Explosive Threat Responder Robot

By

Capt M. Arsalan Khalid
Capt Usama Ahmed
Capt Waqar Akram
Capt Asad Ullah

Submitted to the Faculty of Department of Electrical Engineering,

Military College of Signals, National University of Science and Technology,

Rawalpindi in fulfillment for the requirements of a B.E Degree in

Electrical (Telecom) Engineering

JUNE 2016

ABSTRACT

This project outlines the strategy adopted for detection of minefield and IEDs using various techniques. There are many countries including Pakistan are affected by landmines and IEDs which present a major threat to lives and cause economic problems. Landmines are most used explosive device in insurgency areas by insurgents, harmful because of their unknown positions and often difficult to detect where IEDs are the improvised version of detonating explosive which is subject to the type and weight of explosive. The development of new demining technologies is difficult because of the tremendous diversity of terrains and environmental conditions in which mines are laid and also because of the wide variety of landmines. Similarly due to various triggering mechanism detection of IEDs are also big challenges to the affected countries. Currently, detecting and clearing mines demand specific expertise with special equipment. Several different techniques have been so far devised for prodding out and defusing landmines/IEDs. Using one and other strategies this robot will provide adequate security and protective measures to the moving troops against minefields and IEDs. Robot will take command from the user in the form of control signals and performs the required action. At present only three countries (USA, UK and Israel) have been able to develop such counter IED equipment's. Researching in subject will enhance the state of art use of technology in future projects of military.

CERTIFICATE

It is hereby certified that the contents and form of the project report entitled" **Explosive Threat Responder Robot"** submitted by 1) Captain Muhammad Arsalan Khalid 2) Captain Usama Ahmed 3) Captain Waqar Akram 4) Captain Asad Ullah have been found satisfactory as per the requirement of the B.E. Degree in Electrical (Telecom) Engineering.

Supervisor:
Assistant Professor
Col (Retd.) Raja Iqbal
MCS, NUST

____

DECLARATION

We hereby declare that no content of work presented in this report has been submitted in support of another award of qualification or degree either in this institution or anywhere else.

DEDICATED TO

Our Lovely parents without whom we could not have achieved today

To our families for bearing the hardship

To our honorable teaching faculty

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

Chapter 1

Introduction

1.1 Project Overview

ETRR (Explosive threat responder robot) is the outcome idea of the team after detailed searching and analysis of counter IED devices around the world. Such solutions are available in market but with much higher cost as only few countries have been able to reach the market with their products (i.e. TALON, SUGV, Packbot and Throwbots). They are lightweight, portable, unmanned and tracked military robot designed but very costly. Though our design is a prototype but it will be much capable of designed robot based on the modern requirement in the field such as live video stream, safe distance, size, reliability, marking detected location, analysis via sensors, availability of components and cost effective.

1.2 Problem Statement

The project will be able to deliver solutions to the problem pertaining to modern techniques in warfare such as:

a. Route Clearance for the troops and convoy

b. Directly monitoring the enemy area

c. Risk of soldier’s causality

d. IED determination and disposal

1.3 Motivation

Present causality rate of our troop are maximized due to IEDs, to curb that project is an idea.

1.4 Scope, Specification and Deliverables

1.4.1 Scope

ETRR will be able to be controlled by the operator same as unarmed vehicle from standoff distance. Live video stream back on operator display unit (ODU) will guide him to control the ETRR. On board installed sensor will detect the metal/explosive followed by alarm on ODU and log will be simultaneously maintained from GPS for studying the pattern of installation. Operator can also prod the package using robotic arm. The purpose of the design is to be able to check possible components of anomalies by using two types of detectors that are portable, compact and lightweight. Following are the scopes determined in order to complete the project:

a. Application of control signals

b. Programming Microcontroller using C++

c. Interfacing GPS and various sensors

d .Thorough understanding of PROTEUS and similar software

e. Combustible gases like butane, propane, methane alcohol and smoke detection (Explosive traces)

f. Metal detection

1.4.2 Specifications

a. Arduino Mega 2560

The Mega 2560 is a microcontroller board based on the ATmega2560. It has following:

1) 54 digital input/output pins (of which 15 can be used as PWM outputs)

2) 16 analog inputs

3) 4 UARTs (hardware serial ports)

4) 16 MHz crystal oscillator

5) USB Connection

6) Power Jack (5v)

7) ICSP Header

8) C++ based Software to burn the programme

b. nRF24L01 Single Chip Transceiver

1) Worldwide 2.4Ghz ISM band operation

2) Upto 2Mbps (Air data rate)

3) Low Power Operation

4) On chip voltage regulator

5) 1.9 to 3.6V Supply range

c. TowerPro MG995 Metal gear Servo motor

1) Dimension: 40mm x 19mm x 43mm

2) Weight: 69g

3) Operating Speed : 0.13sec / 60 degrees (6.0V no load)

4) Stall Torque : 15 kg-cm (208.3 oz.-in) at 6V

5) Operation Voltage : 4.8 - 7.2Volts

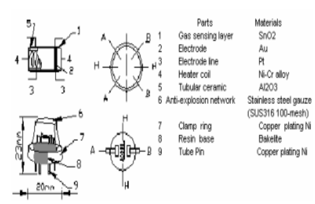
6) Gear Type: All Metal Gears

7) Connector Wire: Heavy Duty, 11.81" (300mm)

d. MQ-2 Gas Sensor

1) Sensor type : Semiconductor

2) Standard Encapsulation: Bakelite



3) Detection: Combustible gas and smoke

4) Concentration: 300 -10000ppm

5) Loop Voltage: <24V DC

e. Camera

1) 2 x Megapixel Camera

2) 2.4 Ghz Tx/Rx for Video Feed

f. GPS

1) ublox neo 6M

2) Supply: 2.7 – 3.6v

3) Interface: USB, SPI, DDC (PC)

4) 50 channels GPS (L1 Freq)

5) Start time: 1s to 27s

6) Position accuracy: 2.5m

1.4.3 Deliverables

Following are the deliverables of ETRR:

a. IED Detection from standoff distance

b. Live Camera feed

c. Dual Detection System (Explosive and Metal)

d. GPS Log of detected IED to study pattern on Arduino platform

e. Robotic disposal vehicle with robotic arm

1.5 Project Approach

The solution to the above stated issues are achieved by designing the modern gadgetry equipped model i.e. ETRR. Flow chart depicted below is used to summarized the approach

Figure 1 – Project Approach

Chapter 2

Background Study

2.1 Explosive Threat Responder Robot - ETRR

ETRR is a robotic project which is mainly guided by controlled signals. As it is explosive threat responder so primarily we are focusing on various detection techniques by experimenting. Landmines will be detected by the magnetic inductance and ground penetrating radar technique as in Geological survey where for IED, detection of non-explosive components of IED will be incorporate by applying various technique of detection of vapors and traces of explosives using either Thermal Imaging sensors and vapors sensors depends upon budget and availability.

2.2 Explosive Detection Technique

Detecting and identifying chemicals is critical for addressing security threats such as explosives. Those handling explosives tend to contaminate surfaces they touch with trace particles. Traditional trace detection technologies require surfaces to be swabbed and the swab placed into an instrument for analysis. For many reasons, non-contact methods are preferred, but these need to be safe to use around people, sensitive to small amounts of threat material and sufficiently selective to distinguish chemicals of

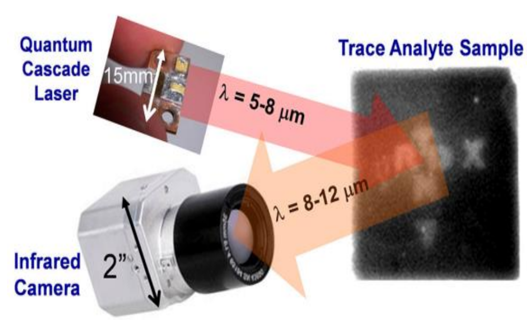


Figure 2 - Exposive Detection by IR

interest from the broad variety of surface types (vehicles, clothing, luggage, packages) in typical security scenarios.

2.2.1 Explosive Sensors

There are two types of sensors that have been developed economically using standard silicon-based micro fabrication techniques by Center for Entrepreneurship and Technology (CET) Community, UK.

a. **Micro Membrane**. This sensor chip consists of an array of gold-coated parylene micro membranes fixed around its perimeter. Each membrane has a bottom electrode with an air gap between the electrodes. Different membranes, separated by a glass cover, can be selectively immobilized with thiolated receptors. These receptors being selective to a particular gas will interact only with that gas/molecule. Due to these selective interactions, the membrane experiences a surface stress thereby undergoing a deflection. The membrane deflection is then detected by using capacitive signal readout. The required measurement circuits have been incorporated within a single board. The board includes a fabricated membrane sensor chip, capacitance to digital converter (CDC) chips, microprocessor, USB interface, temperature control, etc.

b. **Micro Cantilever**. This sensor chip utilizes an array of gold-coated silicon nitride cantilevers fixed at one end and free at the other end. The free end of cantilever has a light reflective paddle. Different cantilevers are separated from each other using a glass cover which is attached to the chip. The gold coated surface of the cantilever can be selectively immobilized with different receptors to detect the corresponding targets. When an interaction takes place between receptor and target molecules, a cantilever experiences the surface stress resulting in its deflection. The deflection of the free end of the cantilever is then detected using an optical system consisting of a laser and Charged-Coupled Device (CCD) camera system. This allows the real time detection of explosive gases.

c. **Peptide-based Receptors**. Phage display has been employed to obtain peptide-based receptors capable of detecting target molecules with high selectivity. The process utilizes a large combinatorial library of M-13 bacteriophage expressing candidate receptors on the pIII(Tourain) region of their protein coat. The library of potential receptor-bearing phage is allowed to incubate with the target molecule, such as Dinitrotoluene (DNT). Nonspecific binders are washed away, while specifically bound phage are eluted from the target and captured. This screening process is repeated multiple times until best binding phage is obtained.

The amino acid sequence of this specific binding phage is determined. This amino acid sequence constitutes the receptor. The DNT receptor has been screened rigorously against Trinitrotoluene (TNT) to ensure the selectivity of the receptor to DNT. The test showed that it binds weakly to TNT even though the structural difference between DNT and TNT is only a single NO2 group.

2.2.2 Flammable Gas Sensors

Gas sensors interact with a gas to initiate the measurement of its concentration. The gas sensor then provides output to a gas instrument to display the measurements. Common gases measured by gas sensors include ammonia, aerosols, arsine, bromine, carbon dioxide, carbon monoxide, chlorine, chlorine dioxide, Diborane, dust, fluorine, germane, halocarbons or refrigerants, hydrocarbons, hydrogen, hydrogen chloride, hydrogen cyanide, hydrogen fluoride, hydrogen selenide, hydrogen sulfide, mercury vapor, nitrogen dioxide, nitrogen oxides, nitric oxide, organic solvents, oxygen, ozone, phosphine, saline, sulfur dioxide, and water vapor. Important measurement specifications to consider when looking for gas sensors include the response time, the distance, and the flow rate. The response time is the amount of time required from the initial contact with the gas to the sensors processing of the signal. Distance is the maximum distance from the leak or gas source that the sensor can detect gases. The flow rate is the necessary flow rate of air or gas across the gas sensor to produce a signal. Gas sensors can output a measurement of the gases detected in a number of ways. These include percent Lower Explosive Limit (LEL), percent volume, trace, leakage, consumption, density, and signature or spectra. The Lower Explosive Limit (LEL) or Lower Flammable Limit (LFL) of a combustible gas is defined as the smallest amount of the gas that will support a self-propagating flame when mixed with air (or oxygen) and ignited. In gas-detection systems, the amount of gas present is specified in terms of % LEL: 0% LEL being a combustible gas-free atmosphere and 100% LEL being an atmosphere in which the gas is at its lower flammable limit. The relationship between % LEL and % by volume differs from gas to gas. Also called volume percent or percent by volume, percent volume is typically only used for mixtures of liquids. Percent by volume is simply the volume of the solute divided by the sum of the volumes of the other components multiplied by 100%. Trace gas sensors given in units of concentration is ppm. Leakage is given as a flow rate like ml/min. Consumption may also be called respiration, given in units of ml/L/hr. Density measurements are given in units of density: mg/m^3. A signature or spectra measurement is a spectral signature of the gases present; the output is often a chromatogram.

Common outputs from gas sensors include analog voltage, pulse signals, analog currents and switch or relays. Operating parameters to consider for gas sensors include operating temperature and operating humidity.

2.3 Metal Detection Techniques

Metals are them most used material in IEDs for which it can be easily detect using metal detection techniques out of landmines are easy-to-make, cheap and effective weapons that can be deployed easily over large areas to prevent enemy movements. Mines are often laid in groups, called mine fields, and are designed to prevent the enemy from passing through a certain area, or sometimes to force an enemy through a particular area. While more than 350 varieties of mines exist, they can be broken into two categories, namely, anti-personnel mines and anti-tank mines. Anti-tank and anti-personnel are the types of landmines desgined to damage/kill enemy and vehicles, typically ranging from 9 kg to 158 kg depend upon its type. Most commonly used methods are as follows:

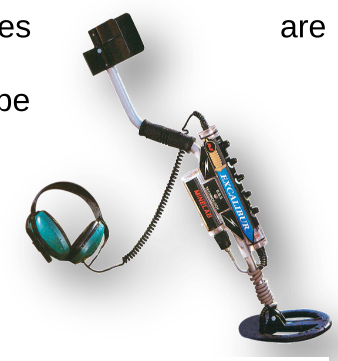


Figure 3 – Metal Detector

a. Probing the ground

b. Metal detection

c. Ground Penetrating Radar (GPR)

d. Use of trained dogs and rats

2.3.1 Working of Metal Detector

Different metal detectors work in various different ways, but the science behind one of the simpler kinds. A metal detector contains a coil of wire (wrapped around the circular head at the end of the handle) known as the transmitter coil. When electricity flows through the coil, a magnetic field is created all around it. As you sweep the detector over the ground, you make the magnetic field move around too. If you move the detector over a metal object, the moving magnetic field affects the atoms inside the metal. In fact, it changes the way the electrons (tiny particles "orbiting" around those atoms) move. Now if we have a changing magnetic field in the metal, Maxwell described that we will have an electric current moving in there too. In other words, the metal detector creates (or "induces") some electrical activity in the metal. But then if we have electricity moving in a piece of metal, it must create some magnetism as well. So, when you move a metal detector over a piece of metal, the magnetic field coming from the detector causes another magnetic field to appear around the metal.

It's this second magnetic field, around the metal, that the detector picks up. The metal detector has a second coil of wire in its head (known as the receiver coil) that's connected to a circuit containing a loudspeaker. As you move the detector about over the piece of metal, the magnetic field produced by the metal cuts through the coil. Now if you move a piece of metal through a magnetic field, you make electricity flow through it. So, as you move the detector over the metal, electricity flows through the receiver coil, making the loudspeaker click or beep. The closer you move the transmitter coil to the piece of metal, the stronger the magnetic field the transmitter coil creates in it, the stronger the magnetic field the metal creates in the receiver coil, the more current that flows in the loudspeaker and the louder the noise.

2.3.2 Factors influencing Depth

Many scholarly researchers has already carried out research to particular subject but so far now it can be assumed no such answer is available but it may vary from situation to situation but generally maximum depth is about 20-50cm, few factor which influence the depth of detection are:

a. The size, shape, and type of the buried metal object: bigger things are easier to locate at depth than small ones.

b. The orientation of the object: objects buried flat are generally easier to find than ones buried with their ends facing downward, partly because that creates a bigger target area but also because it makes the buried object more effective at sending its signal back to the detector.

c. The age of the object: things that have been buried a long time are more likely to have oxidized or corroded, making them harder to find.

d. The nature of the surrounding soil or sand you're searching.

2.4 Landmines

Landmines are easy-to-make, cheap and effective weapons that can be deployed easily over large areas to prevent enemy movements. Mines are often laid in groups, called mine fields, and are designed to prevent the enemy from passing through a certain area, or sometimes to force an enemy through a particular area. While more than 350 varieties of mines exist, they can be broken into two categories, namely, anti-personnel mines and anti-tank mines.

2.4.1 Anti-Personnel Mines.

Anti-personnel mines are designed to kill or injure enemy

Type	Anti-Personnel-Mine
Operation	Blast mine
Diameter	125 mm
Height	65 mm
Weight	370 g
Explosive weight	110 g
Explosive type	TNT
Operating pressure	5-30 kg
Detectability	Fairly easy to detect
Manufacturer	USSR

Table 1 - Anti Personnel Mine

combatants. They are usually buried 10mm to 40mm beneath the soil and it requires about 9 kg minimum pressures to detonate them. The face diameter of most the anti-personal mines ranges from 5.6cm to 13.3cm

2.4.2 Anti-Tank Mines

An anti-tank mine is a type of land mine designed to damage or destroy vehicles including tank and armored fighting vehicles. An applied pressure of 158 kg minimum is required to detonate it; hence the footstep of a person won't detonate them. Most anti-tank mines possess a larger face diameter compare to anti-personal mines, usually around 33.7cm.

Type	Anti-Tank Mine
Operation	Blast mine
Diameter	316 mm
Height	102 mm
Weight	8.47 kg
Explosive weight	6.34 kg
Explosive type	TNT
Operating pressure	120-400 kg
Detectability	Easily detectable
Manufacturer	Russia

Table 2 - Anti Tank Mine

2.5 Improvised Explosive Devices –IED

IEDs can be made from a wide range of non-military components, chemicals, and compounds that are readily available to civilians in most countries. However, the construction, and to an extent the deployment, of IEDs is made considerably easier if factory-manufactured explosives or complete rounds of ammunition are readily available for adaptation to illicit uses. Diverted conventional ammunition explosives, and military demolition items can be used in a wide range of IED types, ranging from anti- personnel 'booby traps' and improvised mines to roadside bombs and armor-piercing projectiles. Large caliber ammunition, such as artillery shells and mortar bombs, are particularly useful for IED construction, because they contain relatively large quantities of explosive. In addition, military stockpiles frequently contain demolition stores, such as detonators, detonating cord, and plastic explosives, that can greatly facilitate the construction of IEDs.

2.5.1 IED Component Parts

Generally all IEDs consist of the following component parts

a. Main Charge

b. Initiator

c. Firing Switch

d. Safety and arming switch

e. Container (Plastic/Metal)

2.5.2 Types of IED and Initiation modes

IEDs will differ depending on the role that the users intend them to perform. They may be designed to cause widespread loss of life and destruction of infrastructure, or for targeted attacks on personnel and vehicles. Their role depends on where they are situated, their destructive capabilities, and how the explosive device is 'delivered' to the target. IED technology is only limited by the ingenuity of the person manufacturing or deploying the devices, so multiple configurations are always plausible. One design constraint, however, relates to the attackers' preferences for proximity to the target. In some cases, the attackers may choose to commit suicide in the process of carrying out the attacks; in others, they may wish to escape harm or detection by remaining distant from the device.

Type of Delivery	Target	Remarks
Vehicle-Borne	Personnel/ Infrastructure	LVBIED VBIED
Person-Borne	Personnel	PBIED
Passive	Personnel/ Vehicles	Land mine type
Directional	Vehicle/ Infrastructure	Projected devices, missile and rockets
Placed	Personnel/ Vehicles/ Infrastructure	

Table 3 - Type of IED Delivery System

Initiation Mode	Initiation System	Remarks
Timed	Chemical Decay	
	Clockwork	
	Electronic Timer	
Command-Initiated	Suicide	PBIED
	Radio Controlled (RCIED)	
	Command Wire (CWIED)	
	Passive Infrared	
	Active Infrared	
	Projectile-Controlled	PCIED
Victim-Operated	Booby traps	
	Pressure pads	
	Pull Switches	

Table 4 - IED Initiation Modes

2.4 Transmission/Reception of Control Signals

To control the various gadgetry mounted on the chasis by stand-off distance complete configuration of various controls are required. By encompassing the knowledge of signals and system we have already studied encompassed with C Programming, transmission and reception of various modules mounted on ETRR are controlled. Radio with 2.4 Ghz freq is used to Tx and Rx the complete array of date from ODU to Chasis and vice versa. Motor drivers are used to drive the chasis and robotic arms are controlled using servo motors, whereby scanning arm will controlled by the stepper motor. Linear Control System is the final subject to control and understand the concept of motors. Finally to transmit the video from Chasis to ODU 2.4Ghz freq transmitter will be integrated into the chasis.

Chapter 3

Detailed Design

3.1 Project Specification

Specification and desigin alogrithm for programming is depicted in flow chart as:

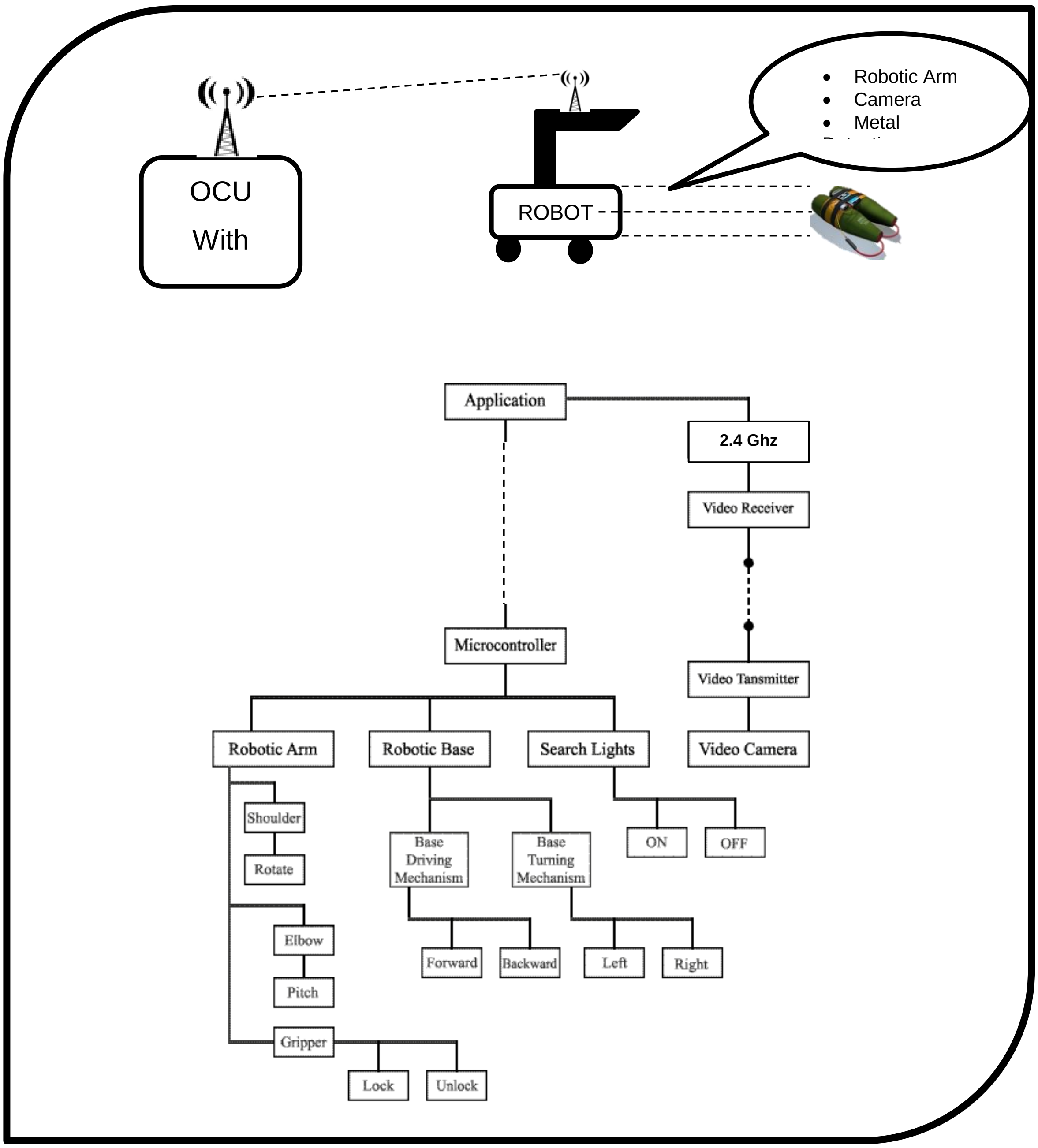


Figure 4 - ETRR Flow Diagram

3.2 Design Requirement

ETRR construction is primarily working through the effective use of sensor and broad applications of microcontrollers. The microcontroller will be programmed in order to augment the different information(i.e. control signals, video feed, sensors data and arm controllers). Operator Control Unit (OCU) will also encompass microncontroller which is connected to the robot through wireless medium, data will be relayed to OCU which then be given input to another microcontroller to be accessed by the operator or automatically by program. OCU will buzz alarm in case it detect any explosive or landmine which then operator will access through data analysed by detector and sensors so to take necessary precautions.

Bearing all above action we have already researched for the required microcontroller for which ATmega2560(Arduino Mega) is compatible. Till now we have been able to implement the Tx and Rx of data through Radio transmitter (2.4 Ghz).

Few general design requirements as per now are:

3.2.1 Cost

Around PKR 1,000,00 has been expendited till now

3.2.2 Geometry

Chasis Size	-	14 x 8 x 6 cm
Weight	-	6-7 Kg (Fully loaded)

3.2.3 Input

Chasis	-	12v, 2A
Robotic Arm	-	12v, 2A

Stepper Motor - 5v, 2 A

Camera - 5v

3.3 Misc Items

Following is the list of list which is up till now procured and installed:

S/No.	Item	Quantity
1.	NRF24L01 PA LNA	3
2.	NRF24L01	2
3.	MQ-2 Gas Sensor	1
4.	VGA Video Camera	2
5.	2.4Ghz Tx/Rx for Video	1
6.	Arduino Nano	2
7.	Arduino Mega	2
8.	Tracked Chassis	1
9.	Robotic Arm	1
10.	Servo (Large)	4
11.	7" LCD for Video feed	1
12.	Scanner arm Assembly	1
13.	Misc. Sensors (Temp, BtyStatus)	4
14.	Misc. Electronic Items	1

Table 5 - Item List

3.4 Design Implementation

3.4.1 Proteus Model

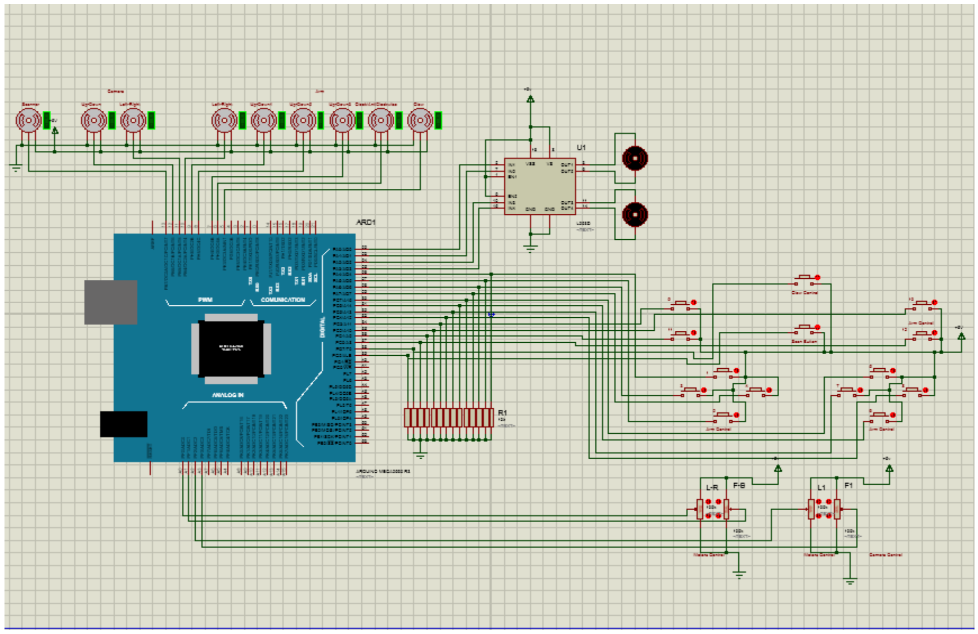


Figure 5 – Proteus Model

3.4.2 Problems Faced

Integrating chassis, robotic arm, camera, radio, microcontroller and design of OCU is so far achieved after trying many methodologies. Few problems faced by the team while integration phase are:

a. While writing code we had to face worst problem of code optimization and data integration in array, was able to solve after many hit and trials using Proteus Software and Arduino Programmer.

b. Procuring parts from different vendors across Pakistan, had to wait long from delivery of items from abroad.

c. Initially installed motors were of plastic which can’t sustain power whereas we required movement in difficult terrain, so new motors with metallic gear was installed.

d. Transmitting data from OCU to Chassis unit over wireless had been tried using RF Module, Xbee and finally NRF module felt more suitable after getting desired results. (i.e. data rate and range)

e. Arm required normally 4-10 A while two modules provides 4A to all servos, alternate was provided by increasing the number of power module to handle each servo separately.

f. While fixing all gadgetry onto chassis different techniques were applied resulting in either burning of gear motors and stalling, plastic sheets are then decided to be used as the base plates as well as the OCU’s box.

g. Apart from all above many components are either burnt or damaged by team members but practicing on them made us all well acquaint by now on circuitry.

Chapter 4

Design Structure

4.1 ETRR Architecture

ETRR architecture comprises of different subsystems which are as following:

a. Chassis Assembly
b. Robotic Arm and Clipper
c. Video Camera
d. Communication
e. Explosive Detection
f. Metal Detector
g. Operator Control Unit

4.2 Block Diagram

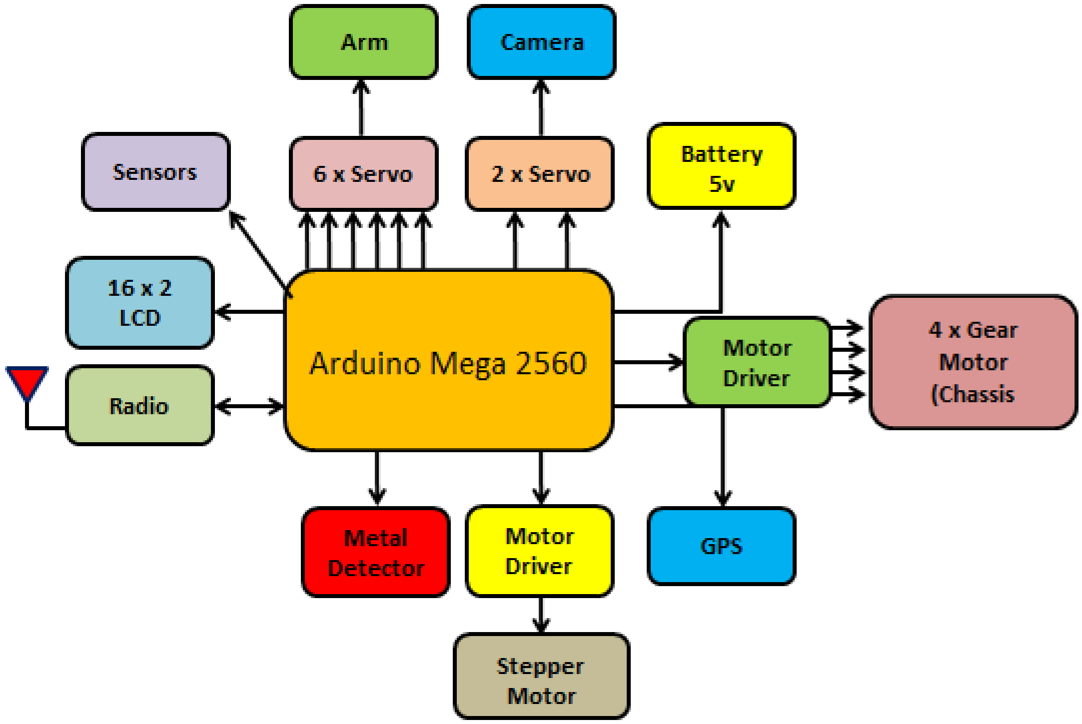


Figure 6 - Block Diagram

4.3 Chassis Assembly

4.3.1. Body Specification

Aluminum alloy frame, novel and elegant appearance, solid structure. It uses high power 2 x double gear motor, with powerful, run quickly, high stability. This tank/chassis has maneuverability so that it can turn around, back, left, and right. Some of the very features are:

a. Size - 385mmx206mmx80mm (length x width x height)

b Solid Aluminum structure

c. 4 x Sprockets

d. 4 x Tracks

4.3.2. Gear Motors

4 x Gear motors are installed in it for movement. After having some calculations keeping in mind terrain, surface clearance and load we preferred to use 12v DC Gear Motor. These motors are intended for use at 12 V, though in general, these kinds of motors can run at voltages above and below the nominal voltage (they can begin rotating at voltages as low as 1 V). Lower voltages might not be practical, and higher voltages could start negatively affecting the life of the motor. The 6 mm diameter gearbox output shaft works with the Pololu universal aluminum mounting hub for 6mm shafts, which can be used to mount larger wheels (80mm- and 90mm-diameter) and mechanisms to the gear motor’s output shaft.

4.3.3. Power Supply/ Battery

To power and drive the motors we are using 12v 7AH dry battery.

4.3.4. Working

DC motors consist of rotor-mounted windings (armature) and stationary windings (field poles). In all DC motors, except permanent magnet motors, current must be conducted to the armature windings by passing current through carbon brushes that slide over a set of copper surfaces called a commutator, which is mounted on the rotor. The commutator bars are soldered to armature coils. The brush/commutator combination makes a sliding switch that energizes particular portions of the armature, based on the position of the rotor. This process creates north and south magnetic poles on the rotor that are attracted to or repelled by north and south poles on the stator, which are formed by passing direct current through the field windings. It's this magnetic attraction and repulsion that causes the rotor to rotate. To drive the motors, code is programmed as that if operator desires to move ahead all motors are given power whereby for reverse we programmed it for reverse polarity and if we desire to move right, both right motors are given signal where other is not and if we desire to move left we give signal both left motors. LM293 H-Bridge Motor is used for controlling and speed of motors, Hence controlling the maneuverability of chassis.

4.4 Robotic Arm/Gripper

4.4.1. Specification

Robotic arm is another important section of project. It is required to move in all direction and at the head of clipper is installed for grabbing and cutting (Optional). Most suitable option available to us in the market is off the shelf arm. It delivers fast, accurate, and repeatable movement. Its specification is:

a. Material – Alloy

b. 6- Degree of Freedom (DOF)

c. 6 x Servo Motors (6v)

d. PWM Interface

4.4.2. Servo Motors

6 x Servo Motors are used in the robotic arm to control its movement. We are using two different types of servo motors for the purpose i.e.

a. **TowerPro MG995 Metal gear Servo motor**

(1) Dimension: 40mm x 19mm x 43mm

(2) Weight: 69g

(3) Operating Speed: 0.13sec / 60 degrees (6.0V no load)

(4) Stall Torque: 15 kg-cm (208.3 oz.-in) at 6V

(5) Operation Voltage: 4.8 - 7.2Volts

(6) Gear Type: All Metal Gears

(7) Connector Wire: Heavy Duty, 11.81" (300mm)

b. **MG996R Metal Gear Digital Torque servo motor**

(1) Operating speed: 0.14sec / 60 degrees (6.0V no load)

(2) Stall torque: 11 kg-cm at 6V

(3) Operation voltage: 4.8 - 7.2Volts

4.4.3. Working

Position command is given from OCU having variable resistor as position sensors. They pass analogue value to microcontroller which it transmits to robotic arm via radio link. Position sensors are installed as:

a. Left Right Movement

b. Up Down Movement Section 1

c. Up Down Movement Section 2

d. Up Down Movement Section 3

e. Clockwise/Anti clockwise Movement

f. Gripper Movement

4.5 Video Camera/ Live Feed

An analog wireless camera is used to transmit video to the Operator Control Unit on LCD, which helps in controlling the robot remotely and in Object analysis or disposal. It is mounted using 2 x servo motors for up/down and left/right movement. The camera has its own wireless transmission system. Power is supplied to camera is made through the use of 7809 voltage regulator in between 12v AH battery. At OCU end 2 x servo motors are controlled through variable resistor as position sensor connected to microcontroller which transmits the data back to camera assembly via radio link to another microcontroller at base end.

4.6 Communication

The wireless transmission has been accomplished by using off the shelf transmitters and receivers. Various option are available but according to our requirement most suitable is nRF24L01. The nRF24L01 is a single chip 2.4GHz transceiver with an embedded baseband protocol engine (Enhanced Shock Burst), designed for ultra-low power wireless applications. The nRF24L01 is designed for operation in the world wide ISM frequency band at 2.400 - 2.4835GHz. An MCU (microcontroller) and very few external passive components are needed to design a radio system with the nRF24L01. The nRF24L01 is configured and operated through a Serial Peripheral Interface (SPI.) Through this inter-face the register map is available. The register map contains all configuration registers in the nRF24L01 and is accessible in all operation modes of the chip. The embedded baseband protocol engine (Enhanced Shock Burst) is based on packet communication and supports various modes from manual operation to advanced autonomous protocol operation. Internal FIFOs ensure a smooth data flow between the radio front end and the system's MCU. Enhanced Shock-Burst reduces system cost by handling all the high-speed link layer operations. The radio front end uses GFSK modulation. It has user configurable parameters like frequency channel, output power and air data rate. The air data rate supported by the nRF24L01 is configurable to 2Mbps. The high air data rate combined with two power saving modes makes the nRF24L01 very suitable for ultra-low power designs. Internal voltage regulators ensure a high Power Supply Rejection Ratio (PSRR) and a wide power supply range.

4.6.1. Key Features

a. Worldwide 2.4GHz ISM band operation

b. Up to 2Mbps on air data rate

c. Ultra low power operation

d. 11.3mA TX at 0dBm output power

e. 12.3mA RX at 2Mbps air data rate

f. 900nA in power down

g. 22µA in standby-I

h. On chip voltage regulator

i. 1.9 to 3.6V supply range

4.6.2. Working

Connection of radio is made with microcontroller at both end. Connection to microcontroller is given in schematic diagram.

4.7 Explosive Detection

Gas sensor is used for detecting the traces from the buried or suspected material. They are the most expensive element in complete project though we have managed to achieve results using this sensor but had it been replaced with mature gas and explosive sensor would have given excellent results. The MQ series of gas sensors use a small heater inside with an electro-chemical sensor. They are sensitive for a range of gasses and are used indoors at room temperature. They can be calibrated more or less but a known concentration of the measured gas or gasses is needed for that. The output is an analog signal and can be read with an analog input of the Arduino.

4.7.1. Wiring

The preferred wiring is to connect both 'A' pins together and both 'B' pins together. It is safer and it is assumed that is has more reliable output results. Although many schematics and datasheets show otherwise, you are advised to connect both 'A' pins together and connect both 'B' pins together. In the picture, the heater is for +5V and is connected to both 'A' pins. This is only possible if the heater needs a fix ed +5V voltage.

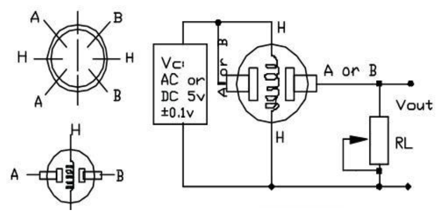


Figure 7 - MQ-2 Wiring

The variable resistor in the picture is the load-resistor and it can be used to determine a good value. A fixed resistor for the load-resistor is used in most cases. The Vout is connected to an analog input of the Arduino.

4.7.2 **The Heater**

The voltage for the internal heater is very important. Some sensors use 5V for the heater, others need 2V. The 2V can be created with a PWM signal, using analogWrite() and a transistor or logic-level mosfet. The heater may not be connected directly to an output-pin of the Arduino, since it uses too much current for that. Some sensors need a few steps for the heater. This can be programmed with an analogWrite() function and delays. A transistor or logic-level mosfet should also in this situation be used for the heater. If it is used in a battery operated device, a transistor or logic-level mosfet could also be used to switch the heater on and off. The sensors that use 5V or 6V for the internal heater do get warm. They can easily get 50 or 60 degrees Celsius. After the "burn-in time", the heater needs to be on for about 3 minutes (tested with MQ-2) before the readings become stable.

4.7.3 Load-Resistor

The sensor needs a load-resistor at the output to ground. It's value could be from 2kOhm to 47kOhm. The lower the value, the less sensitive. The higher the value, the less accurate for higher concentrations of gas. If only one specific gas is measured, the load-resistor can be calibrated by applying a known concentration of that gas. If the sensor is used to measure any gas (like in an air quality detector) the load-resistor could be set for a value of about 1V output with clean air. Choosing a good value for the load-resistor is only valid after the burn-in time.

4.7.4. Specification (MQ-2)

a. Detection Gases: Combustible gas and smoke

b. Concentration: 300 – 10000ppm

c. Heater Voltage: 5v DC

d. Heater Resistance: 31Ohm

e. Heater Consumption: 900mW

4.7.5. Gas Concentration Graph

Using the graph as a reference, analogue voltage determined by the Arduino will alert the operator about IED. Presently MQ-2, MQ-8 and MQ-9 is integrated into the project for trivial assessment.

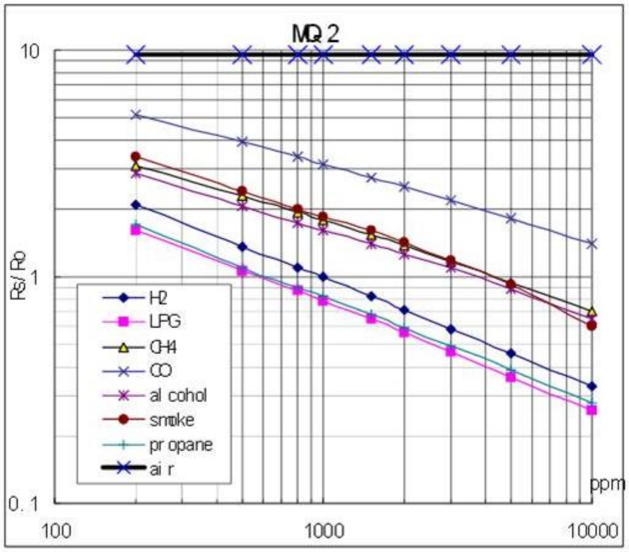


Figure 8 - MQ 2 Gas Concentration Chart

4.8 Metal Detection

Simple resonance metal detection circuit using BFO is used for detecting the metal. Following is the circuit diagram for metal detector.

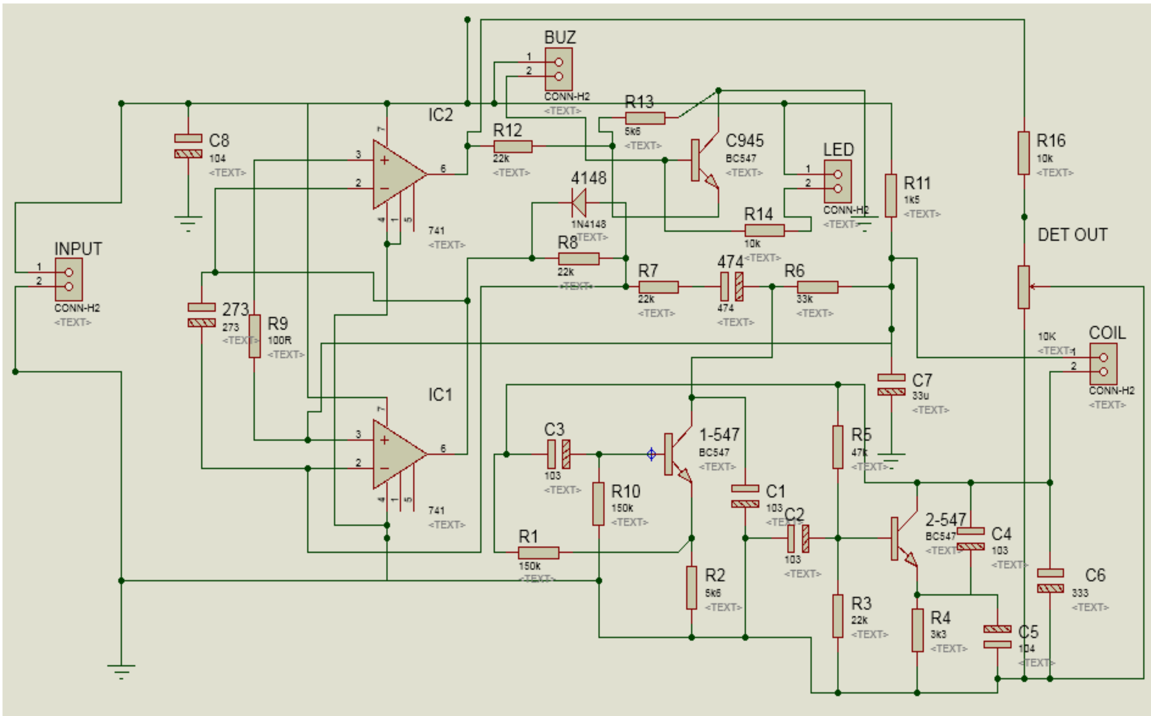


Figure 9 - Metal Detector Design

4.8.1 Search Coil

The most important characteristic of the search coil is its size. Surprisingly enough the actual inductance doesn't seem to have much effect on sensitivity. The greater the coil diameter the greater the penetration depth, but the less sensitive it is to small objects. As a general rule the penetration is about equal to the search coil diameter, while the sensitivity is roughly proportional to the cube of the object diameter. Sensitivity is also inversely proportional to the sixth power of the distance between the coil and the object. All this means is that if the object size is halved the sensitivity is reduced to one-eighth. Also, if the depth is doubled the sensitivity is reduced to one sixty-fourth. It's easy to see why all metal detectors which are designed to pick up small objects use small coils, (150 to 300 mm diameter) and really only skim the soil surface. In this circuit we are producing the frequency of about 110 kHz.

4.10 ETRR Schematic Diagram

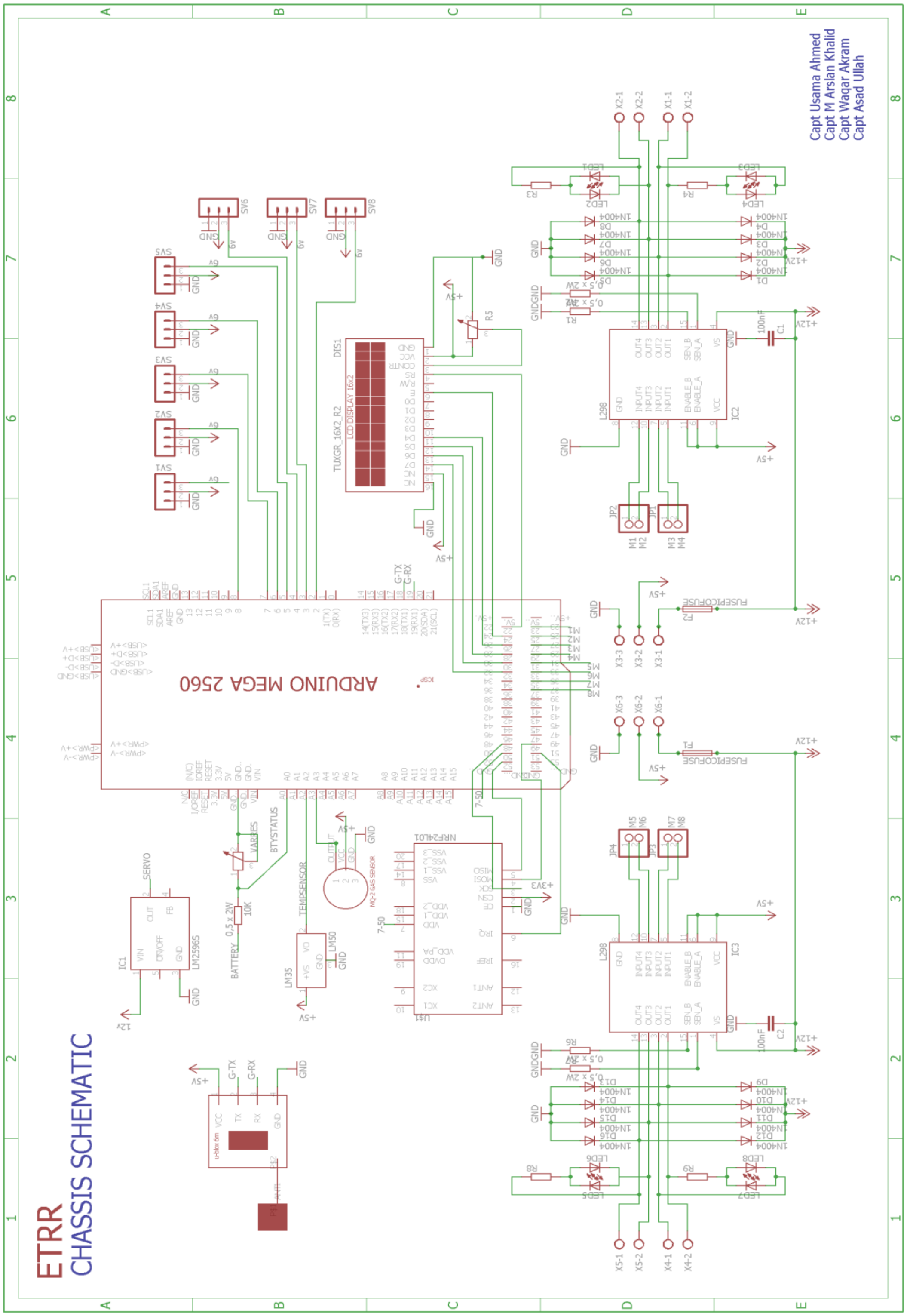


Figure 10 - ETRR Schematic Diagram

Chapter 5

Results and Analysis

5.1 Data Communication

Communication is an important chapter in this project on which the whole soul of circuitry is dependent. ETRR primary aim is to give standoff distance to an operator which was solely dependent on range of radio. Initially we were 433MHz RF Module for the transmission of data but due to its data rate and range we had to switch to some other mean. Xbee then considered for the said purpose we grab the concept but couldn’t append it to project due to its cost. Finally, we tried NRF24l01 2.4 GHz radio. Specification of said radio is already mentioned in previous chapter. We first checked the range of radio with very little data which was considerably best as far as the other competition concerned with it.

5.1.1 433MHz RF Module

Without an antenna, range was about 47 feet (14 meters) Then we managed to bit research on enhancing its range by making an 1/4 wavelength antenna and made one out of 22 gauge wire. Results were impressively improved the range by over 200% to 102 feet (31 meters). Test was made by interfacing the module with Arduino UNO

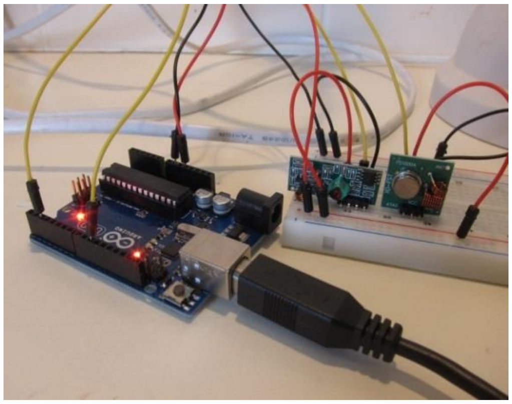


Figure 11 - RF Module Range Testing

model. Arduino has a built in library <RCSwitch.h> to call its desired functions.

5.1.2 nRF24l01 Module

RF module has lesser data rate than nrf24l01 module. As ETRR required to have transmit/receive an array of data which includes:

a. Steering Control Data

b. Metal Detection Sensing Data

c. Gas Detector (Explosive) Data

d. Controlling Servos of Robotic Arm

e. GPS Data

These all data when tested by RF its performance deteriorated and we had to shift to nRF24l01 for the same purpose. It has higher data rate than RF and better range without making additional antenna as in the case of RF module. Without any enhancement we tested this module up to 200m. For enhancing the range another version of this radio is also available but at higher cost it can give excellent communication up to 1300m.

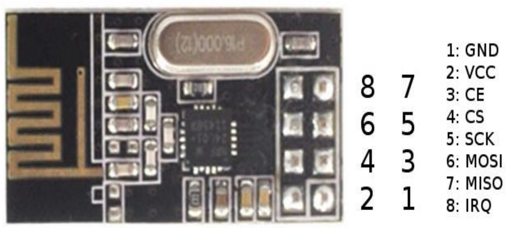


Figure 12 - nRF24l01 2.4 Ghz Module

5.2 Metal Detection

As already discussed in previous chapters, metal can be detected by many methods. So far we have employed the resonance metal detection circuitry which is not up to satisfaction. However we have already prepared another circuit encompassing Beat Frequency Oscillator technique. Presently this detector has very less depth as far as requirements of ETRR is concerned it required to be more enhancement. Following is the table of result using different materials

Table 6 - Metal Detector trials at 5cm appx

Material	Trial No.1	Trial No.2	Trial No.3
Metallic Key	Detected	Detected	Detected
Silver	Detected	Detected	Detected
Copper	Detected	Detected	Detected
Aluminum	Detected	Detected	Detected
Iron	Detected	Detected	Detected
Steel Wire	Detected	Detected	Detected

5.3. Explosive Detection

Explosive has many variants within itself to cover the complete range which is not yet not possible. However by adopting the technique of tracing the gases present in the explosive material we can analyze the threat. Gas sensor MQ-2,MQ-8, MQ-9 evaluates the value from its heating coil which is a numerical value from 0 to 1023. 0 represents no smoke, while 1023 represents smoke at the absolute maximum highest level. Testing of sensor is carried out using different samples of gases and fumes. Following table is the result of different trials carried out till now.

Table 7 - Gas Sensors Trial at 10cm appx

Gas	Trial No.1	Trial No.2	Trial No.3
Butane	Detected	Detected	Detected
Methane	Detected	Detected	Detected
Alcohol	Detected	Detected	Detected
LPG	Detected	Detected	Detected
Smoke	Detected	Detected	Detected
CO2	Not Detected	Not Detected	Not Detected
Freon	Not Detected	Not Detected	Not Detected
Chlorine	Not Detected	Not Detected	Not Detected
Ammonia	Not Detected	Not Detected	Not Detected
Chloroform	Not Detected	Not Detected	Not Detected

Chapter 6

Future Work and Conclusion

6.1 Future Work

This project is presently in the prototype state which made this platform incomplete for additional peripherals. By implementing it in a industrial standard focus will be completely on increasing the sensitivity of sensors and detection. Power management and range is also a subject for future work. By implementing the future work we can enhance the usage and demand to employ it in war zone.

6.2 Conclusion

In this project a concept is visualize to have multi detection scheme on a single platform which enhances the ability to maneuver and control the affected area in use of miscreants. This project has a very high application in modern scenario of the world.

Detection techniques are a vast subject and application gets more broaden when it is applied in pairs. Achieving this is one great idea to be explored more.

Since by overviewing the present situation this project has a high demand and by increasing the peripherals on it will surely profit the law enforcement agencies a higher edge.

References

al., J. e. (1974). *Patent No. 3,815,114.* United States.

C. A. Kendziora, R. M. (2015). *Infrared photothermal imaging for standoff detection applications.* Germany: SPIE.

(1988). *Configuration management and performance verification of explosive detection system, National Research Council (US) Panel on Technical Regulation of Explosive Detection System.* Stanford: National Academic Press.

John C, M. H. (2007). *Robotic Sound-Source Localization and Tracking Using Intl Time Difference and Cross-Correlation.* Sunderland, UK: Center of Hybrid Intelligent System Press.

Miles, R. B., Dogariu, A., & Michael, J. B. (2012, Jan 31). *Feature Semiconductors Optoelectronics.* Retrieved May 23, 2015, from http://spectrum.ieee.org/: http://spectrum.ieee.org/semiconductors/optoelectronics/using-lasers-to-find-land-mines-and-ieds

Nelson, C. V. (2004). Metal Detection and Classification Technologies. *Johns Hopkins APL Technical Digest, Vol 25, No. 1*, 67.

Robinson, G. R. (2008). Pattern Minefield Detection from Inexact Data. *American Management System*, 7.

Robotics Design for Detection of Explosive with 3G Communication Technology. (2009). Tamil Nadu: Periyar Maniammai University, Thanjavur.

Schubert, H., & Kuznestov, A. (2006). *Detection and Disposal of Improvised Explosives.* The Netherland: Springer.

Siegel, M. W. (1991). Robotic Systems for Deployment of. *First International Symposium on Explosive Detection Technology* (pp. 1-8). Pittsburg: Carnegie Mellon University.

Zorpette, G. (2008, August 29). *Countering IEDs.* Retrieved May 21, 2015, from http://spectrum.ieee.org/: http://spectrum.ieee.org/aerospace/military/countering-ieds

APPENDIX A

PROJECT SYNOPSIS

Extended Title: Explosive threat responder Robot based on metal detector with robotic arm and live video feed to carry out scan of target area and marking potential threats.

Brief Description of The Project / Thesis with Salient Specifications:

There's been an increase in causality rate due to Improvised Explosive devices in persisting security environment. Military security personnel need technologies capable of detecting, early warning and marking explosive devices such as minefields/IED for enhanced safety reasons. This project aims at developing a prototype robot that scans the path of advancing troops for Minefields and marks them in case of detection. This Robot is controlled remotely using wireless technology hence providing a safety distance of about 50-60 meters to the operator. Input from the user is transmitted over the RF link to the robot where it is received, identified and relayed to the appropriate module. The real time video is transmitted back to the controller, which will analyze the video and carry out the appropriate action.

Scope of Work :

The current law and order situation in our country makes this project to be an important part of our defense technology. This has been designed not only for minefield/IED detection and marking but also provides real time video stream of target area along with Lat Long's of target for digital marking for future use. Such technology is severely needed in the modern era wars. Moreover this is a user friendly and portable facility which by its numerous merits will tend to revolutionize the field of defense technology.

Academic Objectives :

Project will provide in-depth study of fol:-

a. Micro Controllers and their programming
b. Interfacing different modules and their operation.
c. Wireless hardware control and communication

Application / End Goal Objectives: Developing a robot which could provide a safety distance and prevent causalities by detecting and marking minefields during move of own troops.
Previous Work Done on The Subject : Nil
Material Resources Required: (Approximate Cost Rs 125,000) ➢ RC/GPS/GSM modules ➢ Micro-Controllers ➢ Servos ➢ Miscellaneous Electronic components ➢ Mechanical Spare Parts ➢ Sensors / Cameras ➢ Power supply and batteries ➢ DC motors
No of Students Required : 3-4
Special Skills Required: Fair understanding of robotics is req in addn to above knowledge.

APPENDIX B

COST BREAKDOWN

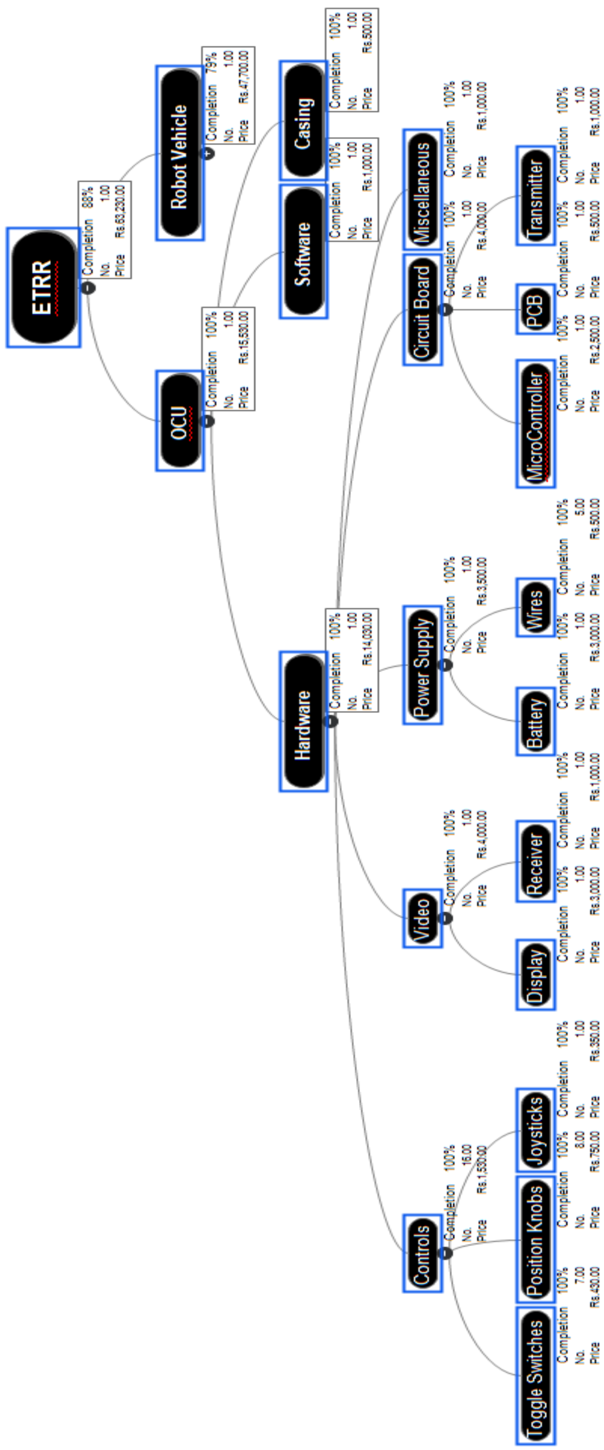


Figure 13 - Expenditure OCU

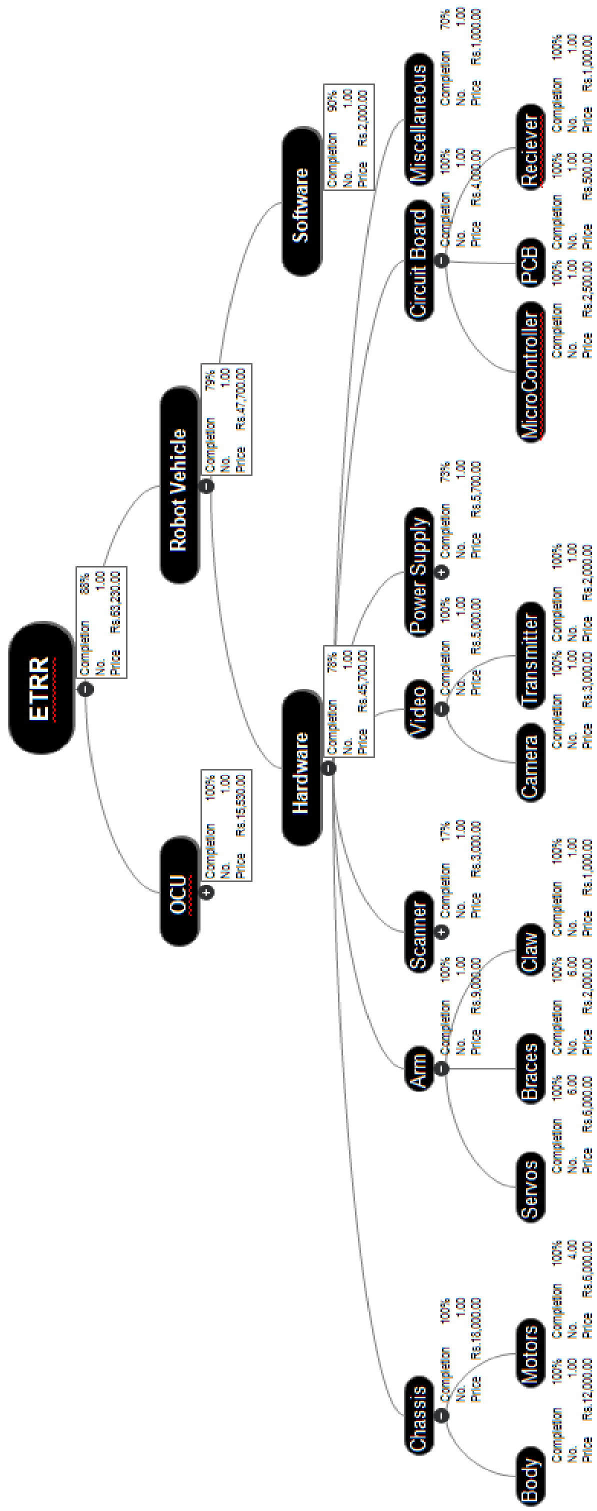


Figure 14 - Expenditure Robotic Vehicle