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Fireman Robot: a prototype design

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Abstract

Each year, tens of thousands of firefighters and bomb diffusers are injured while fighting fires, rescuing people. A robot is defined as a **"** re-programmable multi-functional manipulator**"**. In simple words, it is a mechanical system which consists of sensing and executing organs, controlled by an electronic brain that can perform a number of operations independently within a confined space[1. The objective of this work is to design a Robot prototype to do duties of firefighters and bomb diffusers through its arm to prevent those people from injuries and risks while doing these dangerous jobs. This Robot will be able to do the following jobs: fire extinguish, bomb disposal and indicate gas leakage.

PROJECT HARDWARE REQUIREMENTS

The Microcontroller (PIC)

Typically this IC includes a CPU, RAM, some form of ROM, I/O parts, and timers. Unlike a general-purpose computer, which also includes all of these components, a microcontroller is designed for a very specific task to control a particular control system and other applications. As a result, the parts can be simplified and reduced, which cuts down on production costs. Microcontrollers are sometimes called embedded microcontrollers, which just mean that they are part of an embedded system that is one part of a larger device or system. Also, a microcontroller is a computer on a chip optimized to control electronic devices. It is a type of microcontroller emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor, the kind used in PC. A typical microcontroller contains all the memory and I/O interfaces needed, whereas a general purpose microprocessor requires additional chip to provide these necessary functions or operation to improve the control process. In this project, the PIC 16F877A is used, and is considered as the brain of the project.

Following are the reasons why microcontrollers are incorporated in control systems :

- Cost: microcontrollers with supplementary circuit components are much cheaper than a computer with an analog and digital I/O.
- Size and weight: microcontrollers are compact and light compared to computer.
- Simple application: if the application requires very few number of I/O and the code is relatively small, which do not require extended amount of memory and a simple LCD display is sufficient as a user interface, a microcontroller would be suitable for this application.
- Reliability: since the architecture is much simpler than a computer it is less likely to fail.
- Speed: all the components on the microcontroller are located on singe piece of silicon, so the applications run much faster than it does on a computer.

PIC16F877A Microcontrollers[2],[3]

The PIC is the brains of the device (robot), and controls communication between it and the compact flash card, the LCD display, and other inputs and outputs. PIC (Peripheral Interface Controller) is the IC which was developed to control the peripheral device, dispersing the function of the main CPU. When comparing to the human being. The brain is the main CPU and the PIC shares the part of which is equivalent to the autonomic nervous.

PIC16F877A is one of the most commonly used Microcontrollers especially in automotive, industrial application, Mobile and consumer applications.

PIC16F877A could be used to convert an analog input signal to a digital number represented in 10-bit, convert this HEX number to an equivalent decimal BCD value, display this value on an LCD, very high speed response (200 nanosecond instruction execution) easy-to-program (only 35 single word instructions),CMOS flash-based 8-bit microcontroller. The PIC16F877A features 256 bytes of EEPROM data memory, 5 channels of 10-bit analog-to-digital (A/D) converter, 2 additional timers, 2 capture/compare/PWM functions which is used to control the velocity of motion, the synchronous serial port can be configured as either 3-wire serial peripheral interface (SPI™) or the 2-wire inter-integrated circuit (I^2C™) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for

more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

PIC16F877A Configuration

PIC16F877A device comes in 40 (or 44) pin packages. There is a variety in device packaging. Skinny dual in-line production (PDIP), plastic small outline (SOIC), plastic thin quad flat-pack production (TQFP) and plastic leaded chip carrier (PLCC) are also available.

Special Function Registers : The Special Function Registers are registers used by the CPU and peripheral modules for controlling the desired operation of the device. These registers are implemented as static RAM. The Special Function Registers can be classified into two sets: core (CPU) and peripheral. Core (CPU) registers are associated with the core functions. While the peripheral registers are used to control the peripherals.

To move values from one register to another register, the value must pass through the W register. This means that for all register-to-register moves, two instruction cycles are required. The entire data memory can be accessed either directly or indirectly. Direct addressing may require the use of the RP1:RP0 bits. Indirect addressing requires the use of the file select register (FSR).

I/O Ports

General purpose I/O pins can be considered the simplest of peripherals. They allow the PICmicro™ to monitor and control other devices. To add flexibility and functionality to a device, some pins are multiplexed with an alternate function(s). These functions depend on which peripheral features are on the device. In general, when a peripheral is functioning, that pin may not be used as a general purpose I/O pin. For all ports, the I/O pin's direction (input or output) controlled by the data direction register, called the TRIS register. TRISx controls the direction of PORT A '1' in the TRIS bit correspond to that pin being an input, while '0' correspond to the pin being an output. There are five ports on PIC16F877 A, B, C, D and E and each one has a corresponding TRISx register. Port A is 6-bit bidirectional port, ports B, C, and D are 8-bit bidirectional ports, and port E is a 3-bit bidirectional port all these ports can interfaced to control.[4],[5].

Stages to Program a PIC Microcontroller:

STAGE 1: In order to program a PIC Microcontroller, we need to be able to use LOGICATOR software, using a computer, the flow chart approach is used. The flow chart approach means that there is no need to learn difficult and complex programming languages.

STAGE 2: Once the program has been tested using a compiler on a computer, it can be downloaded to the PROGRAMMER which is attached to the computers "comm. port". Any mistakes to the program are usually found during testing on the computer; however, remember the PIC can be reprogrammed easily. It is not thrown away as it can be reused any number of times.

STAGE 3: The PIC Microcontroller (or PIC as it is usually known) is then taken out of the programmer and placed in the desired project board. The project is controlled by the downloaded program on the PIC's ROM.

MikroBasic Software

As mentioned earlier, a PIC microcontroller which is the 16f877A was used. In order to create the code for the PIC, a compiler called MikroBasic was used. MikroBasic is a rich development tool for PIC microcontrollers supplied by MikroElectronika®. It is designed to provide the easiest solutions for developing applications for embedded systems, without compromising performance or control. MikroBasic allows to quickly develop and deploy complex applications like writing BASIC source code using highly advanced Code Editor. The Code Editor features adjustable Syntax Highlighting, Code Assistant, Parameters Assistant, Auto Correct for common typos, and the Code Templates.

Software Requirements : the MikroBasic is used as software, and this software allows to develop and deploy complex applications :

- Write BASIC source code using the built-in Code Editor (Code and Parameter Assistants, Syntax Highlighting, Auto Correct, Code Templates)
- Use the included MikroBasic libraries to dramatically speed up the development: data acquisition, memory, displays, conversions, communications… Practically all P12, P16, and P18 chips are supported.
- Monitor program structure, variables, and functions in the Code Explorer.
- Generate commented, human-readable assembly, and standard HEX compatible with all programmers.
- Inspect program flow and debug executable logic with the integrated Debugger.
- Get detailed reports and graphs: RAM and ROM map, code statistics, assembly listing, and calling tree.See Fig (1)

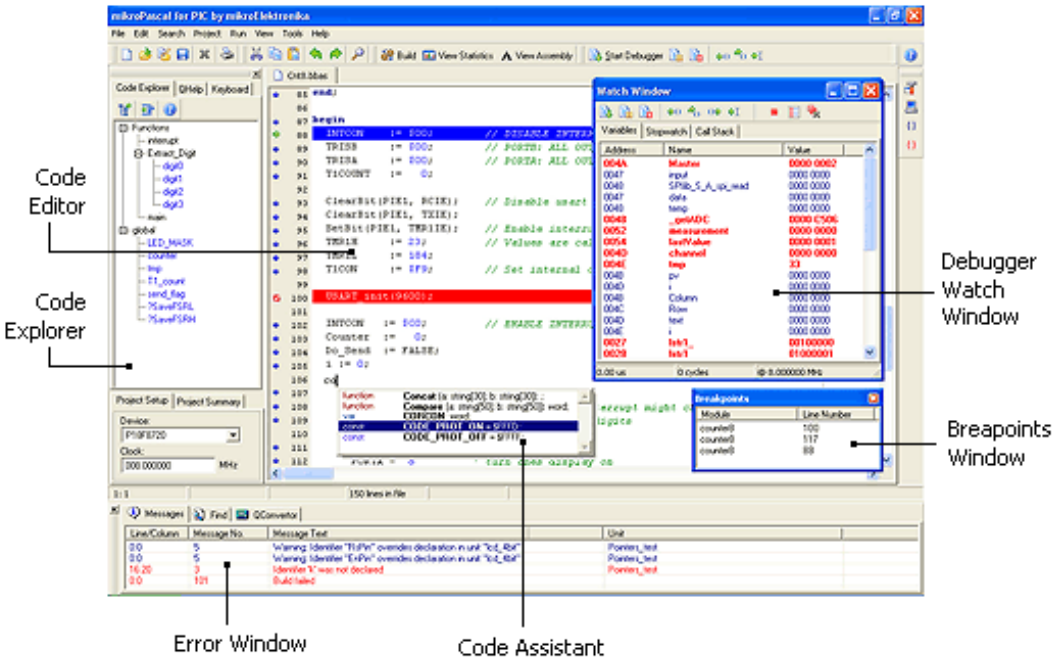

Figure 1: Screenshot of the software MikroBasic

After using the Code Editor to write the code, compiling the code will create a.hex file meaning that the file is in hexadecimal format. This file is then transferred into the ROM of the PIC via the programmer described above using simple serial bit transference [6].

Built-in Routines

MikroBasic compiler provides a set of useful built-in utility functions. Built-in functions do not have any special requirements; you can use them in any part of your project.

Some built-in routines are implemented as “inline”; i.e. code is generated in the place of the call, so the call doesn’t count against the nested call limit.

Motor Driver L293D:

The L293D is a quadruple push-pull 4 channel driver capable of delivering 600 mA (1.2 A peak surge) per channel. The L293D is ideal for controlling the forward/reverse/brake motions of small DC motors controlled by a microcontroller such as a PIC or BASIC Stamp. The L293D is a high voltage, high current four channel driver designed to accept standard TTL logic levels and drive inductive loads (such as relays solenoids, DC and stepping motors) and switching power transistors. The L293D is suitable for use in switching applications at frequencies up to 5 KHz.

Features are :

- 600 mA Output Current Capability Per Driver
- Pulsed Current 1.2 A / Driver
- Wide Supply Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply
- NE Package Designed for Heat Sinking
- Thermal Shutdown & Internal ESD Protection
- High-Noise-Immunity Inputs

Table 1: Truth Table of L293D Driver circuit.

Input	Enable	Output
H	H	H
L	H	L
H	L	Z
L	L	Z

RF Transceivers: To communicate with the robot effectively, there must be a communication system, this means a pair of transmitter and receiver. So a package which consists of two mini half-duplex wireless data transceiver modules is used, and each module is highly integrated with an ultra speed MCU and a powerful RF chip as shown in Fig (2). With the introduction of the innovative yet highly-efficient encoding method, its anti-interference ability and sensitivity are significantly improved. Features like various channel options, ultra long transmission distance (1000 meters) or abundant interfaces (UART/TTL, RS-485 & RS-232) helps make the transmission of data of any size possible and eliminate the needs of writing transmission program and running complicated settings. A software application ("RF-Magic") is offered for free so that users can modify the settings of the module. Besides, its slim size and wide power supply range

makes itself the most popular selection of many applications in different fields [7],[8].

Figure 2: Pair of RF Transceivers

Features:

- Ultra long transmission distance: 800-1000 meters @1200bps
- Working frequency: 431-478Mhz (1KHz step)
- +3.3-5.5V wide power supply range
- -112dBm(9600bps) high sensitivity
- Over 100 channels
- GFSK modulation
- Highly efficient cyclic interleaving error correction encoding
- Flexible software programmed option settings
- Selectable RFID index
- UART/TTL, RS-485 & RS-232
- Large data buffer: 512bytes
- Suitable for massive data transfer
- Built-in watchdog ensures long-term operations

Table 2: RF Transceiver Pins Configuration

Pins	Definition	Description
1	GND	0V
2	VCC	3.3V-5.5V
3	EN	POWER ENABLE(≧1.6V) or SUSPENDED ENABLE(≦0.5V Hibernation)
4	RXD	UART input, TTL
5	TXD	UART output, TTL
6	B/RX	RS485- or RS232 RX
7	A/TX	RS485+ or RS232 TX

Table 3: Settings of "RF-Magic (Ver.: 4.2)":

Settings	Options	Default
Series Rate	1200,2400,4800,9600bps	9600bps
Series Parity	Disable, Even parity, Odd parity	Disable
Types of Series	RS485, RS232	RS485
RFID Disable	Disable, Enable	Disable
RFID Index	0-65536 (16 bit)	12345
RF Frequency	431-478MHz (1kHz step, accuracy ±100Hz)	434MHz
Series rate	1200,2400,4800,9600bps	9600bps
Freq Deviation	5.4, 10.8, 21.6, 43.2, 86.4KHz	21.6 KHz
RF Power	1-10 (10 indicates 20mW)	10 (20mW)

LPG Gas Sensor MQ-6:

This is a simple-to-use liquefied petroleum gas (LPG) sensor, suitable for sensing LPG (composed of mostly propane and butane) concentrations in the air. The MQ-6 can detect gas concentrations anywhere from 200 to 10000 ppm.

This sensor has a high sensitivity and fast response time. The sensor's output is an analog signal. The drive circuit is very simple; all you need to do is power the heater coil with 5V, add a load resistance, and connect the output to an ADC. The sensitivity can be adjusted by a potentiometer.

Specification : Power supply : 5V, Interface type: Analog, Pin Definition: 1-Output, 2-GND, 3-VCC, High sensitivity to LPG, iso-butane, propane, Small sensitivity to alcohol, smoke, Fast response, Stable and long life, Simple drive circuit, Size: 40x20mm

The DC MOTOR:

A DC motor is an electric motor that runs on direct current (DC) electricity, A DC motor works by converting electric power into mechanical work. This is accomplished by forcing current through a coil and producing a magnetic field that spins the motor.

The voltage source forces voltage through the coil via sliding contacts or brushes that are connected to the DC source. These brushes are found on the end of the coil wires and make a temporary electrical connection with the voltage source.

The Arm: The arm is consists of five DC motors, each operates with 3.3 volts. The arm is shown in Fig (3).

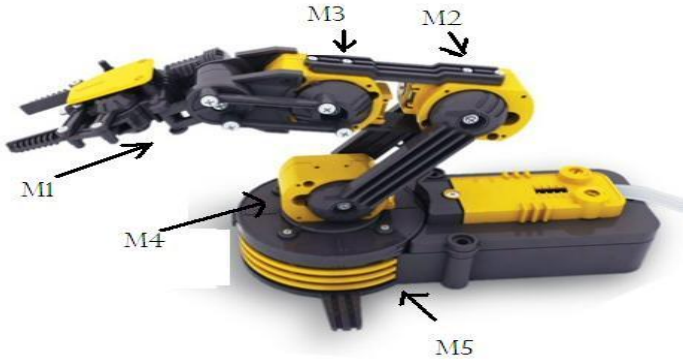

Figure 3: The Arm

The Tank: A small tank is used in this work. The tank consists of two DC motors, each operates with 8 Volts.

Figure 4: The Tank

The Water Pump

The water pump used in this project consists of a DC motor operates with 12 Volts, starting current is 3.5 A and the settling current is 800 mA.

Figure 5: The DC water pump.

Robot Control Unit Block Diagram

- The user sends the control signal through the computer by (USB-Serial) and RF transmitter.
- The RF receiver in Robot, receives the data and delivers it to the micro controller to analyze the data and determine which of the following (car, arm or water pump) will be turned on. Figure (6) shows the block diagram of the Transmitter control unit.

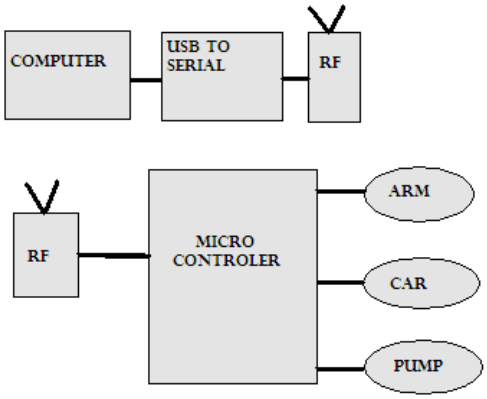

Figure 6: Transmitter Control unit block diagram

The table (4) shows the data given to robot and its function:

Table 4: Data given to robot and operations

Data	Operation
W	Car move forward
S	Car move backward
A	Car move lift
D	Car move right
Q	Car move lift fast
E	Car move right fast
R,F	Arm m1 up, Arm m1 down
T,G	Arm m2 up, Arm m2 down
Y,H	Arm m3 up, Arm m3 down
U,J	Arm m4 up, Arm m4 down
I,K	Arm m5 up, Arm m5 down
O,L	PUMP ON, PUMP OFF

Control Unit Circuit Diagram

- The voltage regulator L7085 is used to provide 5 volts to the PIC microcontroller and RF receiver.

- The resistor 10 kΩ is used to protect the PIC microcontroller.
- Crystal Oscillator of 4MHZ is used according to the specification of the PIC.
- The voltage regulator TS1084 is used to provide 3.3 volts to the motors of the arm.
- The voltage regulator L7808 is used to provide 8 volts to the motors of the car.
- LM293D drive is used to determine if the motors will rotate in the direction of clockwise or anticlockwise.
- The transistor BC547 is used to drive the relay, because the output current of the PIC microcontroller is very small to turn the relay coil on.
- The diode 1N4003 is used to make sure the back EMF of the relay will not go through the transistor, the diode will act as an open circuit.
- The resistor 10 kΩ is placed to limit the current of the Base.

Figure (7) shows the block diagram for the receiver control unit, and Fig (8) shows the detailed circuit connection of the receiver

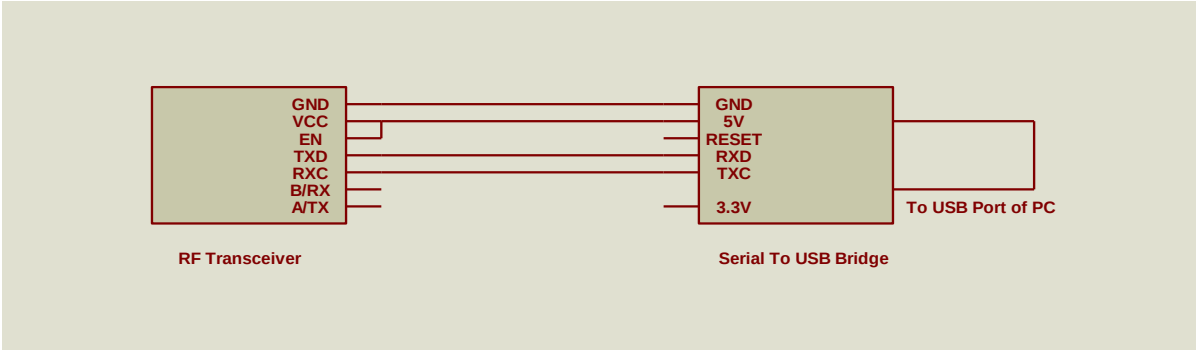

Figure 7: block diagram of the Control unit of the receiver

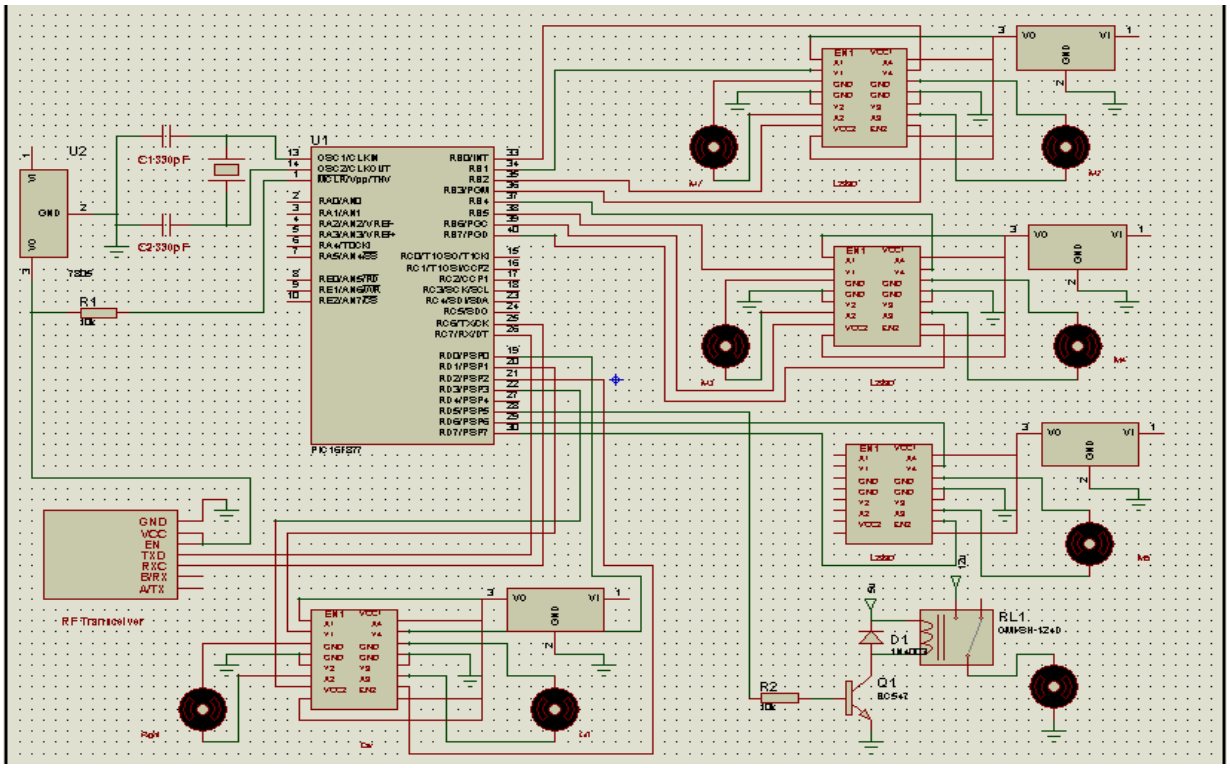

Figure 8: Control circuit of the receiver

Gas Sensor Unit Block Diagram

- the gas sensor detects the gas leakage from the space and transfer the value of this leakage to the PIC microcontroller as an analog signal, the PIC microcontroller converts this analog value to digital value and send the digital value through the RF transmitter.
- The RF receiver receives the digital value and transfers it to PIC microcontroller, the PIC microcontroller interface with LCD to display the value of the gas leakage.

The figure (9) shows the blog diagram of the gas sensor unit.

Gas Sensor Unit Circuit Diagram

The figure (10) shows the circuit diagram of Gas sensor transmitter

The figure (11) shows the circuit diagram of Gas sensor receiver

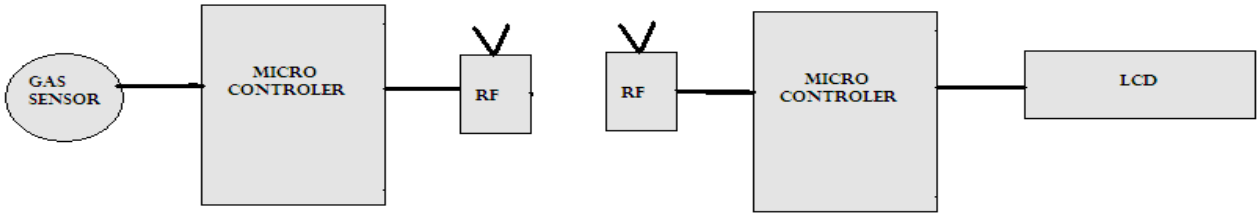

Figure 9: Gas sensor unit block diagram

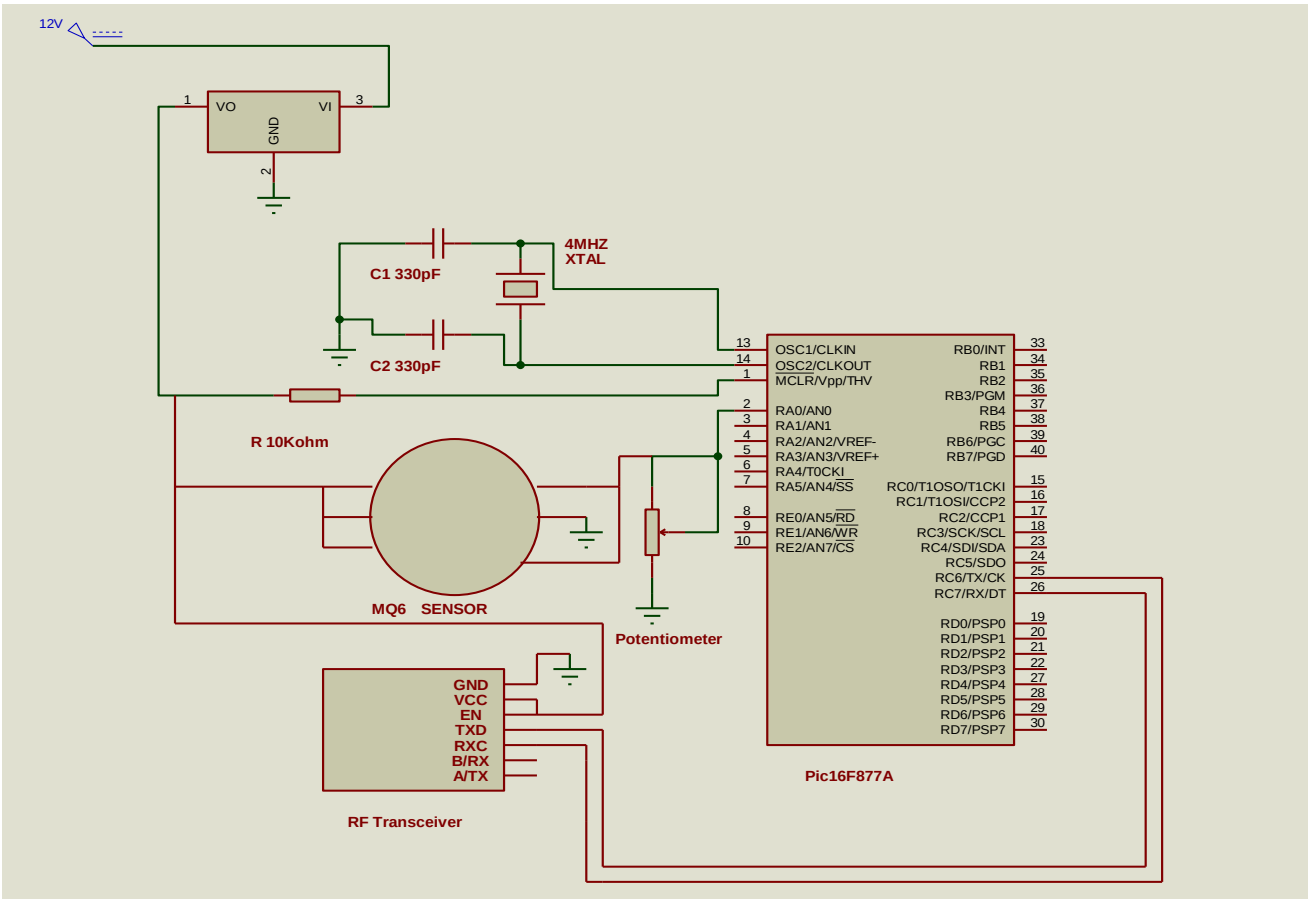

Figure 10: Gas sensor transmitter circuit diagram

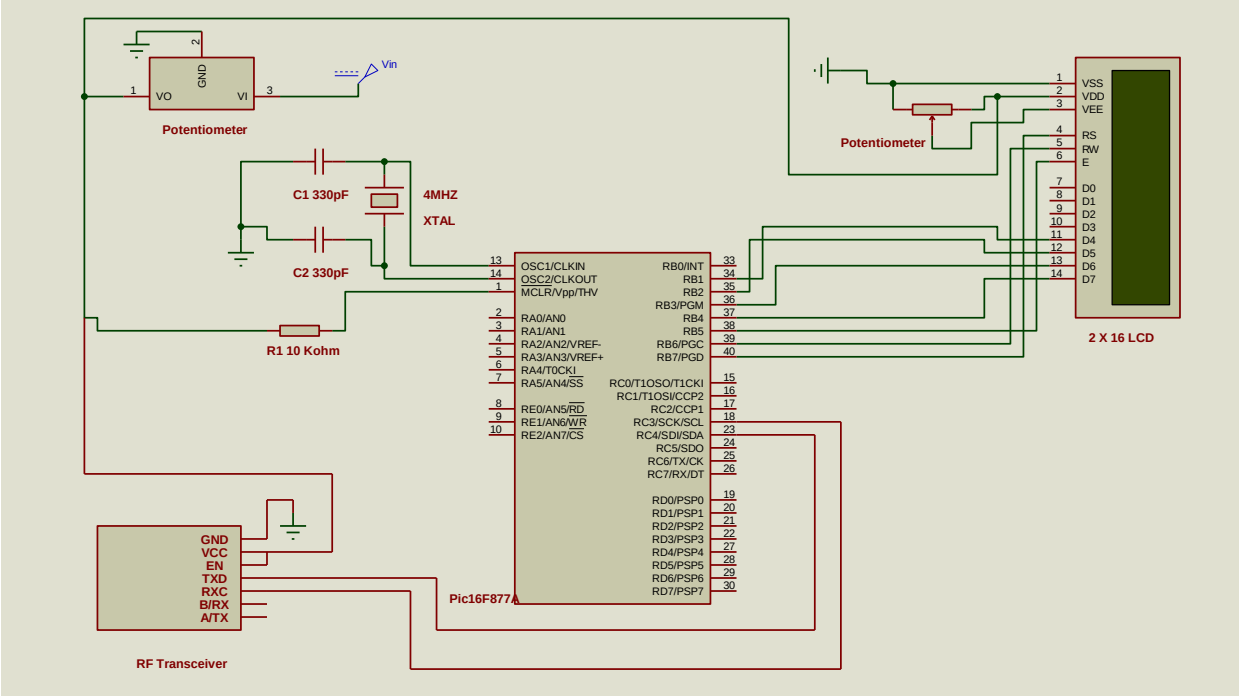

Figure 11: Gas sensor receiver circuit diagram

Software Flow Charts

Control Unit Flow Chart : Fig (12) shows the flow chart for this project, indicating all the incoming and outgoing signals from the gas detector and the commands send by the user to move the Robot in the desired direction.

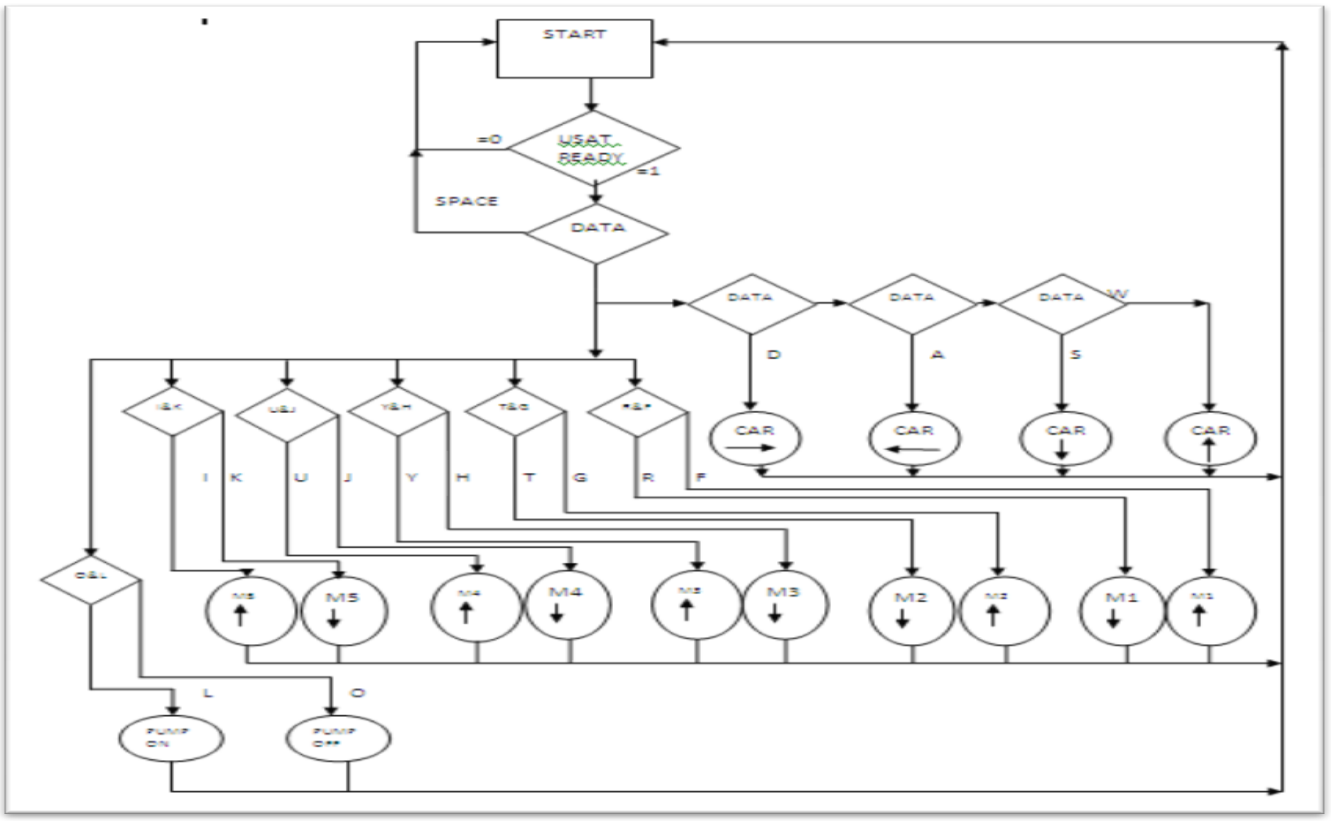

Figure 12: Control Receiver Flow Chart

Gas Sensor Unit Flow Chart

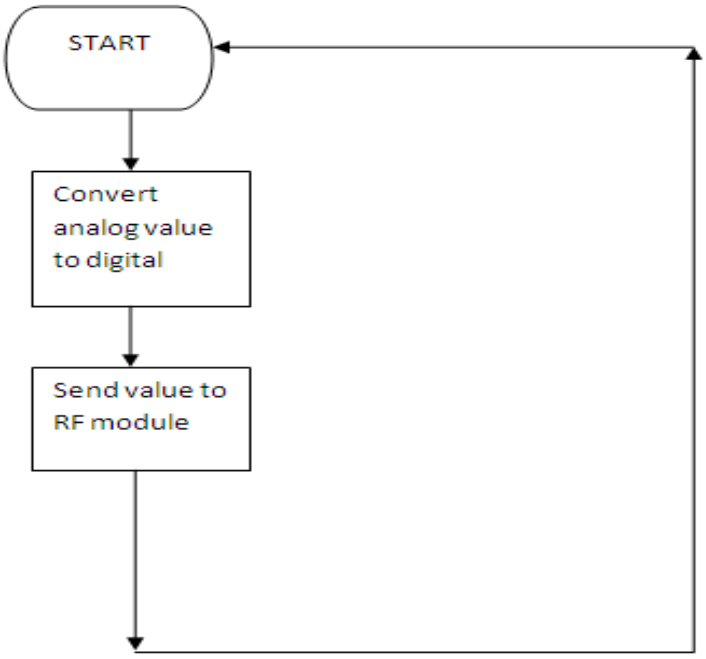

Figure 13: Gas Sensor Transmitter Flow chart

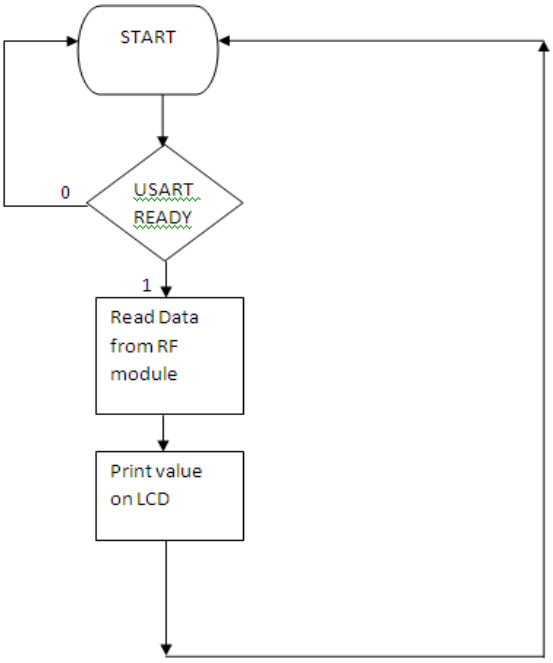

Figure 14: Gas Sensor Receiver Flow Chart

CONCLUSION, TEST AND EVALUATION

This fireman prototype Robot was designed, implemented and successfully tested. The Robot movements in the forward, backward, left and right directions are very accurate and precise. The Robot arm movement is easily controlled in all directions. Gas leakage detection was very sensitive to small gas leakages in the area around the Robot, and gives an alarm signal with no time delay. The power consumption of this Robot was very low. The Transmission and reception of warning and controlling signals was very good and fast, this means that the transmitter and the receiver work with high efficiency, and according to the pre-designed specifications.

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