CONTROLLER AND CIRCUITRY DESIGN AND IMPLEMENTATION FOR FIRE FIGHTING ROBOT FOR MIROC 2014 COMPETITION

By

CHARLIE IVAN ANAK REYFILL KONNIK

FINAL PROJECT REPORT

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

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzwan

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CERTIFICATION OF APPROVAL

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Approved:

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Dr. M. Haris B. Md. Khir
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
August 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Charlie Ivan ak. Reyfill Konnik

ABSTRACT

This project was carried out to develop an optimum circuit design and software algorithm which can be used to participate in the 2014 MIROC Robotics Competition. The said circuitry and algorithm will be implemented onto a robot which have been designed and fabricated with the help of colleagues from the Mechanical Engineering department. The software algorithm design can be broken into two parts; the navigation algorithm, which controls the movement of the actual robot, and the motor control algorithm, which provides for stability. The motor control algorithm is developed by using DC motor control theory, which involves determining the motor's mechanical and electrical parameters.Upon the completion of mechanical fabrication, circuit design and parameter extraction, the process of developing the navigation algorithm begins. This algorithm is designed using an iterative design model, whereby the program is continually tested and improved. The metric that is used to assess the algorithm's success are movement stability, consistency and accuracy.

ACKNOWLEDGEMENTS

I would like to dedicate my most heartfelt appreciation to my project supervisor, Dr. M. Haris B. Md. Khir, and my co-supervisor Dr. Mohamad Naufal bin Mohamad Saad for their continued guidance and tutelage throughout the duration of this project. They have been most understanding and patient in dealing with the problems encountered while working on this project, while also giving feedback and suggestions during our periodic meetings.

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CHAPTER 1
INTRODUCTION

1.1. OVERVIEW OF PROJECT

MIROC (Malaysian International Robotics Competition) is a robotics competition which is held every year in UNIMAP (Universiti Malaysia Perlis). The competition serves as a platform to promote robotics among students from various tertiary educational institutions in Malaysia. MIROC organizes 3 different categories of competition, namely Rope-Climbing Robot, Fire-Fighting Robot and Conquer Robot. In this project, all the problems and solutions discussed will be focused only on the Fire-Fighting Robot.

In order to qualify for the competition, the robot must obey certain rules regarding its weight, dimension and voltage. The tasks which the Fire-Fighting Robot will need to accomplish include navigate a maze, rescue the 'victims' and extinguish the 'flame'. The robot must be able to accomplish this task within 3 minutes, and the winner of this challenge will be determined by the total number of points. Additionally, points will be deducted if the robot is found to have violated the game rules.

To achieve accurate motor control necessary to navigate the maze, the drive motors must be controlled by a motion controller scheme. In turn, in order for the motion controller to function the motor parameters must first be known beforehand. This is achieved by doing parameter extraction, which is the process of determining the motor parameters by monitoring its response to certain input signals.

1.2. BACKGROUND STUDY

During previous editions of MIROC competitions, the robot was built and programmed with minimal intelligence and control. The drive motor programming is implemented using basic differential drive algorithm with encoder feedback, with no attempt at any speed controls for stopping and starting. This resulted in occasional stuttering movements and accuracy suffered. The use of analog distance sensors were nonexistent as there were many difficulties in implementing the sensor. As the robot did not have any spatial awareness, the programmer relied on the maze partitions to calibrate the robot's position. While this method worked to some extent, it is not preferable as physical contact with the partitions might damage the robot. There is also the added risk that the robot would get stuck halfway through the maze and would have to be restarted.

The purpose of this project is to implement true control systems into the movement of the robot, thus enabling more responsive and smoother movement. Parameter extraction methods are also employed so that the calibration of the control systems can be done automatically and with less trial and errors. By using analog sensors and providing the robot with a sense of space, contact with the partition can be avoided. This will ensure more efficient navigation, with less unnecessary movement.

1.3. PROBLEM STATEMENT

Programming a robot to navigate a maze presents its own unique challenges, as the path is narrow and surrounded by walls. Thus the margin for error is very small, and sensors need to be able to ascertain distances at a range of less than 5 centimeters. The physical bulk of the sensors also need to be small in order to ease installation into the robot body. The circuit boards which will be used must also be small-sized to fit into the maximum 15cm x 15cm robot footprint. In addition to its size, the control board also must be able to support a wide variety of analog and digital sensors.

Motor selection is also a challenge facing this project. The drive motors' overall length, including coupling and wheels attached must not exceed 15cm. It also must have in-built encoders to facilitate the parameter extraction process, and a geared head for precision control. The motor used to extinguish the flame must have suitable fan blades attached to generate enough wind. The motor used for the vacuum mechanism to rescue the victims must be able to generate enough suction power to pick up the ping-pong balls. Also, all these motors must run on a maximum voltage of 24 volts.

Parameter extraction is a complex operation and will require a lot of research to carry out effectively. The relevant mathematical models must be researched and implemented on the drive motors, and its performance tested. The actual algorithm which will be used to control the robot in the game field must be stable to ensure consistent performance. As such, the algorithm must be rigorously tested in a simulated game field to mimic the conditions the the real game environment.

1.4. OBJECTIVES AND SCOPE OF STUDY

The main objectives of this project are:

- Select suitable sensors and motors that can perform under stated limitations.
- Select control board with enough capacity and performance to control the robot.
- Describe parameter extraction algorithm and implement in drive motors.
- Develop stable and accurate maneuvering and control algorithm for full system.

The scope of this study is defined to ease the development process as much as possible. The type of sensors used would be only digital and analog sensors, and all the motors used in the completed system will be only brush-less DC motors.

As this project is under the supervision of the Electrical and Electronics Engineering Department, the focus of this project will be more towards the circuitry and programming section. Collaboration is done with colleagues from the Mechanical Engineering Department with respect to the robot design and fabrication.

CHAPTER 2
LITERATURE REVIEW

2.1. CONTROL SYSTEMS

Automation and control systems is more prevalent than ever in modern life. Any complex systems, be it mechanical or biological, natural or man-made utilizes some form of control systems. Given the prevalence of it in the world around us, control systems have been the subject of study by scientists and engineers. Generally, a control system is an assembly of subsystems for the purpose of obtaining a desired output when given a specific input [1]. The figure below illustrates this very general description of any control scheme.

Figure 1: General Control System Block Diagram

Knowledge of control systems is also very useful when designing systems which involves power amplification, such as gears and pulleys, remotely controlled systems, stabilization and steering. As modernization of the workplace become more widespread, it has become necessary to develop more robust and dependable motion controllers due to the increasing use of automation in industry and homes[2]. This is because many applications where human lives are potentially at risk such as car steering mechanism or aircraft avionics depend wholly on its in-built controls to properly and safely function. In line with this, various schemes of actuator control have been expressly developed to solve outstanding problems in motion control [3]. Additionally, the mechanism used for the control system has also evolved through the years. Where earlier applications involved the use of pendulums, water levels, flyball systems and mechanical gyroscopes, more modern applications would employ solid-state electronics, computers and modern communications. Thus, the increase in the quality of hardware and software enabled the development of more accurate, responsive and sensitive control schemes, some of which will be described in the next section.

In this project, only motion controllers with robotic applications will be discussed, as this project is mainly a robotics project. The most well-known and widely used motion controller in industry and engineering is the proportional-integral-derivative (PID) controller [4]. It is also the preferred control system scheme by hobbyists, and a great deal of literature have been produced about this ubiquitous system.

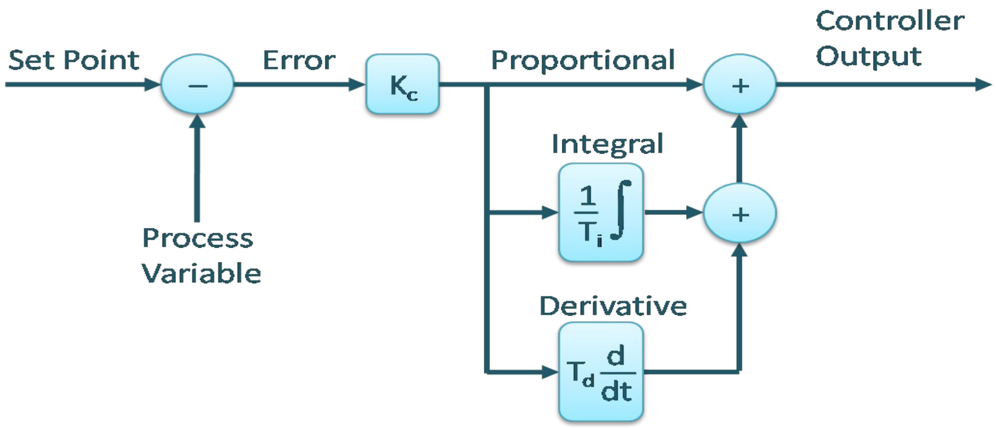

Figure 2: PID Controller Block Diagram [5]

This is because PID is simple to understand and implement, is effective, reliable and can be used to model a nonlinear system [6]. Its reliability is also thanks to its simplicity, where there are only 3 variables which need to be configured: the proportionality constant K_p, integral constant K_i and derivative constant K_d. However, the greatest disadvantage of PID is that it is very difficult to design, as "PID tuning is the key issue in the design of PID controllers and most of the tuning processes are implemented manually resulting in difficulties and time consuming" [7]. In other words, finding the value of Kp, Ki and Kd is mostly based on trial and error, as it is exceedingly impractical to obtain their exact value by other means.

An alternative motion controller is the state feedback (SF) controller. Just like PID, SF is able to model and describe systems which cannot be described by linear differential equations i.e. nonlinear systems. Such systems are usually modeled by using the state-space representation. This property is very useful as all systems in the real world are nonlinear. Linearizing systems would remove essential information, and designers of high performance systems would have to deal with nonlinear equations. Going one step further, SF techniques can and are often used to model systems for computer simulation [8].

This is especially important as given the prevalence of computers in the modern workplace, and the speed at which computers can solve tedious systems of equations, this would mean that research and development can be done with less resources[9].

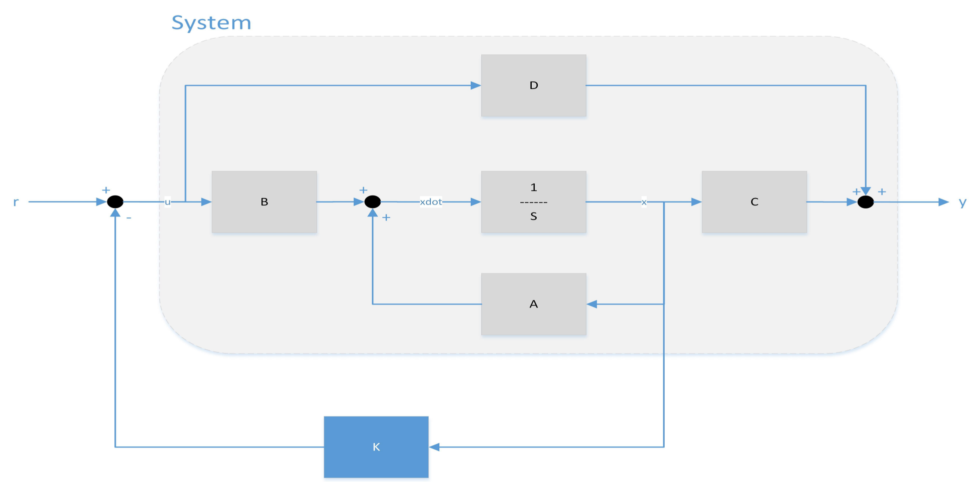

Figure 3: State Feedback Control Block Diagram [10]

2.2. PARAMETER EXTRACTION

Parameter extraction, also known as parameter estimation, is the process of approximating the values of the parameters which will be fed into the control system being used. Before motion controllers can be used, the system parameters must first be determined. The parameter to be estimated is usually a property of the system, such as damping. In this project, the parameter extraction and motion control will be implemented on driving motors by the IRATECH driver board. This is because in a robot the driving actuators are the most critical on-board system[11]. Thus, from the mathematical model of a DC brushed motor, the parameters to be estimated is the moment of inertia (J), and the damping coefficient.

$$T_M = J\frac{d\omega}{dt} + B\omega + T_L$$

Figure 4: DC Brushed Motor Mathematical Model

The parameter extraction technique to be used depends on the mathematical model used to describe the system [12], and there are many parameter extraction methods such as Pasek's method, nonlinear least square methods, pseudo inverse method and frequency response method[13]. In the IRATECH board, the chosen parameter estimation technique is the three-phase estimation method. Each technique has its own pros and cons, and the system designer must determine which scheme is the most suitable.

2.2. THREE-PHASE ESTIMATION METHOD

The three-phase estimation method is used in this project for many reasons. It is relatively simple to implement and requires no special requirement for sampling time rate. Calculating the parameters also do not require solving any differential equations. Firstly, an input signal as shown below is injected into the system.

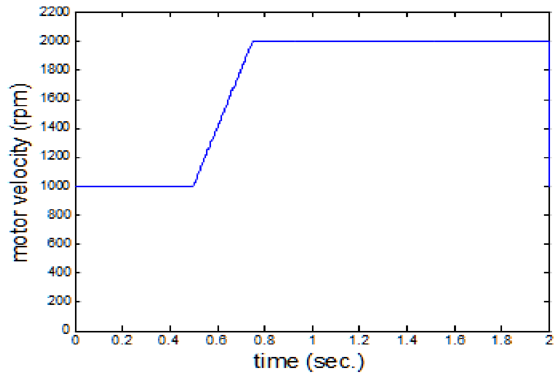

Figure 5: Three-phase Estimation Technique Input

The the output graph of the load torque and viscous damping coefficient is plotted and the parameters are estimated from this graph.

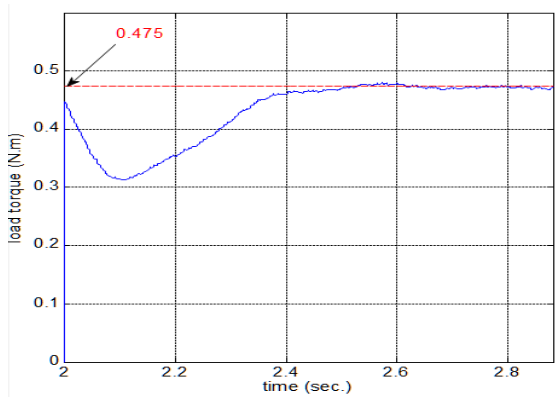

Figure 6: Load Torque Estimation

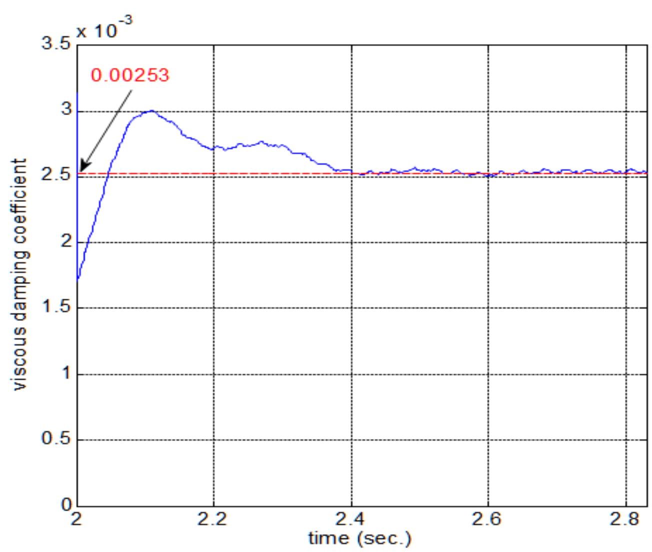

Figure 7: Viscous Damping Estimation

CHAPTER 3
METHODOLOGY AND PROJECT WORK

3.1. FLOW CHART

The methodology section will highlight the process of undertaking this project by using a flow chart and Gantt chart covering the entire 8 months of this project. Also included are descriptions of the hardware used in this project.

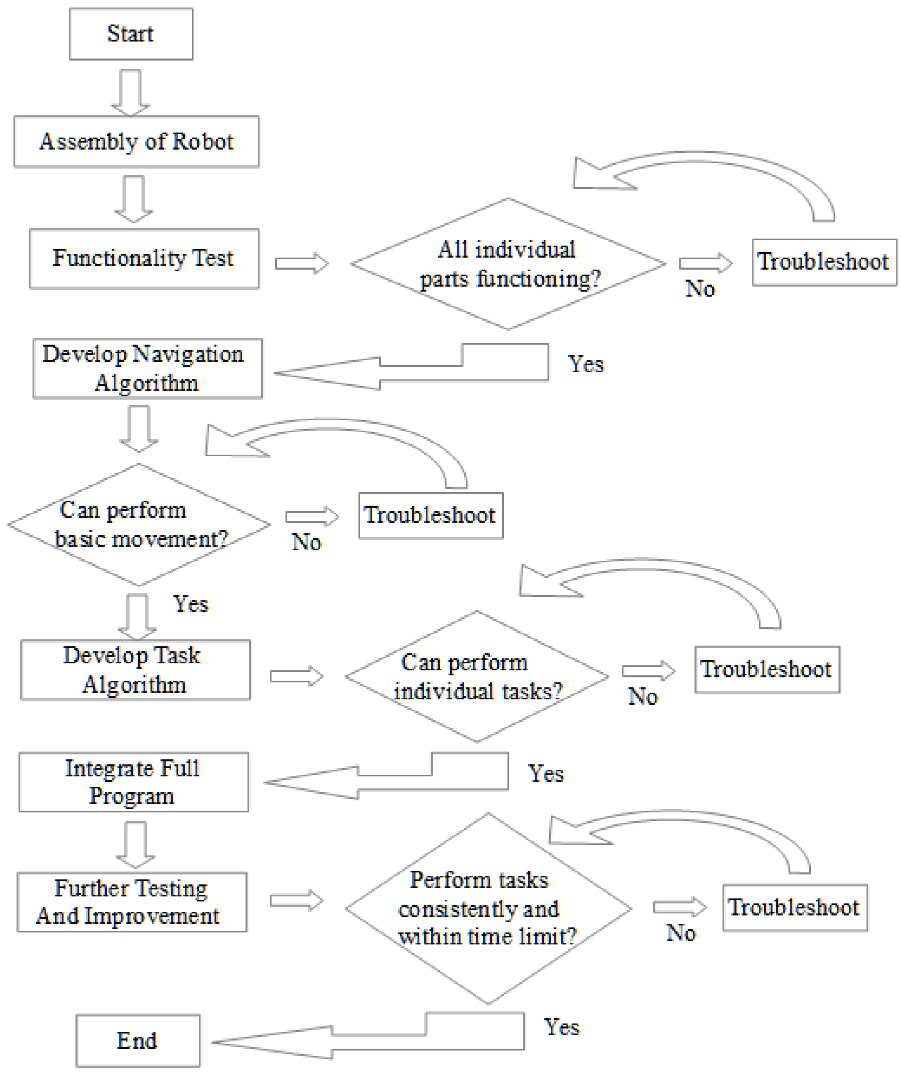

Figure 8: Methodology Flow Chart

GANTT CHART FYP 1

Activity/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FYP Briefing														
Title Selection														
Title Confirmation														
Preliminary Research														
Hardware Procurement														
Initial Experimentation														
Documentation														

Table 1: Gantt Chart FYP 1

GANTT CHART FYP 2

Activity/Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Briefing on FYP 2														
Installation of Actuators and Sensors														
Develop Navigation Program														
Movement Test in Game Field														
Testing of Complete Task and System														
Progress Report Submission														
Pre-Sedex Evaluation														
Project Work Resumes														
Final Report Submission														

Table 2: Gantt Chart FYP 2

3.2. MAIN COMPONENTS

In this sub-section, the main components used in this project are presented. These are components which will determine the success of the project, hence proper justification is given for its selection.

Ultrasonic Ranging Module

Figure 9: Ultrasonic Sensor

This sensor can be used by the robot to detect its precise distance from the walls, thus enabling the robot to center itself in the maze path. It has a very small resolution and a minimum range of 2mm, which makes this sensor perfect for short-range usage in cramped spaces. The important specifications of this sensor are given below.

Sensing Range	: 20-4000mm(adjustable)
Resolution	: 3mm
Dimension	: 15mm x 20mm x 45mm
Operating Voltage	: 5VDC

Drive Motors: Tamiya Plasma Dash

Figure 10: Plasma Dash Motor

This Tamiya Plasma Dash motor is a high-end motor used in the Tamiya line of model racing cars. With a high current and high torque capability, and used with the Tamiya gearbox with variable gear ratios, and appropriately sized wheels, this motor would be enough to drive the robot. The important specifications of this motor are given below.

RPM	: 29000 RPM
Torque	: 20g-cm
Current Consumed	: 4.1A
Operating Voltage	: 3VDC

Suction Motor

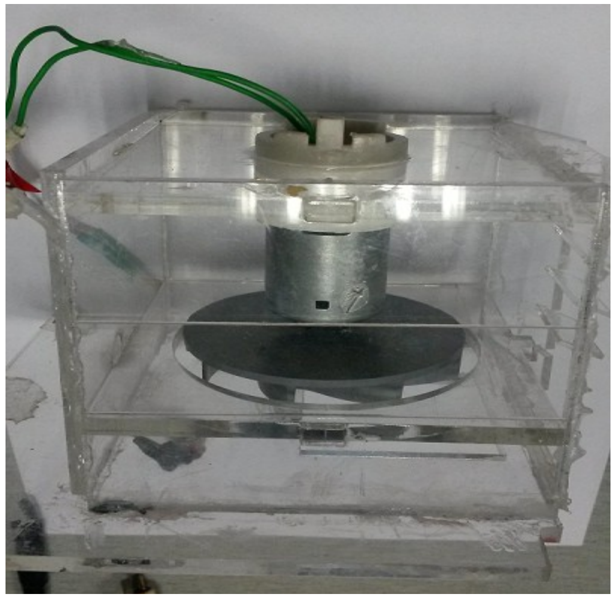

Figure 11: Suction/Blowing Motor

This motor is taken from a hand-held vacuum cleaner, and is the motor responsible for creating the vacuum to collect the ping-pong balls, and also generate the air flow necessary to extinguish the candles. The motor is housed is a custom-made case to protect the rest of the robot and also to direct the outgoing air flow with attached fins. The important specifications of the motor is given below.

Operating Voltage	: 12VDC
Dimensions	: 70mm(length) x 30mm(diameter without propeller)

Arduino Uno Main Board

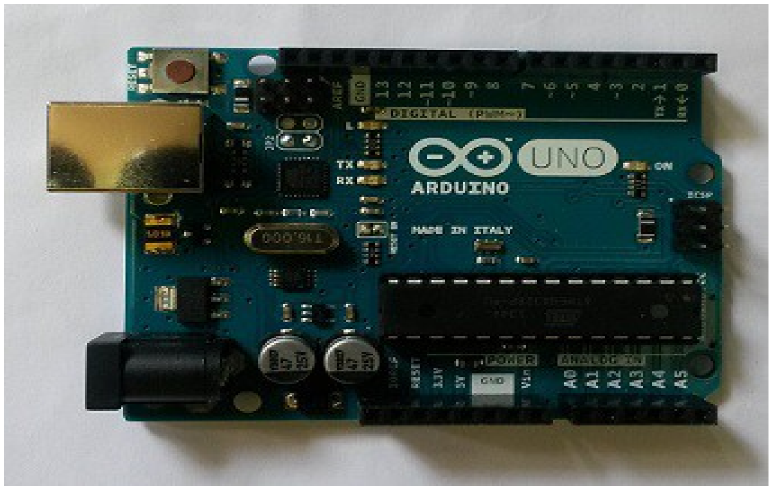

Figure 12: Arduino Uno

The Arduino is the main controller for the robot, and the main navigation algorithm is done within it. This particular model is selected due to ease of usage, a wealth of reference programs, its capability to support the required number of peripherals and its small size. The important features are listed below.

Digital I/O Pins	: 14
PWM Pins	: 6
Analog Input Pins	: 6
Programming Suite	: Arduino IDE
Dimensions	: 25mm x 55mm x 80mm
Operating Voltage	: 5VDC

IRATECH SDDC-110 Servo Drive

Figure 13: IRATECH Servo Drive

This servo drive acts as an interface between the main board and drive motors. Each servo drive can support a maximum of 1 motor. This servo drive can also be connected to a computer via USB, where the user can perform parameter extraction using the supplied software interface. The main characteristics of this board are listed below.

Rated Power	: 400W
Rated Current	: 110A continuous
Dimensions	: 25mm x 75mm x 100mm
Operating Voltage	: 10-50VDC

Lithium-Polymer (Li-Po) Battery

Figure 14: Li-Po Battery

This Li-Po battery is the main power source for the robot. This robot will be powered by 2 batteries, 1 for the circuitry and 1 exclusively for the suction motor. The suction motor consumes so much power that without a separate power source the electronics would be underpowered. The Li-Po type of battery is specifically chosen due to its light weight and small size, although it is more costly than a lead-acid battery with a similar rating. Below are the important characteristics of this battery.

Output Voltage	: 12VDC ± 0.5V
Capacity	: 2000 mAh
No. of cells	: 3
Weight	: 180grams
Dimensions	: 70mm x 35mm x 30mm

DPDT Relay Circuit

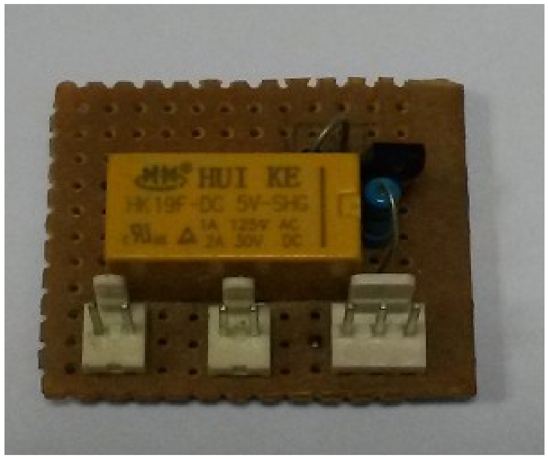

Figure 15: Suction Motor Relay

The main purpose of this relay circuit is to act as the interface between the Arduino control board and the suction motor. This circuit enables control signals from the Arduino to turn the suction motors on/off. A 2N2222 general purpose NPN transistor amplifies the control signal, which is then used to trigger the electromagnetic coil of the relay. A relay with the DPDT (double-pole-double-throw) configuration is used as it is much easier to fit onto a veroboard, though an SPDT (single-pole-double-throw) would work equally well.

Completed Robot Body

Figure 16: Assembled Robot

The above is the image of the completed robot after fabrication. The robot has been given some finishing spray-paint by the fabricators. The following are the mechanical characteristics of the robot.

Dimensions	: 150mm x 150mm x 390mm
Weight	: 2.5 kg
Operating Voltage	: 12VDC
Construction Materials	: Perspex, Aluminium
Wheel Material	: plastic, Rubber
Drive System	: 2 rear wheels, 2 front castors

At this stage the robot will have to undergo further testing to ensure its robustness when operating under normal load conditions, such as the drive motors carrying the robot for a full 3 minutes, and its ability to withstand vibrations from the suction motor.

3.3. SUPPORT TOOLS

Throughout the duration of this project various hardware and software tools have been used to make this project a success. While they do not feature prominently in the final product they are nevertheless an essential element of this project.

No.	Tool	Description
1	Digital Multimeter	Used for troubleshooting and calibrating circuit.
2	Soldering Kit	Used to solder all necessary components.
3	Toolbox (Screwdriver, pliers etc.)	Used to perform small repairs on circuit and robot.

Table 3: Hardware Support Tools

No.	Tool	Description
1	Arduino Integrated Development Environment	Used to write, compile and upload C code used in the Arduino control board.
2	IRATECH DC Tuning Pro	Used to perform motor tuning and parameter extraction by interfacing with IRATECH driver.

Table 4: Software Support Tools

CHAPTER 4
RESULTS AND DISCUSSION

4.1. OVERVIEW

In this sub-section, a comprehensive review of the results obtained from this project is presented. As this project is mainly a robotics project and the main result is the prototype itself, this section will mainly cover the inner workings such as the navigation algorithm and the circuit design.

4.2. CIRCUIT LAYOUT

The circuit can be broadly broken up into 3 separate parts. The first part which is electromechanical, consist of the relay circuit, vacuum motor and DC drive motors. The second part is analog, which is the analog distance sensor. The third part is the digital part, which is the Arduino and IRATECH board. The block diagram of the overall circuit is shown below.

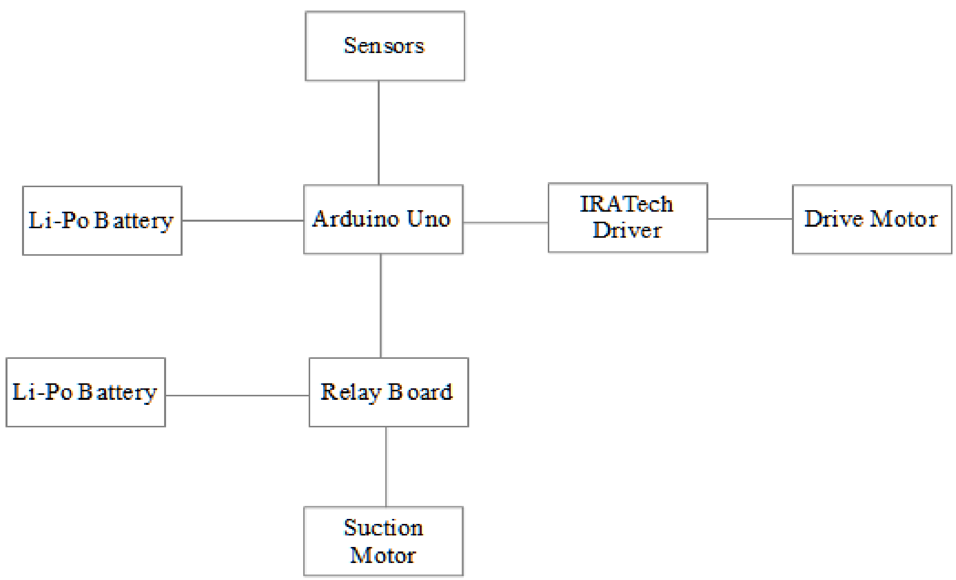

Figure 17: Overall Circuit Layout

The circuit is powered by 2 Li-Po batteries, one exclusively for the suction motors and the other powers the electronics and sensors. This is done because the suction motors consume so much power that without its own dedicated power source the other components would malfunction due to large current drop. The 5V required to operate the circuitry are produced by the IRATECH driver, which has its own in-built 5V voltage regulator.

Generally the circuit operates as follows. The sensors will sense the position of the robot relative to the maze partitions. This information is fed into the Arduino where the algorithm will then calculate the motor speed necessary to maintain its optimum position. This information is then sent to the IRATECH driver which sends the required voltage to the drive motors. The navigation path is already preset in the program, thus no maze-solving algorithm is needed for maneuvering.

The position of the ping-pong balls and candles are known beforehand. Thus, the suction motors are triggered when the robot has reached the target, which is known by information from the rotary encoders. The Arduino then sends the signal to the relay circuit, which acts as a switch for the suction motors.

4.3 NAVIGATION ALGORITHM

The motors are driven mainly by a differential drive algorithm, whereby depending on the relative position of the robot to the maze partition the motor speed will change such that it will reposition itself to the so-called 'neutral' condition. the following is a list of possible configurations that the robot might find itself in, as well as a pseudo-code of the algorithm used to rectify its position.

1. Center (neutral).
2. Swerve left.
3. Swerve right.
4. Turn left 90 degrees.
5. Turn right 90 degrees

1. Center (neutral)

Figure 18: Robot in center position.

In this position the robot is equidistant from the partition walls and consequently the motor speed for both motors are equal.

```
if(distancefromleft == distancefromright)
{
        motorspeedleft==motorspeedright
}
```

2. Swerve left

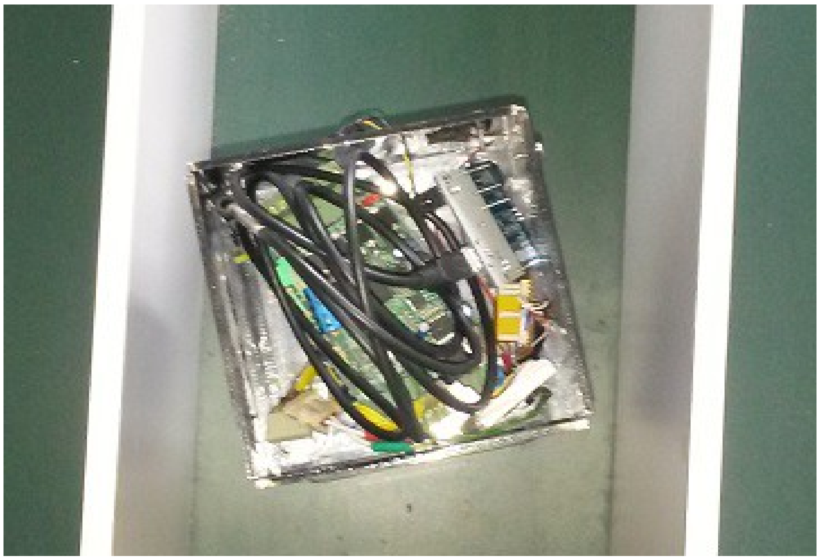

Figure 19: Robot swerving left.

In this position the robot is approaching the left wall, and thus corrective action must be taken to steer it to the right.

```
if(distancefromleft < distancefromright)
{
        motorspeedleft>motorspeedright
}
```

3. Swerve right

Figure 20: Robot swerving right.

This position is the inverse of the one above, so action to be taken is corrective action to the left.

```
if(distancefromleft > distancefromright)
{
        motorspeedleft<motorspeedright
}
```

4. Turn left 90 degrees

Figure 21: Robot turning left.

In this position the robot needs to turn left by 90 degrees. The degree of turn is specified by the preset encoder values, which are determined by trial and error. The right motor turns for a set encoder value while the left motor stops. When the value is reached both motor stops.

```
while(encodervalueright < set_value)
{
        motorspeedright
        stopleftmotor
}
stop
```

5. Turn right 90 degrees

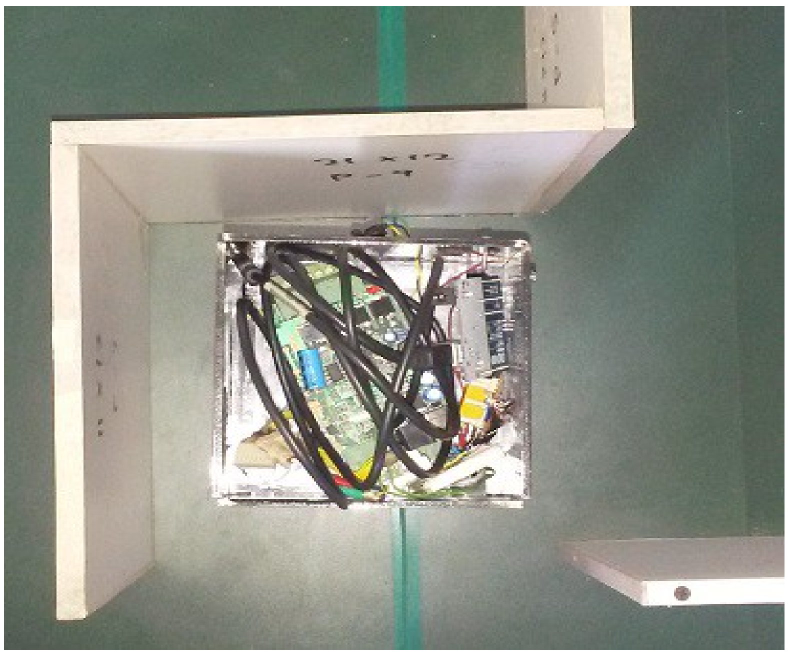

Figure 22: Robot turning right.

This position is the inverse of the above condition, and so the only change is that left motor moves and right motor stops, with the left encoder as feedback.

```
while(encodervalueleft < set_value)
{
        motorspeedleft
        stoprightmotor
}
stop
```

4.4 DISCUSSIONS

From the testing of the robot in the gamefield, consistency of the robot movement is still an issue. This could be due to an issue with the analog sensors getting interfered with each other due to the cramped space. This can also be attributed to irregularities in the gamefield, in which case the issue will have to be dealt with mechanically, such as using better wheels or chassis. A short-term fix would be to improve the programming and algorithm to account for all these unforeseen circumstances and mitigate against them.

The robot still takes between an estimated 2 mins. 45 sec. to over 3 mins. to finish the task by extrapolating from test conditions. This can be further improved by refining the movement algrithm, especially the turns. Overall the robot is able to accomplish the task of picking up ping-pong ball and extinguishing candle with a satisfactory rate of success.

Occasionally when picking up the ping-pong ball, the robot is not able to suck it into the holding chamber, but merely drags it along the floor. While these incidents are rare, it is still worrying as it might disrupt the flow of the program and forcing a restart. This problem can be resolved mechanically by modifying the intake chute. Corollary to this problem are incidents where the candles are not extinguished properly. Again while these incidents are rare they are worrying. This problem can be overcome by moving the robot closer to the flame or blow for a longer period of time.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this project has achieved its objective of implementing parameter extraction and state-feedback control to give the programmer more control and stability over the drive motors. As a result, more accurate stops can be performed with no sudden movements, and the robot's movements are also more stable. Analog distance sensors have also been integrated into the system to give the robot a spatial awareness to ease the development of the navigation algorithm. This eliminates the need for contact with the maze partition, thus further increasing accuracy and reducing the probability of errors and wear and tear.

Several recommendations can be made for this project, most significantly the optimization of the navigation algorithm. The optimizations can be made to reduce the overall time to execute the overall task, as well as to improve the stability and consistency of the robot's movement, which currently remains its biggest problem. More sensitive rotary encoders and distance sensors can also be employed to increase accuracy in movement, however this may limited by the cost and other limitations that are imposed by this project.

This project can be modified and enhanced in order to give it added-value for industrial applications. The IRATECH driver, with its in-built parameter extraction and control algorithm can be implemented on any small-sized industrial actuators. The concept of a maze-solving robot can also be enhanced as an obstacle-avoiding autonomous robot for rescue or exploration operations.

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APPENDICES

APPENDIX A : IRATECH SDDC-110 DATASHEET

APPENDIX B : ULTRASONIC RANGING MODULE DATASHEET

APPENDIX A

iratech
Technology Advance

IRT SDDC-110

High Performance DC Motor Servo Drive

- Auto-tuned servo controller for DC motor (DC input ranged 10-50V) with rated load upto 400W (continuous current rated at 110A at 25 degrees Celcius, 80 A at 100 degrees Celcius).
- Current feedback, overcurrent and overheat protection.
- High frequency 32 bit counter for encoder feedback: 1x, 2x, 4x
- Position and Velocity control with interpolation rwt velocity and acceleration.
- Compatible with LabVIEW, Matlab and Simulink, Visual Studio .NET
- .COM API Library
- USB, I2C, RS485 Connectivities

Overview

The IRATECH SDDC-110 provides configurable servo controller for various motion control application, i.e. DC motor servo control, CNC machine, Multi-DOF Robot manipulator control, etc. It is equiped with various control algorithm with configurable software, especially auto-tuning software which enables the controllers' gains to be tuned automatically during motor's start-up phase. This module can be programmed to be a single motor controller or to be used as a distributed controllers via RS485 to deliver multi-axis, multi-motor control. In a bundle, it is provided with easy-to-use and fully customizable GUI, .COM API and fully compatible with Labview, Matlab and Simulink as well as Visual Studio.NET Application Development.

Specifications

General	
Product Name	IRA SDDC-100
Product Family	Hight Performance DC Motor Servo Drive
Form Factor	USB
Operating System/Target	Windows
Measurement Type	Voltage
RoHS Compliant	Yes
Servo Controller Architecture	
PI Velocity controller	Yes
P-PI Position controller	Yes
State Feedback Controller	Yes
Interpolation wrt velocity and acceleration	Yes
PC connection	USB

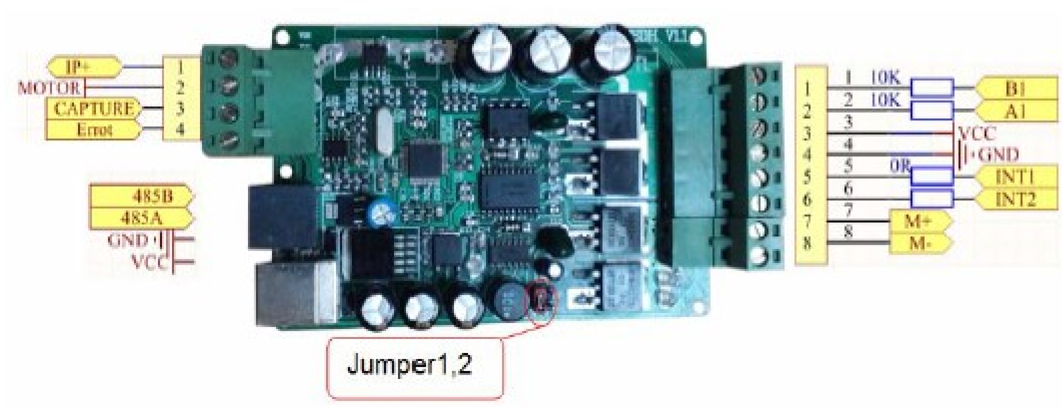
Input command	USB, RS485
Encoder	1x, 2x, 4x with 32 bit high frequency counter
Velocity filter	Yes (Moving average, low pass + acceleration filter)
Operation Specification	
Board Voltage	-0.3-35 V
Operating Voltage	10-50V
Max. Continuous load current at 25 degrees Celcius	110A
Max. Continuous load current at 100 degrees Celcius	80A
Max. Load Power	400W
Logic Levels	TTL
Over-current Protection	Yes
Switching Frequency	48KHz
Peripherial Connectivity	RS485, I2C
Counter/Timers	
Counters	1
Buffered Operations	No
Debouncing/Glitch Removal	No
GPS Synchronization	No
Maximum Range	0 V , 5 V
Max Source Frequency	5 MHz
Pulse Generation	No
Resolution	16 bits
Logic Levels	TTL
Physical Specifications	
Length	100 mm
Width	75 mm
Height	25 mm
I/O Connector	Screw terminals
Timing/Triggering/Synchronization	

Triggering	Digital
Synchronization Bus (RTSI)	No

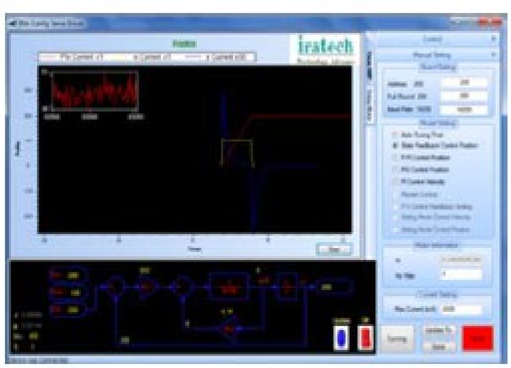
Working environment:

- No dust, no oil mist and no corrosive air.
- Working temperature: 0-50°C;
- Storage temperature: -20 - +80 °C.
- Humidity:40-90RH.
- Cooling method: natural air cooling and forced air cooling.

Connection Layout

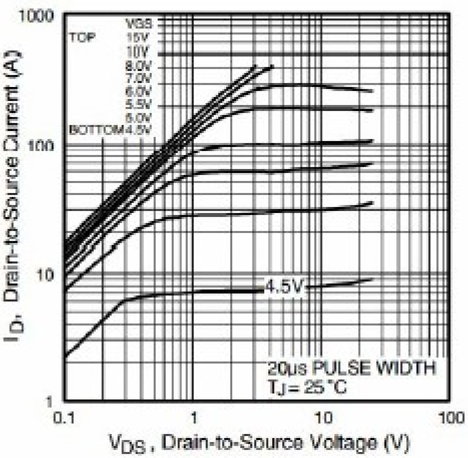


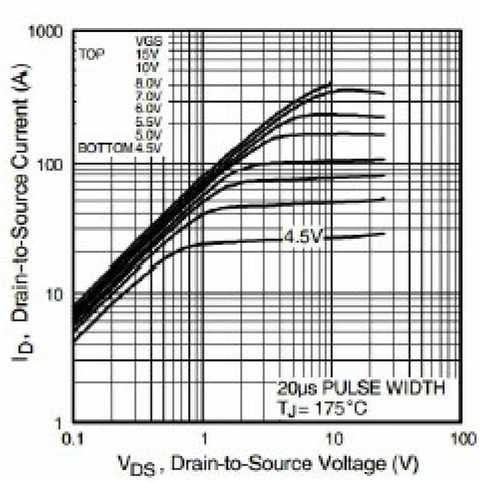
Software Interface

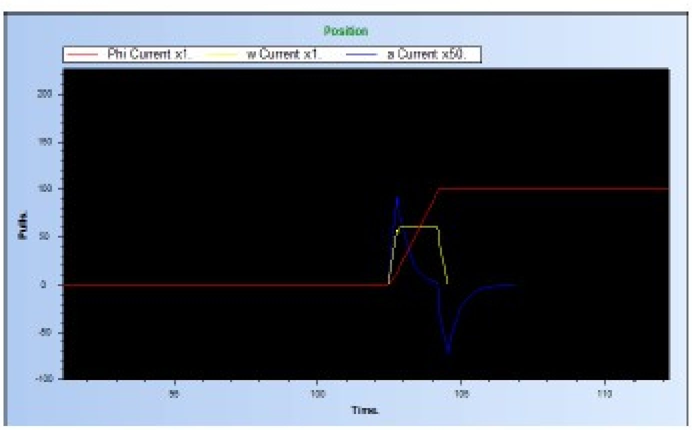


iratech
Technology Advance

MOSFET output & Control response characteristics







APPENDIX B

1.0 INTRODUCTION

The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object like bats or dolphins do. It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use package. From 2cm to 400 cm or 1" to 13 feet. It operation is not affected by sunlight or black material like Sharp rangefinders are (although acoustically soft materials like cloth can be difficult to detect). It comes complete with ultrasonic transmitter and receiver module.

Features:

- Power Supply :+5V DC
- Quiescent Current : <2mA
- Working Currnt: 15mA
- Effectual Angle: <15°
- Ranging Distance : 2cm – 400 cm/1" - 13ft
- Resolution : 0.3 cm
- Measuring Angle: 30 degree
- Trigger Input Pulse width: 10uS
- Dimension: 45mm x 20mm x 15mm

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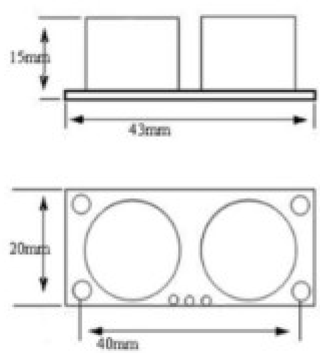
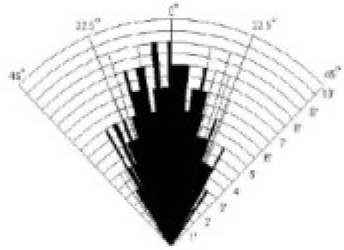
3.0 PRODUCT LAYOUT

VCC = +5VDC
Trig = Trigger input of Sensor
Echo = Echo output of Sensor
GND = GND





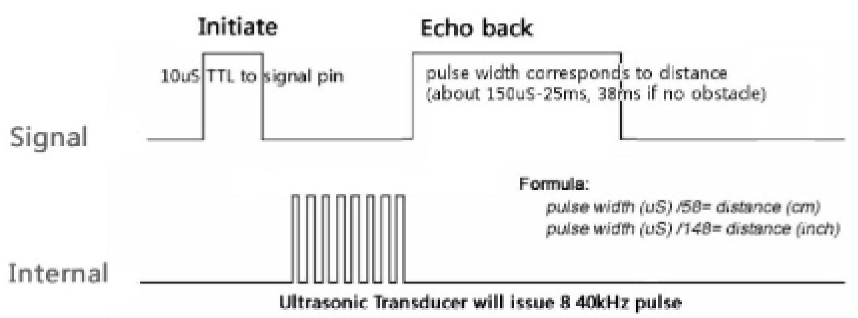
Practical test of performance,
Best in 30 degree angle

5.0 OPERATION

The timing diagram of HC-SR04 is shown. To start measurement, Trig of SR04 must receive a pulse of high (5V) for at least 10us, this will initiate the sensor will transmit out 8 cycle of ultrasonic burst at 40kHz and wait for the reflected ultrasonic burst. When the sensor detected ultrasonic from receiver, it will set the Echo pin to high (5V) and delay for a period (width) which proportion to distance. To obtain the distance, measure the width (Ton) of Echo pin.

Time = Width of Echo pulse, in uS (micro second)

- Distance in centimeters = Time / 58
- Distance in inches = Time / 148
- Or you can utilize the speed of sound, which is 340m/s



Note:
- Please connect the GND pin first before supplying power to VCC.
- Please make sure the surface of object to be detect should have at least 0.5 meter^2 for better performance.

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