256	$0F	Family built around this device
MC68HC11A1	0	512	256	$0D	ROM disabled
MC68HC11A0	0	0	256	$0C	ROM and EEPROM disabled

Table 2 Ordering Information

Package	Temperature	CONFIG	Description	MC Order Number
48-Pin Plastic DIP (P suffix)	–40°to + 85°C	$0F	BUFFALO ROM	MC68HC11A8P1
	–40°to + 85°C	$0D	No ROM	MC68HC11A1P
	–40°to + 105°C	$0D	No ROM	MC68HC11A1VP
	–40°to + 125°C	$0D	No ROM	MC68HC11A1MP
	–40°to + 85°C	$09	No ROM, COP On	MC68HCP11A1P
	–40°to + 105°C	$09	No ROM, COP On	MC68HCP11A1VP
	–40°to + 125°C	$09	No ROM, COP On	MC68HCP11A1MP
	–40°to + 85°C	$0C	No ROM, No EEPROM	MC68HC11A0P
52-Pin PLCC (FN suffix)	–40°to + 85°C	$0F	BUFFALO ROM	MC68HC11A8FN1
	–40°to + 85°C	$0D	No ROM	MC68HC11A1FN
	–40°to + 105°C	$0D	No ROM	MC68HC11A1VFN
	–40°to + 125°C	$0D	No ROM	MC68HC11A1MFN
	–40°to + 85°C	$09	No ROM, COP On	MC68HCP11A1FN
	–40°to + 105°C	$09	No ROM, COP On	MC68HCP11A1VFN
	–40°to + 125°C	$09	No ROM, COP On	MC68HCP11A1MFN
	–40°to + 85°C	$0C	No ROM, No EEPROM	MC68HC11A0FN

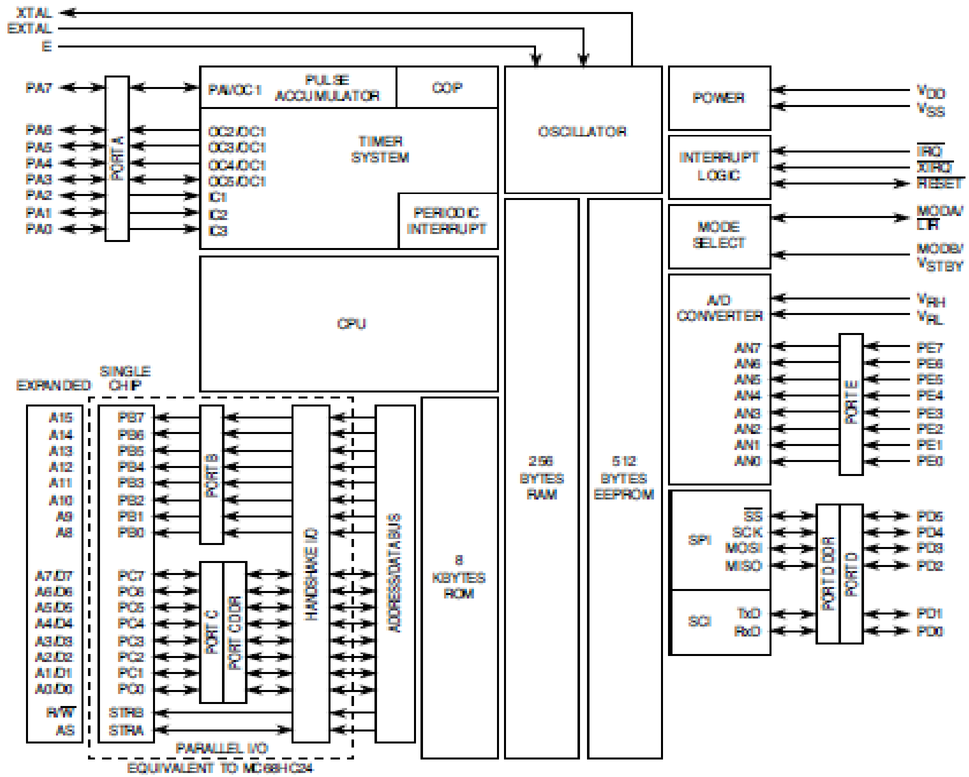


Figure 1 MC68HC11A8 Block Diagram

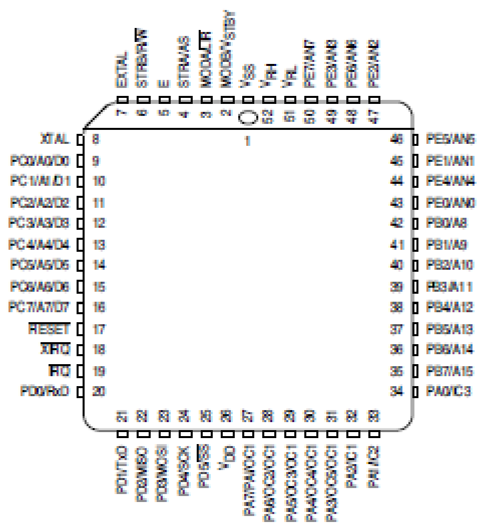


Figure 2 52-Pin PLCC Pin Assignments

10 Analog-to-Digital Converter

The A/D converter system uses an all capacitive charge redistribution technique to convert analog sig nals to digital values. The MC68HC11A8 A/D system is an 8-channel, 8-bit, multiplexed-input, succes sive-approximation converter and is accurate to ±1 least significant bit (LSB). It does not requir external sample and hold circuits because of the type of charge redistribution technique used.

Dedicated lines V_{RH} and V_{RL} provide the reference supply voltage inputs. Refer to the A/D converte block diagram.

A multiplexer allows the single A/D converter to select one of 16 analog signals, as shown in the ADCTI register description.

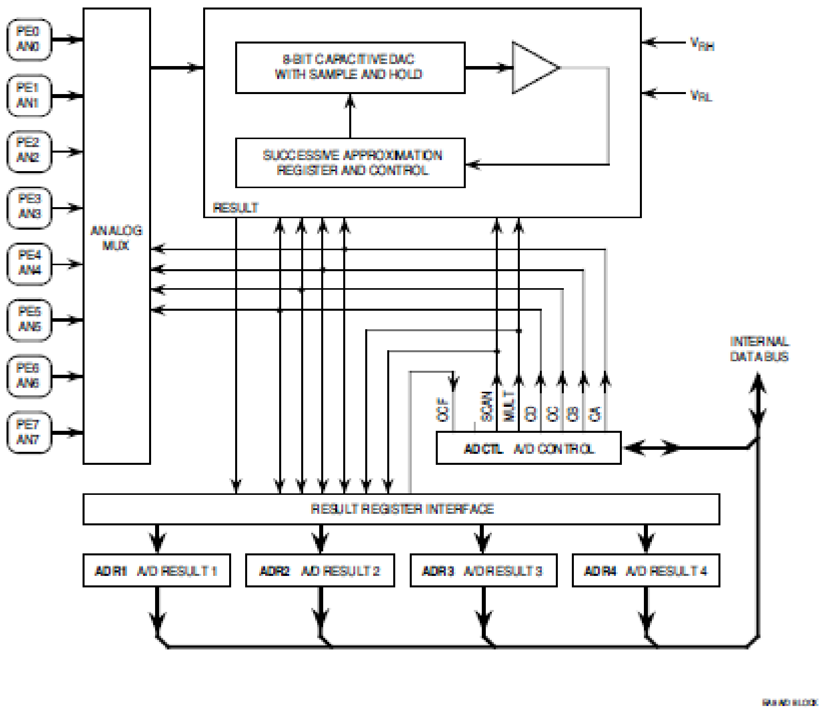


Figure 13 A/D Converter Block Diagram

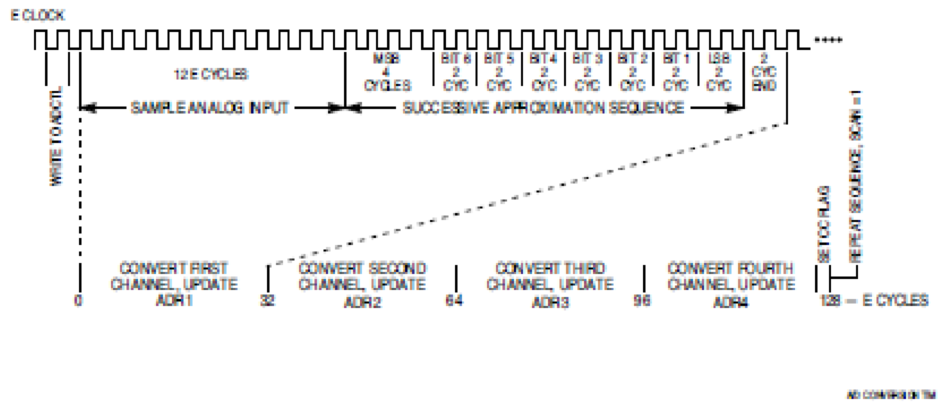


Figure 14 A/D Conversion Sequence

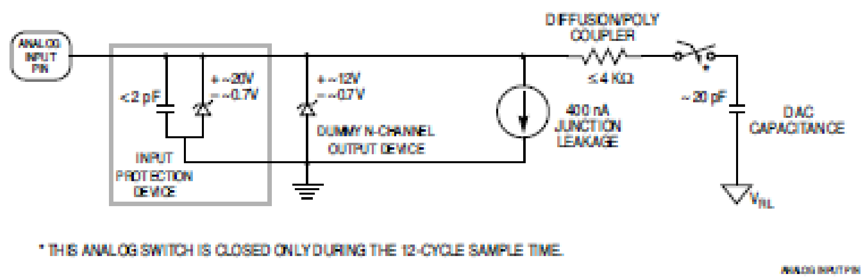


Figure 15 Electrical Model of an Analog Input Pin (Sample Mode)

ADCTL — A/D Control/Status **$1030**

	Bit 7	6	5	4	3	2	1	Bit 0
	CCF	0	SCAN	MULT	CD	CC	CB	CA
RESET:	U	0	U	U	U	U	U	U

CCF — Conversions Complete Flag
Set after an A/D conversion cycle. Cleared when ADCTL is written.

SCAN — Continuous Scan Control
0 = Do four conversions and stop
1 = Convert four channels in selected group continuously

MULT — Multiple Channel/Single Channel Control
0 = Convert single channel selected
1 = Convert four channels in selected group

CD–CA — Channel Select D through A

Table 10 A/D Converter Channel Assignments

Channel Select Control Bits				Channel	Result in ADRx if
CD	CC	CB	CA	Signal	MULT = 1
0	0	0	0	AN0	ADR1
0	0	0	1	AN1	ADR2
0	0	1	0	AN2	ADR3
0	0	1	1	AN3	ADR4
0	1	0	0	AN4*	ADR1
0	1	0	1	AN5*	ADR2
0	1	1	0	AN6*	ADR3
0	1	1	1	AN7*	ADR4
1	0	X	X	Reserved	ADR1–ADR4
1	1	0	0	V_{RH}**	ADR1
1	1	0	1	V_{RL}**	ADR2
1	1	1	0	$(V_{RH})/2$**	ADR3
1	1	1	1	Reserved**	ADR4

* Not available in 48-pin package
**Used for factory testing

ADR1–ADR4 — A/D Results **$1031–$1034**

	Bit 7	6	5	4	3	2	1	Bit 0	
$1031	Bit 7	6	5	4	3	2	1	Bit 0	ADR1
$1032	Bit 7	6	5	4	3	2	1	Bit 0	ADR2
$1033	Bit 7	6	5	4	3	2	1	Bit 0	ADR3
$1034	Bit 7	6	5	4	3	2	1	Bit 0	ADR4

Table 11 Analog Input to 8-Bit Result Translation Table

	Bit 7	6	5	4	3	2	1	Bit 0
% (1)	50%	25%	12.5%	6.25%	3.12%	1.56%	0.78%	0.39%
Volts (2)	2.500	1.250	0.625	0.3125	0.1562	0.0781	0.0391	0.0195

(1) % of V_{RH}–V_{RL} (2) V_{RL} = 0.0 V; V_{RH} = 5.0 V

OPTION — System Configuration Options **$1039**

	Bit 7	6	5	4	3	2	1	Bit 0
	ADPU	CSEL	IRQE*	DLY*	CME	0	CR1*	CR0*
RESET:	0	0	0	1	0	0	0	0

*Can be written only once in first 64 cycles out of reset in normal modes, or any time in special modes.

ADPU — A/D Power Up
0 = A/D Converter powered down
1 = A/D Converter powered up

CSEL — Clock Select
0 = A/D and EEPROM use system E clock
1 = A/D and EEPROM use internal RC clock

IRQE — $\overline{IRQ}$ Select Edge Sensitive Only
Refer to **3 Resets and Interrupts**.

DLY — Enable Oscillator Start-Up Delay on Exit from STOP
Refer to **3 Resets and Interrupts**.

CME — Clock Monitor Enable
Refer to **3 Resets and Interrupts**.

CR1, CR0 — COP Timer Rate Select
Refer to **3 Resets and Interrupts**.

APPENDIX D

Datasheets LM324

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

Single Supply Quad Operational Amplifiers

The LM324 series are low–cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V with quiescent currents about one–fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

Features

- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum (LM324A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps on the Inputs Increase Ruggedness without Affecting Device Operation
- NCV Prefix for Automotive and Other Applications Requiring Site and Control Changes
- Pb–Free Packages are Available

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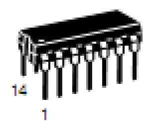
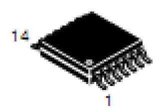


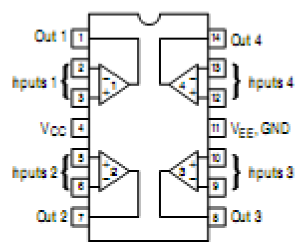
PDIP–14
N SUFFIX
CASE 646

SOIC–14
D SUFFIX
CASE 751A



TSSOP–14
DTB SUFFIX
CASE 948G

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 10 of this data sheet.

DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 12 of this data sheet.

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

MAXIMUM RATINGS (T_A = +25°C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltages Single Supply Split Supplies	 V_{CC} V_{CC}, V_{EE}	 32 ±16	Vdc
Input Differential Voltage Range (Note 1)	V_{IDR}	±32	Vdc
Input Common Mode Voltage Range	V_{ICR}	−0.3 to 32	Vdc
Output Short Circuit Duration	t_{SC}	Continuous	
Junction Temperature (Note 2)	T_J	150	°C
Thermal Resistance, Junction−to−Air (Note 3) Case 646 Case 751A Case 948G	$R_{\theta JA}$	118 156 190	°C/W
Storage Temperature Range	T_{stg}	−65 to +150	°C
ESD Protection at any Pin Human Body Model Machine Model	V_{esd}	 2000 200	V
Operating Ambient Temperature Range LM224 LM324, 324A LM2902 LM2902V, NCV2902 (Note 4)	T_A	 −25 to +85 0 to +70 −40 to +105 −40 to +125	°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. Split Power Supplies.
2. For supply voltages less than 32 V, the absolute maximum input voltage is equal to the supply voltage.
3. All $R_{\theta JA}$ measurements made on evaluation board with 1 oz. copper traces of minimum pad size. All device outputs were active.
4. *NCV2902 is qualified for automotive use.*

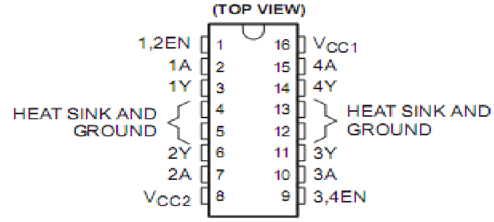
APPENDIX E

Datasheets L293 D

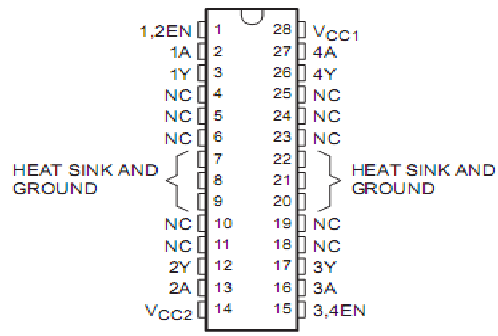
SLRS008C – SEPTEMBER 1986 – REVISED NOVEMBER 2004

- **Featuring Unitrode L293 and L293D Products Now From Texas Instruments**
- **Wide Supply-Voltage Range: 4.5 V to 36 V**
- **Separate Input-Logic Supply**
- **Internal ESD Protection**
- **Thermal Shutdown**
- **High-Noise-Immunity Inputs**
- **Functionally Similar to SGS L293 and SGS L293D**
- **Output Current 1 A Per Channel (600 mA for L293D)**
- **Peak Output Current 2 A Per Channel (1.2 A for L293D)**
- **Output Clamp Diodes for Inductive Transient Suppression (L293D)**

L293 . . . N OR NE PACKAGE
L293D . . . NE PACKAGE
(TOP VIEW)



L293 . . . DWP PACKAGE
(TOP VIEW)



description/ordering information

The L293 and L293D are quadruple high-current half-H drivers. The L293 is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled, and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

ORDERING INFORMATION

T_A	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	HSOP (DWP)	Tube of 20	L293DWP	L293DWP
	PDIP (N)	Tube of 25	L293N	L293N
	PDIP (NE)	Tube of 25	L293NE	L293NE
		Tube of 25	L293DNE	L293DNE

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

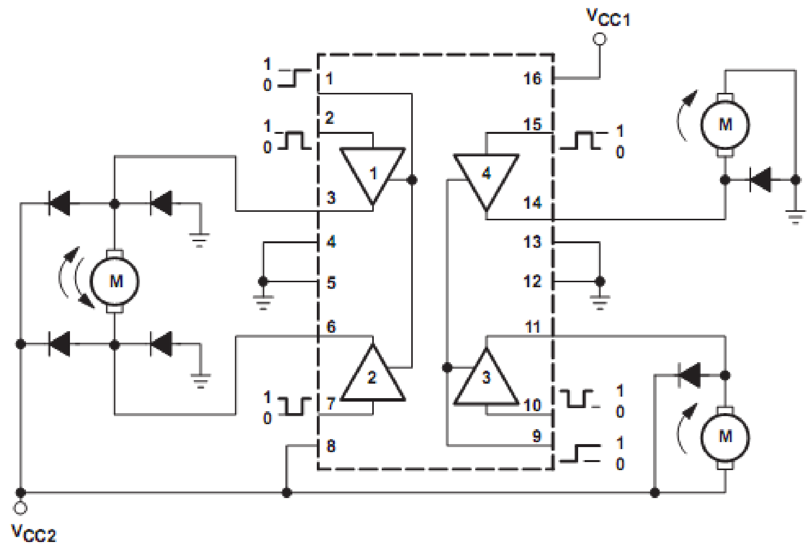
description/ordering information (continued)

On the L293, external high-speed output clamp diodes should be used for inductive transient suppression.

A V_{CC1} terminal, separate from V_{CC2}, is provided for the logic inputs to minimize device power dissipation.

The L293and L293D are characterized for operation from 0°C to 70°C.

block diagram



NOTE: Output diodes are internal in L293D.

FUNCTION TABLE
(each driver)

INPUTS†		OUTPUT
A	EN	Y
H	H	H
L	H	L
X	L	Z

H = high level, L = low level, X = irrelevant,
Z = high impedance (off)

† In the thermal shutdown mode, the output is in the high-impedance state, regardless of the input levels.

recommended operating conditions

			MIN	MAX	UNIT
	Supply voltage	V_{CC1}	4.5	7	V
		V_{CC2}	V_{CC1}	36	
V_{IH}	High-level input voltage	$V_{CC1} \le 7$ V	2.3	V_{CC1}	V
		$V_{CC1} \ge 7$ V	2.3	7	V
V_{IL}	Low-level output voltage		−0.3†	1.5	V
T_A	Operating free-air temperature		0	70	°C

† The algebraic convention, in which the least positive (most negative) designated minimum, is used in this data sheet for logic voltage levels.

electrical characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage		L293: $I_{OH} = -1$ A L293D: $I_{OH} = -0.6$ A		$V_{CC2} - 1.8$	$V_{CC2} - 1.4$		V
V_{OL}	Low-level output voltage		L293: $I_{OL} = 1$ A L293D: $I_{OL} = 0.6$ A			1.2	1.8	V
V_{OKH}	High-level output clamp voltage		L293D: $I_{OK} = -0.6$ A			$V_{CC2} + 1.3$		V
V_{OKL}	Low-level output clamp voltage		L293D: $I_{OK} = 0.6$ A			1.3		V
I_{IH}	High-level input current	A	$V_I = 7$ V			0.2	100	µA
		EN				0.2	10	
I_{IL}	Low-level input current	A	$V_I = 0$			−3	−10	µA
		EN				−2	−100	
I_{CC1}	Logic supply current		$I_O = 0$	All outputs at high level		13	22	mA
				All outputs at low level		35	60	
				All outputs at high impedance		8	24	
I_{CC2}	Output supply current		$I_O = 0$	All outputs at high level		14	24	mA
				All outputs at low level		2	6	
				All outputs at high impedance		2	4	

switching characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	L293NE, L293DNE			UNIT
			MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low-to-high-level output from A input	$C_L = 30$ pF, See Figure 1		800		ns
t_{PHL}	Propagation delay time, high-to-low-level output from A input			400		ns
t_{TLH}	Transition time, low-to-high-level output			300		ns
t_{THL}	Transition time, high-to-low-level output			300		ns

switching characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	L293DWP, L293N L293DN			UNIT
			MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low-to-high-level output from A input	$C_L = 30$ pF, See Figure 1		750		ns
t_{PHL}	Propagation delay time, high-to-low-level output from A input			200		ns
t_{TLH}	Transition time, low-to-high-level output			100		ns
t_{THL}	Transition time, high-to-low-level output			350		ns

APPLICATION INFORMATION

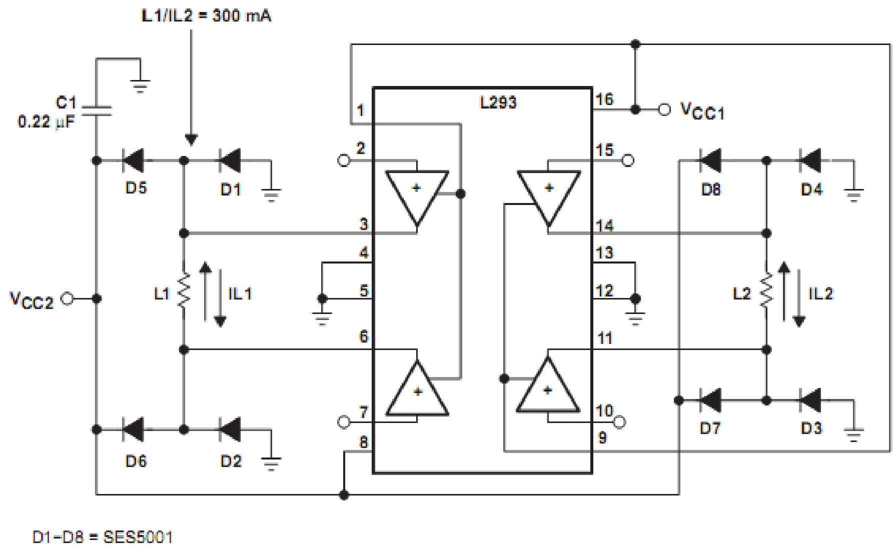


Figure 6. Bipolar Stepping-Motor Control

mounting instructions

The Rthj-amp of the L293 can be reduced by soldering the GND pins to a suitable copper area of the printed circuit board or to an external heat sink.

Figure 9 shows the maximum package power P_{TOT} and the θ_{JA} as a function of the side ℓ of two equal square copper areas having a thickness of 35 µm (see Figure 7). In addition, an external heat sink can be used (see Figure 8).

During soldering, the pin temperature must not exceed 260°C, and the soldering time must not exceed 12 seconds.

The external heatsink or printed circuit copper area must be connected to electrical ground.

"All the trademark and copyrights use herein are property of their respective owner. References of information from other sources are quoted accordingly; otherwise the information presented in this report is solely work of the author."

Signature : ______________________________

Author : MOHD ANWAR BIN JAHRANI

Date : 12 MAY 2009

Specially dedicated to

My beloved parent

LIST OF ABREVIATIONS

MCU	–	Microcontroller 68HC11
PWM	–	Pulse Width Modulation
RAM	-	Random Access Memory
ADC	-	Analog Digital Converter
DAC	-	Digital Analog Converter
IR	-	Infra Red
DC	-	Direct Current
MOSFET	-	Metal Oxide Semiconductor Field Effect Transistor
TTL	-	Transistor Transistor Logic

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CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays, robot is become important in industrial. Robot are widely used un manufacturing, assembly and packing, transport, earth and space exploration, surgery, weaponry, laboratory research and mass production of consumer and industrial goods. A scientist invent robot to help people by performing simple, repetitive tasks and helping people to do an impossible task. There are many jobs which humans would rather leave to robots. The job maybe boring, domestic cleaning, or dangerous, such as exploring inside a volcano. Other jobs are physically inaccessible, such as exploring another planet and cleaning inside of a long pipe

In the industry carriers are required to carry products from one manufacturing plant to another which are usually in different buildings or separate blocks. Conventionally, carts or trucks were used with human drivers. Unreliability and inefficiency in this part of the assembly line formed the weakest link. The project is to automate this sector, using carts to follow a line instead of laying railway tracks which are both costly and an inconvenience.

This project using MC68HC11 as a main component to build a line following robot that can follow a single line which is can solve that entire problem. Motor control was performing with servo-motor and all the wiring was done using wire wrap. Line following robot can be easily design by using concept on and off but this type of design will make robot follow a line smoothly and sometimes robot tends to move out of track. To overcome this problem we try to using more sensors to get an accuracy input.

1.2 Objectives

The main objective of this project is to build a prototype of line following robot that can follow a path way either straight or turn and will stop moving when the end of the line.

1.3 Scope of projects

This project is focused to design and build the prototype line follower robot using MC68HC11. Therefore, this prototype will cover the other scope which is programming using assembly language. In the end of the project, robot will be able to tracking line smoothly.

1.4 Thesis organizations

This thesis consists of five chapters. This chapter discuss about overview of project, objective research, project scope, problem statement and thesis organization.

Chapter 2 contains a detailed description of Line follower. It will explain about the concept of algorithm of line follower robot and MC68HC11 as a controller.

Chapter 3 includes the project methodology. It will explain how the project is work and the flow of process in completing this project. Also in this topic discusses the methodology of the system, circuit design, software design and the mechanical design.

Chapter 4 will be discussing about the result obtained in this project and a discussion about the result.

Finally, the conclusions for this project are presented in chapter 5. This chapter also discusses about the recommendation for the project and for the future development. It also discuss about problem encountered during project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The line follower is one of the self operating robot that follows a line that drawn on the floor. The basic operations of the line are as follows:

Capture line position with optical sensors mounted at front end of the robot. Most are using several numbers of photo-reflectors, and some leading contestants are using an image sensor for image processing. The line sensing process requires high resolution and high robustness.

2.2 Eye-Bo the Line Following Robot

Eye-Bo's brain is a small microcontroller board based on Atmel's AVR mega128 microcontroller. This microcontroller is one of the most capable chips with sporting 128K of flash program space and 4K of RAM. This microcontroller is different with MC68HC11 because MC68HC11 is Classy and easy to use peripherals and It's dealt with C compilers pretty well. MC68HC11 also offers various subsystems such as ADC, interrupts, timers, etc. Otherwise, its offer a simple assembly language because the processor uses the Von Neumann architecture. [1]

These robot use the CMUcam vision sensor to track the line. CMUcam functions to report the centroid of the white objects it. Thus, if the line curved to the right or left, the centroid shifted as well. The centroid could then be used as an indicator to determine how the steering servo should be driven. This robot also using white line as a track line. It is different from using IR led that detect a dark space or white space and give a high or low signal as an input.

2.3 A Line-follower Robot by Jaseung Ku

This simple robot is designed to be able to follow a black line on the ground without getting off the line too much. The robot has two sensors installed underneath the front part of the body, and two DC motors drive wheels moving forward. A circuit inside takes an input signal from two sensors and controls the speed of wheels' rotation. The control is done in such a way that when a sensor senses a black line, the motor slows down or even stops. Then the difference of rotation speed makes it possible to make turns. If the sensor somehow senses a black line, the wheel on that side slows down and the robot will make a right turn.

The sensors used for the project are Reflective Object Sensors, 0PB710F. The single sensor consists of an infrared emitting diode and a NPN Darlington phototransistor. When a light emitted from the diode is reflected off an object and back into the phototransistor, output current is produced, depending on the amount of infrared light, which triggers the base current of the phototransistor. In this robot, the amount of light reflected off a black line is much less than that of a white background, so it can detect the black line somehow by measuring the current which is the current is converted to voltage.

The motor used for the project is DC motor. A constant voltage was applied across a DC motor and repeated switch on and off the motor with a fixed voltage (Vcc). This is done by sending a train of PWM (Pulse Width Modulation) pulses to a power MOSFET in order to turn it on and off. Then, the motor sees the average voltage while it depends on duty cycle of PWM pulses. The speed of rotation is proportional to this average voltage. Controlling DC motor using PWM method is an easier way than by directly controlling the voltage across it. The only way to do is to

modulate pulse width, in order words, a duty cycle. Also, a power MOSFET consumes only negligible power in switching.

2.4 FailureBot 5 - A Line Following Robot by Micah Carrick

FailureBot 5 is a fairly good robot base which could easily be adapted to maze solving, obstacle avoiding, or other applications of a small, 2-wheeled robot. The robot consists of 2 plastic round decks, differential drive using 2 DC gearhead motors, a sensor board with 5 photo-transistor/LED sensors, an L293D H-Bridge motor controller board, and an Atmel ATMega8 processor board.

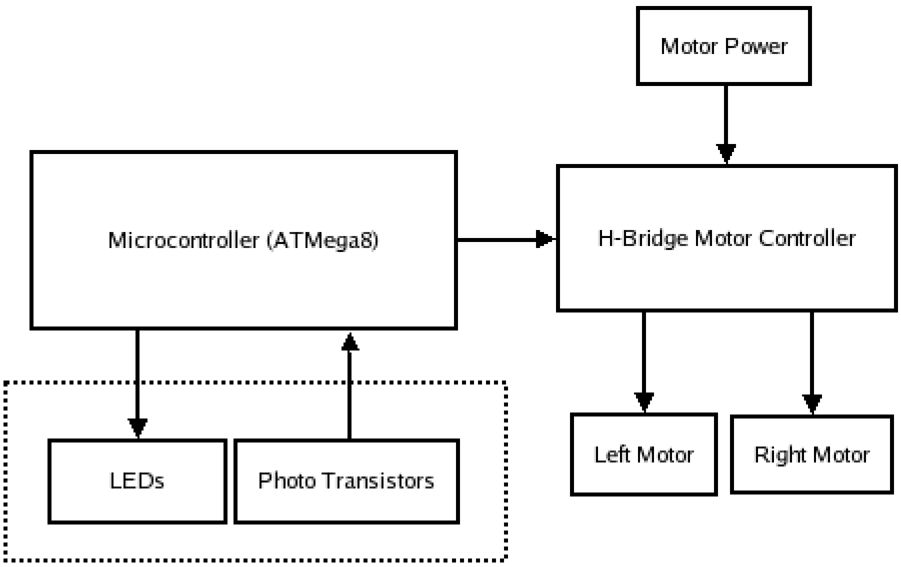

Figure 2.1: Block diagram of FailureBot5

A sensor board with 5 sensors shines light downward at the ground. If the line is underneath the sensor, then the little/no light will be reflected back to a paired phototransistor. If the line is not underneath the sensor, more of the light will be reflected back. A microcontroller measures the output of each of the phototransistors

through its analog-to-digital converter (ADC). Based on the position of the line underneath the robot, the microcontroller adjusts the speed or direction of the DC motors to steer the robot. There are 5 line sensors. Each line sensor consists of a single red LED and a photo-transistor. This robot used a piece of acrylic plastic which is spray painted black in numerous thin coats to ensure that it was solid.

This robot has used an Atmel AVR ATMega8 as a controller. The software for the robot is written in C language for the Atmel AVR microcontrollers using avr-libc and the GNU gcc compiler. The software is still relatively primitive. The robot is able to handle 90 degree turns, inconsistent floor color and intersections at a very decent speed. At this point in time, the gear motors have such a high reduction ratio which mean the robot do not need to use PWM to change the speed, however, the robot was originally designed to allow for PWM.

When turned on, the robot spins in circles on the line for a couple seconds while it calibrates the sensors. Once this calibration is complete, the robot begins its line detection algorithm in a loop. However, the motors are disabled. By pushing a button, the motors are enabled and the robot follows the line. Pushing this button again disables the motors again. So, the robot is always performing the line following. However, it only moves when the motor enable button is activated.

CHAPTER 3

HARDWARE AND SOFTWARE DEVELOPMENT

3.1 Introduction

This chapter explains detail about the methodology of the whole system and flow of step that used in develop line follower robot. This chapter describes further more about the RC servo motor control circuit, development on RC servo motor control, circuit design of MC68HC11 microcontroller, pin configuration, software development using THRsim11 and mechanical design.

3.2 Basic design and requirements

The robot is build using MC68HC11, L293D as a driver motor, IR Sensor, LM324 as a comparator sensor, platform consisting body chassis, two RC servo motor and controlling wheels. It has infrared sensors on the bottom for detecting black tape. Line position is captured with the help of these optical sensors called opto-coupler mounted at the front end of the robot (which each consists of IR transmitter and IR receiver). When sensors detect the dark surface, output from comparator, LM324 is low, while for the white surface the output is high. It sent as input to microcontroller for accurate control and steering of the motor.

3.3 Basic operation

Figure 3.1 shows the basic operations of the line follower robot as followed:

i. Capture line position with the IR sensors mounted at the front end of the robot. The line sensing process requires high resolution and high robustness.

ii. Steer robot to track the line with suitable steering mechanism. To achieve this we use two wheel tires powered by RC servo motor that run the motion of the wheel of either side.

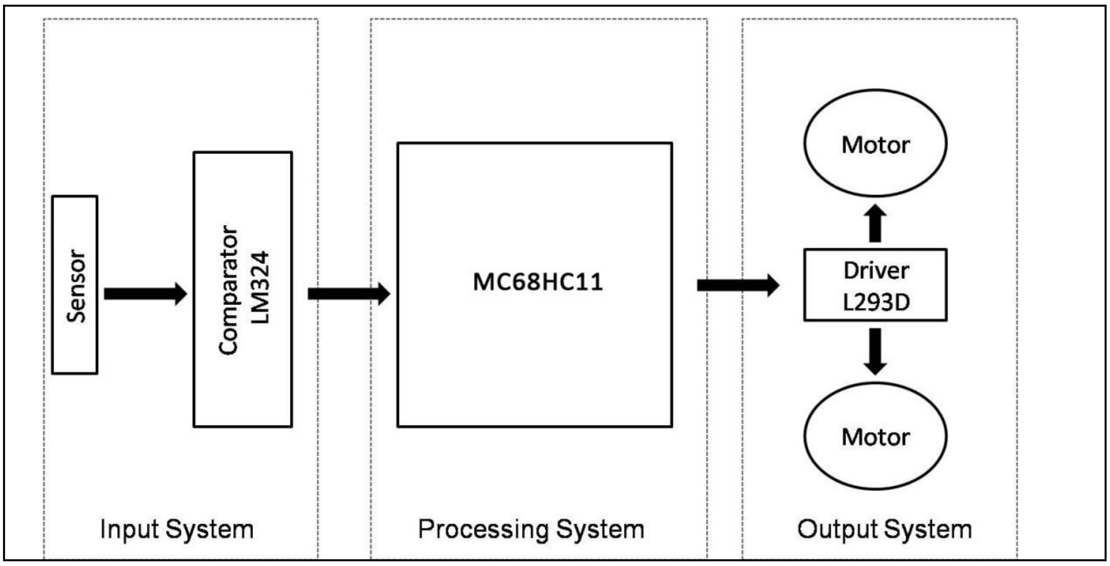

Figure 3.1: Block diagram of line follower robot using MC68HC11

3.4 Input system

The input system covers IR sensors, functions of comparator and IC LM324 used as comparator plus how to arrange the sensors.

3.4.1 IR sensors

Each IR sensor has one transmitter and one receiver. Shows if white surface beneath the IR sensor, IR rays are reflected and sensed by receiver, while in case of black surface, the light get absorbed and hence receiver does not sense IR rays. Figure 3.2 show the illustration of the different surfaces can affect the reflection of the IR rays.

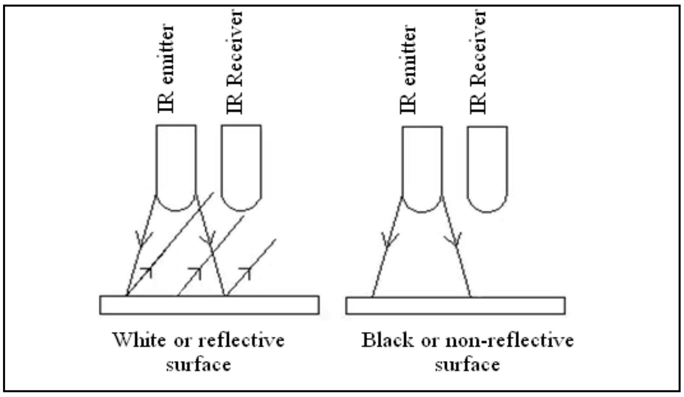

Figure 3.2: IR sensor and surfaces

IR sensors has a property that IR rays falls on, its electrical resistance decrease. For sensing the change in resistance we use voltage divider circuit as shown in figure 3.3

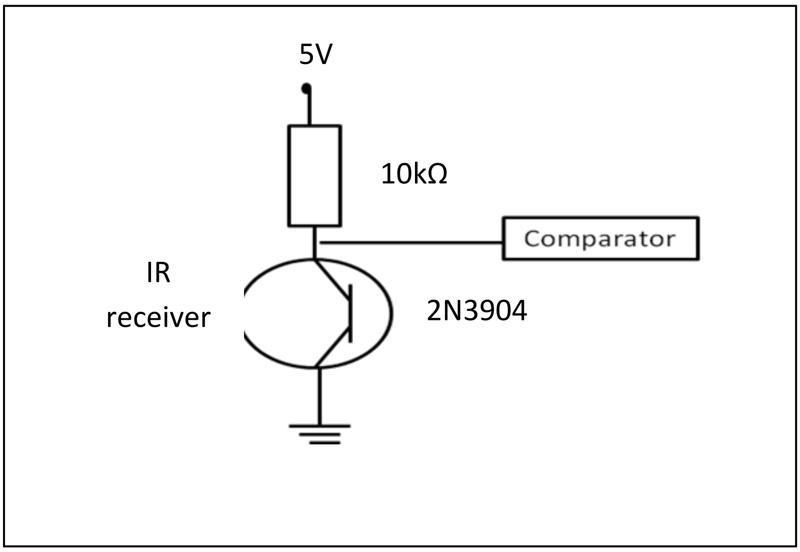

Figure 3.3: voltage divider

3.4.2 Comparator

Figure 3.4 show comparator schematic. Comparator is a device which compares two input voltages and gives an output as high or low. In a circuit diagram it is normally represented by having triangle.

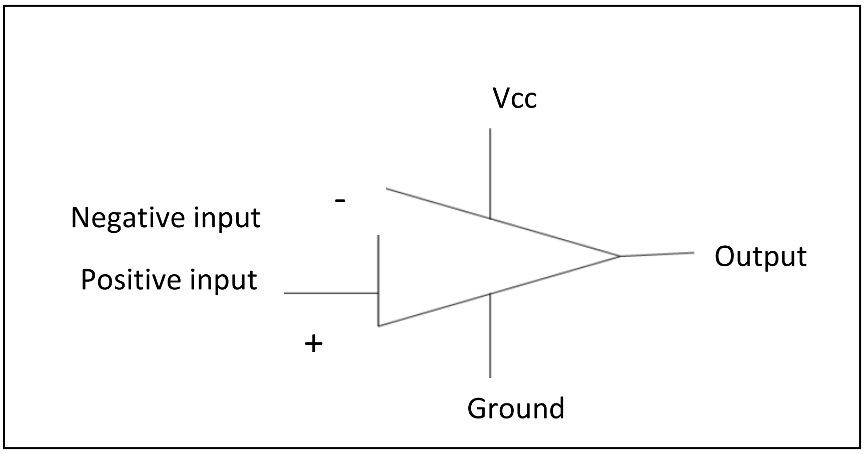

Figure 3.4: Comparator

As above we see that two inputs are required for comparators. One input is from IR receiver and one input generated from potentiometer (preset). The second voltage is called as reference voltage for the sensor. Reference voltage can be varying by using potential meter, such that it can vary from 0V until Vcc. We use reference voltage as mean value of the sensor outputs measured with or without light.

3.4.3 IC LM324

The LM324 series are low−cost, quad operational amplifiers with differential inputs. They have several advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V with quiescent currents about one−fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

Features:

- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum (LM324A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps on the Inputs Increase Ruggedness without Affecting Device Operation
- NCV Prefix for Automotive and Other Applications Requiring Site and Control Changes

These devices consist of four independent high-gain frequency compensated operational amplifiers that are designed specifically to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is 3 V to 32 V (3 V to 26 V for the LM2902), and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational-amplifier circuits that now can be more easily implemented in single-supply-voltage systems. For example, the LM124 can be operated directly from the standard 5-V supply that is used in digital systems and provides the required interface electronics, without requiring additional ±15-V supplies. IC LM324 contains four comparators as shown in figure 3.5

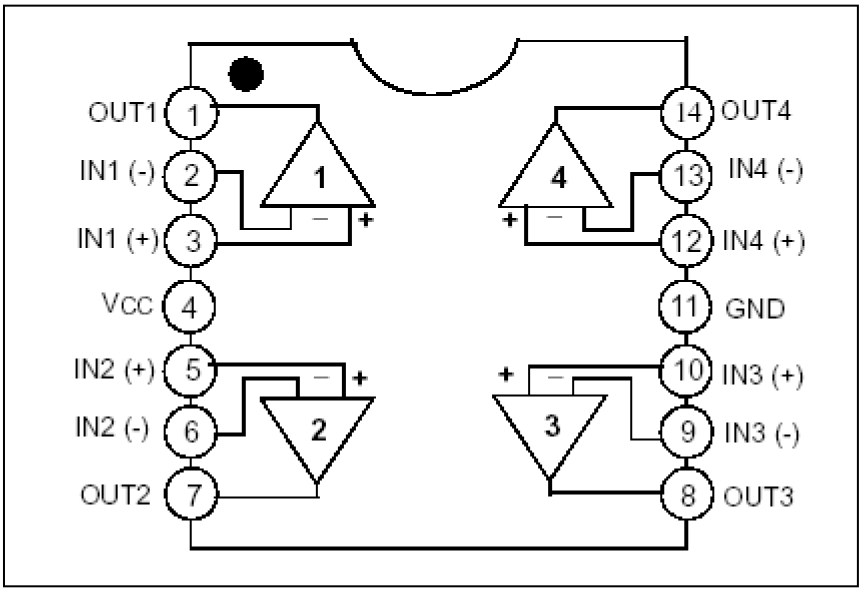

Figure 3.5: LM324 schematic

3.4.4 Arrangement of sensors

An array of sensors arranged in straight in row pattern is bolted under the front of the robot. We can use any number of sensors. If we have lesser number of sensors then robot will move not smooth and it may face problems at sharp turn. If use higher numbers of sensors robot movement will become smooth and reliable for the sharp turn, however it requires complex programming and more hardware. Thus we choose optimum numbers of sensors.

The distance of the sensors depends on:

1) Numbers of sensors we used.
2) Width of the straight line.
3) Distance between sensors may not be constant (it depends on the logic)

The figure 3.6 and shows the arrangement of the sensors from above and side

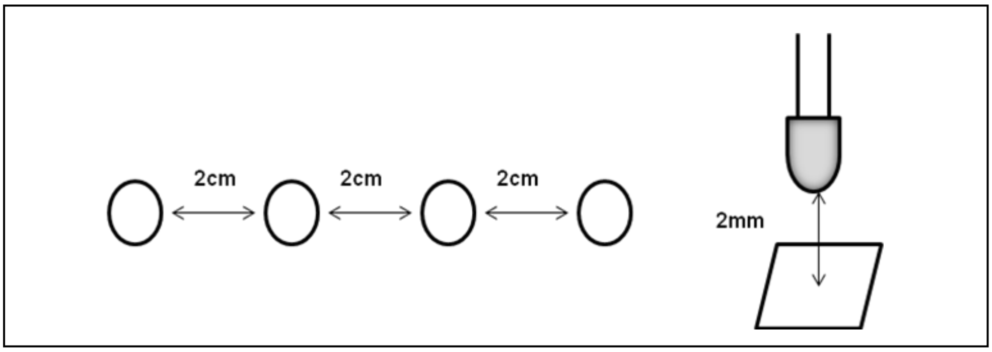

Figure 3.6: Top and side view of sensors

Combination of number sensors used and arrangement of sensors produce circuit as in figure below. Figure 3.7 shows full schematic diagram of IR sensors:

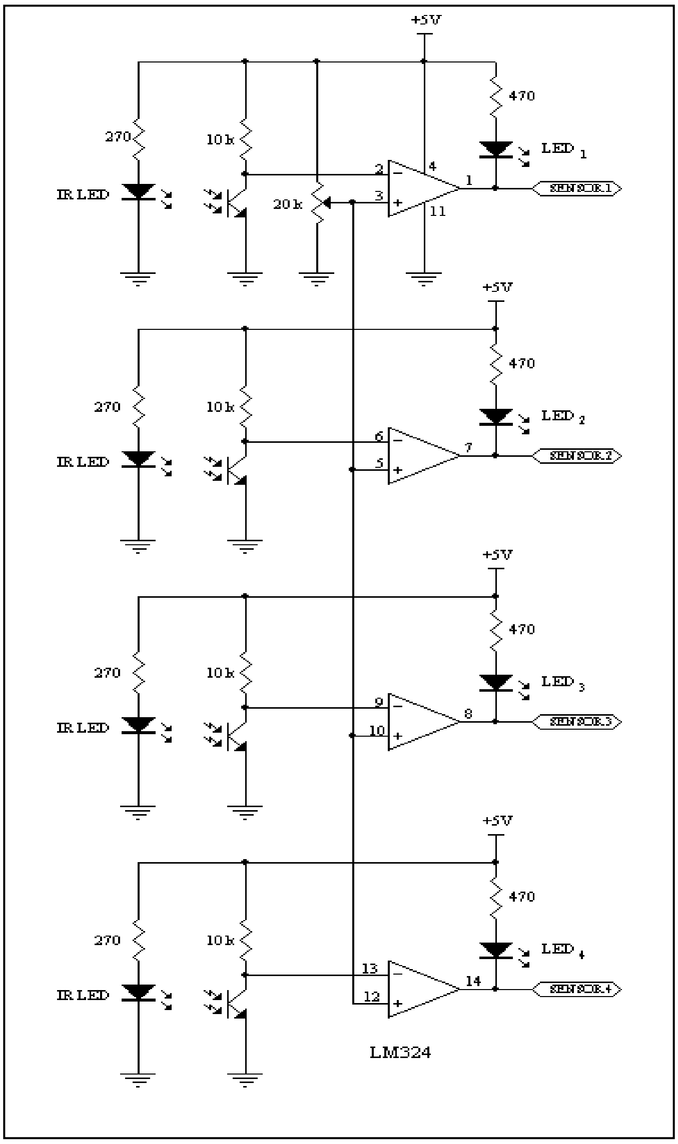

Figure 3.7: IR sensors circuit schematic

Voltage references are used in [ADCs]() and [DACs]() to specify the input or output voltage ranges. Figure 3.8 show a graph voltage references for LM324.

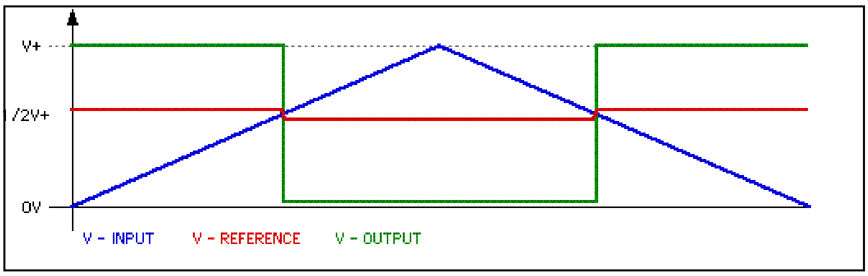

Figure 3.8: Vref graph for LM324

Below it show calculation to determine Vref value for LM324 :

$$V_{ref} = \frac{V_{high} + V_{low}}{2}$$

$$= \frac{4.675 + 2.500}{2}$$

$$= 3.5875 \text{ V}$$

3.5 Processing system

Processing system is act like a brain of robot, which generated a desired output for corresponding input. For that we use microcontroller for example ATMEL, INTEL, Microchip other manufacturer. But in this project we use MC68HC11 from Motorola because it is easy to get and as it has 48 input/output pins. The development circuit is design based on bootstrap mode operation. WP11 is used in order to erase and load program into microcontroller. The entire program is written in assembly language using THRsim11.

Figure 3.9 show the MC68HC11 pins details:

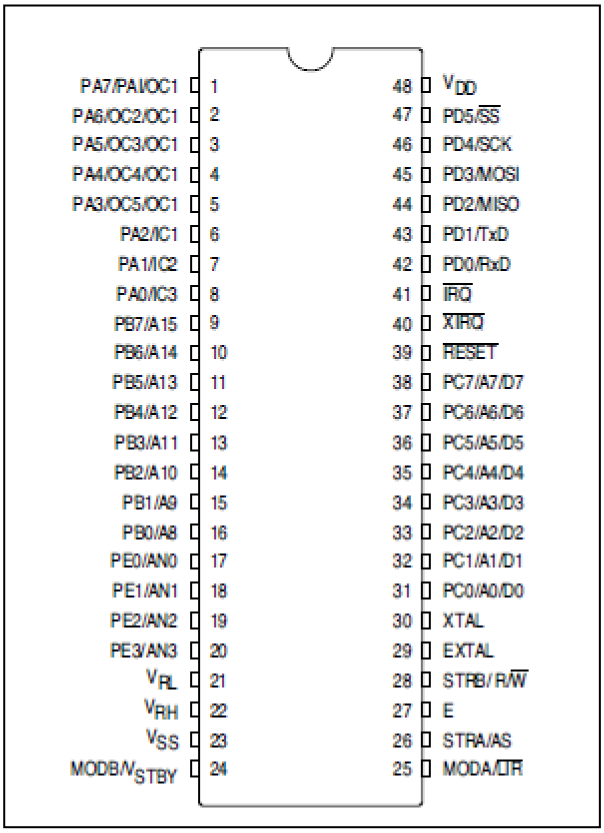

Figure 3.9: MC68HC11 pins

3.5.1 Voltage regulator

MC68HC11 needs a constant 5V from the source in order to operate and it need to build a separate circuit to power up by using voltage regulator (7805). 7805 gives fixed 5V dc if input voltage is in between 7.5V to 25V. They help maintain a steady voltage level despite varying current demand and input variations. If input is less 7.5V then regulation won't be proper, but there are some other parameters for the voltage regulator like maximum output current capability and line regulation that need a consideration. Figure 3.10 shows the voltage regulator schematic.

3.5.2 IC 7805

The LM7805 series of three terminal positive regulators are available in the TO-220 package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents. The circuits for IC7805 show in figure 3.10.

Features

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

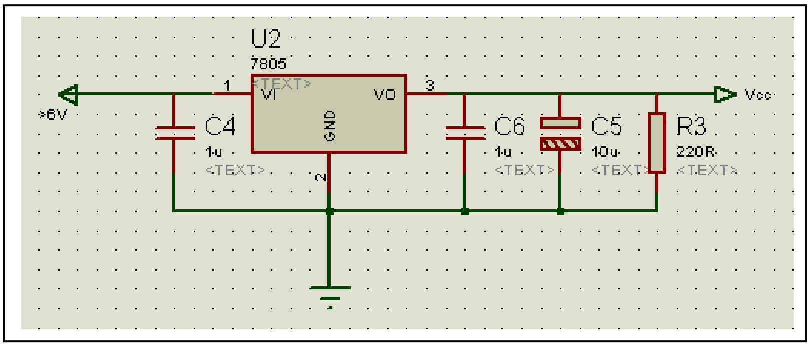

Figure 3.10: Voltage Regulator circuits

3.5.3 Oscillator

Figure 3.11 show the oscillator circuit that used by MC68HC11 as clock to operate the program especially for PWM features.

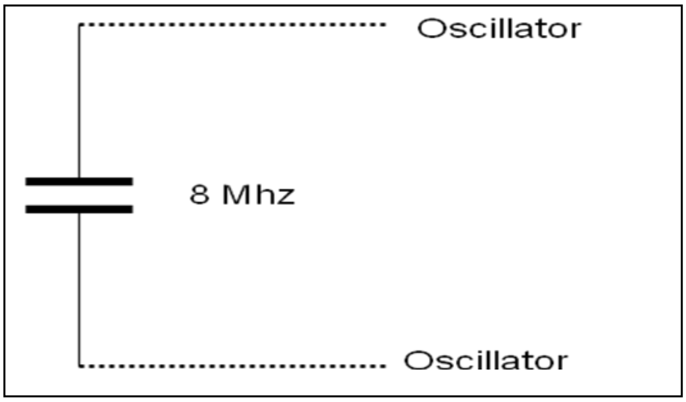

Figure 3.11: Oscillator Schematic

Figure 3.12 shows that the full schematic for MC68HC11 basic circuit where it contains all the power circuit, oscillator circuit and preset circuit. These circuits cover the entire basic requirement to make MC68HC11 to works properly.

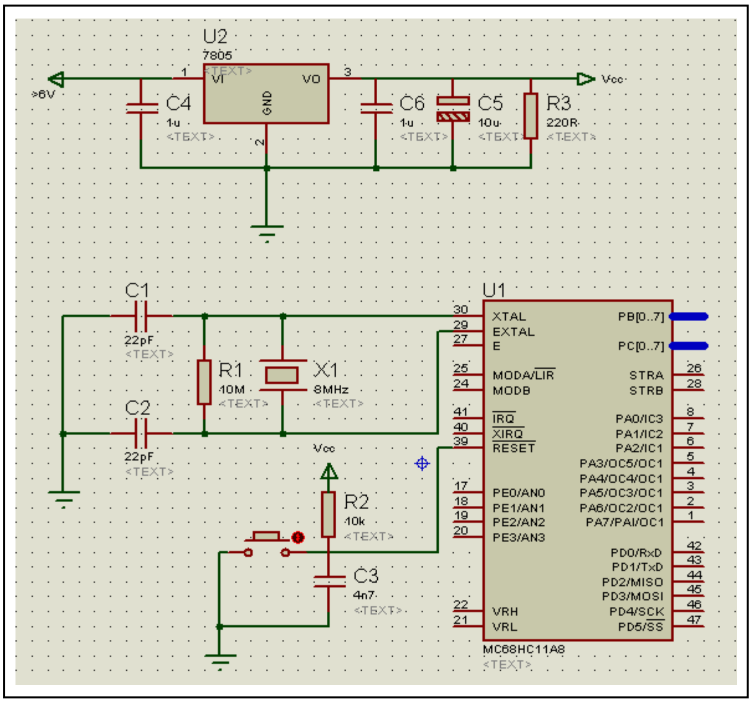

Figure 3.12: MC6811 basic circuit

3.6 Output system

For moving a robot we have RC servo motor attached to wheels and gears system. RC servo motors are most easy to control. One RC servo motor requires only two signals to operate. Change direction can be done by reverse the polarity of power supply across it. Figure 3.13 show a flowchart for motor control:

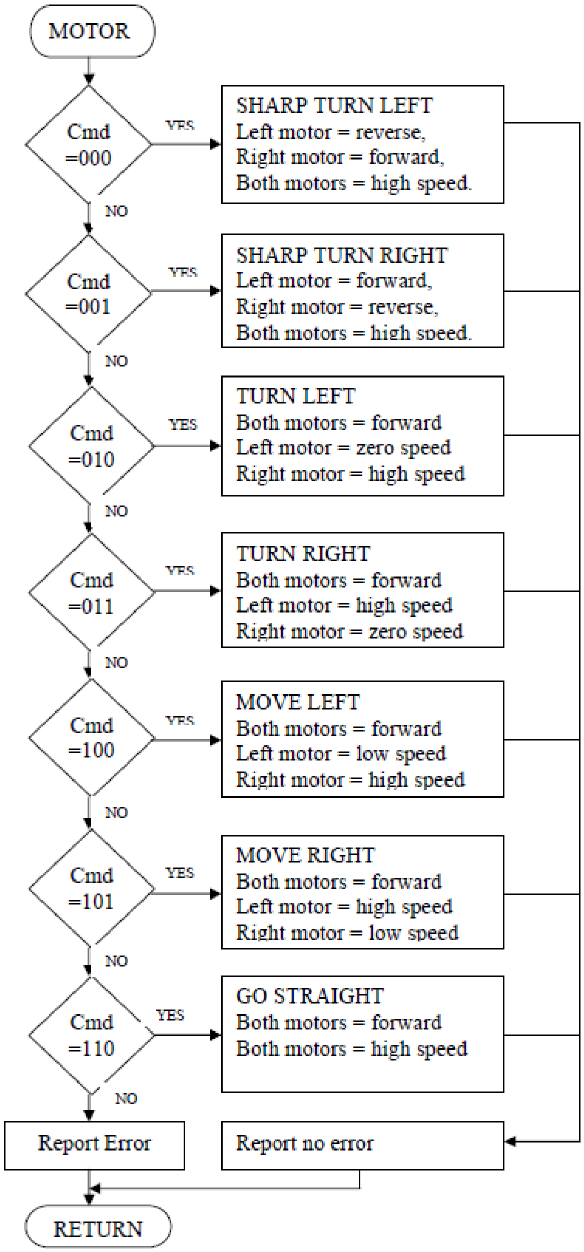

Figure 3.13: Motor flow

3.6.1 Use of driver

From microcontroller we cannot connect a motor directly because microcontroller cannot give sufficient current to drive the RC servo motor. Motor driver is a current enhancement device where it can act as a switching device. Which is motor driver is need to integrate with RC servo motor. Motor driver takes the input from microcontroller and generates output for motor.

3.6.2 IC L293D

Figure 3.14 shows IC L293D schematic. This is a motor driver IC that can drive two motor simultaneously.

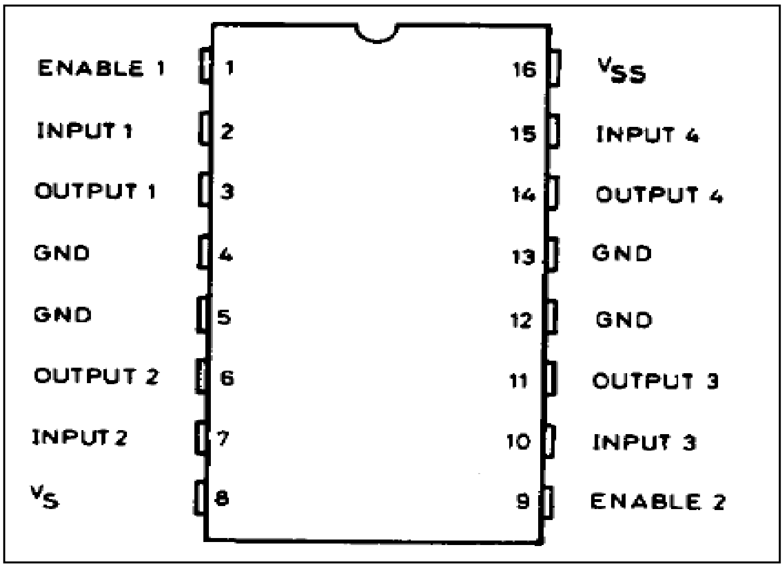

Figure 3.14: L293D schematic

The L293 and L293D are quadruple high-current half-H drivers. The L293 is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled and their outputs are high and in phase with their inputs. When the enable input is low, those drivers are disabled and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

On the L293, external high-speed output clamp diodes should be used for inductive temporary suppression.

A V_{CC1} terminal, separate from V_{CC2}, is provided for the logic inputs to minimize device power dissipation. Figure 3.15 shows all the connection between microcontroller, L293 and RC servo motor.

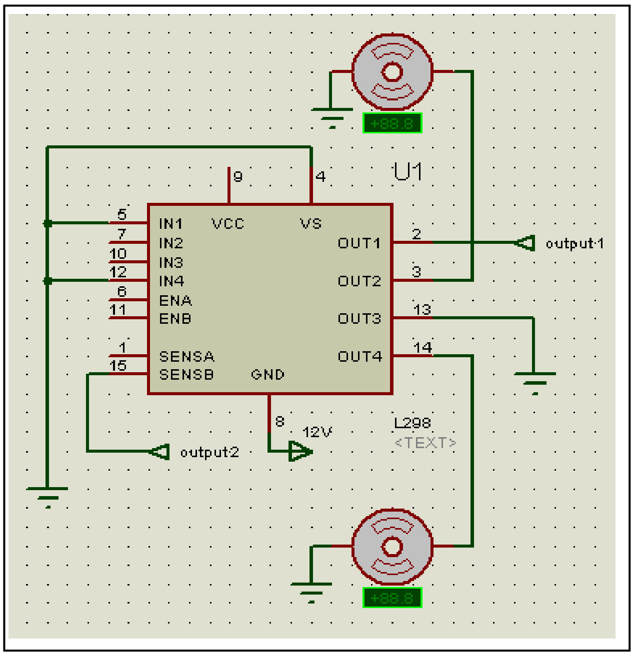

Figure 3.15: Motor connection

Logical supply voltage will decide what value of input voltage should be considered as high or low. If the logical supply voltage is setting equal to +5V, then -0.3V to 1.5V will be considered as input low voltage and 2.3V to 5V will be considered as input high voltage. Motor will moving forward when the input voltage for both motor is high and turning left or right when one of the motor receive input high voltage and the other one receive input low voltage.

3.7 Circuits integration

Figure 3.16 shows how the connection between all modules that involve in making the line follower robot using MC68HC11.

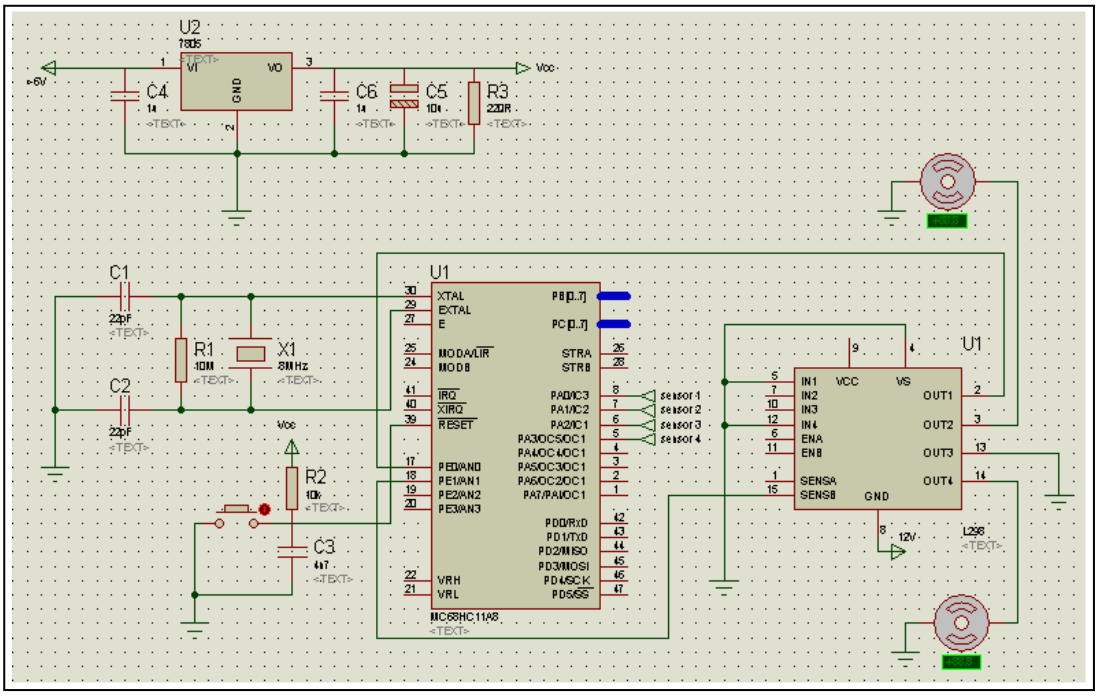

Figure 3.16: Circuit connection

3.8 Pulse width modulation (PWM)

PWM is a method to generate periodic square wave of various frequency (time periods) of duty-cycle. The periodic wave has two level (high or low), with some constant frequency and duty-cycle. Figure 3.17 explain the details about PWM.

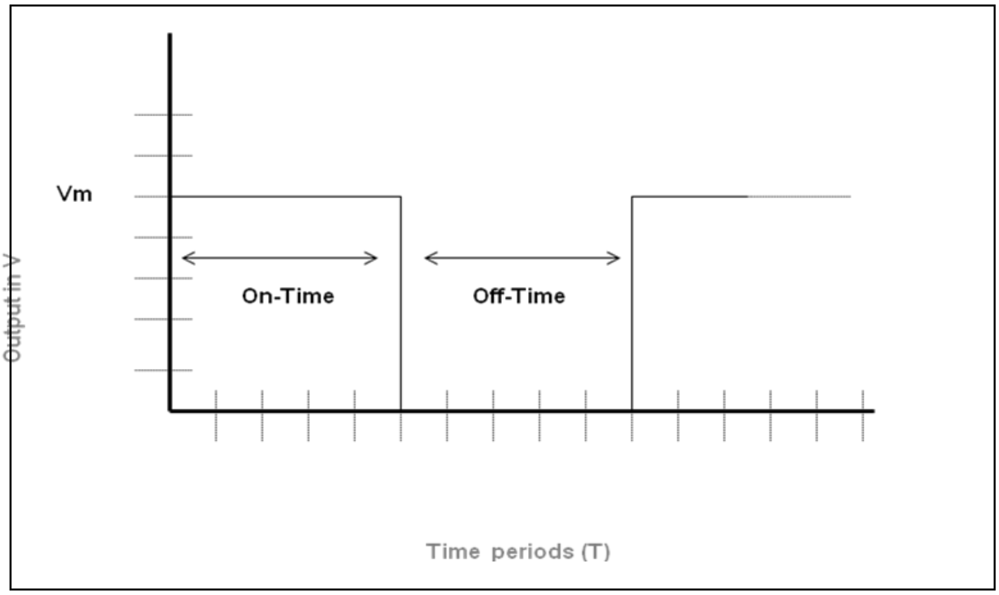

Figure 3.17: PWM graph

3.8.1 PWM in servomotor.

PWM can be use to drive the motor with variable speed even though it has constant voltage supply. Variable resistance need to add in series with the motor as an alternative for PWM. Figure 3.18 show the circuit connection.

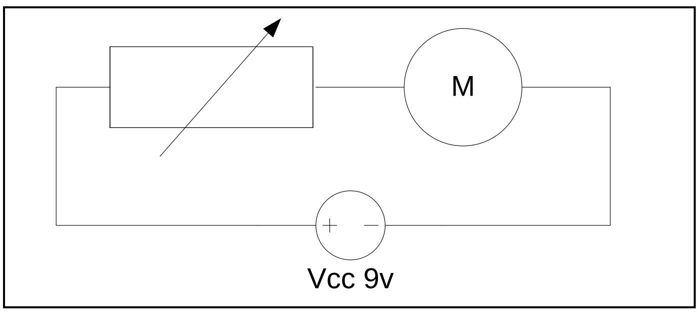

Figure 3.18: Circuit analogy

The drawbacks of this condition are:

1. The resistance value cannot varied dynamically (automation is difficult)
2. There will be an unnecessary power loss across resistor.

Now by adjusting the duty cycle of the signal (modulating the width of the pulse), speed of the motor can be control. In other words varying duty cycle we are getting different values of the average voltage (Vavg) across the motor resulting differential speeds. Figure 3.19 shows the system.

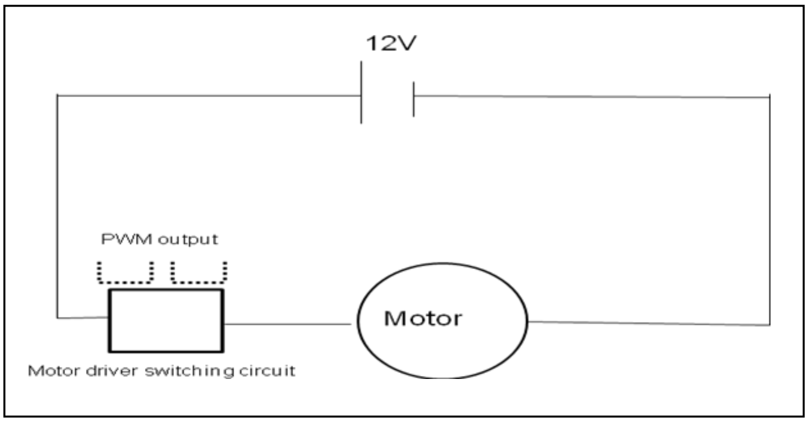

Figure 3.19: PWM system

3.9 Software configuration

There are three type of software that available in this project. First one is the system design on programming MC68HC11 using THRsim11, load and reset program using WP11 and the third one is Proteus 7.1 to simulate the program.

3.9.1 THRsim11

THRsim11 is a program suitable with MC68HC11 which is can edit, assemble, simulate and debug programs for the MC68HC11 on windows PC.

It can simulate the CPU, ROM, RAM, and on-board peripherals. You can also use THRSim11 also can debug the program on compatible board

When the assembly program is loaded into the target board the graphical user interface makes it possible to view and control every register (CPU registers and I/O registers) and memory location (data, program, and stack) of the real microcontroller. It is possible to stop the execution at any address and inspect or change the registers and memory.

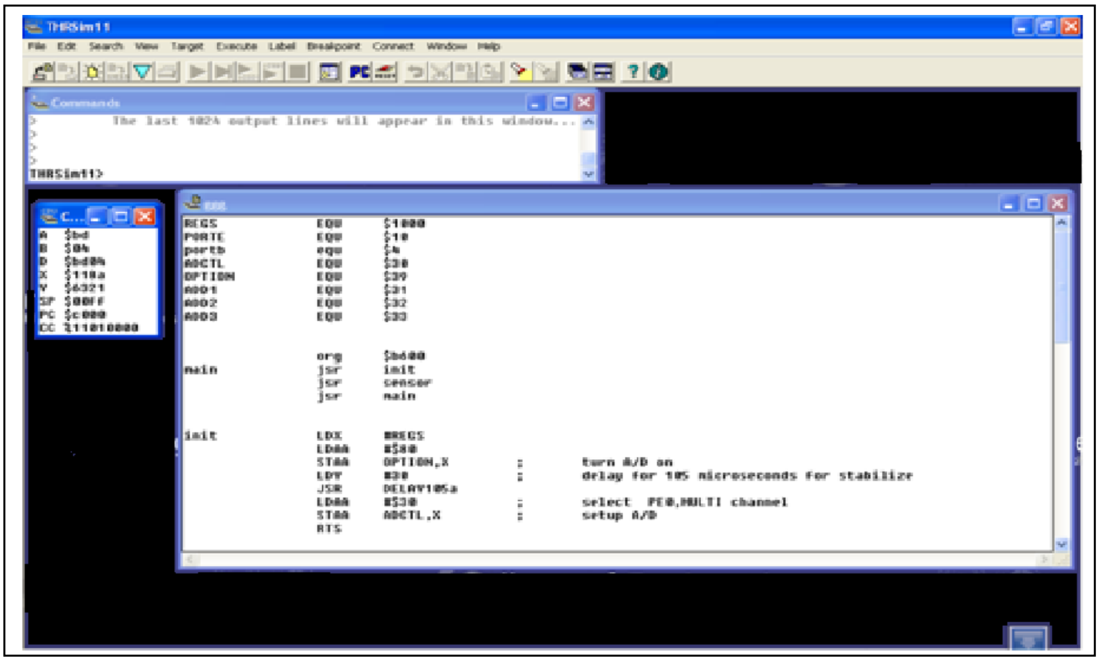

Figure 3.20: THRsim11 programmer

3.9.2 WP11.exe

WP11.EXE takes input from object code files created with 68HC11 assemblers or compilers. These object code files may be in Motorola S-record, Intel Hex or binary memory image formats. This software also allows the operator to perform many other useful programming functions such as erasing, blank checking & verifying devices, displaying, editing, exporting and changing the format of the object code files and filling unused memory locations with a user specified "fill" byte. The software was designed to work with our P11 Programming Board but will also work with any hardware that supports the 68HC11 special bootstrap mode of operation.

In order to allow this software to program MC68HC11, it requires a minimally configured IBM PC or compatible with at least 64Meg RAM memory, one 3.5" disk drive, one free serial port designated as COM1-COM4 and Windows 3.1, 98, ME, NT, 2000 or XP. Presently WP11 supports Motorola MC68HC711E9 MC68HC711E20 MC68HC811E2, MC68HC711D3, MC68HC11A1/A8, and MC68HC711K4 family. [wp11man]

WP11.EXE takes input from object code files created with 68HC11 assemblers or compilers. These object code files may be in Motorola S-record, Intel Hex or binary memory image formats. The software also allows the operator to perform many other useful programming functions such as erasing, blank checking & verifying devices, displaying, editing, exporting and changing the format of the object code files and filling unused memory locations with a user specified "fill" byte. The software was designed to work with our P11 Programming Board but will also work with any hardware that supports the 68HC11 special bootstrap mode of operation. [wp11man]

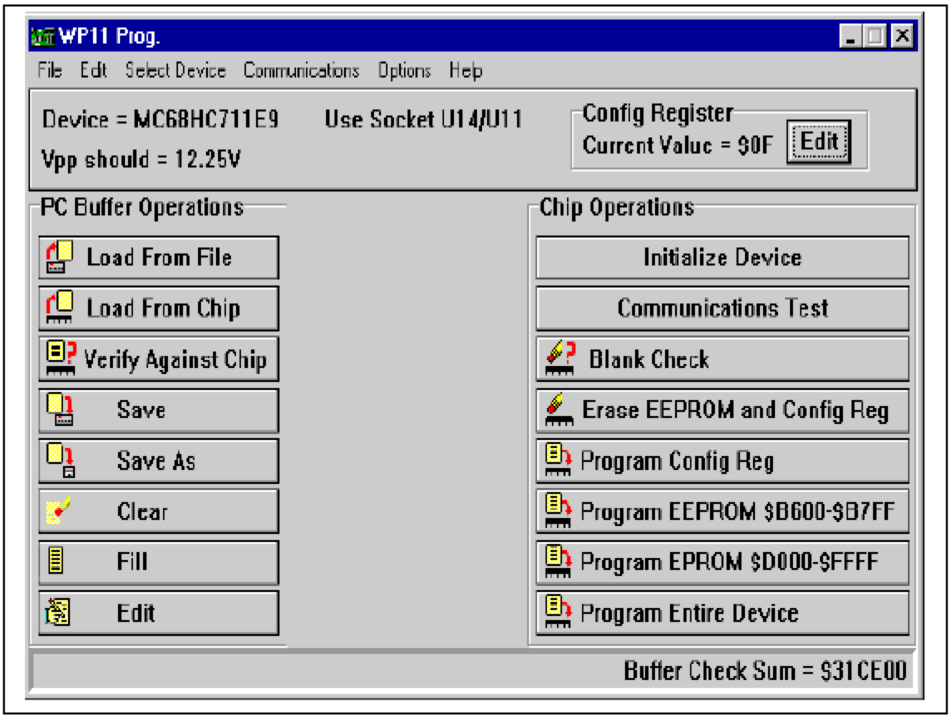

Figure 3.21: WP11 Programmer interface

3.9.3 Proteus 7 Simulator

For this project, this Proteus 7 Professional software is used to do the simulation of the project. To make sure that all the system is running based on the theoretical side, the simulation is very important to this project.

According to that, all kind of connection will be design in this software first before assemble them in electronic design. The programming for the MCU also will be simulated in this software before apply it to the real MCU to make sure that the programming is correct.

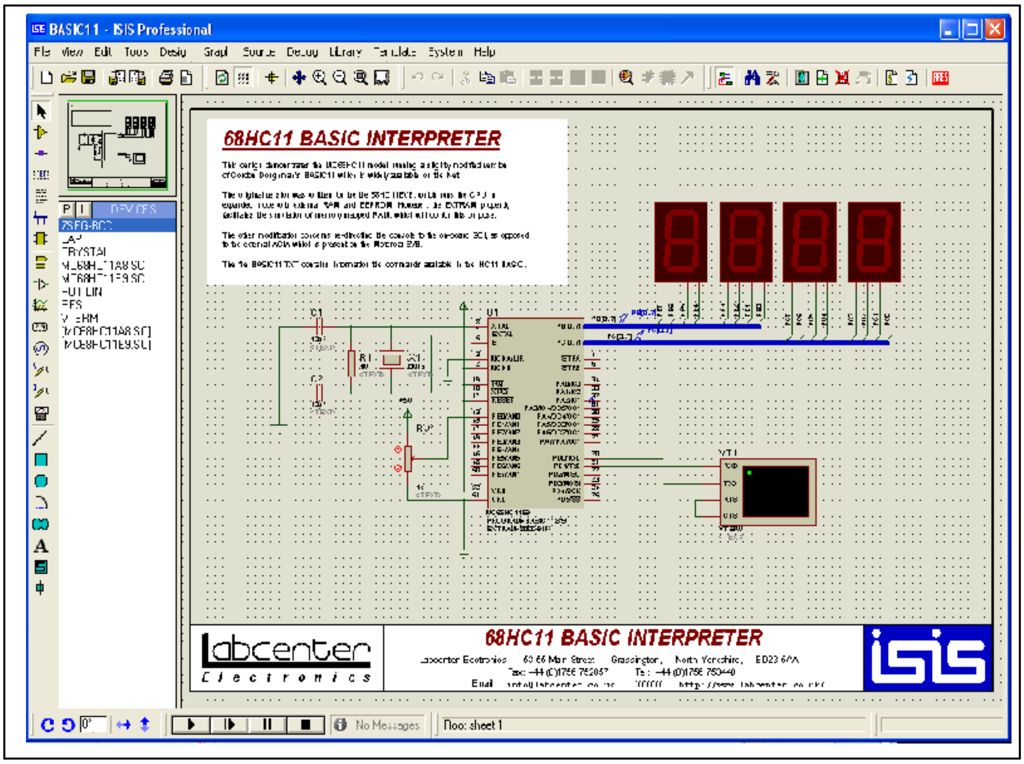

Figure 3.22: Interface of Proteus 7 Professional Simulator

3.10 Programming MC68HC11

In order to control the position of the robot, MC68HC11 microcontroller is an option to be applied. In this device, there are five ports, Port A, Port B, Port C, Port D and Port E. But in this project only two of them we used as Input/output pin (I/O pin).

Port	Input/output
E0,E1,E2,E3	Input
B0,B1	Output

Table 3.1: Port and functions

Therefore, the flow of process have been created before begin to programming the MC68HC11 and shown on Figure 3.23 below:

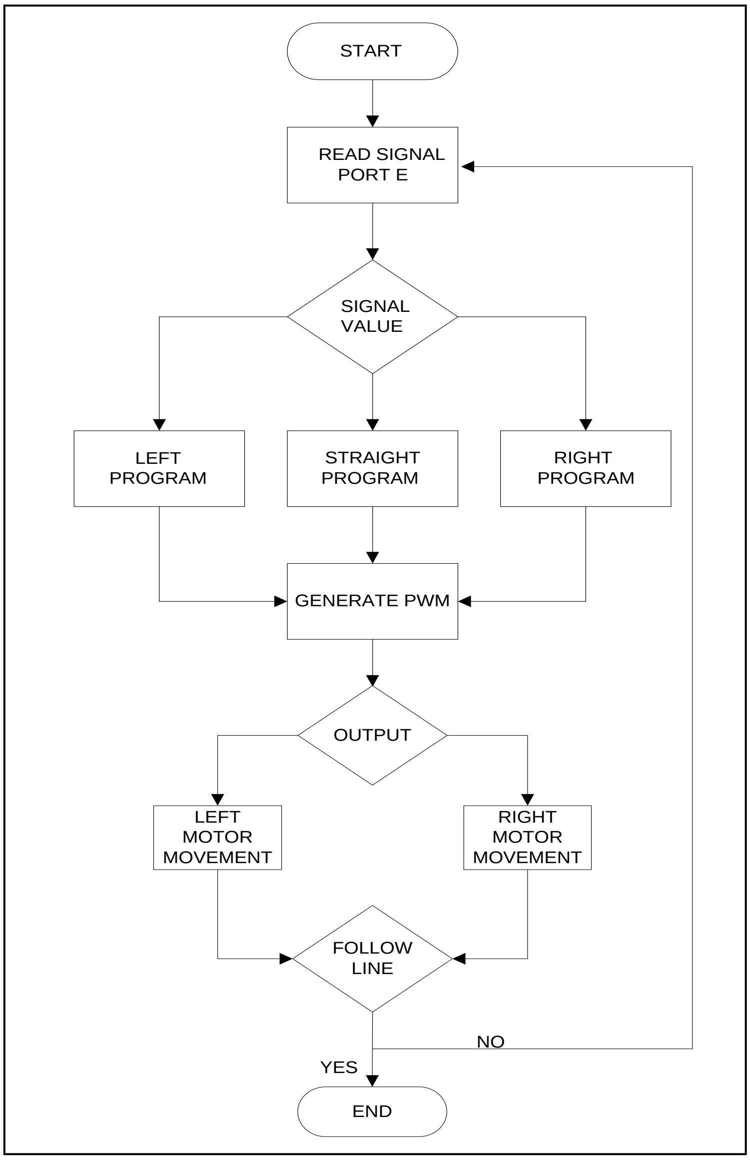

Figure 3.23: Programming flow

An input will be received from IR sensors through port E. That input will select case to determine whether position was selected and execute the related process. In this project, it is important to get a precision location by determine the binary input received from sensors converted into numerical value by MCU for next course of action. Before any work is operate, the position of the robot must be in centered of the line.

3.11 SUMMARIZATION

This project uses two RC servo motor as the mover. The motor will be controlled by the processor. MC68HC11 microprocessor has been used as the processor. The processor will do the task depend to the received input from the sensors. Source code for this project will be show in appendix.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter consists of the discussion about the simulations speed of RC servo motor represented in term of pulse width modulation (PWM) using Proteus 7.1. This chapter also discussed about the operation of hardware which the result of simulation is used in programming and implemented to the hardware.

4.2 Simulation of motor speed

The RC servo motor will not move accurately if there are mistake in the control programming. Therefore, the Proteus 7.1 is used to see the speed of motor is right and follow the design instruction. For this simulator, it shows a different speed in left or right motor.

4.2.1 PWM simulation

The robot move based on sensor detection whether left or right. Figure below shows a waveform form both motor left and right. Yellow waveform represented left motor and pink waveform represented right motor.

4.2.1.1 Robot corner right:

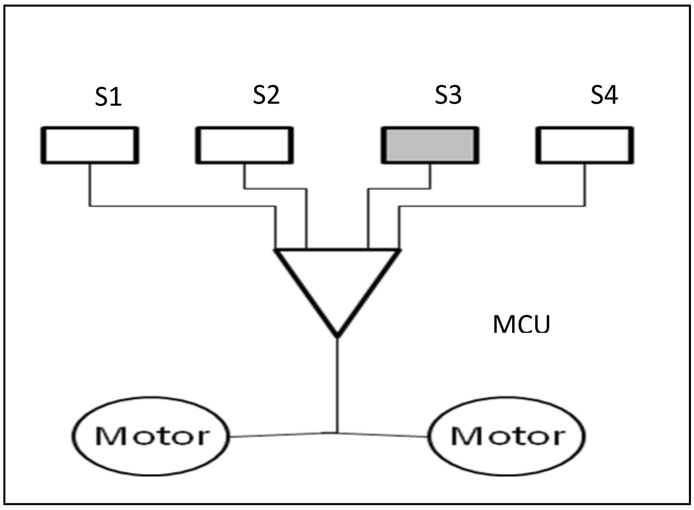

Figure 4.1: Right sensors

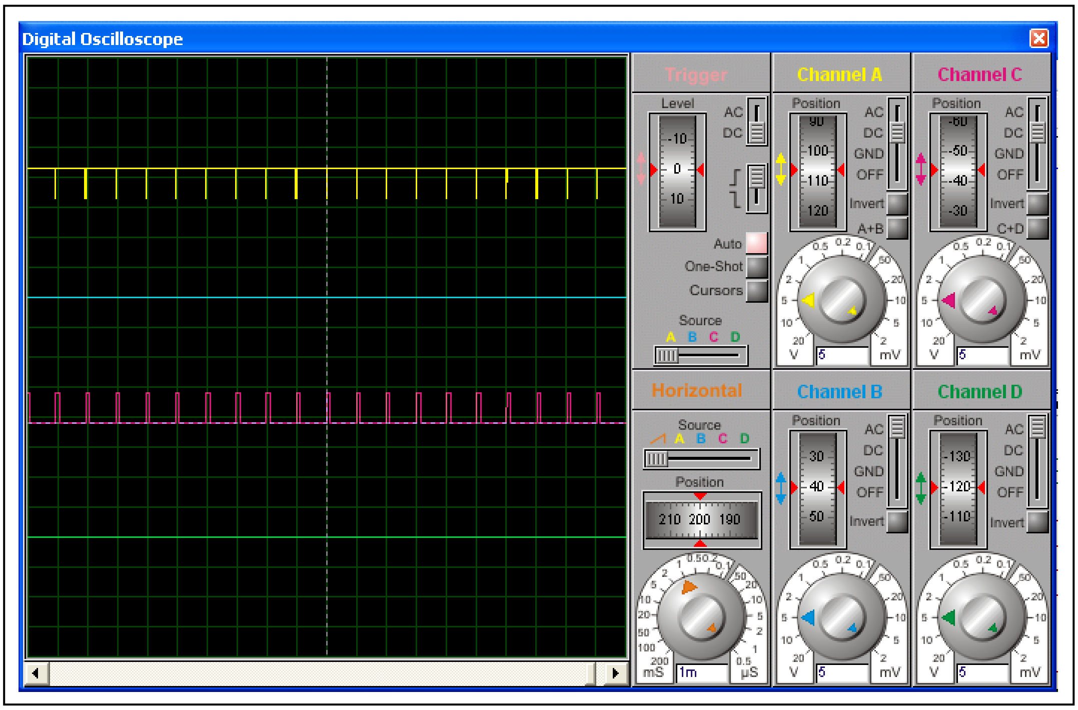

Figure 4.2: Right PWM

Motor	Duty cycle (0-255)	Speed Utilization (%)
left	178	70
right	25	10

Table 4.1: Right PWM

Left and right motor moving forward with a different speed. Left motor move with greater speed than right motor. Robot will turn right with both motor running forward but with a different speed.

4.2.1.2 Robot corner greater right:

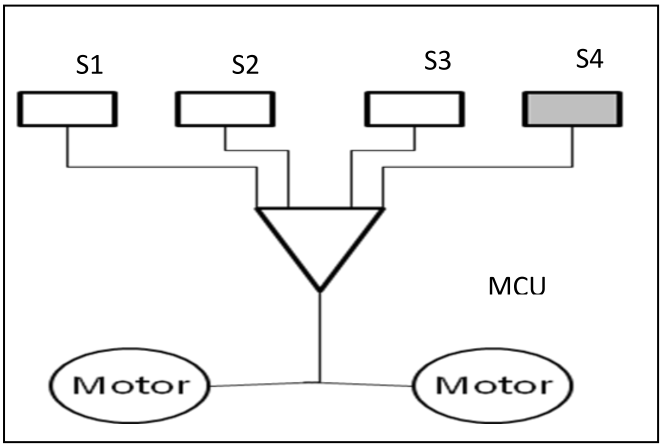

Figure 4.3: Greater right sensors

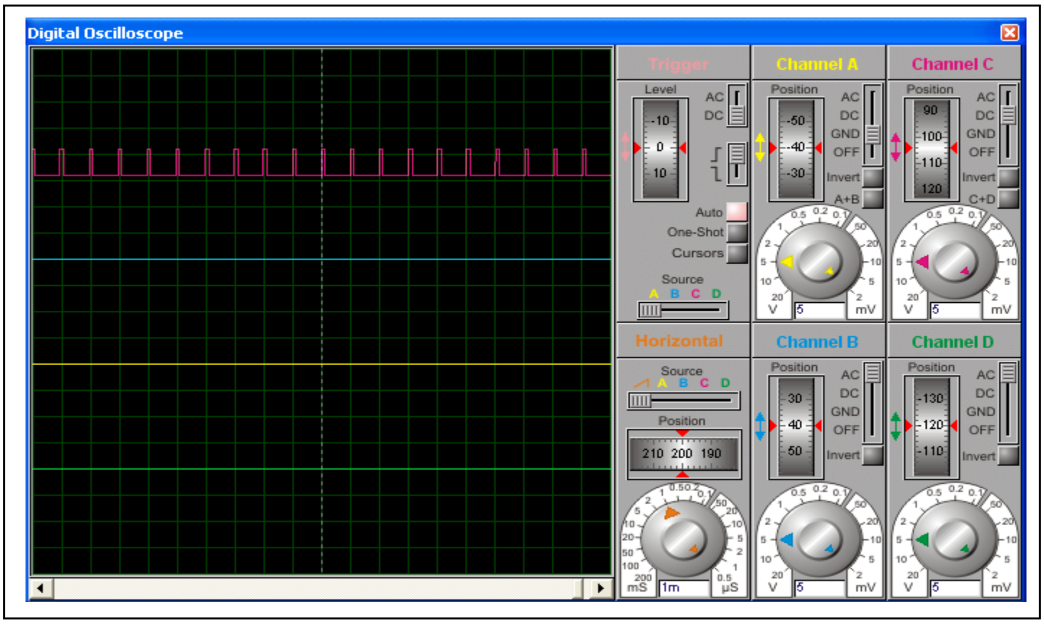

Figure 4.4: Greater right PWM

Motor	Duty Cycle (0-255)	Speed Utilization (%)
left	204	80
right	0	0

Table 4.2: Greater right PWM

Left motor moving forward and right motor stop moving. Speed utilization also increase when robot need to turn greater right. Robot will turn greater right with right motor stop moving and turn 90° to the right.

4.2.1.3 Robot corner left:

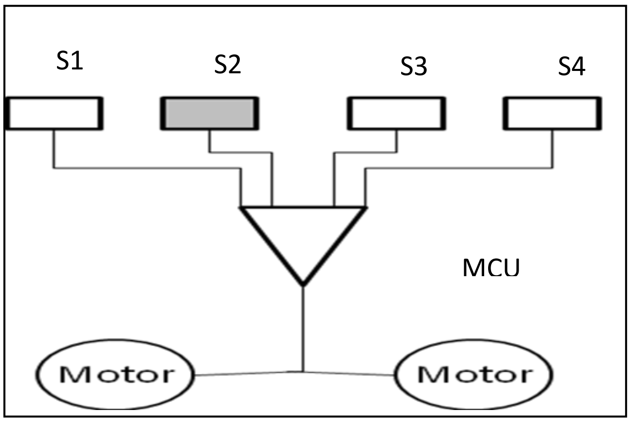

Figure 4.5: Left sensors

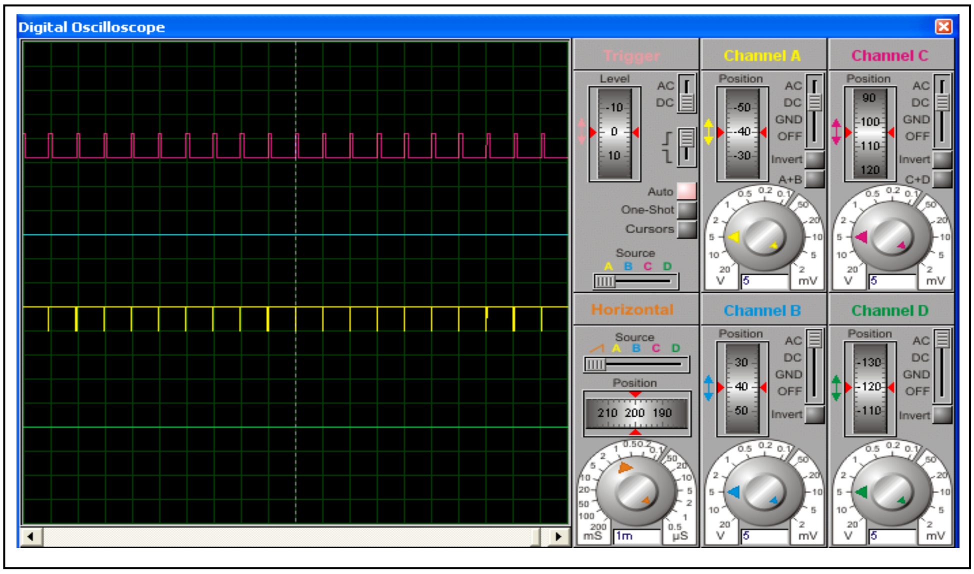

Figure 4.6: left PWM

Motor	Duty Cycle (%)	Speed Utilization (%)
left	25	10
right	178	70

Table 4.3: Left PWM

This condition same as robot turn right but the different here is right motor running with a greater speed than left motor. Robot will turn left with both motor running forward but with a different speed.

4.2.1.4 Robot corner greater left:

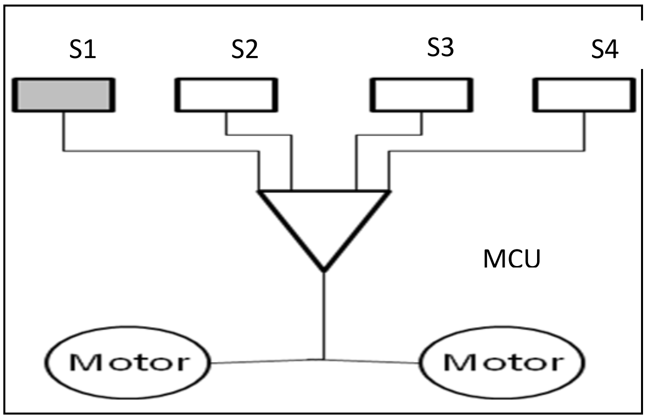

Figure 4.7: Greater left sensors

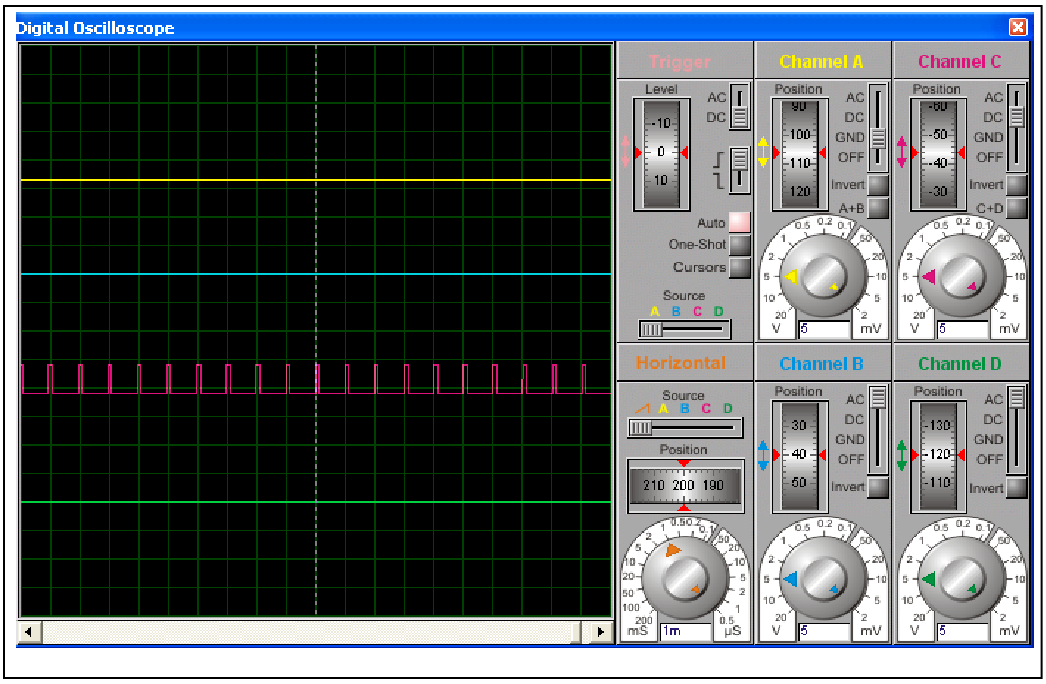

Figure 4.8: Greater left PWM

Motor	Duty Cycle (%)	Speed Utilization (%)
left	0	0
right	204	80

Table 4.4: Greater left PWM

This condition same as the robot turn greater right. Right motor will moving forward and left motor stop moving. Speed utilization also increase when robot turn greater left. Robot will turn greater left with left motor stop moving and turn 90° to the left.

4.3 Costing

The costs of this project which contains three different parts that is sensory, processing and output. The table 4.8 shows all components used in this project.

PROCESSING COMPONENTS			
Component	Quantity	Unit price (RM)	Amount (RM)
MC68HC11A1	1	40.00	40.00
Crystal 8MHz	2	1.20	2.40
Capacitor 22pF	2	0.07	0.14
Capacitor 4.7µF	1	0.07	0.07
IC Base 48-pin	1	0.65	0.65
Resistor 10MΩ	1	0.06	0.65
Resistor 10KΩ	1	0.06	0.06
		Total :	43.97

SENSORY COMPONENTS			
Component	Quantity	Unit price (RM)	Amount (RM)
IR Sensor Set	6	5.00	30.00
LM 324	1	1.50	1.50
Potential Meter (20kΩ)	2	1.20	2.40
Resistor (10kΩ)	4	0.10	0.40
Resistor (270Ω)	4	0.10	0.40
Resistor (470Ω)	4	0.10	0.40
LED	4	0.50	2.00
		Total:	31.30

OTHER COMPONENTS			
Component	Quantity	Unit price (RM)	Amount (RM)
Driver L293D	1	13.00	13.00
Robot Base Set	1	150.00	150.00
Board	3	5.00	15.00
Power Connector	1	2.00	2.00
		Total:	180.00
		Total cost:	255.27

Table 4.9: Cost of components

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The design of the line follower robot using MC68HC11 has been presented in this project. The track made from black tape on white surface are sensed by IR sensors make the sensory part of robot function properly. The sensors circuit can communicate with black and white line. Servo motor can run when it connect to supply directly.

It is become easy if the controllers used are from PIC family but in this project which is use Motorola 6811 that is need a research and understanding in Motorola family to complete this project.

In conclusion, the objective of this project is not fully successful achieved. It is happen because of the communication between MC68HC11 and motor circuit can not be integrate. The problems also occur between sensor circuit and MCU which that MCU can not synchronize with an input.

5.2 Problem encountered

When the board development is still in progress, there are a few problems that had been encountered such as limited budget. This project need an extra budget for component because when the hardware is testing, there will be a broken component and need to change. In this project, the sensor change many time because of not function. When troubleshooting in progress, current flow in sensor is over limit and cause the sensor broken and can not be used.

5.3 Future recommendations

It is recommended that the future development should considering two things which are mechanical design and data acquisition mechanism. The quantity of the IR Sensor should increase because with increase number of sensor the more efficient controller can operate. The body of robot also need to be adjusted like the bolt need to be change into roller that can support the body and rolling with less friction unlike bolt that cause robot moving in hiccup. Wheel chair or three wheel drive can be use to reduce traction and get more grip to wheel.

For the additional, PID controller can be implement to get a smooth movement. PID controller can reduce error when it tracking line. It also can add bump detection system to avoid bump such as rock to prevent robot go out of line.

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