**UNIVERSITI MALAYSIA PAHANG**

# BORANG PENGESAHAN STATUS TESIS♦

**JUDUL:** **MOBILE ROBOT – TRANSMITTER MODULE**

**SESI PENGAJIAN: 2007/2008**

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# MOBILE ROBOT – TRANSMITTER MODULE

**NG KOK MING**

**A thesis submitted in partial fulfillment of the requirement for the degree of bachelor of electrical engineering (Electronics)**

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**NOVEMBER 2007**

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

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## DEDICATION

***Specially dedicated to***

***My beloved parents, brothers, sisters***

***and all of my best friends.***

## ACKNOWLEDGEMENT

First of all, I would like to thank my project supervisor Mr. Nik Mohd. Kamil Bin Nik Yusoff, who has given me much strong logistic support while implementing the project given. He has always assisted me when I handling my project. Besides, I would like to express my sincere appreciation for his valuable advises, guidance and encouragement. This has aspired me more confident in trying new things.

Secondly, I would like to thank my family members for giving me their loves and supports throughout my four years of studies in UMP Gambang, Pahang.

Special thanks to staff FKEE, who have given me a great help in accomplishing this project.

At last but not least, I would like to say millions of thanks to all my course mates and those who has lending me their helping hand.

Thank you.

# ABSTRACT

In this technology era, robots have become a common device to help human to do several of work especially those dangerous or heavy work that not easily done by human kind. Thus, there must be a communication between the robots and the human. The robots would be able to communicate with the operator through computer. This project is concern on the FM wireless communication between the computers with the robot. It requires to construct a mobile robot from scratch and a parallel port interface board enabling computer communication via the parallel port. The robot can measure the light density and the temperature within it and it also can perform obstacle detection and avoidance. Half-duplex communication is performed to suit the transmitter and receiver modules of the same carrier frequency. Acknowledged and unacknowledged protocol communication is implementtted to demonstrate the efficiency in bi-directional PC-Robot communication. As a result, this robot can be implemented as the device to scout the parameter of a hazard area.

## ABSTRAK

Pada zaman berteknologi ini, robot merupakan satu peralatan umum yang membantu manusia untuk melaksanakan pelbagai kerja terutamanya kerja-kerja yang merbahaya dan berat di mana kerja-kerja tersebut tidak mudah dilakukan oleh manusia. Oleh itu, komunikasi antara robot dan manusia mesti diwujudkan. Robot-robot ini berupaya berkomunikasi dengan operator melalui komputer. Projek ini, menitikberatkan pembangunan system komunikasi FM tanpa wayar antara komputer peribadi dan robot. Projek ini melibatkan pembinaan robot dan litar antaramuka liang selari komputer peribadi yang menjadi saluran asas komunikasi. Robot ini berupaya untuk memantau keamatan cahaya dan suhu di sekitarnya dan pengesanan dan mengelak objek juga merupakan sebahagian daripada fungsi robot. Komunikasi *half-duplex* dilaksanakan bagi memenuhi penggunaan modul-modul penghantar dan penerima sedia ada, yang mempunyai frekuensi pembawa yang sama. Protokol *acknowledged* dan *unacknowledged* diaplikasikan bagi menunjukkan kecekapan komunikasi dua hala komputer dan robot. Kesimpulannya, robot ini boleh digunakan untuk memantau parameter di kawasan yang merbahaya.

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| | | |
|---|---|---|
| IR | - | Infra Red |
| IRPD | - | Infra Red Proximity Detector |
| KHz | - | kilo Hertz |
| MHz | - | Mega Hertz |
| $^{0}$ | - | Degrees |
| Ω | - | Ohm |
| λ | - | Wavelength |
| m | - | meter |
| cm | - | centimeter |
| nm | - | nanometer |
| f | - | Frequency |
| c | - | Light velocity in free space |
| A | - | Ampere |
| mA | - | miliampere |
| V | - | Volts |
| DC | - | Direct Current |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

In the recent years, microcontrollers have taken the place of microprocessors in many electronic control devices. Such big changes are due to the more demanding features of microcontrollers. Before microcontroller exists in the market, boards of microprocessors circuit were the heart of many electronic control devices. However, because the microprocessors circuit required external Read Only Memory (ROM), Electrical Erasable Programmable Read Only Memory (EEPROM), Random Access Memory (RAM), input and output ports, thus the circuit board will be larger. As compare to the microcontroller, the Integrated Circuit (IC) itself has the ability of the whole circuit board of the microprocessor unit. Not only does it has built-in ROM, EEPROM, RAM and input and output ports, there are also other useful features built internally such as timers, analogue to digital converter (ADC), pulse width modulation (PWM), serial port interface, synchronous and asynchronous. All these depend on the version of such microcontroller.

There are various types of microcontroller available nowadays, from various manufacturers, with different functionalities. MC68HC11 from Motorola, PIC, and Basic Stamp are among of the commonly used microcontroller in electronic control devices today. Some applications of microcontroller are controlling the movement of the lift, reading and measuring engine parameters, controlling the stability of vehicle. Even in the robotic field, microcontroller plays a major role as the brain of the robots. The type of microcontroller used depends on the applications, functionalities and parameters to be controlled. For example, to control a lift, PIC (Peripheral Interface Controller) would be adequate. Similarly, a Basic Stamp would be sufficient to build an obstacle-avoiding robot. On the other hand, a multi-task robot would require a multi-featured MC68HC11.

Robots are commonly utilized in this century for numerous applications in industries, building securities, house monitoring and moon exploration. Such implementation has facilitate the man-kind by reducing risk of life in performing dangerous task such as handling harmful chemicals and attending hazardous process.

Communication is a very important aspect in our life. Present technologies have made it possible to communicate to each other everywhere by means of wired or wireless system. With wireless communication is being widely developed, modern telecommunications are striving towards wireless system. Such application adapting wireless communication includes remote switching, remote data communication such as in wireless Local Area Network (LAN), and telemetry systems and robots communication.

This project aims to implement PC-Robot communication via a wireless link. Autonomous movement of the robot and data telemetry demands it to be monitored by human operator in order to ensure a directed movement of the robot so as to avoid a situation where the robot wanders around and contributes to a waste of time. This project requires knowledge of robotic, wireless and data communication.

## 1.1 Design Objectives

The objective of this project is to develop an autonomous mobile robot with built-in telemetry systems.

The aim of the autonomous telemetry mobile robot is to scout certain parameter in an unknown environment, to convert readings into digital form and to send the data along with its current location to the PC. At the same time, it detects obstacle and sends this information to the PC for mapping purposes.

In addition to the mapping of robot location, the robot informs the PC the intensity of light and temperature at various areas in the environment.

In order for the robot to scout every inch of the environment, an autonomous navigation scheme or algorithm will be implemented. Wheel encoders are attached to the robot to record its movement. Its location and previous pathway taken are plotted in term of X-axis and Y-axis.

## 1.2 Thesis Overview

The remaining chapters of this thesis are outlined as follows.

Chapter 2 outlines the architecture used to implement the system. This includes robot autonomous movement algorithm and the communication protocol.

This is important because it provides the basis for the implementation of the project. The architecture of each subcomponent in the system is described as it is implemented in the system.

Chapter 3 provides a description of the robot hardware for this project. It briefly describes the physical structure of the robot.

Chapter 4 describes the software that is the MC68HC11 programming language used to programming the robot. It briefly describes the flow of the software.

Chapter 5 covers various testing of each module used and also the integration of the whole system. This is important to demonstrate modular development of a complex system.

Chapter 6 summarizes the overall project design and its future development.

# CHAPTER 2

# SYSTEM ARCHITECTURE AND OPERATION

Design and building an autonomous mobile robot requires knowledge of robot mobility taking into account the manoeuvre of the robot, sensing features, obstacle avoiding capabilities, communication protocol and others. This chapter discusses elaborately the system designs that have been implemented in the final system.

## 2.1 System Block Diagram

Figure 2.1 is a simple block diagram of the system. Basically, there are two parts that need to be designed, the PC as the receiver module and the robot as the transmitter module.

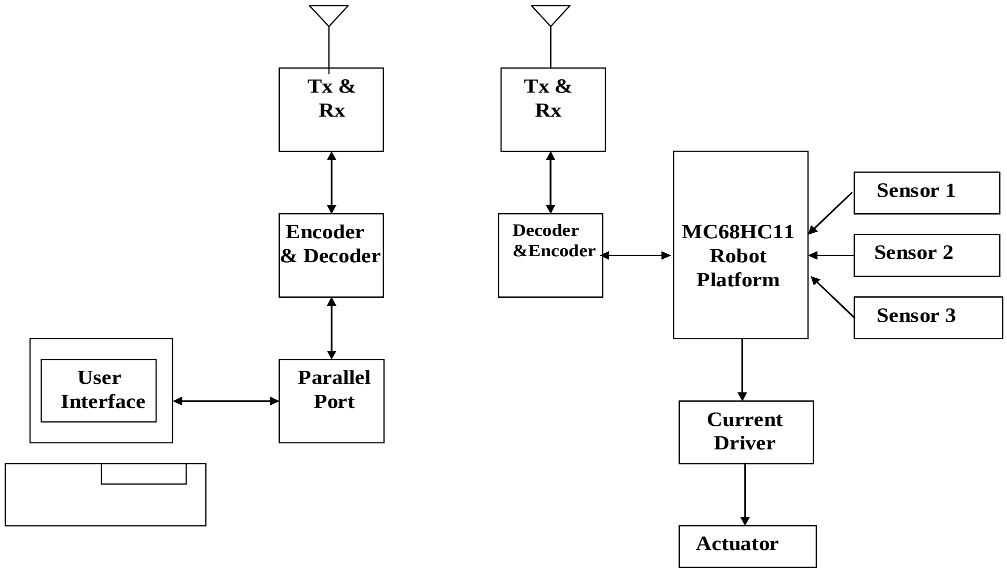


Figure 2.1: Block Diagram for Wireless Communication on MC68HC11-Base Robot

The robot, which is the transmitter module of the whole system, is the module that will be designed in this project. Basically, from the block diagram, this module can be divided into 4 parts, they are FM wireless communication, microcontroller main circuit, sensor system and the actuator.

For the FM wireless communication, the transmitter (Tx), receiver (Rx), encoder and decoder will make up the module. This module will be used to perform the operation of data transmission where the process of transmission will be handled by the transmitter and encoder while the process of reception will be handled by the receiver and decoder.

For the microcontroller main circuit, microchip MC68HC11E1 from Motorola is being used. External circuit for clock, reset, power supply and serial communication is being constructed together with the MC68HC11E1 to be a complete microcontroller main circuit.

The sensors module consists of four types of different sensors that are light sensors, temperature sensor, bumper switches and Infra Red Proximity Detector (IRPD). The light sensors and temperature sensor are used to scout the light and heat intensity respectively while the bumper switches and IRPD are used to detect the obstacle.

The L293D motor driver, TAMIYA gear box, and two DC motors will make up the actuator part. This part is important for the motion of the robot.

## 2.2 Controlling the Robot Motion

Two bi-directional DC motors are utilized to drive the mobile robot in this project. These motors are configured in such a way that the robot will be able to move forward, reverse and spins right or left on its axis. Controlling DC motors is tricky. If continuous high logic is provided to DC motor, it will drive at maximum speed. This situation is not suitable for the robot as it needs to monitor its surroundings.

To overcome this problem, a constant stream of pulses is generated at a duty cycle of 50% to drive the DC motors. This would allow the motors to move at desired speed. The duty cycle supplies high and low logic alternately at the same interval as shown in figure 2.2.

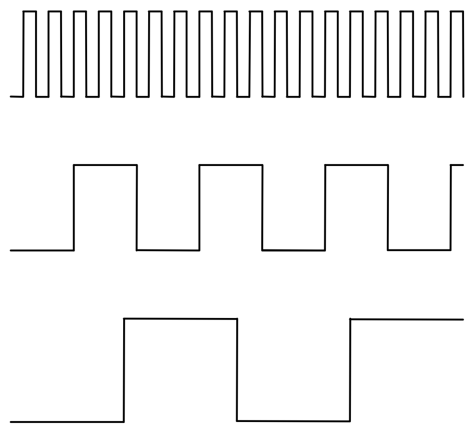

Figure 2.2: Pulses with different period

The period of the pulse is calculated to ensure that each pulse provides torque to move the motors. If the period is small, it would not drive the motor. Similarly, if the period is too long, it would effect in jinking.

Four configurations of motor rotations are defined to move the robot forward, reverse and spin right or left. Table 2.1 shows the configurations to move the robot in four different directions. Figure 2.3 illustrates the four combinations of the rotation of both the DC motors.

Table 2.1: Combinations of Rotation of Right & Left DC Motors

| **Movement** | **Left Motor** | **Right Motor** |
|---|---|---|
| Forward | CCW | CW |
| Reverse | CW | CCW |
| Right | CCW | CCW |
| Left | CW | CW |

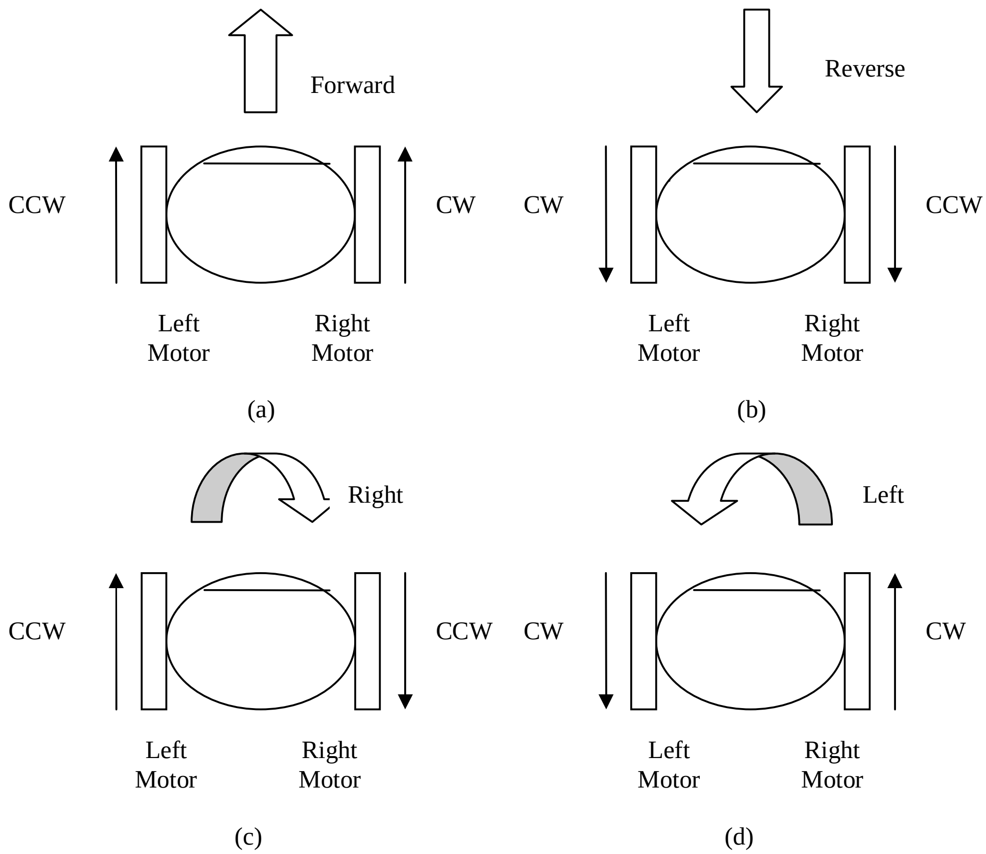


Figure 2.3: Rotation of the Right and Left DC Motors

## 2.3 ODOMETRY

A common technique used to implement odometry in robot is by using the wheel encoder. There are various kinds of wheel encoders that can be built. However, two popular methods are reading infrared light reflection from a black and white disk and counting light beam cut by a slotted disk [4]. Figure 2.4 shows the operation of the black and white disk.

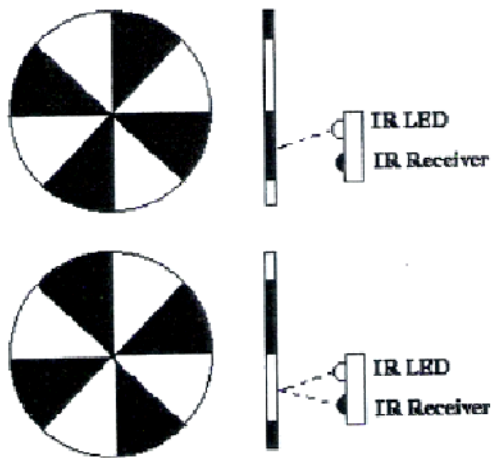


Figure 2.4: Reflection of IR Beam On Black & White Surfaces

An infrared light beam is flashed to the disk. White surface reflects all colors and black absorbs them. When the wheel shaft rotates along with the disk, pulses yielding from the reflection are generated. The microcontroller then reads the logic either high or low, positive or negative edge trigger that take place during the wheel revolution and counts them [4].

Another better method is slotted disk. It makes better then previous wheel encoder in view of the fact that other sources of infrared light might interface the main source. This might effect in false trigger of the wheel encoder. Sunlight, consisting of various frequencies of light, is among the interference. Slotted disk consists of tiny several equivalent distanced thin slots allowing a phototransistor to pick up light beam from the source when a slot exposes the source [4]. Figure 2.5 illustrated the operation of the slotted disk.

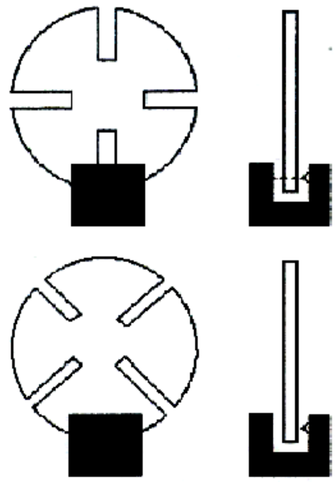

Figure 2.5: Position of Slots during and Effects on the Optical Encoder

Counting wheel revolution does not imply 360 degrees angle rotation as one rotation. One wheel revolution may consist of several rotations at certain degrees dependent on the number of black and white stripes or slots. Figure 2.6 shows the schematic of the optical encoder interface.

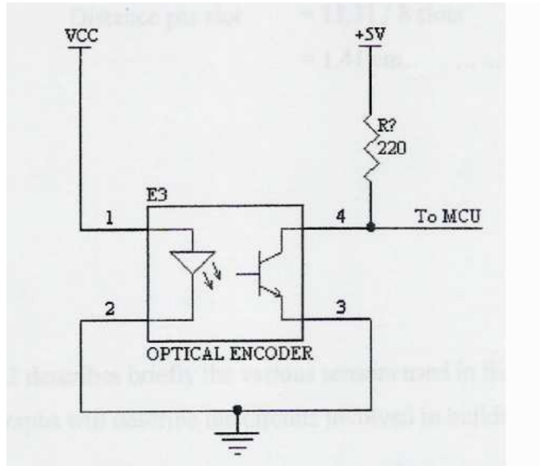


Figure 2.6: Optical Encoder Pin Connections

The optical encoder works together with the slotted disk to count the wheel rotation. Note that from the figure 2.6, the supply for the light emitter and the receiver comes from different source. This is to avoid the emitter from draining the current of the receiver so that the possibility of wheel encoder to malfunction can be avoided.

**2.4 Obstacle Sensing**

In order to build a robot, one has to mimic the behavior of living things such as the ants. Therefore the most criteria is to control the motion of the robot, that is to sense its surroundings in order to decide on its consequent pathway.

A range of sensors can be applied to recognize one or many object of interest. Such sensors are camera where it can do image recognition. However, pattern recognition is not the main focus in this project, but it can be implemented when improvising the robot at a higher level. Sensors are frequently applied in robot to avoid obstacles. At a higher level mapping obstacles could also be informative as implemented in this project. Other sensors include radar, sonar, and bumper switches and infrared obstacle detection, which will be discussed elaborately.

### 2.4.1 Bumper Whiskers

Bumpers are the most simple obstacle sensor that can be built only with a few lengths of thin wire and micro switches. The wire is assembled to the micro switches and bent in such a way that it extends a few inches out of the robot platform. This is to prevent the robot bumping into objects before realizing that the micro switch has been pushed. Since the purpose of the bumper switches is to inform the robot the proper movement for the next wheel revolution, it is important that there are at least two of them in front of the robot. Each sensor is attached on the left and right side of the robot to detect the presence of object on the perspective side.

When object is detected on left, that is when the left micro switch is pushed, the robot will spin to the right. Similarly, if an object is detected by the robot on the right side, the microcontroller sends signals to turn the robot to the left. Thus a simple obstacle-avoiding algorithm is implemented.

### 2.4.2 Infra Red Proximity Detector (IRPD)

Infra red proximity detector (IRPD) is another detector that can be used to operate as robot sensor. Unlike the previous detector, IRPD is based on light reflection. Since the Infra red light is not within the visible light spectrum, it does not obey all the same properties as visible light [5]. Infrared can pass through certain types of plastics, colors and some other materials. It reflects off most objects. Even variables such as texture and reflectivity affect its reliability. There are 2 types of infra red, that is near infra red, that operates at 800 to 1000nm, and the far infra red light that is normally used in security systems or night vision goggles and operates from 2000 to 10000nm.

This type of sensor is called a proximity detector, because it can only detect an obstacle which is within range of distance. An IRPD works by illuminating in front of the robot with infra red light. When the light is reflected by an obstacle in front of the robot, the infra red detector will register that light as an obstacle.

Since there are other sources of infra red light, the frequency of infra red light used is generated between 35 kHz to 40 kHz. This is because there are very few sources of infra red lights at these frequencies resulting in less possibilities of interference. The infra red light modulated at certain frequencies normally work in pair with a detector equipped with a band pass filter with the same centre frequency.

The advantage of using IRPD is that it makes possible for the robot to detect an object without bumping into it. However, the IRPD may not be able to detect object with black surfaces.

In designing the IRPD, one might place two pairs of infrared LED and infrared detectors, which is each pair on each side of the robot for monitoring purposes. Normally in this arrangement, both the left and right infrared LED always activated. Infra red light spreads out of the LED in many directions flooding the front of the robot. In this situation, both the detector receives infrared light. To overcome this problem, instead of always turning on both infrared LED, either one is turned on when checking the corresponding side of the robot for objects. This will also help to saving the power supply and possible to detect both infrared LED's reflection signal by using only one infrared detector. In other words, not only that the microcontroller had to assign one input pins for the infrared detectors, the microcontroller must also spare two output pins to control both the infrared LED.

### 2.5 Communication Protocol

In general, the lower nibble is transmitted and it is followed by the higher nibble. Nevertheless, there should be a mechanism to distinguish between both nibbles in order to retrieve a byte as it is transmitted.

For this project, the robot and PC communicate bi-directionally as both are able to send and receive data. Due to cost and time limitation, two pairs of transmitter and receiver module are applied in order to provide a half duplex communication. Since both transmitter modules are operating at the same frequency carrier, it allows only one transmitter to transmit at one time. If both of them are transmitting simultaneously, data will be corrupted due to data collision.

In order to overcome the collision problem and identify nibbles, a simple non-standardized communication protocol is implemented. Header or trailer is used to distinguish the higher nibble from the lower nibble.

Figure 2.7 shows how a header or trailer can be appended to a byte before transmitting. The size of the header or trailer is 4 bits length. If header is implemented, receiver will scan for the header before reading the low nibble followed by the higher nibble. If received nibble matches a specified header, the following nibbles are saved as a byte in a variable. Otherwise, the nibble will be discarded and the following nibble repeats the same process. Figure 2.8 illustrates this process.

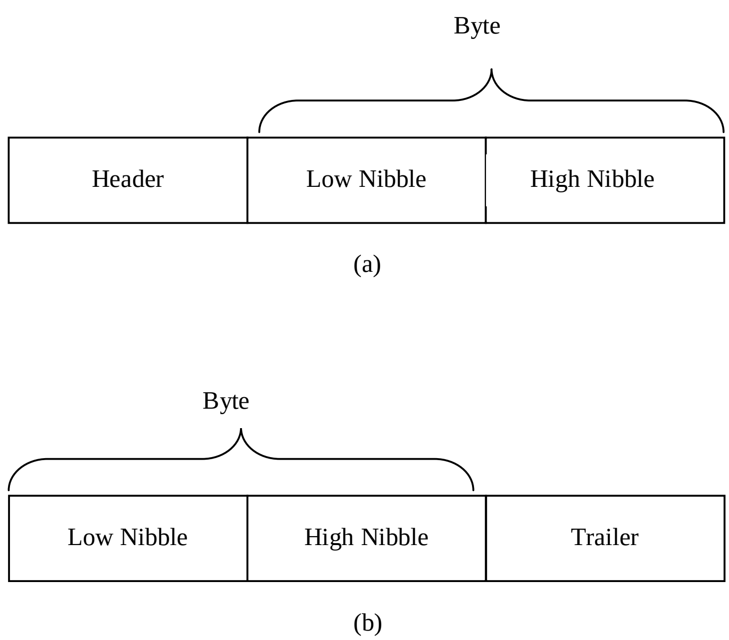


Figure 2.7: Appending Header & Trailer to a Byte

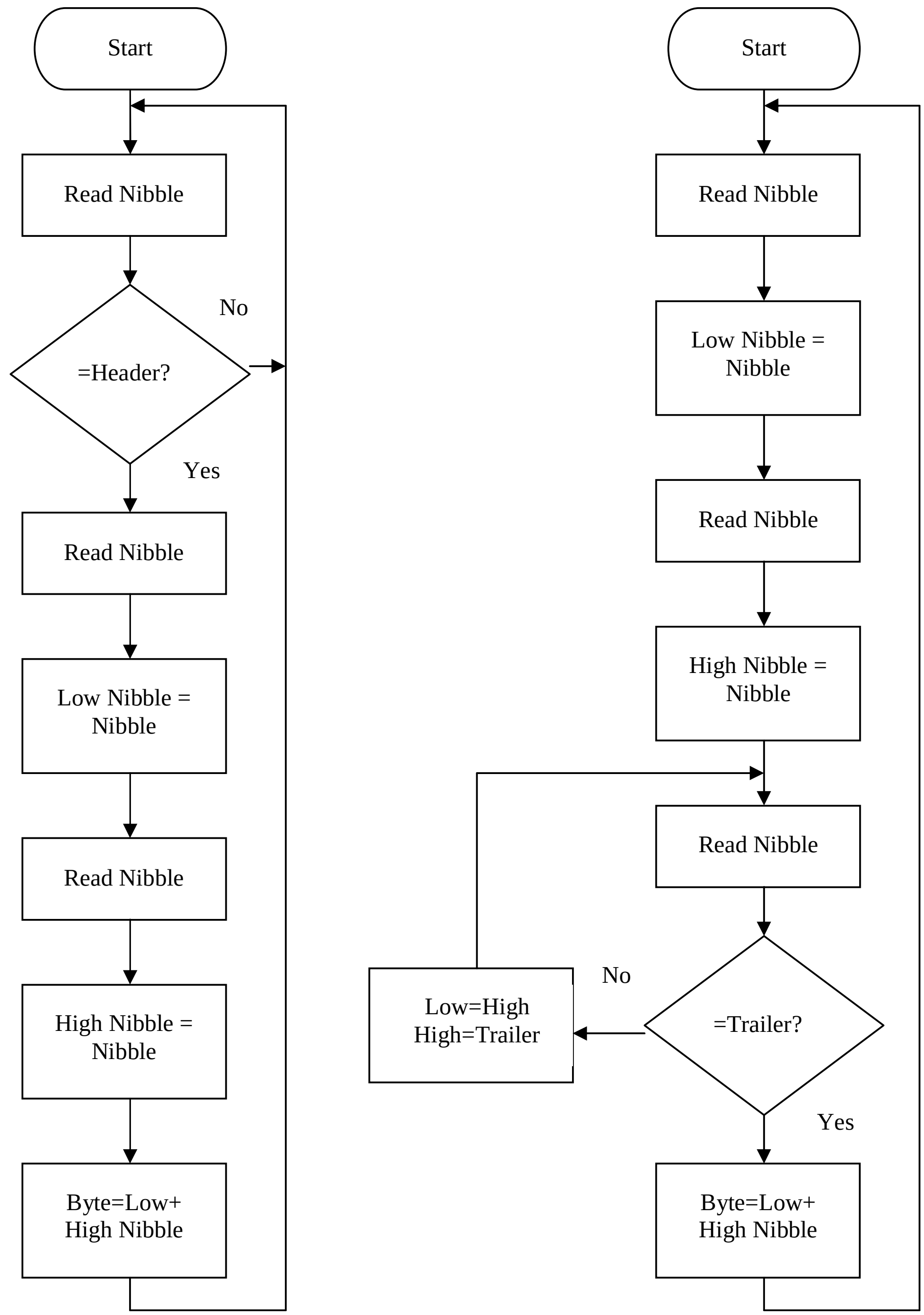


Figure 2.8: Checking Header & Trailer

On the contrary, if the trailer technique is implemented, the first nibble received is saved as the low nibble, and the second is considered as the higher nibble. The third nibble will be compared to the trailer. If they match, the high and low nibble will be combined to form a byte. Otherwise, the previous low nibble will be saved as the low nibble, and the third nibble received is saved as the high nibble. The consequent nibble accepted will be compared to the trailer again and this procedure is repeated until the trailer matches a specified figure.

Establishing a half-duplex communication is a more complex task than implementing a full-duplex. Either side of the system must be assigned as master or slave. Normally, the master device initiates the transmission by sending data. The slave waits until the master terminates transmission before it can respond to the master device. Generally the master device gives command or request for data. A valid transmission mechanism is implemented to recognize the terminating transmission of the master device.

Delay between each transfer of the data of the master device is important to ensure correct data is received. This is to prevent both master and slave device transmits at the same instance. The amount of delay applied is determined by several tests carried out.

There are two type of protocol communication that is unacknowledged and acknowledged. Each one has its own advantages and drawbacks. Normally, for short blocks of data, the unacknowledged protocol is preferred. It is fast thus the real-time data are updated at its best performance. However the protocols are unable to recover lost data. Also it only works best if the data transferred is a single real-time data. In this protocol, the master device only receives data that are transmitted continuously by the slave device. This can be drawn from the previous Figure 2.8.

For transferring several data in blocks, it is most appropriate if the receiver could recognize which data belongs to which variable. To apply this, the acknowledged protocol is used. For example if the master device sends request data number 2, then the slave will reply data 2 along with a header or trailer number 2. This way, the master device would be able to ensure that the data it receives is the data it requests. In this mode, the master device would also be able to detect data lost or damaged and retrieve it again. Figure 2.9 demonstrates the flow of the acknowledged communication protocol for the slave device.

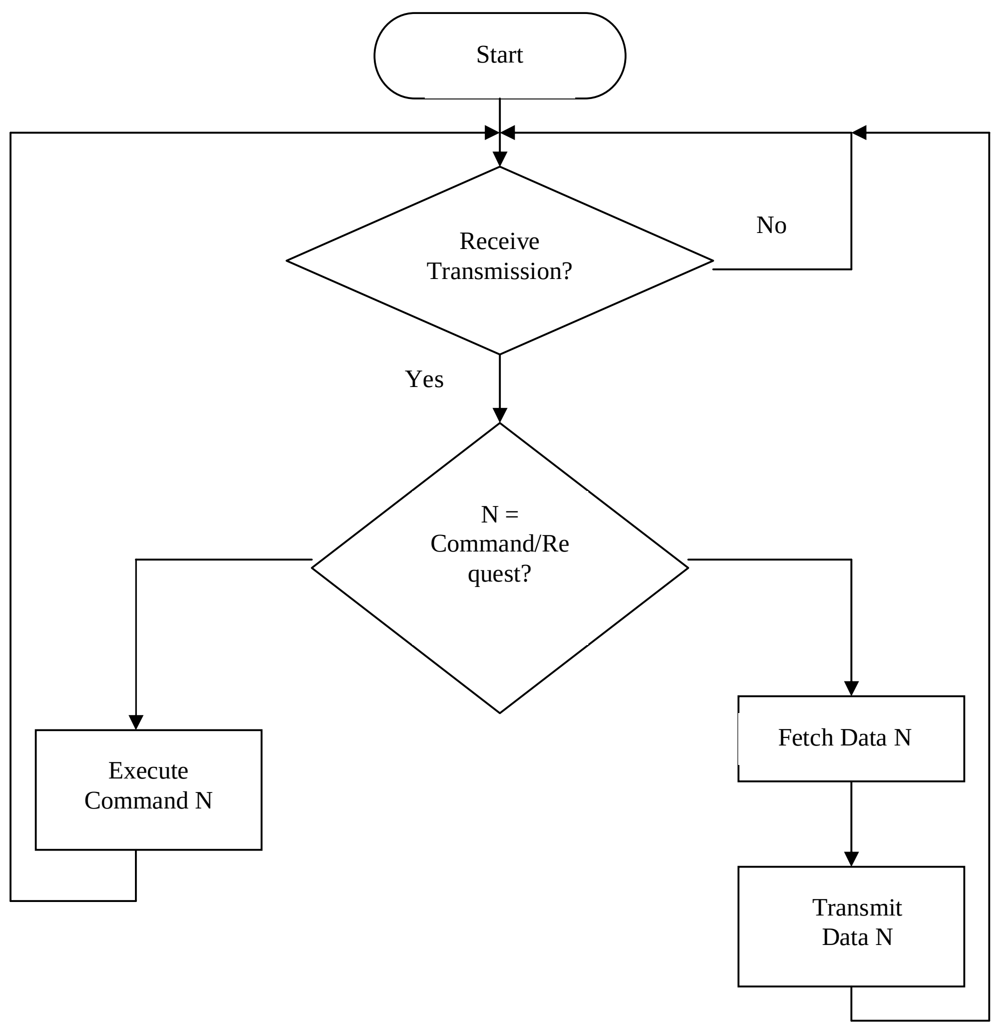


Figure 2.9: Acknowledged Slave Device Algorithm

## 2.6 Overall Operation

This project, as a whole, demonstrates the important of PC-Robot communication. Implementing wireless communication is a complex task and depends on the hardware architecture applied to achieve the objectives of this project. Due to the limitation confronted, the following algorithm is best applied to ensure the aims of this project are attained.

In this project, the PC plays the role of the master device while the robot as the slave. Therefore the robot waits for the transmission from the PC to decide its proper action either it be command or request data. When the robot receives data, it translates and performs as it is programmed. As initial stage, the PC has to send data to inform the robot to operate either autonomous or manual control.

In autonomous mode, the robot runs the autonomous algorithm that defined in Chapter 4. For each motion, the robot will read the IRPD and transmits both the IRPD and bumper data making up two bytes. In this case, the PC waits for data transmitted by the robot. This mode demonstrates the implementation of unacknowledged protocol communication explained earlier and this is the most suitable protocol to be applied in view of the fact that only two bytes of data are being transferred.

On the other hand, the manual mode of operation implements the acknowledged protocol communication. The robot remains in its static position until the PC sends command or request data. Upon receiving command data, the robot moves as it is commanded. When the robot recognizes the requests data transmission, it fetches the data corresponding to the requests data and transmit them together back to the PC.

# CHAPTER 3

# HARDWARE DESIGN

## 3.1 Robot System

Robots require a microprocessor to calculate logical and arithmetic operations. In addition, several input and output ports must be attached to the robot to read parameters from the surrounding for pre-programmed task. For these reasons, microcontroller is the best solution for this task. There are various microcontrollers that can be found with various features. However, for this particular robot, the microcontroller must be able to control a two DC motor via pulse generation, scan various sensors. In addition, the microcontroller can transmit and receive data to and from the PC via a FM wireless link.

### 3.2 MC68HC11 Microcontroller Unit (MCU)

An MC68HC11 would be able to do various task. For MC68HC11E1 version, it has 512 bytes of EEPROM and RAM while the ROM is disabled. This is a 8-bit microcontroller that have 5 ports that are Port A, Port B, Port C, Port D and Port E.[3] Several of features are built-in in the MC68HC11E1 that contain:

• M68HC11 CPU
• Power Saving STOP and WAIT Modes
• Low-Voltage Devices Available (3.0 – 5.5 Vdc or 2.7 – 5.5 Vdc)
• 512 Bytes of On-Chip RAM, Data Retained During Standby
• 512 Bytes of On-Chip EEPROM with Block Protect for Security
• Asynchronous Nonreturn to Zero (NRZ) Serial Communications Interface (SCI)
• Synchronous Serial Peripheral Interface (SPI)
• 4-Channel 8-Bit Analog-to-Digital (A/D) Converter
• 16-Bit Timer System
— Three Input Capture (IC) Channels
— Four Output Compare (OC) Channels
— One Additional Channel, Selectable as Fourth IC or Fifth OC
• 8-Bit Pulse Accumulator
• Real-Time Interrupt Circuit
• Computer Operating Properly (COP) Watchdog System
• 38 General-Purpose Input/Output (I/O) Pins
    — 16 Bidirectional I/O Pins
    — 11 Input-Only Pins.
    — 11 Output-Only Pins.

Figure 3.1 illustrates the architecture of the MC68HC11E Series port functionality.

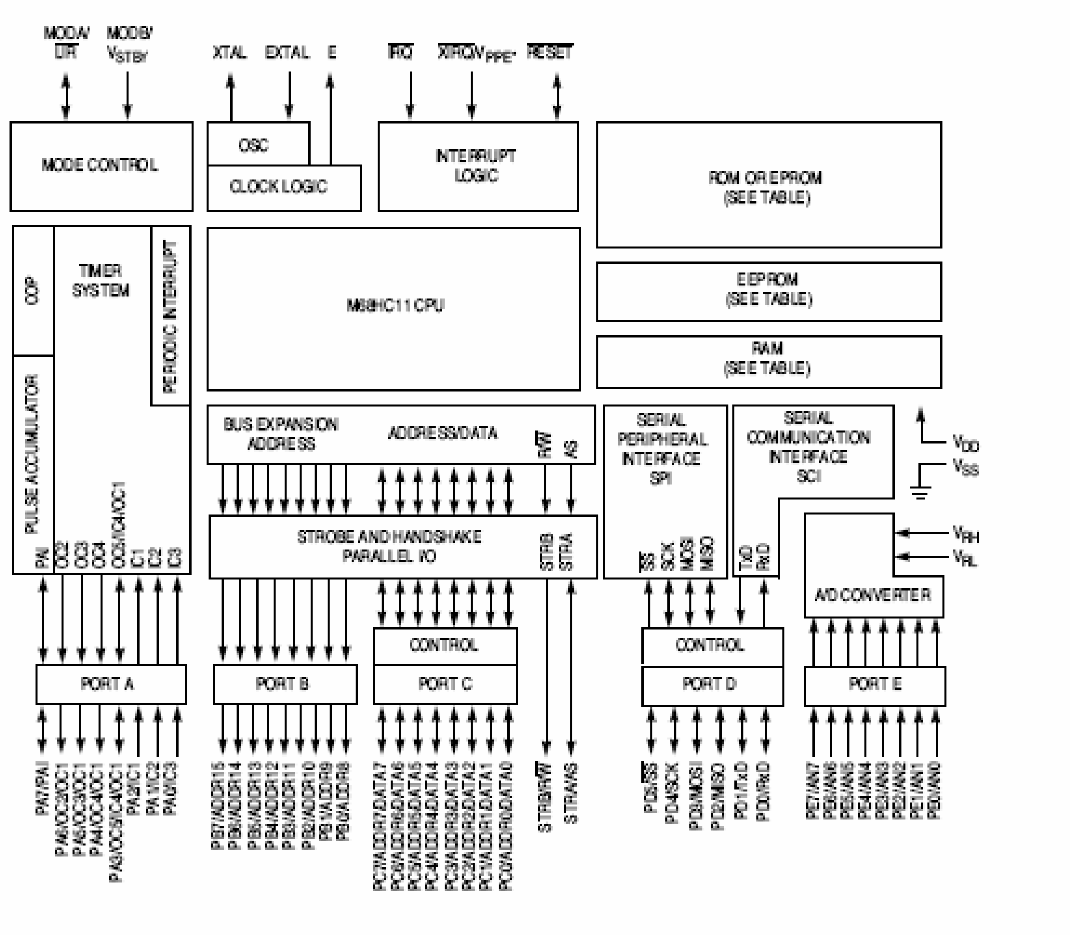


Figure 3.1: MC68HC11 E Series Block Diagram

### 3.2.1 Mode of Operation

There are four mode of operation available for the MC68HC11E1 that they are Bootstrap, Single Chip, Special Test and Expanded. Bootstrap mode allow the user to download programs into the built-in EEPROM of 512bytes, Single Chip will download the program into the built-in EPROM which is bigger size than EEPROM, Single Test is the special option for MOTOROLA company to test the functionality of the microcontroller unit and the last option, Expanded allow user to use extra memory and input/output port [3]. In this project, Bootstrap mode is being used due to the factor of size, cost, and the weight of the robot. Tying both pins MODA and

MODB to ground activates this mode of operation. Bootstrap mode allows the user to download programs into the MCU EEPROM of 512 bytes.

### 3.2.2 Bootstrap Mode Circuit

Figure 3.2 is the basic circuitry for operating the MCU in bootstrap mode with the connection with MAX 233 for the serial communication. MAX 233 is used for the RS-232 line to connect between PC and the MCU so that the programs from PC can be loaded into the MCU EEPROM. The crystal for this set-up is 8.0 MHz yielding an E-clock of 2 MHz.

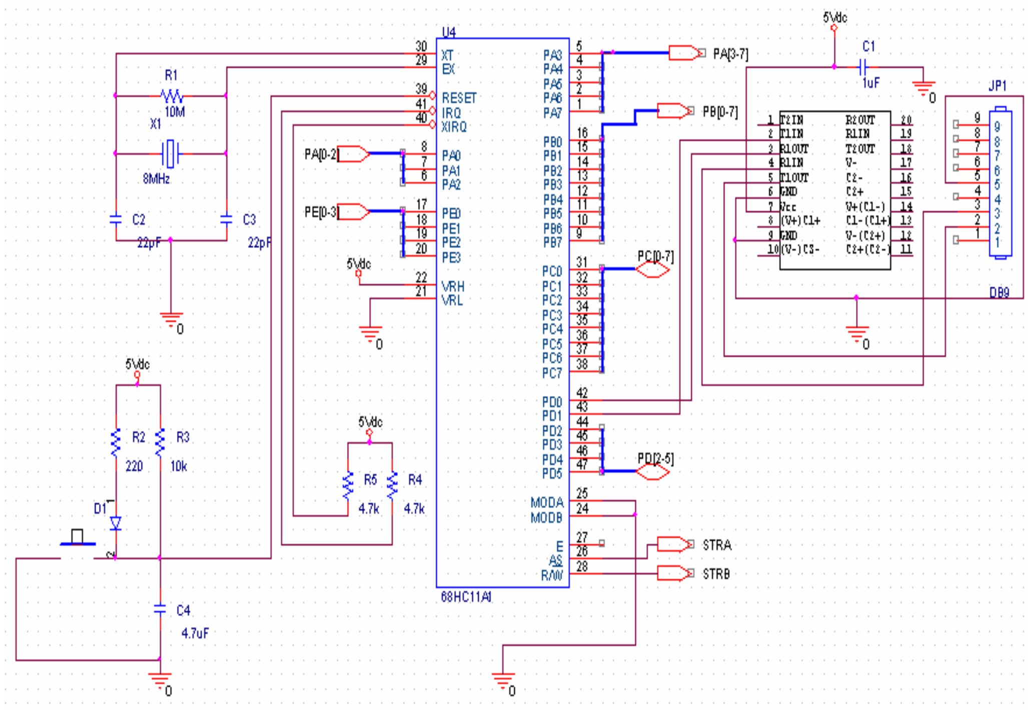


Figure 3.2: MC68HC11 E1 Bootstrap Mode Basic Circuit

Note that when loading the programs into the MCU EEPROM, the Load mode should be choosen by letting the pin RxD and TxD without short both of them. To execute the program addressed at $B600 in the bootstrap mode, the RxD pin of the MCU must receive a break value, $00 from the TxD pin by shorting both of them together. In this case, this is called Run mode.

### 3.2.3 MC68HC11 E1 Pin Assignments

The robot has three main functions. One of these functions is to perform as an actuator to control the motion of the robot. The other functions are the sensors, consisting of the whiskers bumper and IRPD for obstacle detection, and the light and heat intensity sensor. There are also the data handling function to receive and transmit data in nibbles with the PC.

For each specific function, specific ports are assigned to suit the requirements. Table 3.1 describes in detail the MCU pin assignments for every function of the robot.

Table 3.1: MC68HC11 E1 Base Robot Pin Assignments

| | **Function** | **Pin Assignment** | **I/O** |
|---|---|---|---|
| **Actuator** | On/off Motors,<br>Speed Control | PA5, PA6 | Output |
| | Directional Control | PB0…PB3 | Output |
| **Sensors** | Bumper Right<br>Bumper Left | PA0<br>PA1 | Input |
| | IR Reflection<br>Signal<br>IR LED RIGHT<br>IR LED LEFT | PA2<br>PA3<br>PA4 | Input<br>Output<br>Output |
| | LDR Right<br>LDR Left | PE0<br>PE1 | ADC Input |
| | Temperature<br>Sensor | PE2 | ADC Input |
| **Data Management** | Data Enable<br>Data Out | PD4<br>PC4…PC7 | Output |
| | Valid Transmission<br>Data In | PA7<br>PC0…PC3 | Input |
| **Indicator** | LED Indicator<br>Right<br>LED Indicator Left<br>LED Indicator<br>Light | PD2<br><br>PD3<br><br>PB4…PB7 | Output |

As can be seen from the table, all the I/O ports of the MCU are utilized. This shows that the MC68HC11E1 has served well the requirements to build a multi-functional robot with the capability of obstacle detection and avoidance, sensor reading, and wireless communication. The schematic and hardware design for each function of the robot will be depicted in the following sub-topics.

**3.3 Actuator**

As expressed in chapter 2 of this thesis, two DC motors control the robot. However, DC motors alone would not be sufficient to trigger the robot in motion. Moreover, attaching the wheel directly to the shaft of the motors would be rotating the wheels too fast. For a more stabilize rotation, the TAMIYA Gear Box is used.

There are various types of gearbox available, however the Twin Gear Box Set is the most suitable to control a mobile robot. The Twin Gear Box can be configured in three ways to define the speed, gear ratio and the position of the shaft. The 58:1 gear ratio is not suitable as it is very fast and does not exert enough power to move the whole system including the batteries. Type C is the best choice and even though it is slow, the gear ratio applies more force to put the wheel in rotation. Figure 3.3 illustrates the three different configuration of the Twin Gear Box.

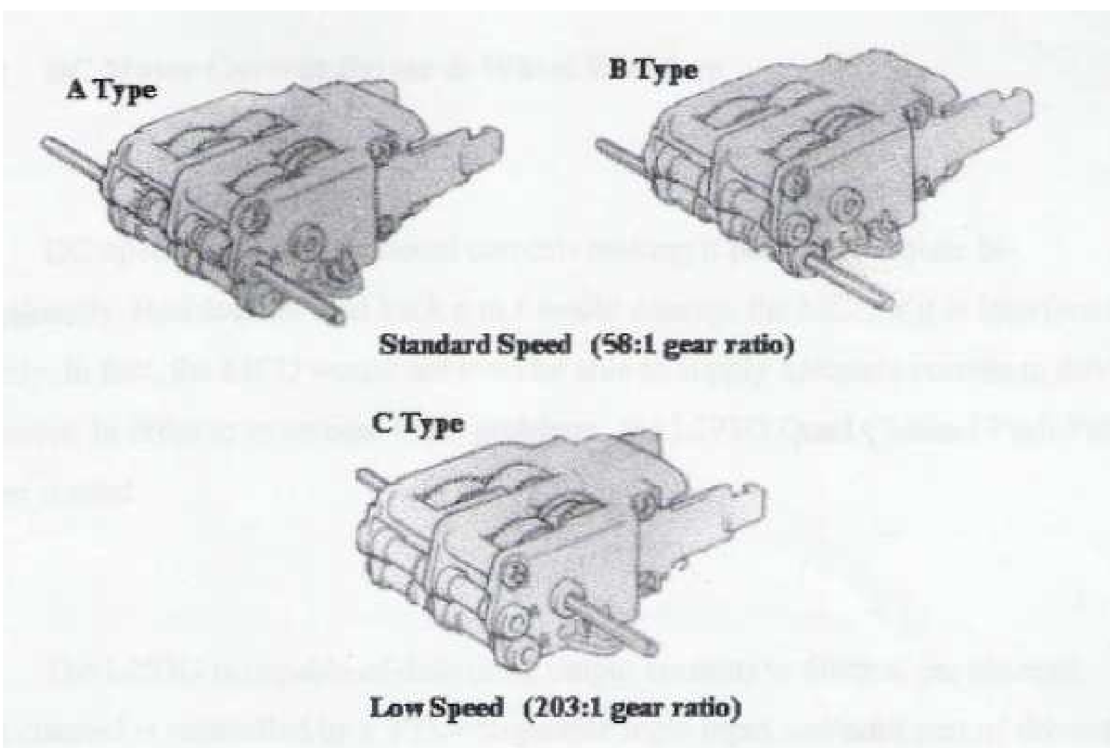


Figure 3.3: TAMIYA Twin Gear Box Configurations

This gearbox equips with two 4.5 Volts DC motors. This allows each wheel to be controlled separately. The wheel used is the TAMIYA Truck Tire Set that fits the shaft well with strong rubber tyre grip.

### 3.3.1 DC Motor Current Driver

To drive the DC motor, a motor driver IC called L293D Quad Channel Push-Pull Driver is used because of the current of the MCU would not be enough to drive the motor and the feed back electromagnetic force (e.m.f) of the motor would damage the MCU if the motor is directly connected to the MCU. The L293D is capable of delivering output currents to 600mA per channel. Each channel is controlled by a TTL-compatible logic input and each pair of drivers is equipped with an inhibit input which turns off all four transistor. A separate supply input is provided for the logic so that it may be run off a lower voltage to reduce dissipation. Normally the L293D includes the output clamping diodes within the IC for complete interfacing with inductive loads so that the problem with the feedback e.m.f can be solved. Thus, there is no need extra diode to construct the H-bridge diode. Figure 3.4 and table 3.2 shows the bi-directional DC motor control.

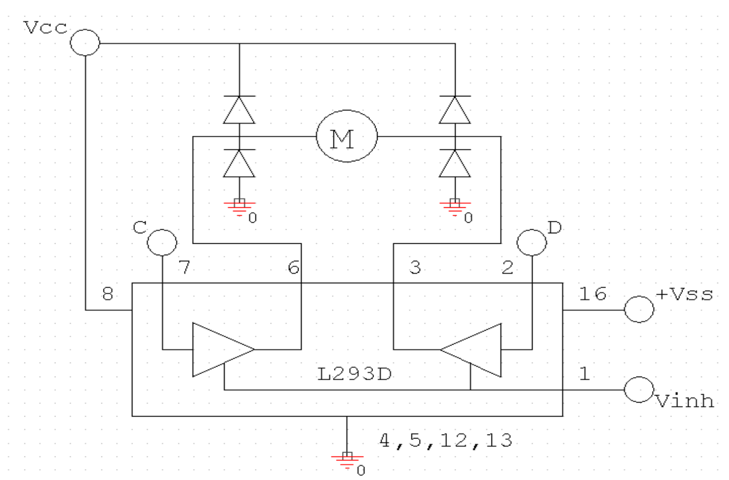


Figure 3.4: Bi-directional DC Motor Control

Table 3.2: Inputs to L293D and their function

| INPUTS | | FUNCTION |
|---|---|---|
| $V_{INH}$ = H | C = H; D = L | Turn Right |
| | C = L; D = H | Turn Left |
| | C = D | Free Motor Stop |
| $V_{INH}$ = L | C = X; D = X | Free Running Motor Stop |

L = LOW, H = HIGH, X = Don’t Care

### 3.4 Sensors

Chapter 2 describes briefly the various sensors used in the mobile robot. The following paragraphs will describe the circuits involved in building the robot’s sensors.

#### 3.4.1 Bumper Switches

Figure 3.5 is a simple circuit design of whisker bumper. It consists of micro switch and a single core thin wire. A metallic piece of bendable strip is used to tie the tip of the micro switch to the single core wire. Referring to the figure, the wire is bent to detect object on the sides of the robot. Figure 3.5(b) shows that the switch is pressed when object makes a contact to the wire. The circuit sends logic HIGH when the switch is pressed as illustrated in Figure 3.6.

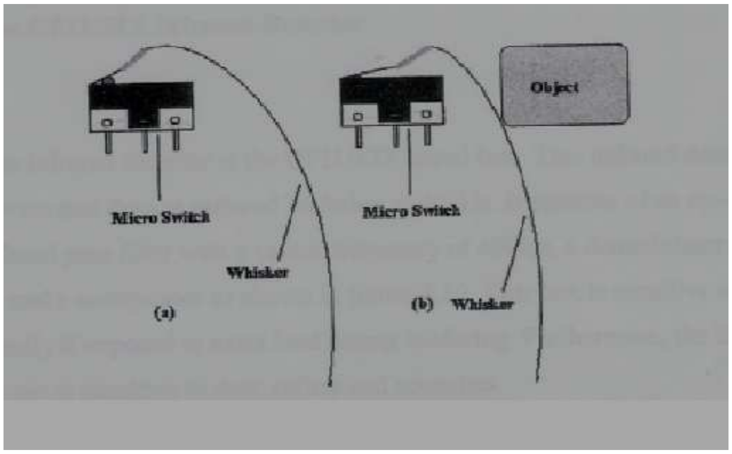


Figure 3.5: Whisker Bumper When Knocking Into Objects

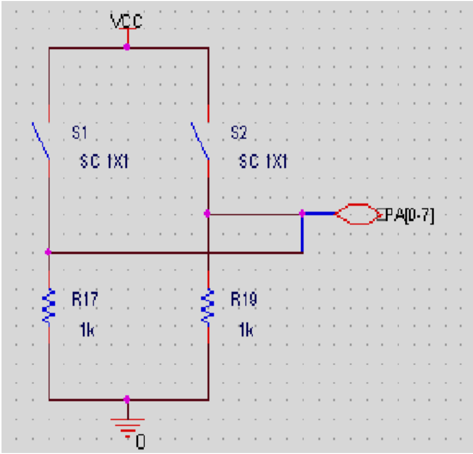


Figure 3.6: Simple Whiskers Bumper Schematic.

### 3.4.2 Infra Red Proximity Detector Module (IRPD)

The IRPD consist of two parts, which are the IS1U60 infrared detector and the 555 timer infra red circuit.

**3.4.2.1 The IS1U60 Infrared Detector**

The infrared detector is the IS1U60 module manufactured by SHARP. This infrared detector is a special device that detects infrared emission at 38 kHz. It consists of an op-amp, limiter, a band pass filter with a centre frequency of 38 kHz, a demodulator, integrator and a comparator as shown in figure 3.7 [5]. This module is sensitive and would damage easily if exposed to extra heat during soldering. Furthermore, the light detecting unit is sensitive to dust, refuse and scratches.

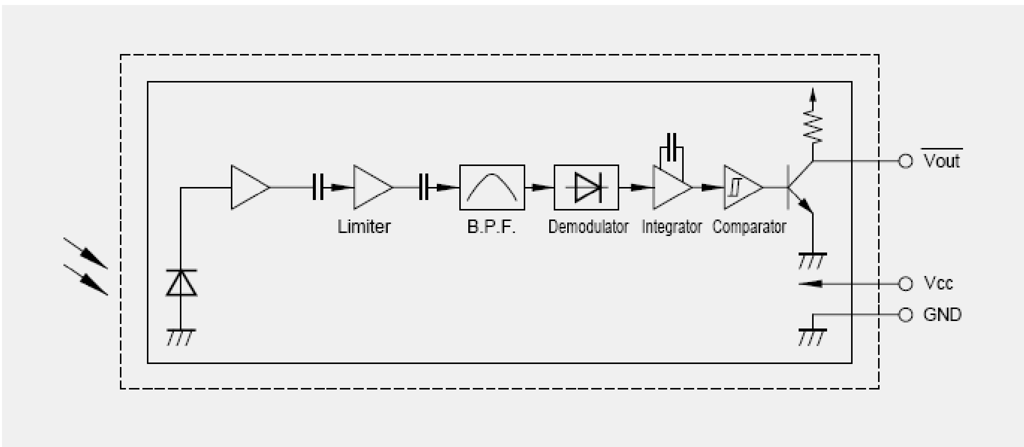


Figure 3.7: Internal Circuit of the IS1U60.

As shown in the figure, the output pin of the IS1U60 is an active LOW. The advantage of using the IS1U60 is the ability to reject noisy light signals. When it is used to detect infrared reflections, its maximum detection distance is 8 inches with the detection range is cover $30^0$ left and right. Direct line of sight of the infrared light source could make it up to 5 meters.

### 3.4.2.2 IRPD Schematic

The circuit of IRPD module is depicted in figure 3.8. It consists of two 555 Timer IC to generate the transmitted signal.

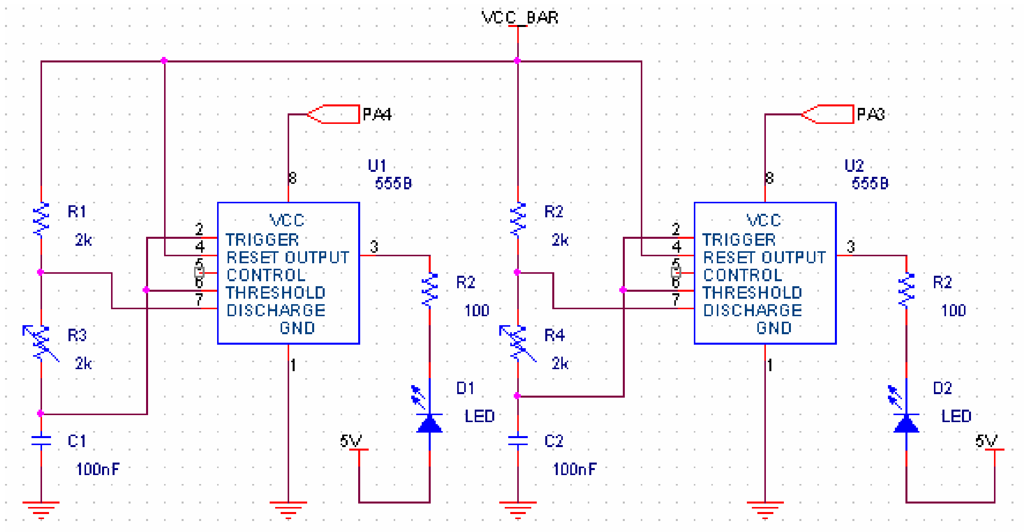


Figure 3.8: IRPD module Schematic

This circuit uses two 555 Timer IC to generate square wave with frequency of 38 kHz to drive on both the IR LED. The potential meter is used to adjust the frequency of the square wave so that the desired frequency can be met. The voltage supply of both the 555 Timer IC is controlled by the MC68HC11E1. This is to save the power so that it will on only when the robot needs to use to perform obstacle avoidance. The connection of the IR LED, the output of the 555 Timer is connected to the cathode of the IR LED. The anode will be connected to the 5 volts power supply. This is because the output signal from 555 Timer is not capable to drive the IR LED for a long distance. By switching the connection of the IR LED, as shown in figure 3.8, the IR LED now can be driven up to few meters without using external transistor to amplify. The R2 register is used to control the current that flow through the IR LED so that it will not be overloaded. The desired distance of the reflection of the IR LED also can be controlled [5]. Both the IR LED also needed to be covered with PVC tube so that it can be focused on certain point and also prevent leakage IR signal from side to the IS1U60 IR receiver.

### 3.5 Light and Heat Intensity

Not only the robot is used to avoid obstacle, it is also used to read light and heat intensities. The purpose of this function is to sense the analogue parameter of its surroundings. Both of this analogue value is converted to digital value by the internal 8-bit ADC feature of the MCU.

#### 3.5.1 Light Sensor

For the light sensor, the TSL250R, Light-to-Voltage Optical Sensor is used. There are two sensors attached to the system, each for measuring light on the right of the robot and the other on the left. Both of them are isolated from each other in a way that when one is shined by a source of light, the other will get only its shadow. This arrangement is useful in a way that the robot might be able to use this concept to spin itself towards one source of light.

The TSL250R combining a photodiode and a transimpedance amplifier (feedback resistor = 16 MW) on a single monolithic IC. Output voltage is directly proportional to the light intensity (irradiance) on the photodiode. These devices have improved amplifier offset-voltage stability and low power consumption and are supplied in a 3-lead clear plastic side looker package with an integral lens [6]. Figure 3.9 shows the functional block diagram of the TSL250R.

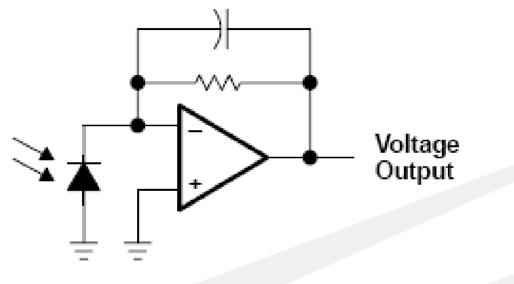


Figure 3.9: Functional Block Diagram of TSL250R.

When the light floods the TSL250R, the output will be reached up to 3.3volts depending on the intensity of the light while if there are no light floods on it, the minimum of dark voltage is 0volts. The irradiance responsivity is about 135 mV/(µW/cm$^2$). This means that for each increasing of 1 µW/cm$^2$ of light intensity, the output voltage will increasing 135mV and vice versa.

**3.5.2 Heat Measurement Capabilities**

As for the heat measuring, the LM35 temperature sensor is used. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry easy [6]. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. Its sensitivity is + 10.0 mV/°C. Figure 3.10 shows the pin connection of the LM35.

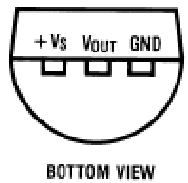


Figure 3.10: Pin connection of the LM35

Because of the sensitivity of LM35 is small, thus a program is needed to manipulate the data of the ADC that it convert from the output of LM35 before the data is being displayed on the seven segment.

### 3.6 FM Wireless System Modules

This FM wireless system module consists of four components that are encoder, decoder, transmitter and receiver. In order to transmit data to a specific receiver, both the encoder and decoder must have the same address. Since both the robot and PC have encoders and decoders, addressing is important to distinguish the PC-Robot link from the Robot-PC link. This phenomenon is overcome by implementing a half-duplex transmission since the carrier of both sets is operating at the same frequency of 433MHz. Following are the description of each component for this project.

### 3.6.1 Encoder

The encoder implemented in this project is the HT12E from HOLTEK. This encoder has 8-bit address and 4-bit data pins.

The encoder is used to send 4-bit data along with address bits appended to it in order to define to which receiver would receive the data. This encoder is chosen, due to its ability to encode 12 bit data. The preset address and current data will be encoded and sent together once the transmit enable pin is triggered low.

Other features includes that it operates on low power, CMOS technology that provides high noise immunity, low standby current, built-in oscillator, data code has positive polarity and requires minimal external components. In addition, the input pins for addressing and data can be externally set to VSS (logic LOW) or left open (logic HIGH).

The encoder begins a 4-word transmission cycle upon receipt of a transmission enable. This cycle repeats as long as the transmission enable is held low. Once the /TE (transmission enable) returns high, the encoder output completes its final cycle and then stops as shown in figure 3.11 below.

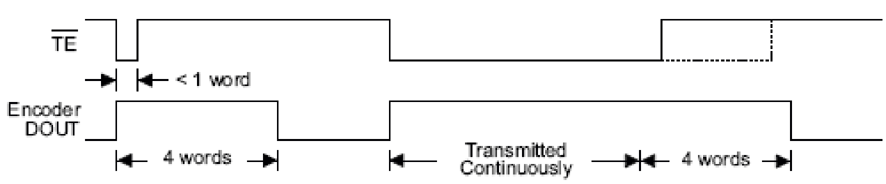


Figure 3.11: Timing Diagram for HT12E.

The status of each address/data pin can be individually pre-set to logic "high" or "low". If a transmission-enable signal is applied, the encoder scans and transmits the status of the 12 bits of address/data serially in order A0 to AD11.

During information transmission, these bits are transmitted with a preceding synchronization bit. If the trigger signal is not applied, the chip enters the standby mode and consumes a reduced current of less than 1µA for a supply voltage of 5V.

For this project, the address pins are all connected to 5V, while data is taken from the PC parallel port, and from the MCU on the robot. The operation of the HT12E encoder is summarized in figure 3.12.

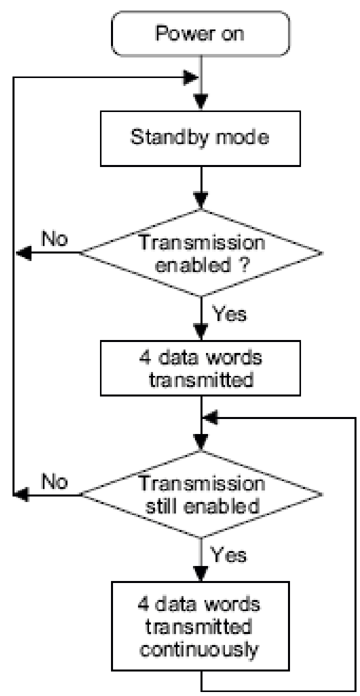


Figure 3.12: HT12E Flow of Operation

### 3.6.2 Decoder

The HT12D decoder is chosen as it has the same number of addresses and data format as that of HT12E encoder. It consists of 8 address bits and 4 bits data bits.

Received codes are checked 3 times, plus it has a valid transmission indicator. It is also easy to be interfaced with an RF transmission medium. The HT12D provides 4 latch type pins whose data remain unchanged until new data are received.

The decoders received data that are transmitted by the encoder and interpret the first N bits of code period as addresses and the last 12-N bits as data, where N is the address code number. A signal in the $D_{IN}$ pin activates the oscillator, which in turn decodes the incoming address and data. The decoders will then check the received address three times continuously. If the received address codes all match the contents of the decoder's local address the 12-N bits of data are decoded to activate the output pins and the VT pin is set high to indicate a valid transmission. This will last unless the address code in incorrect or no signal is received [8].

The oscillator is disabled in the standby state and activated when a logic "high" signal applies to the $D_{IN}$ pin. That is to say, the $D_{IN}$ should be kept low if there is no signal input. Figure 3.13 and 3.14 are the decoding process flowchart and the decoder's timing diagram respectively.

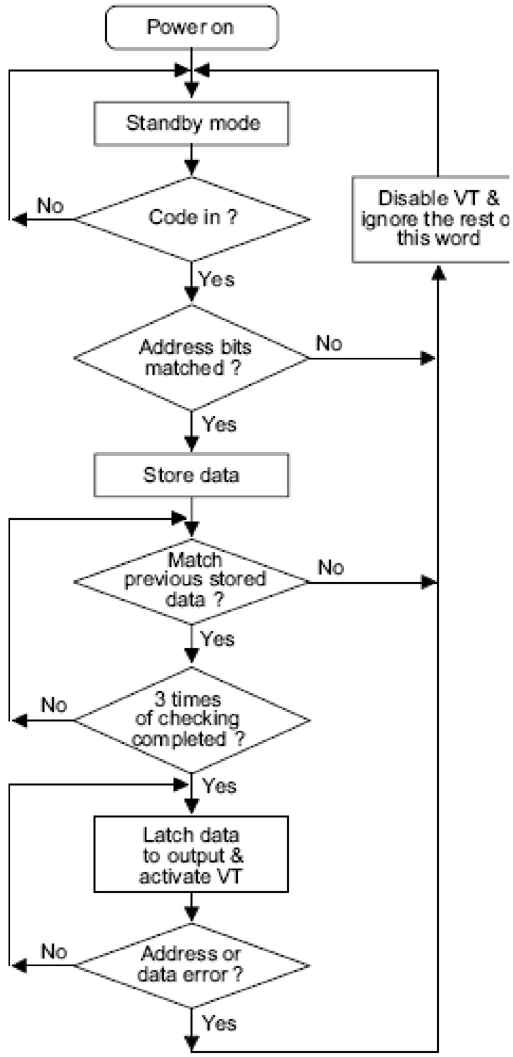


Figure 3.13: HT12-D Flow of Operation

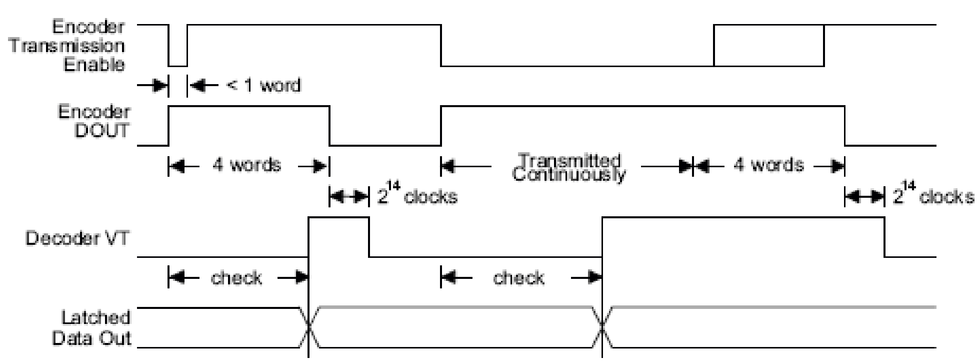


Figure 3.14: HT12D Decoder Timing Diagram

### 3.6.3 Transmitter Module

Transmitter module that had used in this project is the FMTX1-433a. It is a complete single in line board module capable of transmitting analogue or digital data up to 200 meters. It is suitable for general purpose telemetry applications where small size and high data rates are required. Therefore it is most suitable option for this project. The transmitter is designed to be used in conjunction with the receiver FMRX1-433a.

In general, $Data_{IN}$ can accept data in either digital or direct analogue form (AFSK). The input frequency bandwidth ranges from DC to 10 kHz. However, it is not possible to pass data with a DC component because of frequency errors and drifts between the transmitter and receiver.

Data should be driven in from a CMOS logic output that and will be the HT12E encoder for this project. The power supply for the CMOS circuit should be the same as that for the transmitter.[7]

### 3.6.4 Receiver Module

The FMRX1-433a is a compact board SIL Modules that can be used to capture R.F data from the FM transmitter such as the FMTX1-4331a as described recently. When used in remote control system, range of up to 200 meters can be achieved.

This receiver module is a double conversion FM Superhet with a data slicer driven by the AF output. Additionally, a fast acting carrier detect signal is available to indicate to external circuits that a signal is present. This signal is extremely useful when implementing duty cycle power save circuits or to indicate to external logic that is signal is being received. It is externally derived from the degree of noise quieting due to the presence of a received carrier.

### 3.6.5 Antenna Design

The range achieved from the system is dependent on the choice of antenna. The space around the antenna is as important as the antenna itself. The optimum position is to locate the antenna so that it sticks out directly out of the top of the robot. Batteries are kept away form the antenna to get the best range. Three type of design antenna is available. They are helical, loop, and whip antenna. Normally, the whip antenna gives the best range that is around 200 meters. Whip antenna can be made up of rod, wire or PCB track of certain length determines by the frequency being used. The length of the antenna is ¼ wavelengths long. This can be calculated using the formula below:

$$\lambda = \frac{c}{f} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

$$\lambda = \frac{3\times10^{8}}{433.92M}$$

$$\lambda = 0.6914m$$

$$\lambda = 69.14cm$$

$$\ell = \frac{1}{4}\lambda$$

$$\ell = 17.285cm \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Where, λ = wavelength of signal used

ℓ = length of antenna used

$f$ = frequency of signal/transmitter or receiver frequency

c = velocity of propagation

Therefore, the length of the antenna for optimum range is 17.32cm. A small extendable rod is used for the antenna on the robot platform.

### 3.6.6 FM Wireless Application Circuit

Figure 3.15 the schematic of the transmission module consisting of the HT12E encoder and the FMTX1-433aMHz. The address used for robot-PC transmission is $FF. This value is fixed as the address for the operating system.

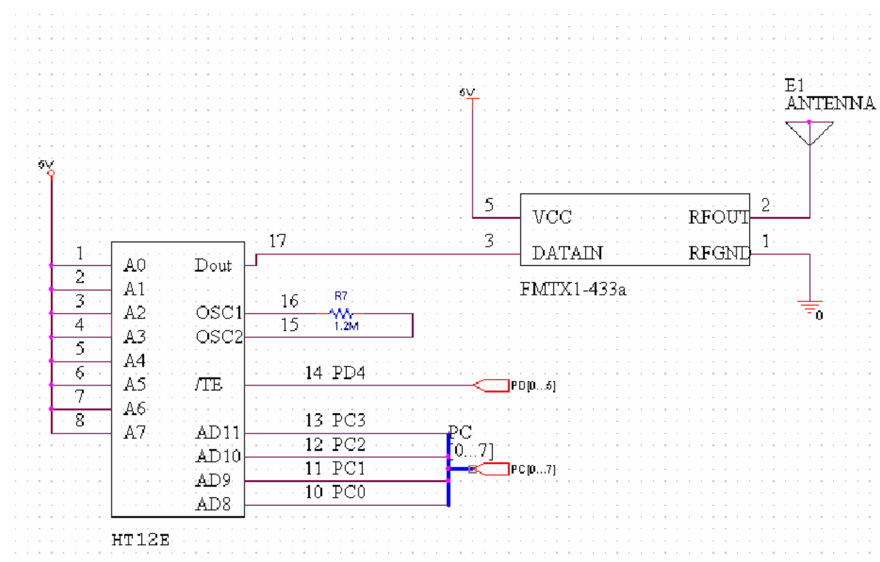


Figure 3.15: Transmission Module

The /TE pin is controlled by the MCU. This is because it cannot be activated simultaneously with the transmission module on parallel board to avoid data collision. Therefore, the pin /TE must be giving logic “high” to off the transmission as it is the slave device. The pin /TE will only be given logic “low” when it needs to transmit data to the PC.

Figure 3.16 is a simple schematic for the reception module. The address for this module is fixed address of $00.

The VT pin plays an important role in the view that the decoder has a latch feature. The VT pin is scanned for logic HIGH, and when this happened, the nibble is read. This is to ensure data read is the latest data received.

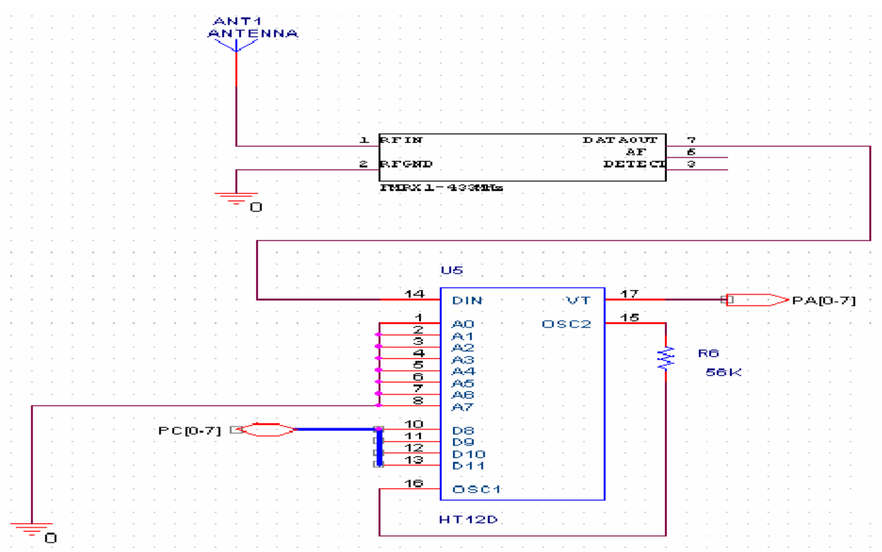


Figure 3.16: Reception Module

### 3.7 Robot Power Supply

The robot uses 6 rechargeable batteries with AA size as one power supply with the voltage of 7.2 Volts and 2500mA operating current for the actuator part. A 9V battery is used as the power supply for the microcontroller circuit. Figure 3.17 shows the power supply circuit with connected to a 5V voltage regulator to ensure the system is operating at 5V level.

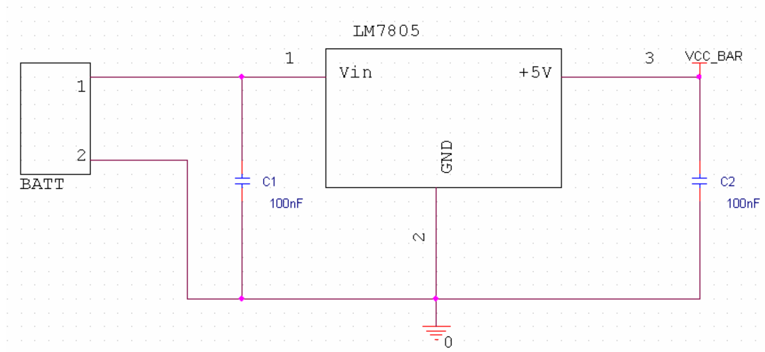


Figure 3.17: Power supply Schematic

The robot needs two separate power supply so that the supply for the microcontroller board is differ with the actuator part. This is because the actuator would just cause current drain if it shares the same power supply with the microcontroller circuit.

# CHAPTER 4

# SOFTWARE IMPLEMENTATION

## 4.1 MC68HC11 Programming Language

The program for the robot is developed using the MC68HC11 assembly language. Going through the code listing, the program consists of four main parts. They are the Equate Directives, RAM Directives, the main Program and the Subroutines. Five main subroutines are initialization, analogue to digital conversion, motion and wheel counting, data transmission and obstacle sensing.

In the initialization part, the program initializes the MC68HC11 E1 internal registers, input and output ports, activates the built-in ADC function and places the transmission module in an inactivate mode. The analogue to digital conversion part starts the conversion of the three analogue parameters, left and right light sensors and heat. After the conversion process is completed, these values are stored in the RAM, which is processed in the main program explained in the later part of this chapter.

The following subroutine incorporates the motion of the robot and wheel counting for odometry purposes. The wheel rotation must be taken into account to record every motion made by the robot. The wheel count is then transmitted to the PC for mapping pathway. The core to wireless transmission is in the data transmission subroutine. This part provides two transmission format depend on the mode of operation. In the autonomous mode, the robot transmits two bytes of data that is the wheel count and obstacles detected whereas in manual mode only one byte data is transmitted along with a 4-bit trailer. Obstacle sensing scans the bumper whiskers and the IRPD. 4 bits are used to represent each sensor. These bit are stored in the RAM. Then, it is transmitted to the PC for mapping obstacles confronted.

### 4.1.1 The Robot Main Program

The robot operates on two modes, autonomous and manual. In this project, the robot is as the slave device that will be commanded by the PC.

The program begins with the initialization of the MCU I/O ports. This includes setting the variables in the RAM directives, assigning the input and output ports and deactivates the transmitter module that has been attached to the system. It is followed by activating the built-in ADC function in the MCU.

The autonomous mode of operation will implements the autonomous robot algorithm as described in Chapter4. There are two conditions, which defines the autonomous mode of operation. They are the invalid transmission and if the value of $D_{OUT}$ from the decoder is \$05. In order to make this happen, the PC transmits the value \$05 and deactivate the transmitter module at the PC.

Conversely, for the manual mode of operation, the MCU scans for valid transmission and when this occurs, the MCU reads for the value of $D_{OUT}$. Values $05, $06 and $07 are the command data representing forward motion, right and left spin respectively. Three bits are used for PC-Robot communication and 4 bits for Robot-PC communication. Therefore the data only range from $00 to $07. Value $01, $02, $03, $04 and $05 are data requests for right Light sensor, left Light sensor, heat, and wheel count and obstacle detection respectively.

Before sending the three analogue readings, conversion is done by the ADC subroutine. The flowchart in figure 4.1 illustrates the program flow of the MCU.

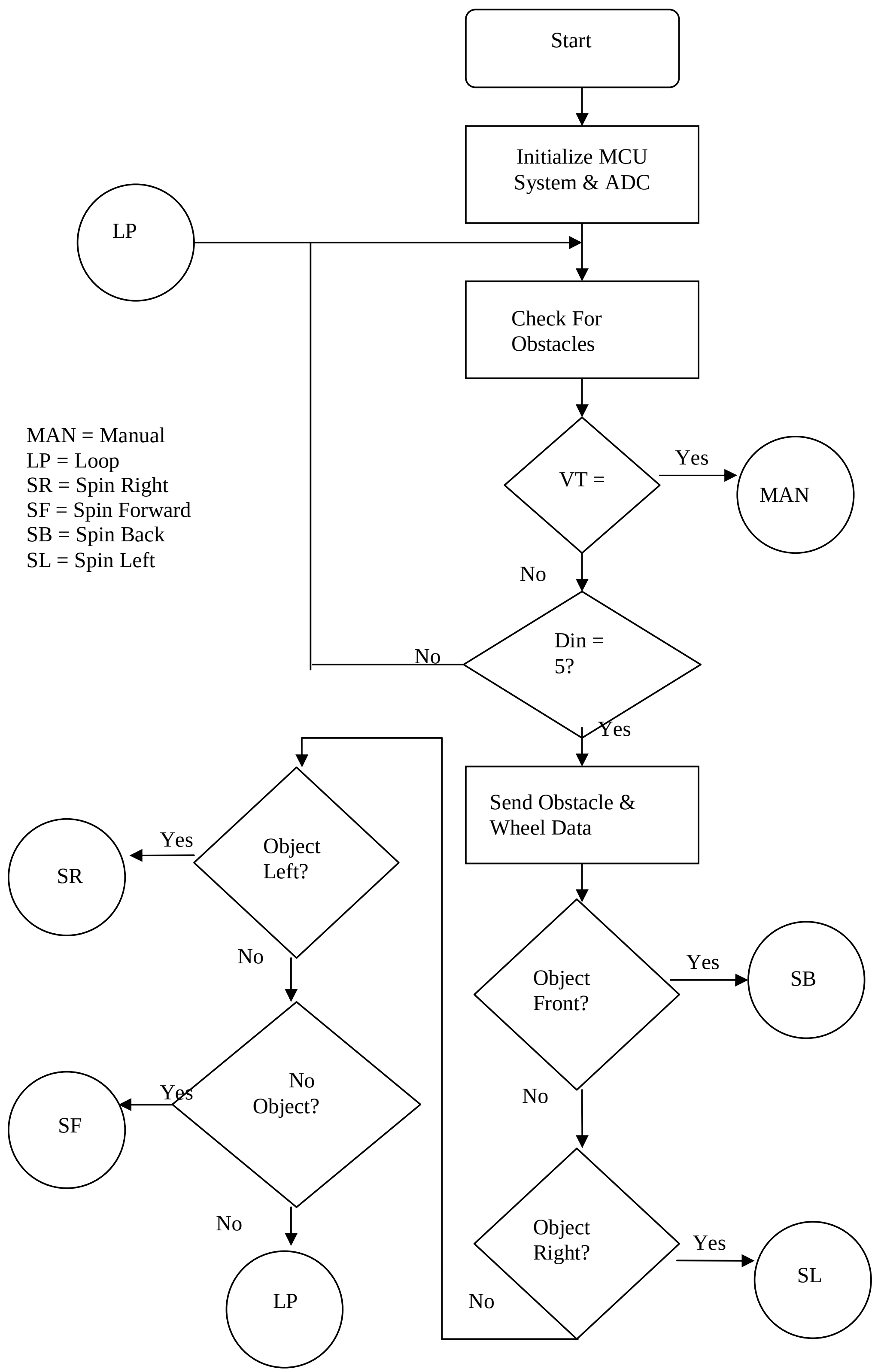


Figure 4.1: MC68HC11 Robot Programming Algorithms

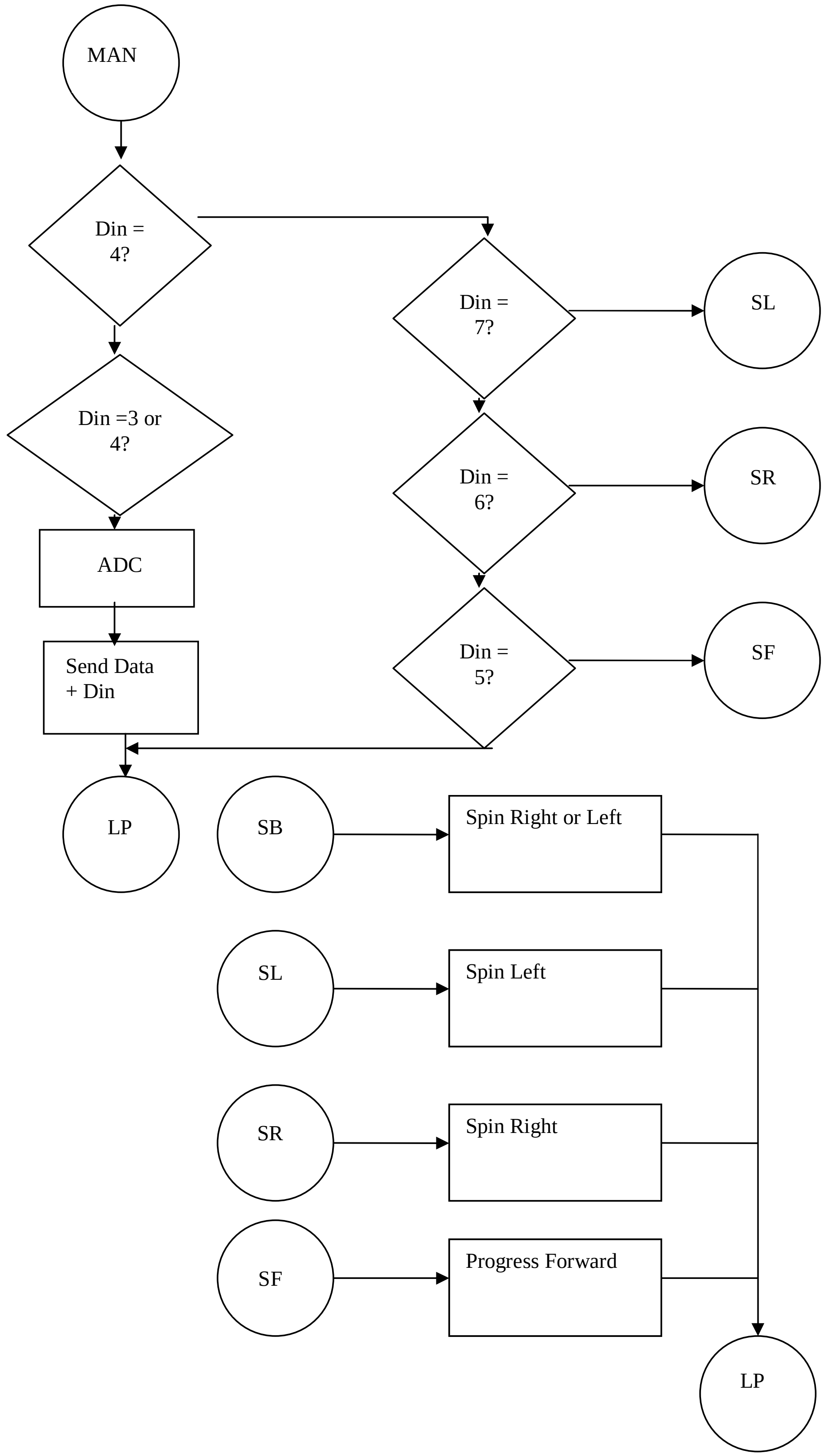


Figure 4.1: MC68HC11 Robot Programming Algorithms (Continued)

### 4.1.2 Autonomous Robot Algorithm

The design of the robot is based on an autonomous mobile robot. The autonomous mobile robot is a robot that moves on wheels with its system moving along with it, and has limited human interaction. As this project focuses on implementing wireless communication on a robot, a simple autonomous algorithm is applied, detect and avoid obstacle. This algorithm is programmed into the microcontroller MC68HC11E1 of the robot.

As shown in figure 4.2, the robot moves forward when there are no obstacles. Every time it spins, right of left, it will save the present spin in a variable *previous*. This variable will be used when it detects object in front of it. This will ensure that is will not spin in the same direction when there is obstacle in front. This simple algorithm causes the robot to wander around without any target in mind.

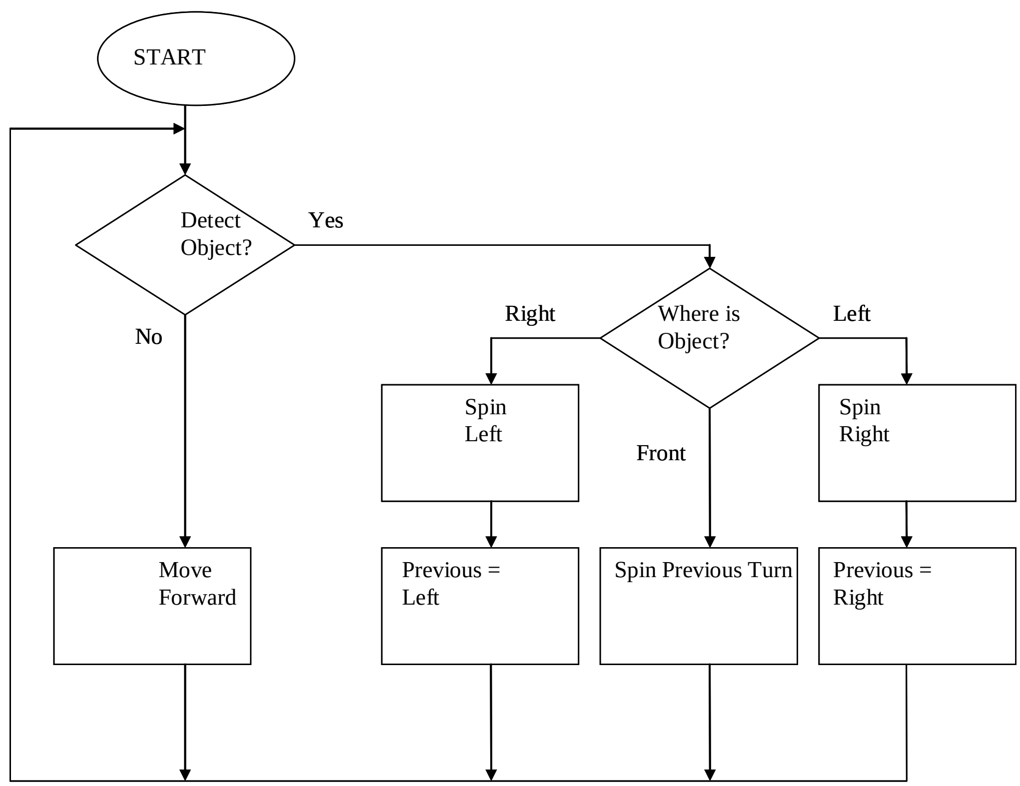


Figure 4.2: Simple Object Detection and Avoidance Algorithm

# CHAPTER 5

# EXPERIMENTAL RESULTS

As part of the project, extensive testing has been performed on the developed system. This chapter describes the approach taken in executing the various tests.

In developing the robot, several tests are conducted on each module to ensure the functionality of the system when these modules are integrated. The modules tested are the microcontroller circuit, FM wireless, IRPD, heat measuring, light sensing, and half-duplex communication.

## 5.1 Microcontroller Circuit Module

As been mentioned before, microcontroller from Motorola, MC68HC11E1 is used in this project. The bootstrap mode is used so that the weight and size of the robot can be made become lighter and smaller. The connection for this module is as shown by Figure 5.1.

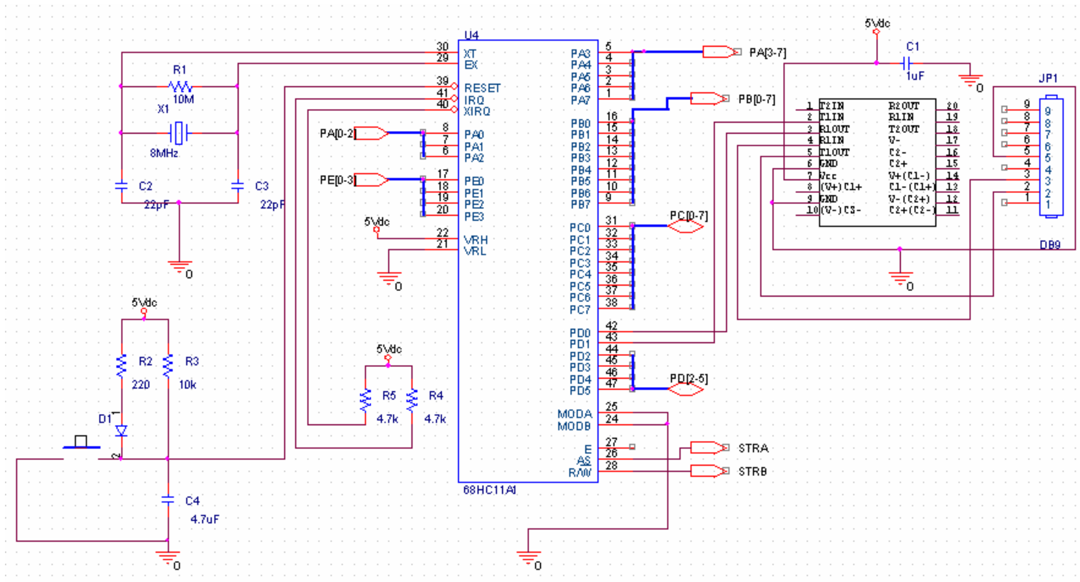


Figure 5.1: Microcontroller Main Circuit

The power supply for this schematic is 5V that provided by the 7805 voltage regulator which its input voltage is supplied from the battery. For bootstrap mode, both the Mod A and Mod B pin must be connected to ground. The reset pin of the MCU is normally set to logic high because it is active-low. When the reset button is pressed, reset pin will be set to logic low and it will be activated. The crystal used in this project is 8MHz. The clock for the MCU is quarter of the frequency of the crystal that being used, that is for this project, the clock of MCU is 2MHz. Thus the clock cycle for each is 0.5µs. MAX 233 is used for the purpose of programming the built-in EEPROM. Cable DB9 is used for the connection within PC and the MCU. MAX 233 is used so that the energy loses that will cause the data from the PC to the MCU lose during the transmission can be avoided. The pin $V_{RH}$ is connected to 5V power supply and the pin $V_{RL}$ is connected to ground to in order to use the ADC. A clock signal with 2MHz frequency and amplitude of about 5V are obtained. Thus, the result of this module reveals that the controller is operating properly.

**5.2 FM Wireless Module Test**

The FM wireless module test is carried out to discover the distance of transmission. In addition, the test is also to understand the operation of the encoder and decoder. For this reason, the test is conducted in two stages. The first stage is transmission of data using the encoder and decoder via a wire as a medium. The second stage is replacing the wired medium with a FM wireless transmission module.

**5.2.1 Encoder & Decoder Test**

The encoder and decoder from HOLTEK are used. The HT12E encoder and HT12D decoder are tested in pair as shown in figure 5.2.

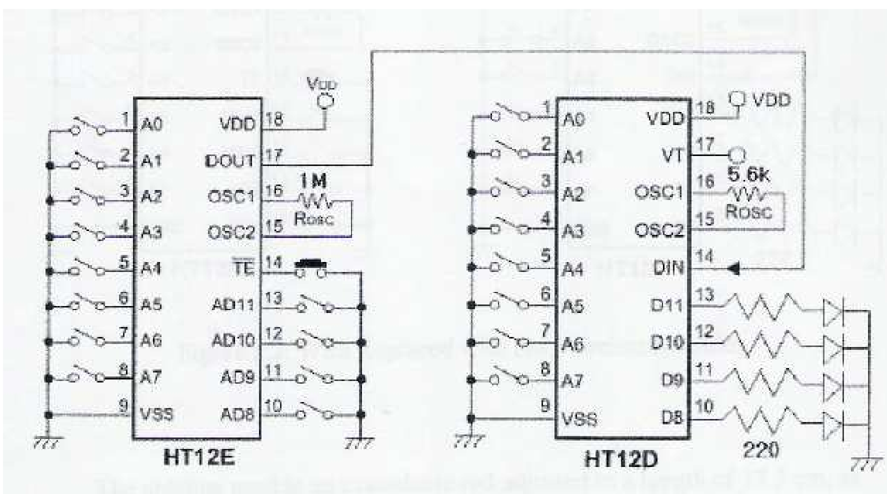


Figure 5.2: Encoder and Decoder Test Circuit

The $D_{OUT}$ of HT12E is connected directly to the $D_{IN}$ of HT12D. The input of HT12E, AD8 through AD11 are connected to switch. In similar manner, the address of both IC (A0 through A7) are connected to DIP 8 ways switch. The Rosc for HT12E is 1Mohm while the Rosc for HT12D is 47kohm. The outputs of HT12D, D0 through D11 are connected to a 220ohm resistor and LED. Pin /TE is connected to a push button and the pin VT can be left in out or connect it with a 220ohm and LED.

To enable the encode and decode process, the both addresses must be same and the push button for the pin /TE must be pressed to enable the transmission. Whenever the /TE is pressed, the pin VT will go high and when VT goes low, /TE is HIGH. If the address is different, the latch output of the decoder would not update the data as sent by encoder. Instead it holds the previous data latched. As a result, the LED at decoder will lights up accordingly to the button pressed at the encoder. The data at the decoder are similar to the data at the encoder once the pin /TE is given a logic “low”. This conclude that both encoder and decoder are performing as expected.

### 5.2.2 FM Transmitter and Receiver Test

To test the FM transmitter and receiver, the direct wire connection from $D_{OUT}$ to $D_{IN}$, is replaced with the FMTX1-433aMhz and the FMRX1-433MHz modules. Figure 5.3 shows the connection of FM wireless module with encoder and decoder.

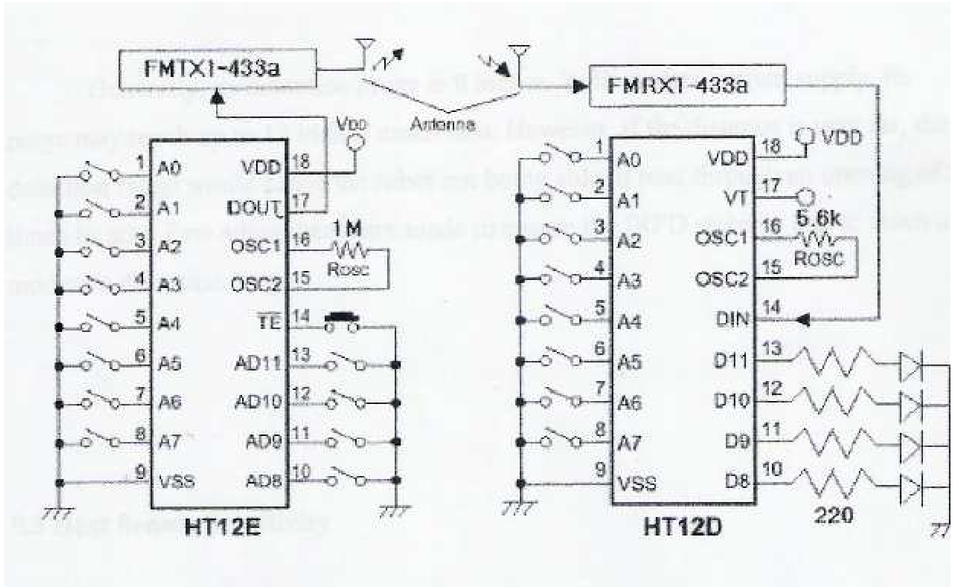


Figure 5.3: FM Wireless Modules

The frequency used by this module is 433 MHz, which will not be interfered by local radio stations. Both the transmitter and receiver must have the same frequency. The antenna used is an extendable rod adjusted to a length of 17.5cm, as calculated in Chapter 3 so that a long transmission of up to 200 meters can be achieved. The distance of the transmitter and receiver also plays an important factor. Data will not be received if the distance is less than a quarter of the wavelength that is 17.32cm. As a result, the LED at decoder will lights up accordingly to the button pressed at the encoder. The data at the decoder are similar to the data at the encoder once the pin /TE is given a logic “low”. This is obvious that the data transmission has functioned satisfactory.

## 5.3 Infra Red Proximity Detection

When IRPD is used in the system, several data must be obtained to ensure that it detects an object. Normally, 10 readings from the IRPD is required to avoid false trigger in the autonomous robot algorithm.

Generally, its detection range is 8 inches. With greater current supply, its range may reach up to 12 inches maximum. Few adjustments are made to ensure the IRPD stability and to reach a moderate detection range. Every time the IR detector detects the infra red signal, the output pin of the IR detector will be logic “low” and vice versa. Hence, this module is working properly. Figure 5.4 illustrates the IR module that had been built on the robot. There are two IR LED and 1 IR detector with green color.

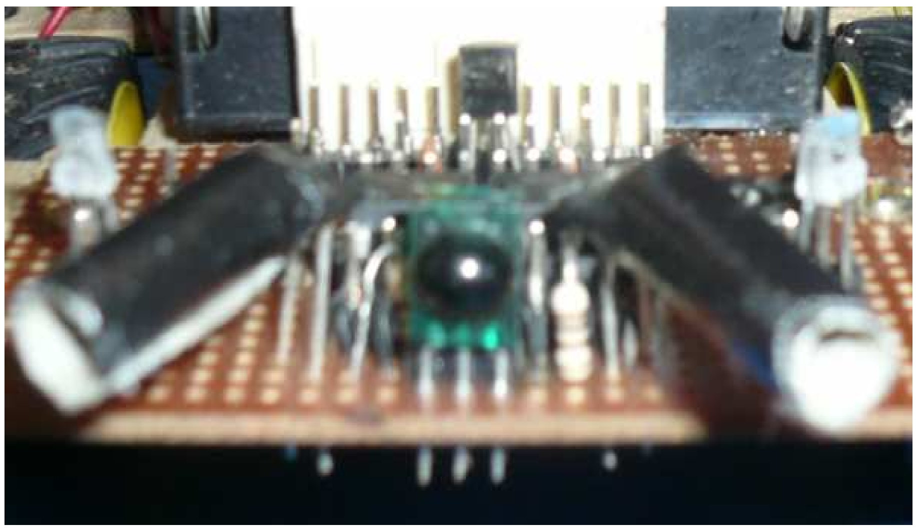

Figure 5.4: IR module built on the robot.

### 5.4 Heat Sensor Sensitivity

Figure 5.5 shows the connection of the LM35 temperature sensor. At the room temperature, the output voltage is approximately 4.4volts. For each degree of Celsius increasing, the output voltage will increase 10mV. Because of the sensitivity of LM35 is small, thus a program is needed to manipulate the data of the ADC that it converted from the output of LM35 before the data is being display on the seven segment.

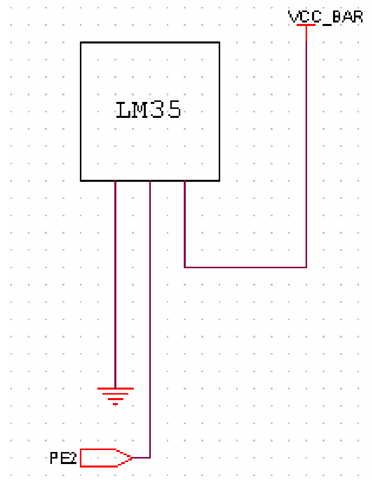


Figure 5.5: Schematic of LM35

**5.5 Light Sensor Sensitivity**

Figure 5.6 shows the connection of the TSL250R light sensor. When there are light directly flood to it, the output voltage is approximately 3.2V. The output voltage will decrease when the light intensity is decrease. When no light floods on it, the output voltage is 0V.

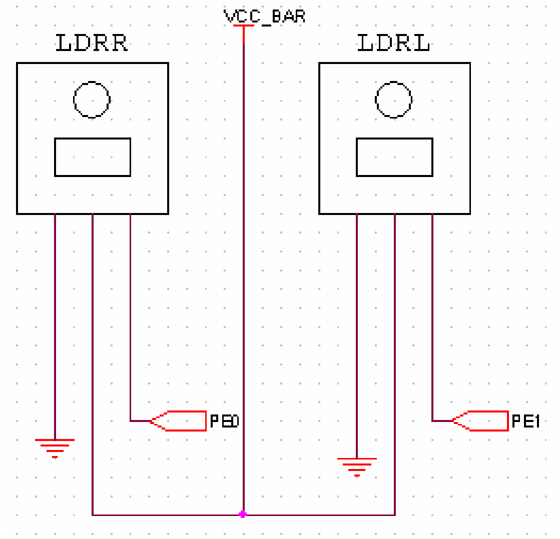


Figure 5.6: Schematic of TSL250R

**5.6 Autonomous Obstacle Avoiding Algorithm**

Before integrating the robot with the PC, a program is loaded into the robot to perform autonomous object detection and avoidance. This test shows that the robot reacts to its environment using the autonomous algorithm described in Chapter 4.

During the test, the robot is allowed to explore a small room. When the robot detects an object in front of it, it will be able to avoid the object. Most of the obstacles are avoided except if the object is black in color or it is a thin object.

# CHAPTER 6

# CONCLUSIONS

This project has successfully developed a wireless communication for an autonomous operation of a mobile robot. To implement the system, a robot is constructed from scratch using the MC68HC11 E1 microcontroller along with actuator and sensors.

In the autonomous mode, the sensors play an important role. Various sensors are applied to implement obstacle detection, and data acquisition such as the light and heat intensity within an environment.

## 6.1 Future Improvements

This project has successfully demonstrated a wireless communication for a mobile robot. Future work on this project may include:

- Full-duplex communication using different carrier frequency for each channel to reduce transmission delay.
- Integrating the manual and autonomous mode, allowing the operator to preset a targeted coordinate and allowing the robot to search the target and avoid obstacles autonomously.
- Development of a automatic charging system so that the robot automatically go to recharge when the battery is reached a critical level.
- More object sensors around the robot for a higher resolution in object detection.
- Implementation of distance measuring sensors to achieve a plot for more accurate distance of object from robot.
- Implementation of Global Positioning System (GPS) to the robot so that it can be controlled from anywhere.

### 6.2.1 Costing and Commercialization

The overall cost of the robot is around RM 400 per unit. However, if it is produced in a large amount, the cost will be reduced greatly. As this robot can be used to scout the parameter of a hazard area, thus it has the potential to be commercialized especially to the chemical field that may produce poison gas or chemical leakage. In addition, this robot also can be used as the toys and the educational equipment for the robotic student.

Furthermore, by producing the robot in a larger size and add on more features such as a robotics arm, this robot can be used to carry heavy objects and by adding a visual sensor, this robot can be used to denote the bomb.

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# APPENDIX A

## Robot Code Listings

```
*MC68HC11 REGISTERS
PORTA   EQU   $00
PACTL   EQU   $26
PORTB   EQU   $04
PORTC   EQU   $03
DDRC    EQU   $07
PORTD   EQU   $08
DDRD    EQU   $09
SPCR    EQU   $28
SCCR2   EQU   $2D
OPTION  EQU   $39
ADCTL   EQU   $30
ADR1    EQU   $31
ADR2    EQU   $32
ADR3    EQU   $33
ADR4    EQU   $34

*++++++++++RAM DIRECTIVE++++++++++++

        ORG   $0000
BILR    RMB   1
BILL    RMB   1
MOV     RMB   1
OBSTAC  RMB   1
LDRR    RMB   1
LDRL    RMB   1
HEAT    RMB   1

*+++++++PROGRAM DIRECTIVE+++++++++++

        ORG   $B600
        JSR   IN_SYS
        JSR   IN_ADC
AG      JSR   IRPD
        JSR   ADC
        JSR   SNDDATA                  ;Send Data
        LDY   #OBSTAC
        BCLR  PORTD,X     $0C
        BRSET 0,Y   $30   GRVS
        BRSET 0,Y   $20   GRGT
        BRSET 0,Y   $10   GLFT
        BRSET 0,Y   $C0   GRVS
        BRSET 0,Y   $40   GLFT
        BRSET 0,Y   $80   GRGT
        BRCLR 0,Y   $30   GFWD
        BRA   AG                       ;Simple Autonomous Object Detection
                                       ;and Avoidance Algorithm

GRGT    LDY   #1
        LDAA  #$09
        STAA  MOV
        BSET  PORTD,X     $08
        JSR   MOVE
        BRA   AG                       ;Spin Right

GLFT    LDY   #1
        LDAA  #$06
        STAA  MOV
        BSET  PORTD,X     $04
        JSR   MOVE
```

```
            BRA     AG                          ;Spin Left

GFWD        LDY     #2
            LDAA    #$0A
            BSET    PORTD,X     $0C
            JSR     MOVE
            BRA     AG                          ;Move Forward

GRVS        LDY     #2
            LDAA    MOV
            BSET    PORTD,X     $00
            JSR     MOVE
            BRA     AG                          ;Spin Previous

++++++++++SYSTEM INITIALIZE++++++++++

IN_SYS      LDX     #$1000
            LDAA    #$08
            STAA    PACTL,X
            LDAA    #$F0
            STAA    DDRC,X
            BCLR    SPCR,X $60
            BCLR    SCCR2,X     $0C
            BSET    DDRD,X      $3C
            LDAA    #$10
            STAA    PORTD,X
            RTS

++++++++++ADC INITIALIZE++++++++++++

IN_ADC      BSET    OPTION,X $80
            BCLR    OPTION,X $40
            BSR     DELAY100
            RTS

DELAY100
            LDAA    #40
DLY100      DECA
            BNE     DLY100
            RTS                                 ;ADC Delay

++++++++++ADC CONVERSATION++++++++++

ADC         LDAA    #$10
            STAA    ADCTL,X
CCF         BRCLR   ADCTL,X     $80     CCF
            LDAA    ADR1,X
            STAA    LDRR
            LDAA    ADR2,X
            STAA    LDRL
            LDAA    ADR3,X
            STAA    HEAT
            RTS                                 ;Converts ADC from PortE to
                                                ;Digital Values

+++++++++++++MOVE++++++++++++++++++

MOVE        STAA    PORTB,X
GO          BSET    PORTA,X     $60             ;Enable Motor Driver
            JSR     MTR_DLY
```

```
            JSR     DIRC
            BCLR    PORTA,X       $60              ;Disable Motor Driver
            JSR     MTR_DLY
            DEY
            BNE     GO
            RTS

+++++++++MOVE DELAY++++++++++++++++

MTR_DLY     PSHX
            LDX     #3000
LP_MTR      DEX
            BNE     LP_MTR
            PULX
            RTS

++++++++OBSTACLE CHECKING+++++++++++

IRPD        PSHY
            LDY     #OBSTAC
            CLR     BILR
            CLR     BILL
            CLR     OBSTAC
            LDAB    #10
            BSET    PORTA,X       $10
CHKR        JSR     IR_DLY
            BRSET   PORTA,X       $04     NOR
            INC     BILR
NOR         DECB
            BNE     CHKR                           ;Check right IR 10 times
            BCLR    PORTA,X       $10

            LDAB    #10
            BSET    PORTA,X       $08
CHKL        JSR     IR_DLY
            BRSET   PORTA,X       $04     NOL
            INC     BILL
NOL         DECB
            BNE     CHKL                           ;Check left IR 10 times
            BCLR    PORTA,X       $08

            LDAA    #$0A
            CMPA    BILR
            BHI     SETIRL
            BSET    0,Y     $10                    ;Set for right IR bit in OBSTAC if
                                                   ;valid

SETIRL      LDAA    #$0A
            CMPA    BILL
            BHI     SETWHR
            BSET    0,Y     $20                    ;Set for left IR bit in OBSTAC if valid

SETWHR      BRSET   PORTA,X       $02     SETWHL
            BSET    0,Y     $40                    ;Set for right wheel bit in OBSTAC if
                                                   ;valid

SETWHL      BRSET   PORTA,X       $01     IRPDQ
            BSET    0,Y     $80                    ;Set for left wheel bit in OBSTAC if
                                                   ;valid
```

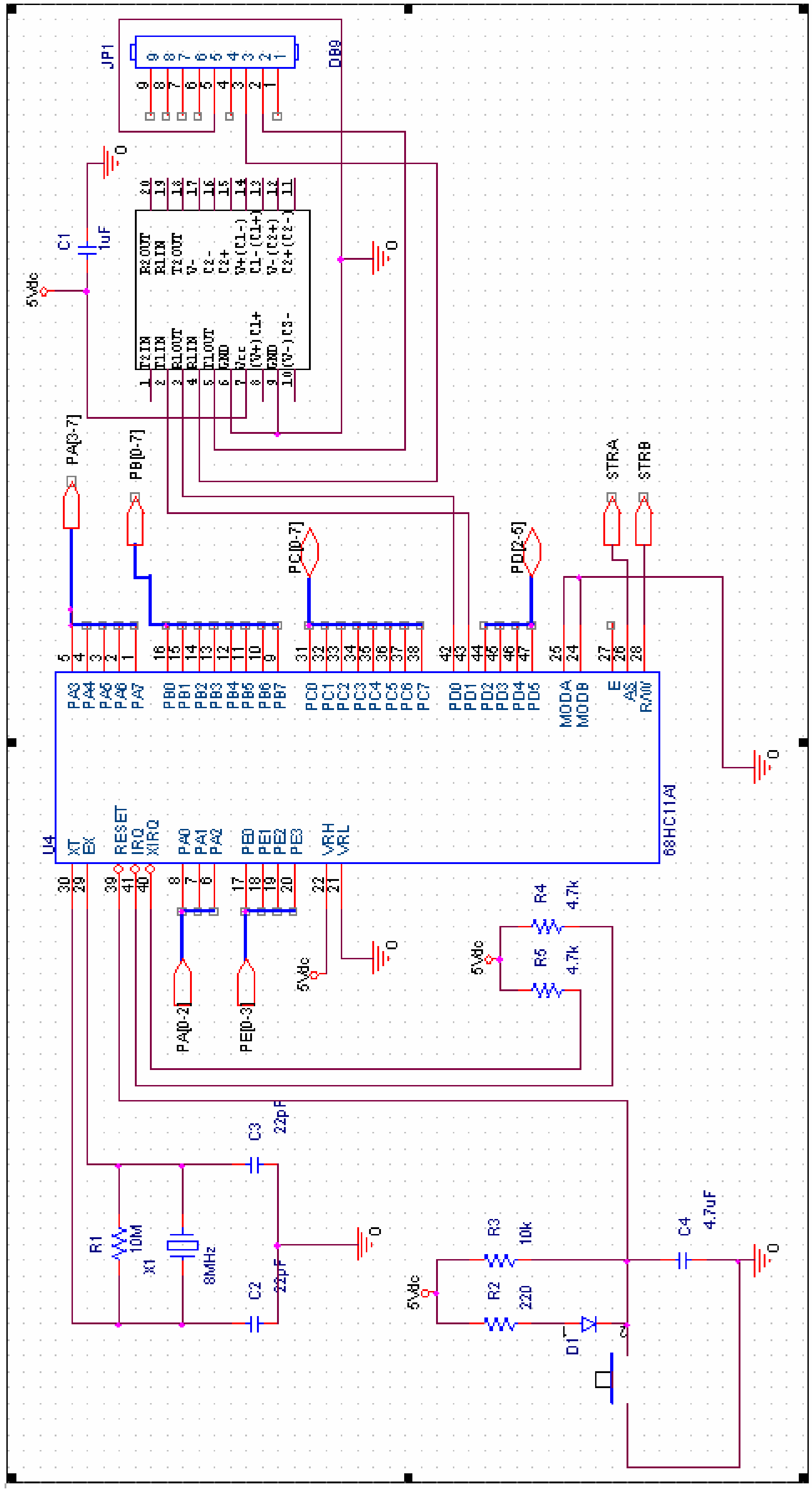
```
IRPDQ    PULY
         RTS

+++++++++++++IR DELAY+++++++++++++++

IR_DLY   PSHX
         LDX    #50
LP_IR    DEX
         BNE    LP_IR
         PULX
         RTS

++++++++++++SEND DATA+++++++++++++++

SNDDATA  BRSET  PORTA,X    $80    SNDDATA
         BSET   PORTD,X    $10
         LDAA   HEAT
         JSR    TX
         JSR    TX_DLY
         LDAA   HEAT
         ROLA
         ROLA
         ROLA
         ROLA
         ANDA   #$F0
         JSR    TX
         JSR    TX_DLY
         RTS

DIRC     PSHA
         LDAA   MOV
         CMPA   #$09
         BEQ    RIGHT
         CMPA   #$06
         BEQ    LEFT
         CMPA   #$0A
         BEQ    FORWARD

RIGHT    LDAA   #$90
         BSR    TX
         BRA    RET

LEFT     LDAA   #$60
         BSR    TX
         BRA    RET

FORWARD  LDAA   #$A0
         BSR    TX
         BRA    RET

RET      PULA
         RTS

+++++++++++++++TRANSMIT++++++++++++++

TX       STAA   PORTC,X
         BCLR   PORTD,X    $10
         BSR    TX_DLY
         BSET   PORTD,X    $10
         RTS
```

++++++++++++TRANSMIT DELAY+++++++++++

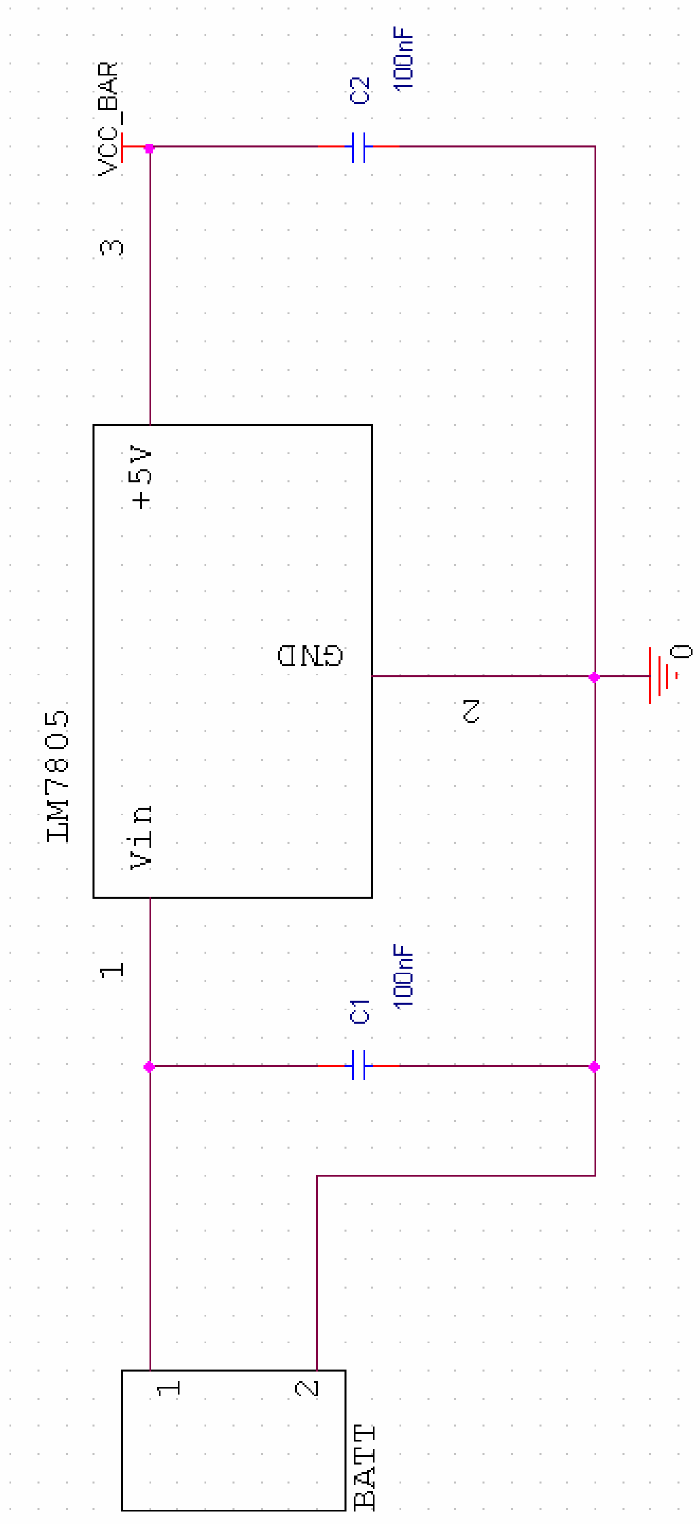
```
TX_DLY    PSHY
          LDY    #300
REAG      DEY
          BNE    REAG
          PULY
          RTS
```

# APPENDIX B

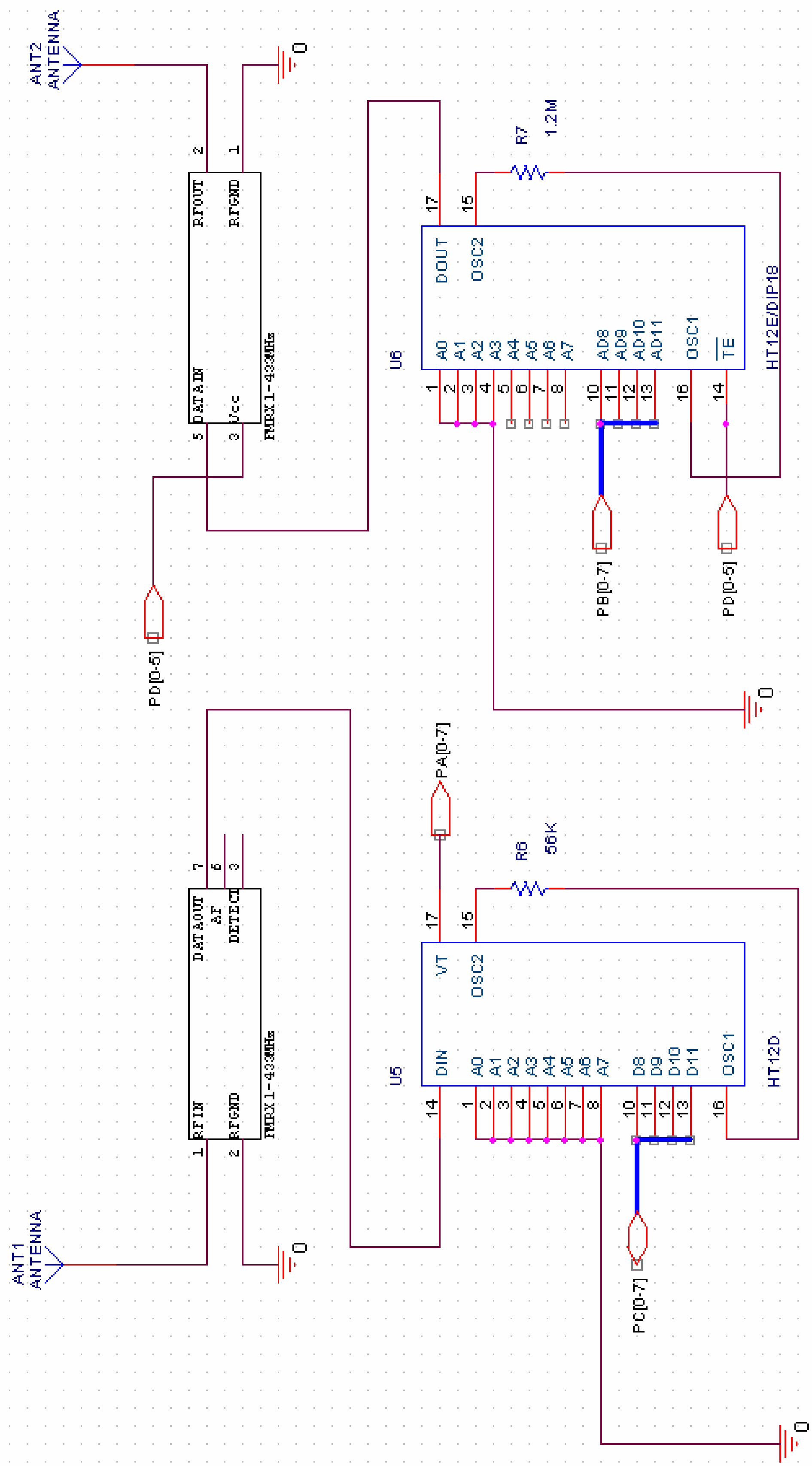
## Robot Schematics



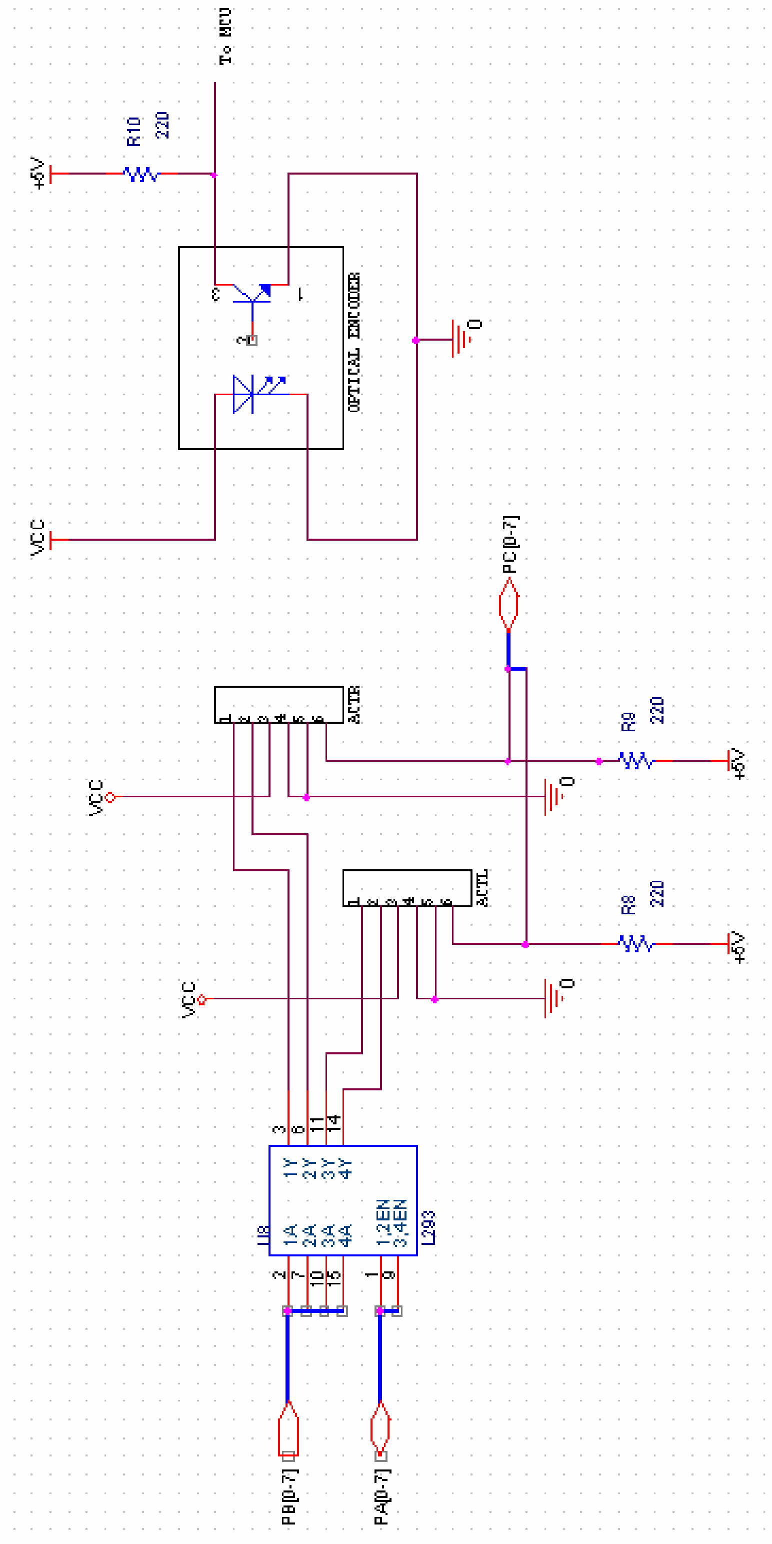

MICROCONTROLLER MAIN BOARD CIRCUIT



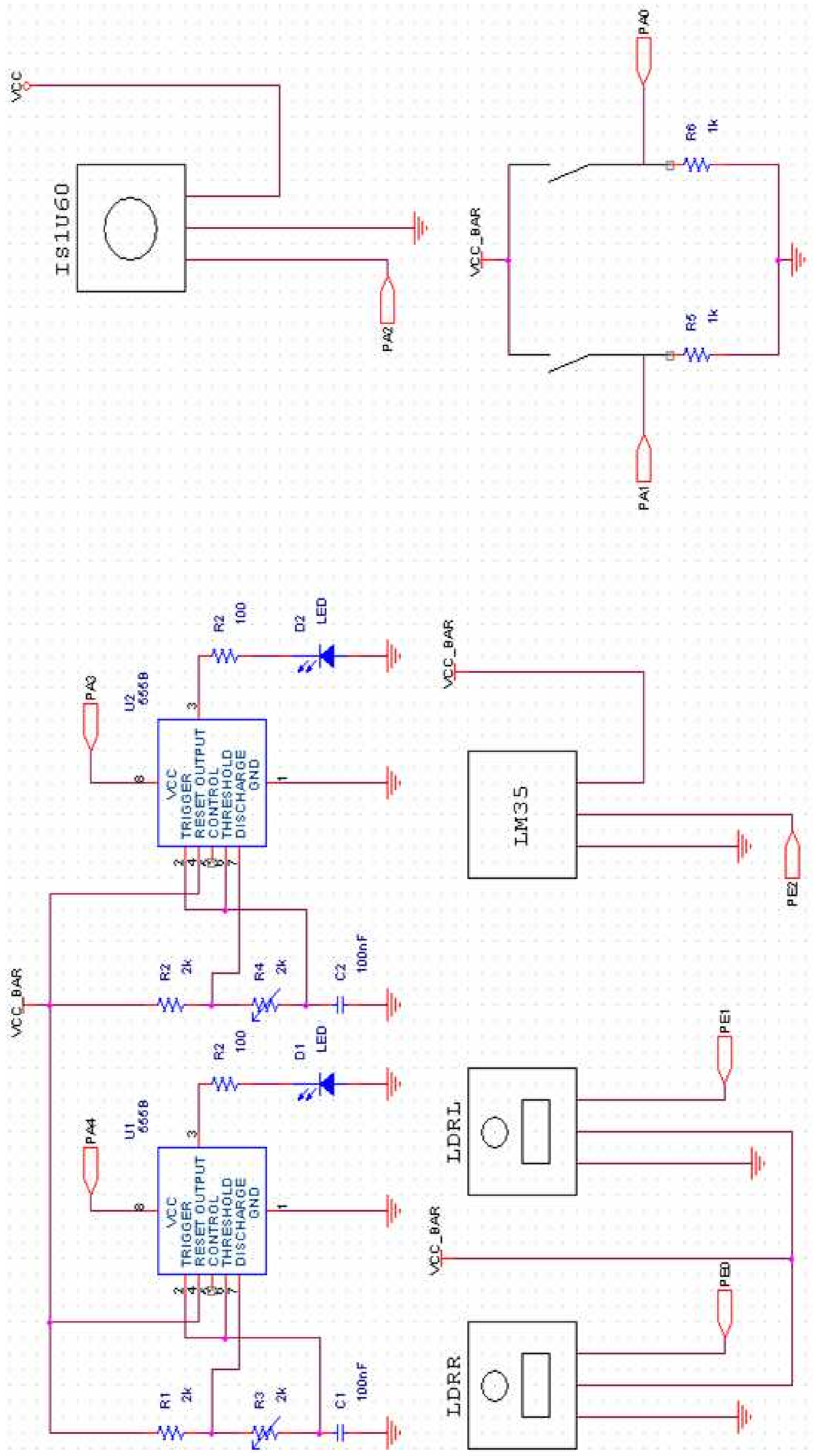

POWER SUPPLY CIRCUIT




FM WIRELESS TRANSMISSION: TRANSMITTER AND RECEIVER SCHEMATIC




MOTOR DRIVER L293D AND OPTICAL ENCODER CIRCUIT

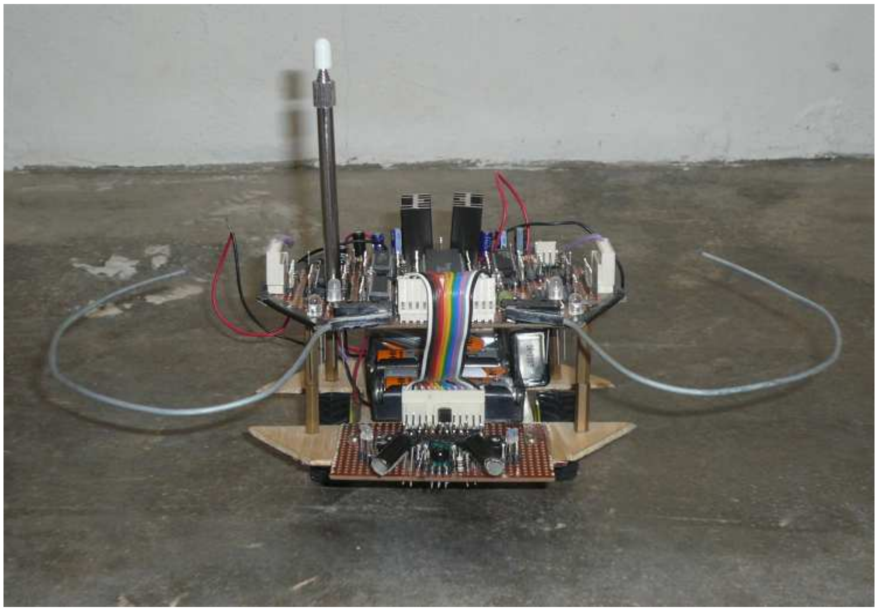


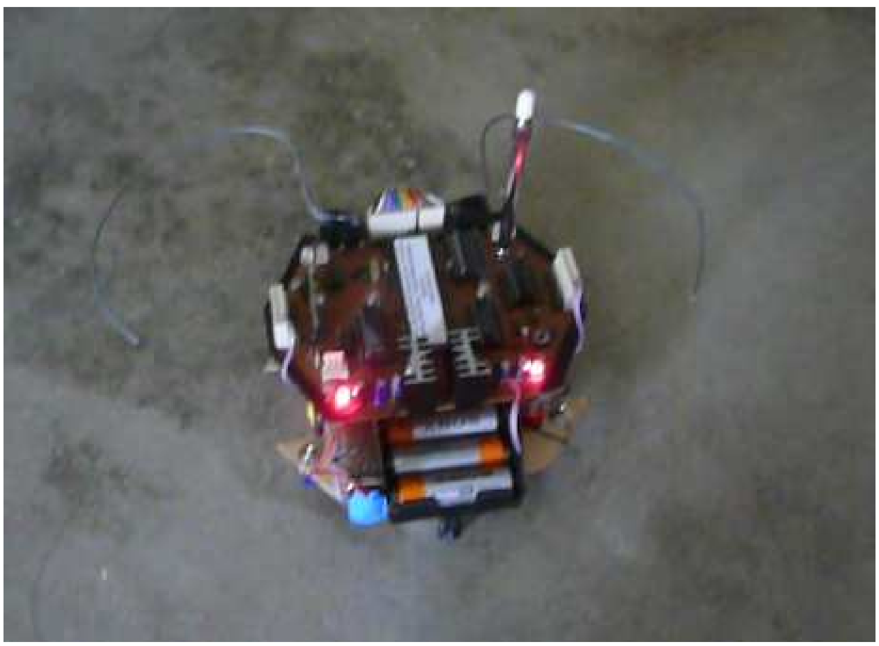

SENSORS CIRCUIT

# APPENDIX C

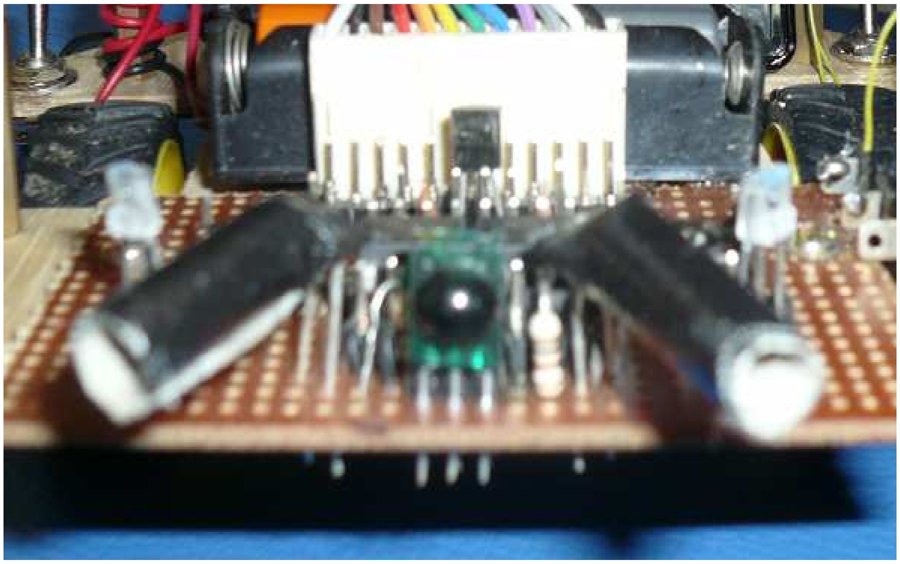
# Photos

**1. The complete structure of the robot**

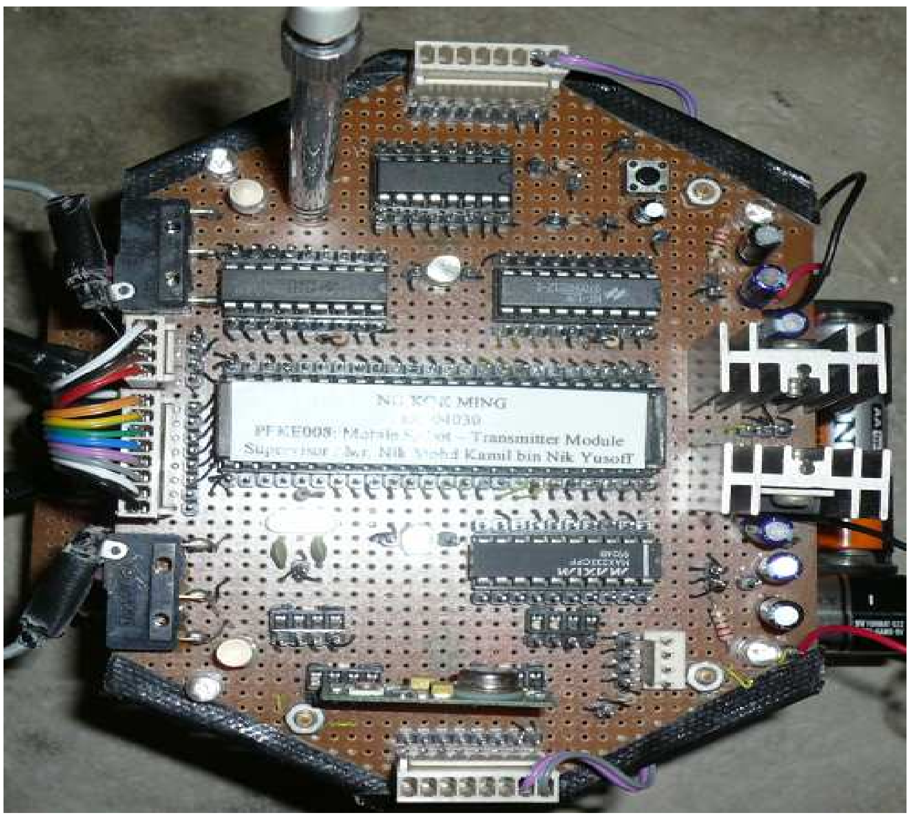




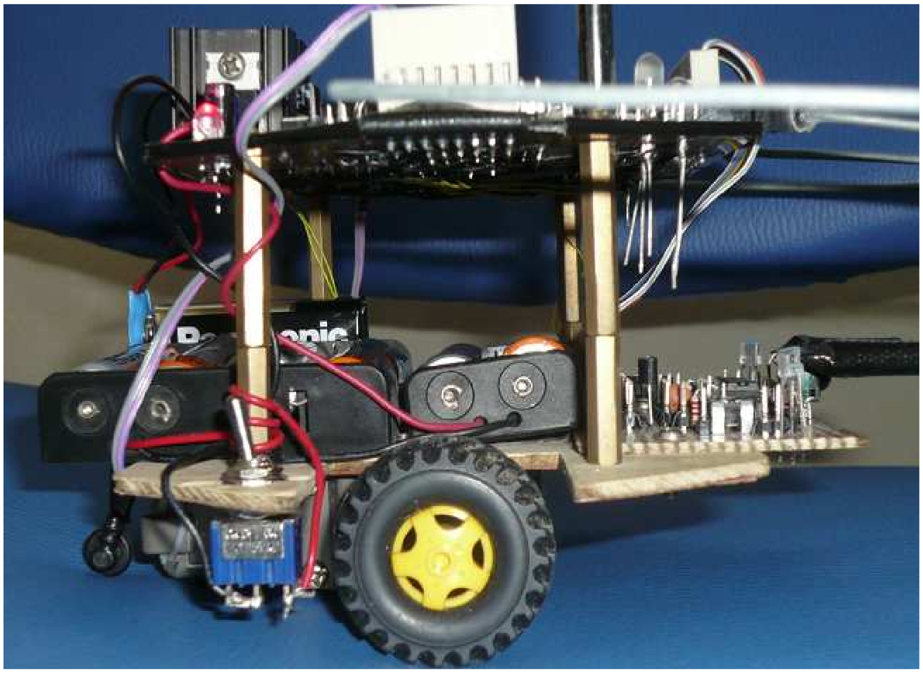
**The head of the robot. LDR, IRPD and Heat sensor are on this segment.**



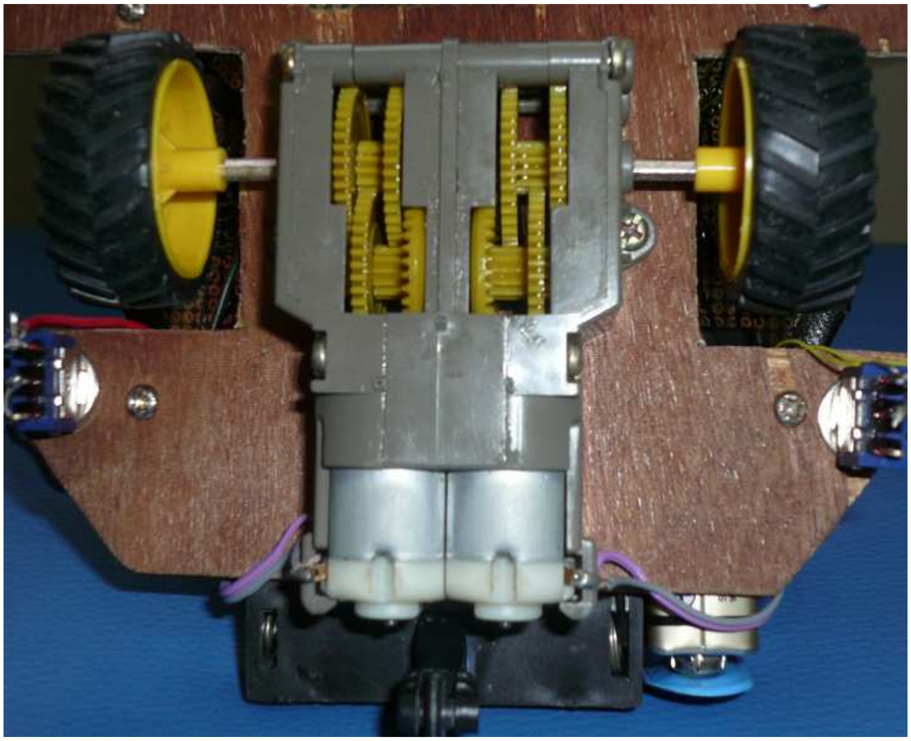
**The Main board of the Robot. Includes the MCU, Motor Driver, FM Wireless Interface, RS-232 Interface & Whisker Bumpers.**



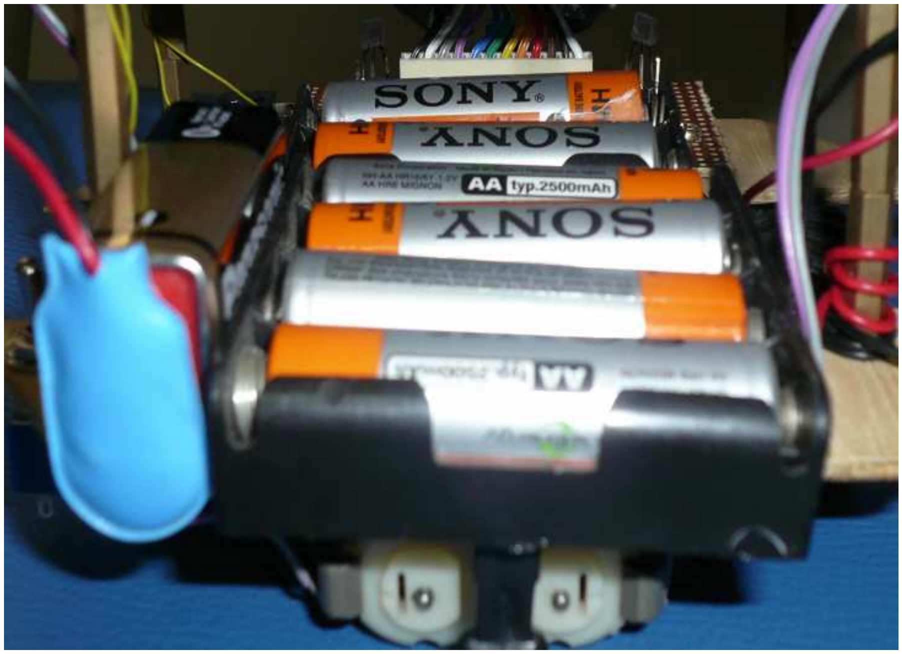
**A side view on the robot platform.**



**A view on the TAMIYA Twin Gear Box Set and the DC motors.**



**The Battery as the Power Supply to the Robot.**



# APPENDIX D

# Datasheets

# M68HC11 E SERIES

## HCMOS MICROCONTROLLER UNIT

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# SECTION 1 INTRODUCTION

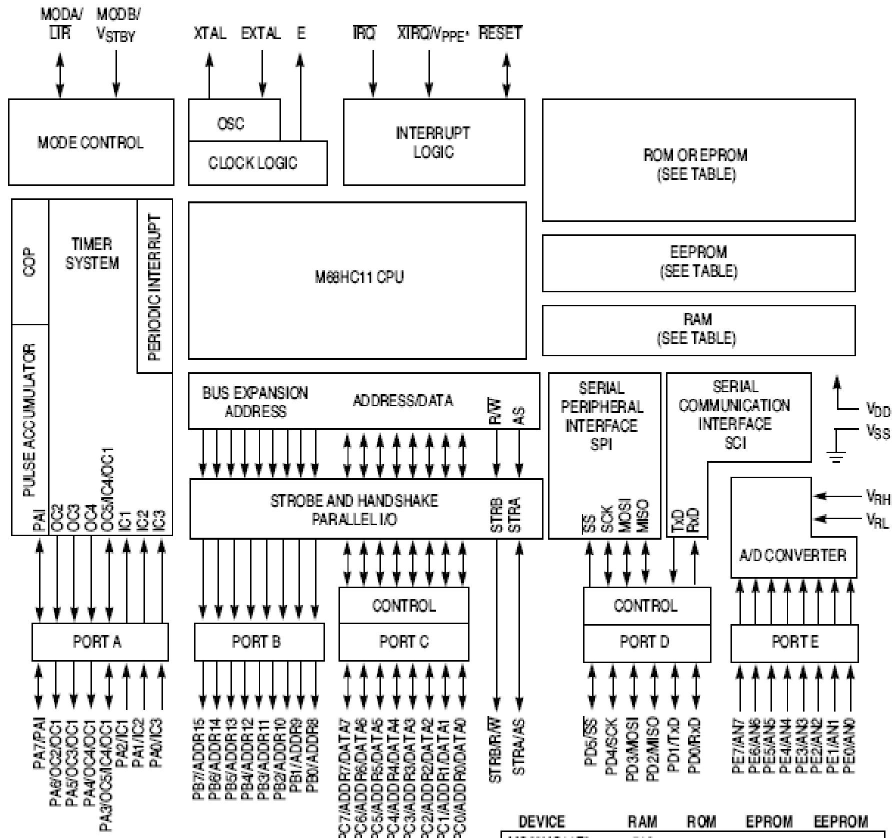
This document contains a detailed description of the M68HC11 E series of 8-bit microcontroller units (MCUs). These MCUs all combine the M68HC11 CPU with high-performance, on-chip peripherals. The E series is comprised of many devices with various configurations of RAM, ROM or EPROM, and EEPROM. Several low-voltage devices are also available. With the exception of a few minor differences, the operation of all E-series MCUs is identical. A fully static design and high-density complementary metal-oxide semiconductor (HCMOS) fabrication process allow E-series devices to operate at frequencies from 3 MHz to dc, with very low power consumption.

## 1.1 Features

- M68HC11 CPU
- Power Saving STOP and WAIT Modes
- Low-Voltage Devices Available (3.0 – 5.5 Vdc or 2.7 – 5.5 Vdc)
- 0, 256, 512, or 768 Bytes of On-Chip RAM, Data Retained During Standby
- 0, 12, or 20 Kbytes of On-Chip ROM or EPROM
- 0, 512, or 2048 Bytes of On-Chip EEPROM with Block Protect for Security
  - — 2048 bytes of EEPROM with selectable base address in MC68HC811E2
- Asynchronous Nonreturn to Zero (NRZ) Serial Communications Interface (SCI)
  - — Additional Baud Rates Available on MC68HC(7)11E20
- Synchronous Serial Peripheral Interface (SPI)
- 8-Channel 8-Bit Analog-to-Digital (A/D) Converter
- 16-Bit Timer System
  - — Three Input Capture (IC) Channels
  - — Four Output Compare (OC) Channels
  - — One Additional Channel, Selectable as Fourth IC or Fifth OC
- 8-Bit Pulse Accumulator
- Real-Time Interrupt Circuit
- Computer Operating Properly (COP) Watchdog System
- 38 General-Purpose Input/Output (I/O) Pins
  - — 16 Bidirectional I/O Pins
  - — 11 Input-Only Pins
  - — 11 Output-Only Pins
- Several Packaging Options
  - — 52-Pin Plastic Leaded Chip Carrier (PLCC)
  - — 52-Pin Windowed Ceramic Leaded Chip Carrier (CLCC)
  - — 52-Pin Plastic Thin Quad Flat Pack, 10 mm X 10 mm (TQFP)
  - — 64-Pin Plastic Quad Flat Pack (QFP)
  - — 48-Pin Plastic Dual In-Line Package (DIP), MC68HC811E2 only
  - — 56-Pin Plastic Dual In-Line Package, .070" Lead Spacing (SDIP)

## 1.2 Structure

Below is the functional diagram of the E-series MCUs. Differences among devices are noted in the table.




| DEVICE | RAM | ROM | EPROM | EEPROM |
|---|---|---|---|---|
| MC68HC11E0 | 512 | — | — | — |
| MC68HC11E1 | 512 | — | — | 512 |
| MC68HC11E8 | 512 | 12K | — | — |
| MC68HC11E9 | 512 | 12K | — | 512 |
| MC68HC711E9 | 512 | — | 12K | 512 |
| MC68HC11E20 | 768 | 20K | — | 512 |
| MC68HC711E20 | 768 | — | 20K | 512 |
| MC68HC811E2 | 256 | — | — | 2048 |

* $V_{PPE}$ APPLIES ONLY TO DEVICES WITH EPROM/OTPROM.

E SERIES BLOCK

**Figure 1-1 M68HC11 E-Series Block Diagram**

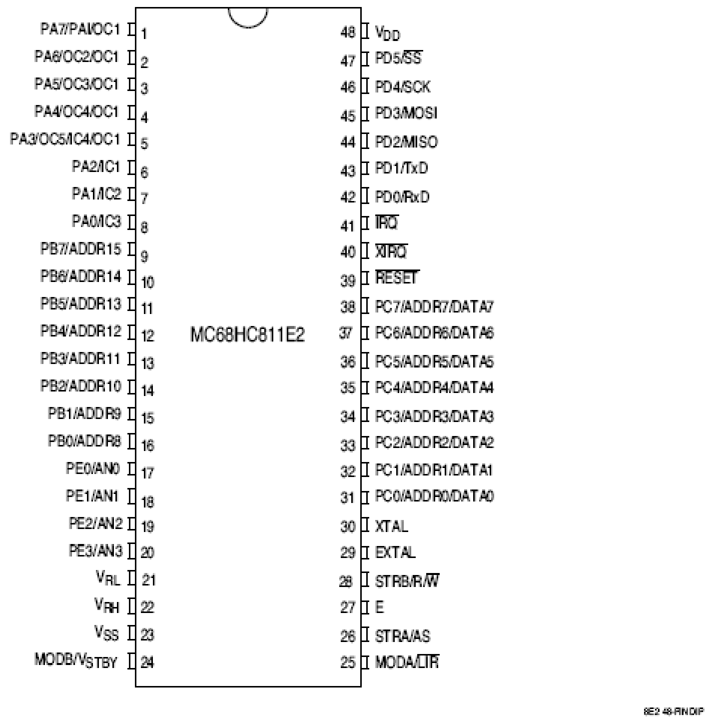



**Figure 2-5 Pin Assignments for 48-Pin DIP (MC68HC811E2)**

### 2.1 $V_{DD}$ and $V_{SS}$

Power is supplied to the MCU through $V_{DD}$ and $V_{SS}$. $V_{DD}$ is the power supply, $V_{SS}$ is ground. The MCU operates from a single 5-volt (nominal) power supply. Low-voltage devices in the E series operate at either 3.0 – 5.5 volts or 2.7 – 5.5 volts. Very fast signal transitions occur on the MCU pins. The short rise and fall times place high, short duration current demands on the power supply. To prevent noise problems, provide good power supply bypassing at the MCU. Also, use bypass capacitors that have good high-frequency characteristics and situate them as close to the MCU as possible. Bypass requirements vary, depending on how heavily the MCU pins are loaded.

### 2.2 $\overline{RESET}$

A bidirectional control signal, $\overline{RESET}$, acts as an input to initialize the MCU to a known start-up state. It also acts as an open-drain output to indicate that an internal failure has been detected in either the clock monitor or COP watchdog circuit. The CPU distinguishes between internal and external reset conditions by sensing whether the reset pin rises to a logic one in less than two E-clock cycles after a reset has occurred. Do

KEC
KOREA ELECTRONICS CO.,LTD.

SEMICONDUCTOR
TECHNICAL DATA

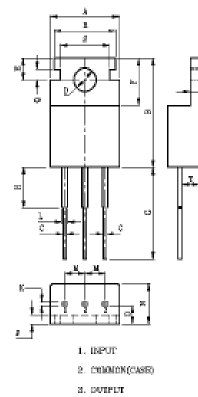
# KIA7805AP/API~ KIA7824AP/API

BIPOLAR LINEAR INTEGRATED CIRCUIT

THREE TERMINAL POSITIVE VOLTAGE REGULATORS
5V, 6V, 8V, 9V, 10V, 12V, 15V, 18V, 20V, 24V.

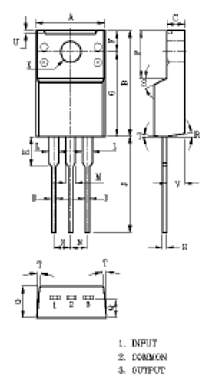
## FEATURES

- Suitable for C-MOS, TTL, the Other Digital IC's Power Supply.
- Internal Thermal Overload Protection.
- Internal Short Circuit Current Limiting.
- Output Current in Excess of 1A.
- Satisfies IEC-65 Specification. (International Electronical Commission).




| DIM | MILLIMETERS |
|---|---|
| A | 10.30 MAX |
| B | 15.30 MAX |
| C | 0.80 |
| D | φ3.60±0.20 |
| E | 3.00 |
| F | 6.70 MAX |
| G | 13.60±0.50 |
| H | 5.60 MAX |
| J | 1.27 MAX |
| K | 0.50 |
| L | 1.50 MAX |
| M | 2.54 |
| N | 4.70 MAX |
| O | 2.60 |
| P | 1.50 MAX |
| Q | 1.50 |
| R | 9.50±0.20 |
| S | 8.00±0.20 |
| T | 2.90 MAX |

TO-220AB




| DIM | MILLIMETERS |
|---|---|
| A | 10.34 MAX |
| B | 15.34 MAX |
| C | 2.70±0.30 |
| D | 0.85 MAX |
| E | φ3.20±0.20 |
| F | 3.00±0.30 |
| G | 12.34 MAX |
| H | 0.75 MAX |
| J | 13.60±0.50 |
| K | 3.34 MAX |
| L | 1.20 |
| M | 1.30 |
| N | 2.54 |
| O | 4.50±0.20 |
| P | 6.00 |
| Q | 2.60±0.20 |
| R | 10° |
| S | 28° |
| T | 5° |
| U | 0.5 |
| V | 2.60±0.15 |

TO-220IS

## MAXIMUM RATINGS (Ta=25℃)

| CHARACTERISTIC | | SYMBOL | RATING | UNIT |
|---|---|---|---|---|
| Input Voltage | KIA7805AP/API~ KIA7815AP/API | $V_{IN}$ | 35 | V |
| | KIA7818AP/API~ KIA7824AP/API | | 40 | |
| Power Dissipation (Tc=25℃) | | $P_D$ | 20.8 | W |
| Power Dissipation (Without Heatsink) | KIA7805API~ KIA7824API | $P_D$ | 2.0 | W |
| Operating Junction Temperature | | $T_j$ | -30~150 | ℃ |
| Storage Temperature | | $T_{stg}$ | -55~150 | ℃ |

19-4323; Rev 10; 8/01

MAXIM

# +5V-Powered, Multichannel RS-232 Drivers/Receivers

MAX220–MAX249

## General Description

The MAX220–MAX249 family of line drivers/receivers is intended for all EIA/TIA-232E and V.28/V.24 communications interfaces, particularly applications where ±12V is not available.

These parts are especially useful in battery-powered systems, since their low-power shutdown mode reduces power dissipation to less than 5μW. The MAX225, MAX233, MAX235, and MAX245/MAX246/MAX247 use no external components and are recommended for applications where printed circuit board space is critical.

## Applications

Portable Computers

Low-Power Modems

Interface Translation

Battery-Powered RS-232 Systems

Multidrop RS-232 Networks

## Features

### Superior to Bipolar

- ♦ Operate from Single +5V Power Supply (+5V and +12V—MAX231/MAX239)
- ♦ Low-Power Receive Mode in Shutdown (MAX223/MAX242)
- ♦ Meet All EIA/TIA-232E and V.28 Specifications
- ♦ Multiple Drivers and Receivers
- ♦ 3-State Driver and Receiver Outputs
- ♦ Open-Line Detection (MAX243)

## Ordering Information

| PART | TEMP. RANGE | PIN-PACKAGE |
|---|---|---|
| MAX220CPE | 0°C to +70°C | 16 Plastic DIP |
| MAX220CSE | 0°C to +70°C | 16 Narrow SO |
| MAX220CWE | 0°C to +70°C | 16 Wide SO |
| MAX220C/D | 0°C to +70°C | Dice* |
| MAX220EPE | -40°C to +85°C | 16 Plastic DIP |
| MAX220ESE | -40°C to +85°C | 16 Narrow SO |
| MAX220EWE | -40°C to +85°C | 16 Wide SO |
| MAX220EJE | -40°C to +85°C | 16 CERDIP |
| MAX220MJE | -55°C to +125°C | 16 CERDIP |

***Ordering Information continued at end of data sheet.***

*Contact factory for dice specifications.*

## Selection Table

| Part Number | Power Supply (V) | No. of RS-232 Drivers/Rx | No. of Ext. Caps | Nominal Cap. Value (μF) | SHDN & Three-State | Rx Active in SHDN | Data Rate (kbps) | Features |
|---|---|---|---|---|---|---|---|---|
| MAX220 | +5 | 2/2 | 4 | 0.1 | No | — | 120 | Ultra-low-power, industry-standard pinout |
| MAX222 | +5 | 2/2 | 4 | 0.1 | Yes | — | 200 | Low-power shutdown |
| MAX223 (MAX213) | +5 | 4/5 | 4 | 1.0 (0.1) | Yes | ✔ | 120 | MAX241 and receivers active in shutdown |
| MAX225 | +5 | 5/5 | 0 | — | Yes | ✔ | 120 | Available in SO |
| MAX230 (MAX200) | +5 | 5/0 | 4 | 1.0 (0.1) | Yes | — | 120 | 5 drivers with shutdown |
| MAX231 (MAX201) | +5 and +7.5 to +13.2 | 2/2 | 2 | 1.0 (0.1) | No | — | 120 | Standard +5/+12V or battery supplies; same functions as MAX232 |
| MAX232 (MAX202) | +5 | 2/2 | 4 | 1.0 (0.1) | No | — | 120 (64) | Industry standard |
| MAX232A | +5 | 2/2 | 4 | 0.1 | No | — | 200 | Higher slew rate, small caps |
| MAX233 (MAX203) | +5 | 2/2 | 0 | — | No | — | 120 | No external caps |
| MAX233A | +5 | 2/2 | 0 | — | No | — | 200 | No external caps, high slew rate |
| MAX234 (MAX204) | +5 | 4/0 | 4 | 1.0 (0.1) | No | — | 120 | Replaces 1488 |
| MAX235 (MAX205) | +5 | 5/5 | 0 | — | Yes | — | 120 | No external caps |
| MAX236 (MAX206) | +5 | 4/3 | 4 | 1.0 (0.1) | Yes | — | 120 | Shutdown, three state |
| MAX237 (MAX207) | +5 | 5/3 | 4 | 1.0 (0.1) | No | — | 120 | Complements IBM PC serial port |
| MAX238 (MAX208) | +5 | 4/4 | 4 | 1.0 (0.1) | No | — | 120 | Replaces 1488 and 1489 |
| MAX239 (MAX209) | +5 and +7.5 to +13.2 | 3/5 | 2 | 1.0 (0.1) | No | — | 120 | Standard +5/+12V or battery supplies; single-package solution for IBM PC serial port |
| MAX240 | +5 | 5/5 | 4 | 1.0 | Yes | — | 120 | DIP or flatpack package |
| MAX241 (MAX211) | +5 | 4/5 | 4 | 1.0 (0.1) | Yes | — | 120 | Complete IBM PC serial port |
| MAX242 | +5 | 2/2 | 4 | 0.1 | Yes | ✔ | 200 | Separate shutdown and enable |
| MAX243 | +5 | 2/2 | 4 | 0.1 | No | — | 200 | Open-line detection simplifies cabling |
| MAX244 | +5 | 8/10 | 4 | 1.0 | No | — | 120 | High slew rate |
| MAX245 | +5 | 8/10 | 0 | — | Yes | ✔ | 120 | High slew rate, int. caps, two shutdown modes |
| MAX246 | +5 | 8/10 | 0 | — | Yes | ✔ | 120 | High slew rate, int. caps, three shutdown modes |
| MAX247 | +5 | 8/9 | 0 | — | Yes | ✔ | 120 | High slew rate, int. caps, nine operating modes |
| MAX248 | +5 | 8/8 | 4 | 1.0 | Yes | ✔ | 120 | High slew rate, selective half-chip enables |
| MAX249 | +5 | 6/10 | 4 | 1.0 | Yes | ✔ | 120 | Available in quad flatpack package |



***For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.***

# +5V-Powered, Multichannel RS-232 Drivers/Receivers



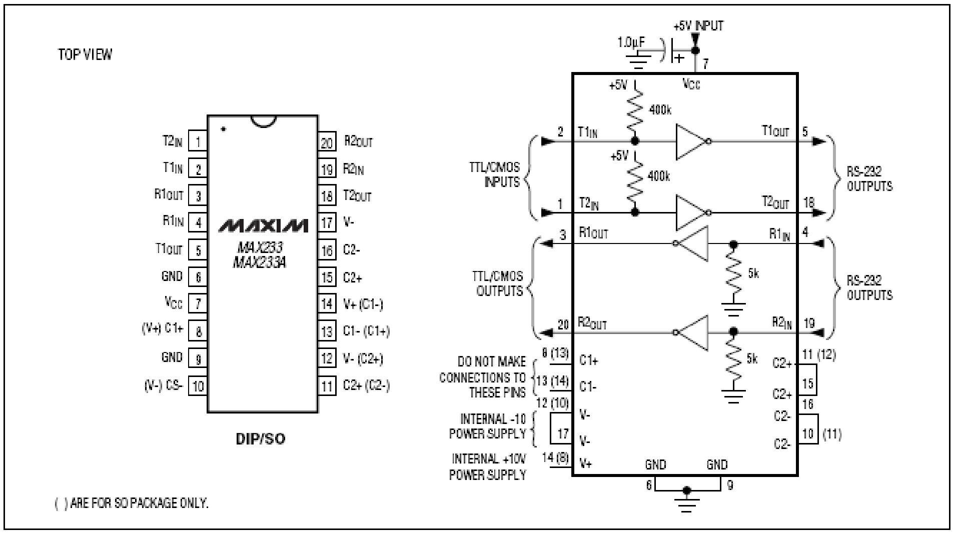



*Figure 11. MAX233/MAX233A Pin Configuration and Typical Operating Circuit*

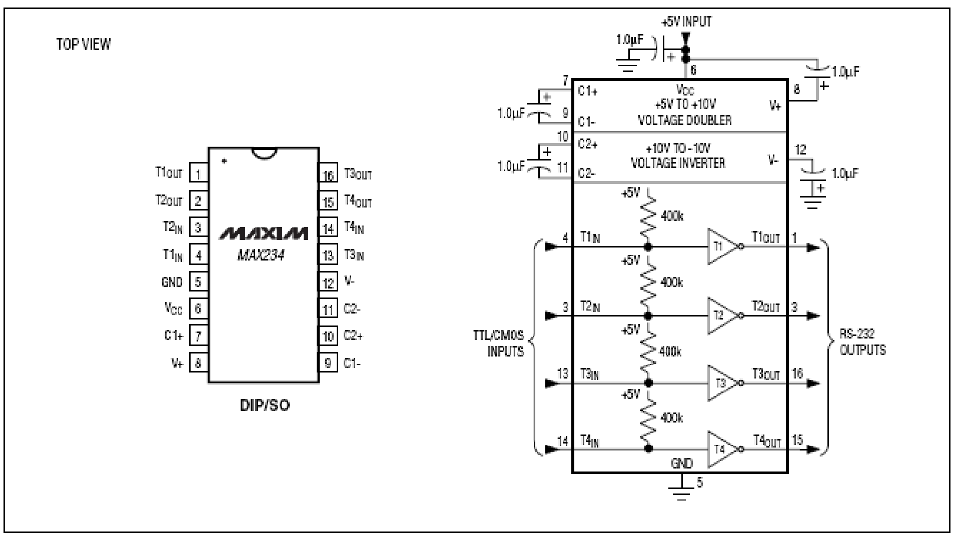



*Figure 12. MAX234 Pin Configuration and Typical Operating Circuit*

# HT12A/HT12E
## $2^{12}$ Series of Encoders

### Features

- Operating voltage
  - 2.4V~5V for the HT12A
  - 2.4V~12V for the HT12E
- Low power and high noise immunity CMOS technology
- Low standby current: 0.1μA (typ.) at $V_{DD}$=5V
- HT12A with a 38kHz carrier for infrared transmission medium
- Minimum transmission word
  - Four words for the HT12E
  - One word for the HT12A
- Built-in oscillator needs only 5% resistor
- Data code has positive polarity
- Minimal external components
- HT12A/E: 18-pin DIP/20-pin SOP package

### Applications

- Burglar alarm system
- Smoke and fire alarm system
- Garage door controllers
- Car door controllers
- Car alarm system
- Security system
- Cordless telephones
- Other remote control systems

### General Description

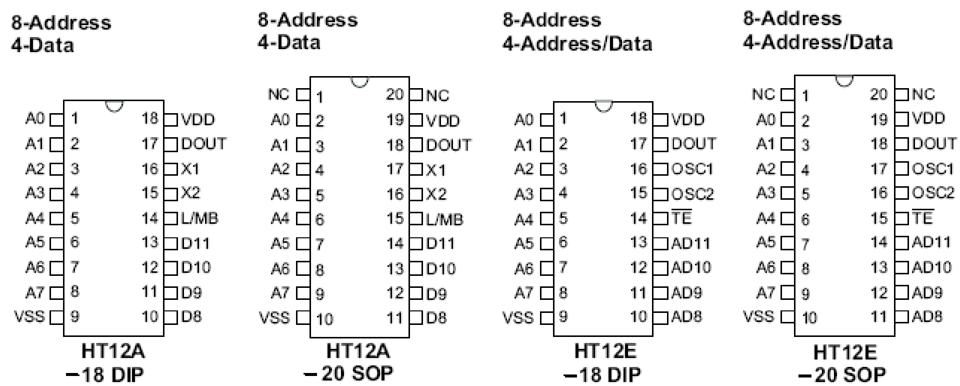
The $2^{12}$ encoders are a series of CMOS LSIs for remote control system applications. They are capable of encoding information which consists of N address bits and 12–N data bits. Each address/data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF or an infrared transmission medium upon receipt of a trigger signal. The capability to select a $\overline{TE}$ trigger on the HT12E or a DATA trigger on the HT12A further enhances the application flexibility of the $2^{12}$ series of encoders. The HT12A additionally provides a 38kHz carrier for infrared systems.

### Selection Table

| Function / Part No. | Address No. | Address/ Data No. | Data No. | Oscillator | Trigger | Package | Carrier Output | Negative Polarity |
|---|---|---|---|---|---|---|---|---|
| HT12A | 8 | 0 | 4 | 455kHz resonator | D8~D11 | 18 DIP<br>20 SOP | 38kHz | No |
| HT12E | 8 | 4 | 0 | RC oscillator | $\overline{TE}$ | 18 DIP<br>20 SOP | No | No |

Note: Address/Data represents pins that can be address or data according to the decoder requirement.

## Pin Assignment




## Pin Description

| Pin Name | I/O | Internal Connection | Description |
|---|---|---|---|
| A0~A7 | I | CMOS IN<br>Pull-high<br>(HT12A)<br>NMOS<br>TRANSMISSION<br>GATE<br>PROTECTION<br>DIODE<br>(HT12E) | Input pins for address A0~A7 setting<br>These pins can be externally set to VSS or left open |
| AD8~AD11 | I | NMOS<br>TRANSMISSION<br>GATE<br>PROTECTION<br>DIODE<br>(HT12E) | Input pins for address/data AD8~AD11 setting<br>These pins can be externally set to VSS or left open |
| D8~D11 | I | CMOS IN<br>Pull-high | Input pins for data D8~D11 setting and transmission enable, active low<br>These pins should be externally set to VSS or left open (see Note) |
| DOUT | O | CMOS OUT | Encoder data serial transmission output |
| L/MB | I | CMOS IN<br>Pull-high | Latch/Momentary transmission format selection pin:<br>Latch: Floating or VDD<br>Momentary: VSS |

HOLTEK

# $2^{12}$ Series of Decoders

## Features

- Operating voltage: 2.4V~12V
- Low power and high noise immunity CMOS technology
- Low standby current
- Capable of decoding 12 bits of information
- Pair with Holtek's $2^{12}$ series of encoders
- Binary address setting
- Received codes are checked 3 times
- Address/Data number combination
  - HT12D: 8 address bits and 4 data bits
  - HT12F: 12 address bits only
- Built-in oscillator needs only 5% resistor
- Valid transmission indicator
- Easy interface with an RF or an infrared transmission medium
- Minimal external components

## Applications

- Burglar alarm system
- Smoke and fire alarm system
- Garage door controllers
- Car door controllers
- Car alarm system
- Security system
- Cordless telephones
- Other remote control systems

## General Description

The $2^{12}$ decoders are a series of CMOS LSIs for remote control system applications. They are paired with Holtek's $2^{12}$ series of encoders (refer to the encoder/decoder cross reference table). For proper operation, a pair of encoder/decoder with the same number of addresses and data format should be chosen.

The decoders receive serial addresses and data from a programmed $2^{12}$ series of encoders that are transmitted by a carrier using an RF or an IR transmission medium. They compare the serial input data three times continuously with their local addresses. If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. The VT pin also goes high to indicate a valid transmission.

The $2^{12}$ series of decoders are capable of decoding informations that consist of N bits of address and 12–N bits of data. Of this series, the HT12D is arranged to provide 8 address bits and 4 data bits, and HT12F is used to decode 12 bits of address information.

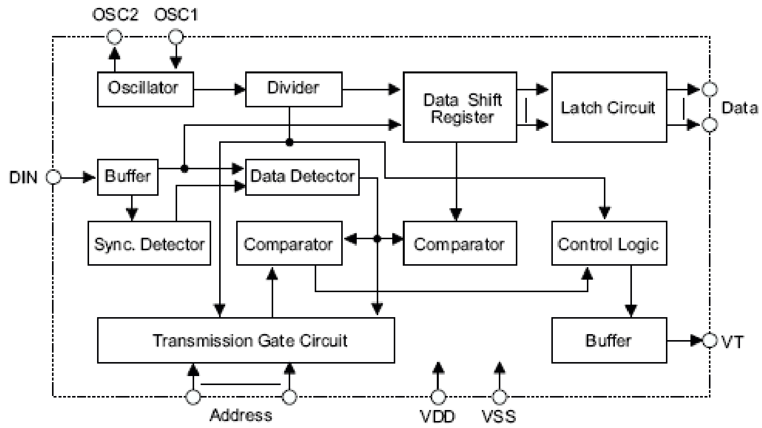
## Selection Table

| Function / Part No. | Address No. | Data | | VT | Oscillator | Trigger | Package |
|---|---|---|---|---|---|---|---|
| | | No. | Type | | | | |
| HT12D | 8 | 4 | L | √ | RC oscillator | DIN active "Hi" | 18 DIP/20 SOP |
| HT12F | 12 | 0 | — | √ | RC oscillator | DIN active "Hi" | 18 DIP/20 SOP |

Notes: Data type: L stands for latch type data output.

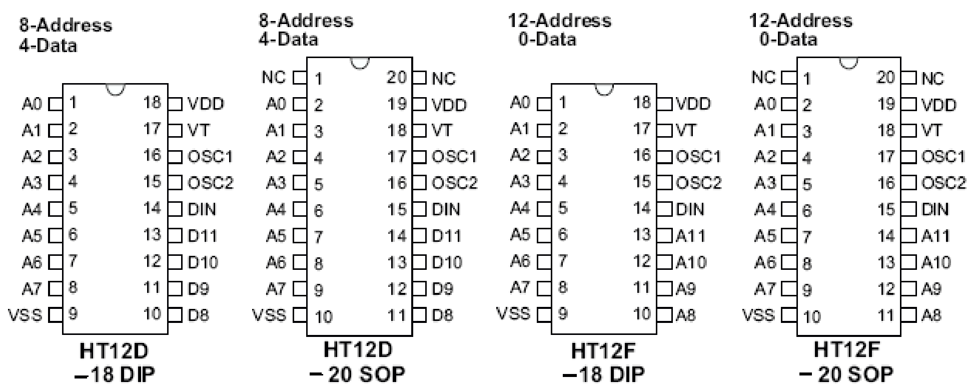
VT can be used as a momentary data output.

## Block Diagram




Note: The address/data pins are available in various combinations (see the address/data table).

## Pin Assignment



SGS-THOMSON MICROELECTRONICS

# L293D
# L293DD

## PUSH-PULL FOUR CHANNEL DRIVER WITH DIODES

- 600mA OUTPUT CURRENT CAPABILITY PER CHANNEL
- 1.2A PEAK OUTPUT CURRENT (non repetitive) PER CHANNEL
- ENABLE FACILITY
- OVERTEMPERATURE PROTECTION
- LOGICAL "0" INPUT VOLTAGE UP TO 1.5 V (HIGH NOISE IMMUNITY)
- INTERNAL CLAMP DIODES

SO(12+4+4) Powerdip (12+2+2)

ORDERING NUMBERS:

L293DD L293D

### DESCRIPTION

The Device is a monolithic integrated high voltage, high current four channel driver designed to accept standard DTL or TTL logic levels and drive inductive loads (such as relays solenoides, DC and stepping motors) and switching power transistors.

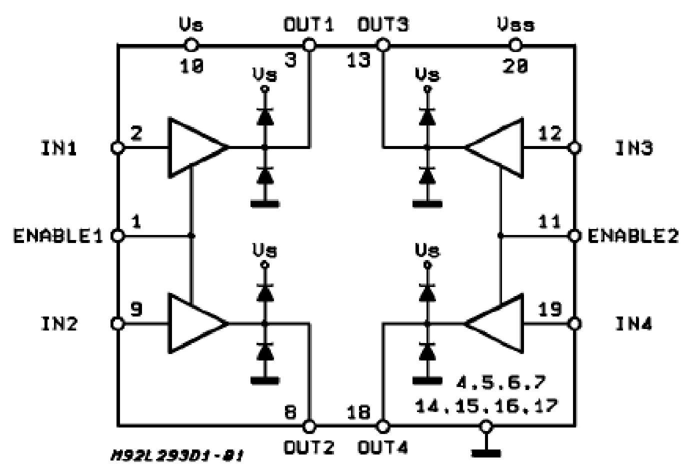
To simplify use as two bridges each pair of channels is equipped with an enable input. A separate supply input is provided for the logic, allowing operation at a lower voltage and internal clamp diodes are included.

This device is suitable for use in switching applications at frequencies up to 5 kHz.

The L293D is assembled in a 16 lead plastic packaage which has 4 center pins connected together and used for heatsinking

The L293DD is assembled in a 20 lead surface mount which has 8 center pins connected together and used for heatsinking.

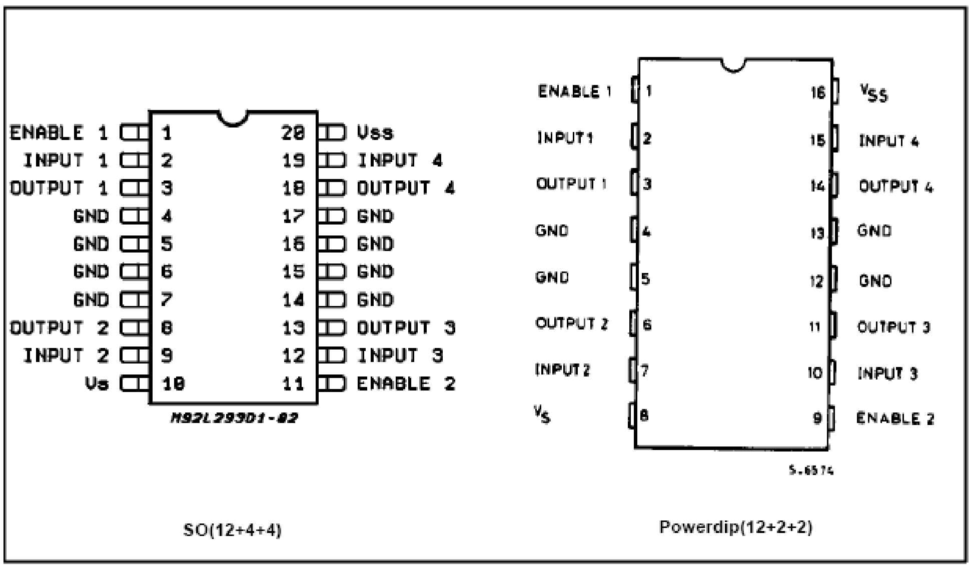
### BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $V_S$ | Supply Voltage | 36 | V |
| $V_{SS}$ | Logic Supply Voltage | 36 | V |
| $V_I$ | Input Voltage | 7 | V |
| $V_{en}$ | Enable Voltage | 7 | V |
| $I_o$ | Peak Output Current (100 μs non repetitive) | 1.2 | A |
| $P_{tot}$ | Total Power Dissipation at $T_{pins}$ = 90 °C | 4 | W |
| $T_{stg}$, $T_j$ | Storage and Junction Temperature | – 40 to 150 | °C |

## PIN CONNECTIONS (Top view)




## THERMAL DATA

| Symbol | Decription | | DIP | SO | Unit |
|---|---|---|---|---|---|
| $R_{th\ j-pins}$ | Thermal Resistance Junction-pins | max. | – | 14 | °C/W |
| $R_{th\ j-amb}$ | Thermal Resistance junction-ambient | max. | 80 | 50 (*) | °C/W |
| $R_{th\ j-case}$ | Thermal Resistance Junction-case | max. | 14 | – | |

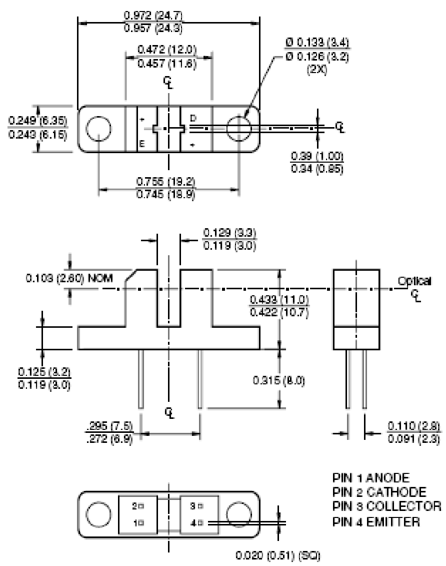
(*) With 6sq. cm on board heatsink.

FAIRCHILD SEMICONDUCTOR®

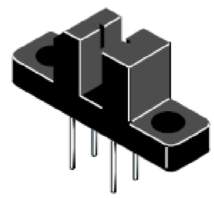
# PHOTODARLINGTON OPTICAL INTERRUPTER SWITCH

## H21B1 H21B2 H21B3

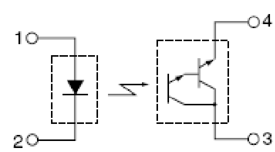
### PACKAGE DIMENSIONS




NOTES:
1. Dimensions for all drawings are in inches (mm).
2. Tolerance of ± .010 (.25) on all non-nominal dimensions unless otherwise specified.



### SCHEMATIC




## DESCRIPTION

The H21B1, H21B2 and H21B3 consist of a gallium arsenide infrared emitting diode coupled with a silicon photodarlington in a plastic housing. The packaging system is designed to optimize the mechanical resolution, coupling efficiency, ambient light rejection, cost and reliability. The gap in the housing provides a means of interrupting the signal with an opaque material, switching the output from an "ON" to an "OFF" state.

## FEATURES

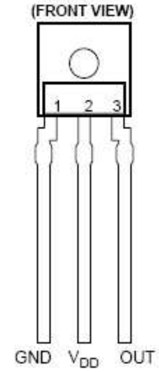
- Opaque housing
- Low cost
- .035" apertures
- High $I_{C(ON)}$

# TSL250R, TSL251R, TSL252R
# LIGHT-TO-VOLTAGE OPTICAL SENSORS

TAOS028A – MAY 2001

- **Monolithic Silicon IC Containing Photodiode, Operational Amplifier, and Feedback Components**
- **Converts Light Intensity to a Voltage**
- **High Irradiance Responsivity, Typically 137 mV/(μW/cm²) at $\lambda_p$ = 635 nm (TSL250R)**
- **Compact 3-Lead Clear Plastic Package**
- **Single Voltage Supply Operation**
- **Low Dark (Offset) Voltage....10mV Max**
- **Low Supply Current......1.1 mA Typical**
- **Wide Supply-Voltage Range.... 2.7 V to 5.5 V**
- **Replacements for TSL250, TSL251, and TSL252**

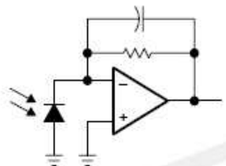
PACKAGE
(FRONT VIEW)




## Description

The TSL250R, TSL251R, and TSL252R are light-to-voltage optical sensors, each combining a photodiode and a transimpedance amplifier (feedback resistor = 16 MΩ, 8 MΩ, and 2.8 MΩ respectively) on a single monolithic IC. Output voltage is directly proportional to the light intensity (irradiance) on the photodiode. These devices have improved amplifier offset-voltage stability and low power consumption and are supplied in a 3-lead clear plastic sidelooker package with an integral lens

## Functional Block Diagram




## Terminal Functions

| TERMINAL NAME | TERMINAL NO. | DESCRIPTION |
|---|---|---|
| GND | 1 | Ground (substrate). All voltages are referenced to GND. |
| OUT | 3 | Output voltage |
| $V_{DD}$ | 2 | Supply voltage |



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Texas Advanced Optoelectronic Solutions Inc.
800 Jupiter Road, Suite 205 • Plano, TX 75074 • (972) 673-0759

National Semiconductor

November 2000



# LM35
# Precision Centigrade Temperature Sensors

## General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

## Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±¼°C typical
- Low impedance output, 0.1 Ω for 1 mA load

## Typical Applications

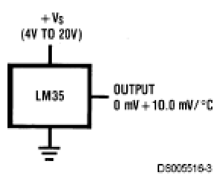
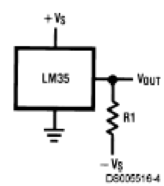



**FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)**




Choose $R_1 = -V_S/50\ \mu A$
$V_{OUT}$ = +1,500 mV at +150°C
= +250 mV at +25°C
= −550 mV at −55°C

**FIGURE 2. Full-Range Centigrade Temperature Sensor**

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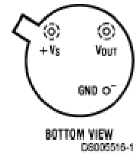
## Connection Diagrams

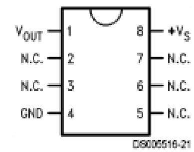
TO-46
Metal Can Package*




*Case is connected to negative pin (GND)

**Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH**
**See NS Package Number H03H**

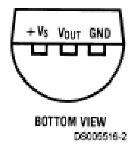
SO-8
Small Outline Molded Package




N.C. = No Connection

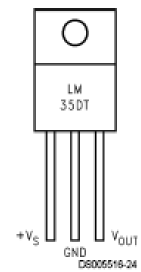
**Top View**
**Order Number LM35DM**
**See NS Package Number M08A**

TO-92
Plastic Package




**Order Number LM35CZ, LM35CAZ or LM35DZ**
**See NS Package Number Z03A**

TO-220
Plastic Package*




*Tab is connected to the negative pin (GND).
**Note:** The LM35DT pinout is different than the discontinued LM35DP.

**Order Number LM35DT**
**See NS Package Number TA03F**

# IS1U60/IS1U60L

## Sensors with 1-Package Design of Remote Control Detecting Functions owing to OPIC

### ■ Features

1. 1-package design owing to adoption of OPIC
2. Compact
   (Volume : About 1/8 compared with **GP1U58X**)
3. B.P.F. (Band Pass Frequency) : (TYP. 38kHz)
4. Aspherical lens

### ■ Applications

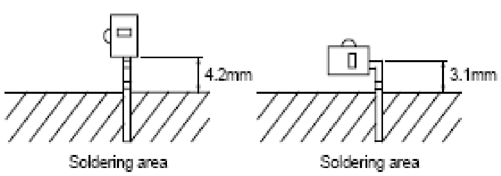
1. Audio equipment
2. Cameras

### ■ Absolute Maximum Ratings

(Ta=25°C)

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| Supply voltage | $V_{CC}$ | 0 to 6.0 | V |
| *1 Operating temperature | $T_{opr}$ | - 10 to +60 | °C |
| Storage temperature | $T_{stg}$ | - 20 to +70 | °C |
| *2 Soldering temperature | $T_{sol}$ | 260 | °C |

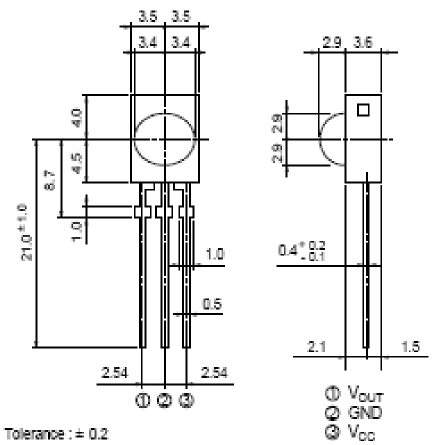
*1 No dew condensation is allowed.
*2 For 5 seconds



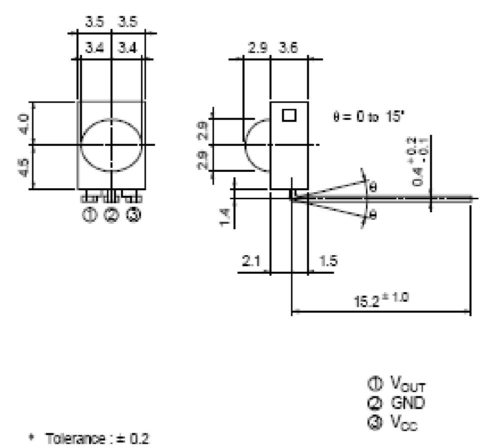

### ■ Outline Dimensions

(Unit : mm)

IS1U60




IS1U60L




* "OPIC" (Optical IC) is a trademark of the SHARP Corporation.
  An OPIC consists of a light-detecting element and signal-processing circuit integrated onto a single chip.

### ■ Recommended Operating Conditions

| Parameter | Symbol | Recommended operating conditions | Unit |
|---|---|---|---|
| Operating supply voltage | $V_{CC}$ | 4.7 to 5.3 | V |

" In the absence of confirmation by device specification sheets, SHARP takes no responsibility for any defects that occur in equipment using any of SHARP's devices, shown in catalogs, data books, etc. Contact SHARP in order to obtain the latest version of the device specification sheets before using any SHARP's device."