Robot Rangers

Low Level Design Document

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1 Introduction

According to the UNICEF[1], almost 10,000 people per year are killed by land mines, most of whom are civilians. Thousands more people lose limbs, livelihoods or loved ones. In many cases, the conflict is long over but the danger remains due to the difficulty of finding and destroying the mines. Yet, destroying them is imperative for long term safety, and with over one hundred million planted world wide it is a daunting task. Substantial action is required, but one must disarm a hundred million deathtraps.

2 Problem Statement and Proposed Solution

The problem is the minefield itself: a large area where a large number of explosive devices are randomly hidden. They cannot be spotted visually, since many are buried or designed to be difficult to detect. Disarming them personally would be extraordinarily hazardous, especially without knowing where the mines are buried.

Our proposed solution is a wirelessly controlled robot capable of locating the mines and marking them for future removal. The main goal is keeping humans out of danger, and by remotely locating the mines, disposing of them becomes much easier. Even if a mine is triggered during the marking process, the loss of a robot is a small price to pay.

3 System Description and Block Diagram

The Mine Detecting Robot system will consist of two main parts: the robot itself and the remote control system used to drive the robot and display information about the metal detectors to the user. The two parts will communicate with each other through a wireless connection that will send control information to the robot and return sensor information to display on the remote.

The core of the robot system will be a microcontroller. The microcontroller will receive input from the metal detecting sensors as well as from the wireless transceiver. The output will be sent to the motor driver circuits and also through the wireless transceiver back to the remote. Our current choice of wireless technology, 802.15.4 (which is discussed more in section 6), will communicate to the microcontroller through an SPI interface. A rough block diagram of the robot system is shown below.

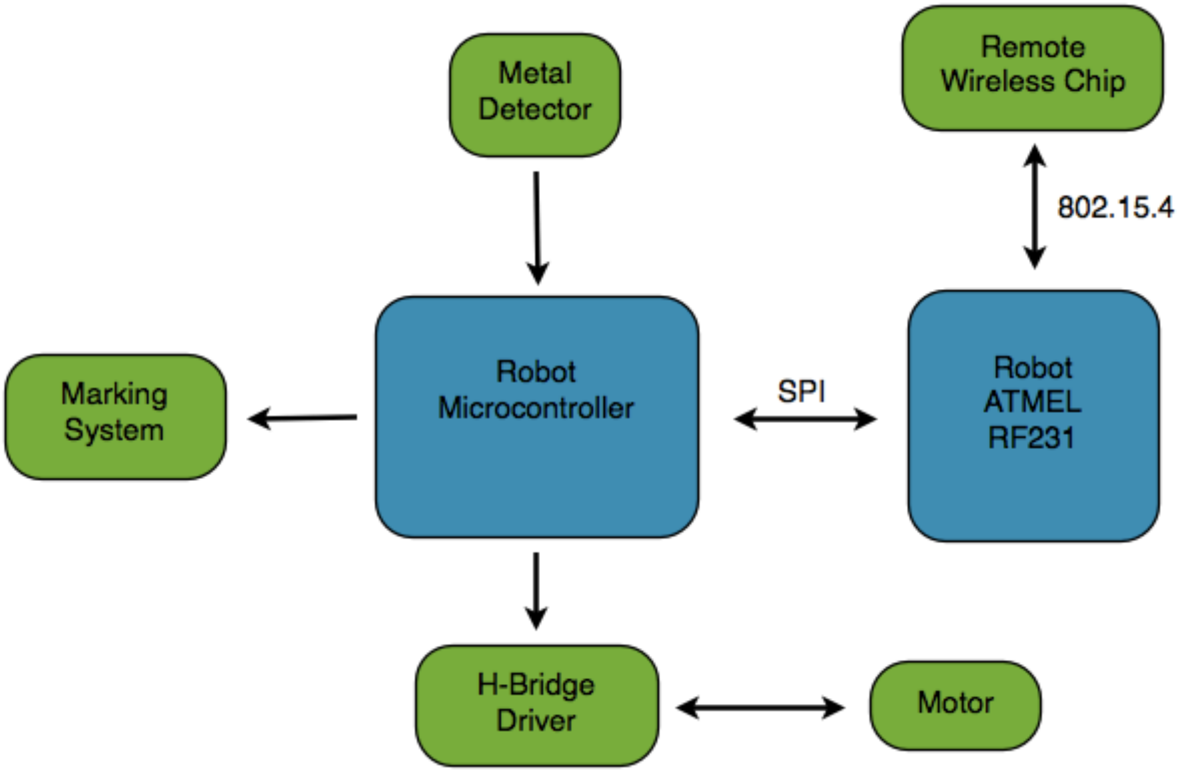

Figure 1. The Robot System

The core of the remote control system is also a microcontroller. This microcontroller will receive inputs from joysticks mounted on the remote control board. Joysticks function as analog potentiometers and will connect to the micro controller through an analog-to-digital converter, which our current choice of microcontroller (section 5.1) supports. The remote control microcontroller will also have a wireless transceiver used to communicate with the robot system. It will send control information to the robot and display information about the metal detector array in an LED configuration on the remote controller board. A rough block diagram of the remote controller system is shown below.

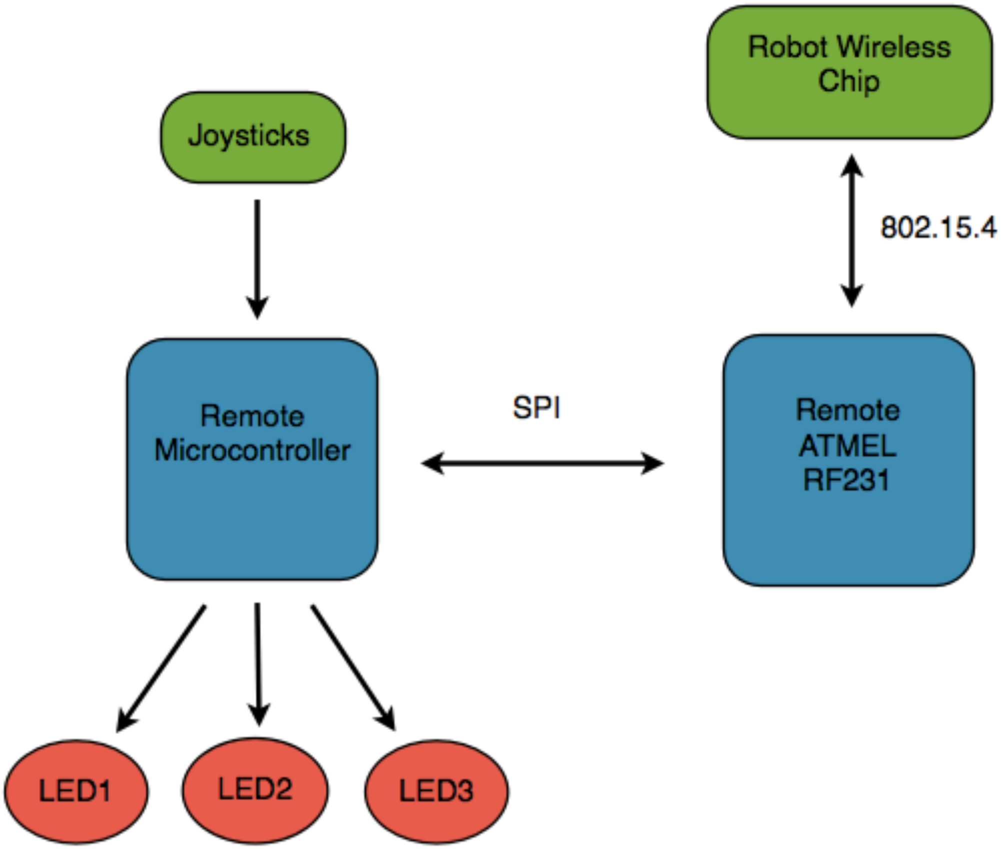

Figure 2. The Remote Controller System

4 System Requirements

4.1 Overall System

OVERALL SYSTEM
Must maintain a wireless connection out to 50 meters
Must have a battery life of at least 30 minutes when in normal operation
Must have a battery life of at least 2 hours when in standby mode
Must detect and mark mines
Must not cause mines to detonate

4.2 Subsystem and Interface Requirements

4.2.1 REMOTE CONTROL SYSTEM
Must run on battery power
Must control movement of robot through two joysticks
Movement of the robot must be able to be controlled through a physical user input interface
Physical user interface must accept inputs based on user input and send outputs to the robot
Physical user interface must send output (i.e. commands) to the robot via a wireless connection
Must have LED configuration to show output of metal detectors to the user
Physical user interface must be easily understood and operated without significant training
Must be powered by either a battery or a power brick connection
Battery life of the unit must last at least 2 hours
Physical user interface must send commands to the robot via a wireless connection

4.2.2

WIRELESS INTERFACE
Must be able to communicate fast enough to ensure no more than 1 second of lag to the robot
Wireless connection must have a range of least 50 meters

4.2.3

MINE DETECTION SYSTEM
Must detect mines within 6” of each side of the robot
Spray paint mark must be at least partially over mine
Must be able to mark a large number of mines
Must not set off mines during scanning and marking process

4.2.4

MICROCONTROLLER
Must have a separate input for each metal detector
Must have enough additional inputs to accommodate the number of sensors needed for autonomous movement to allow for future enhancement
Must have RS232 capabilites
Must be able to generate a PWM signal
Must have SPI functionality to communicate with ATMEL RF231 chip
Must have analog to digital conversion functionality

4.2.5

ROBOT POWER MANAGEMENT
Must be capable of supplying power to robot for at least 30 minutes when in normal operation
Must be able to supply power for at least two hours when robot is in standby mode

4.2.6

MOVEMENT SYSTEM
Must be able to move in response to user input
Must be able to turn in place
Must be able to vary speeds of both treads
Must be able to move in forward and full reverse
Must be able to move on hard surfaces, grass, gravel, dirt, and slightly wet ground

4.3 Future Enhancement Requirements

In order for the robot to be more effective, the wireless range would be extended in the future. This would allow remote operation from a distance further away from the mines and reducing safety concerns related to marking the mines. Instead of a range of 50 meters, it would be helpful to extend our range to above 75 meters.

The robot would be even more effective if it did not require constant supervision and instruction from an operator, which would be accomplished through the addition of an autonomous mode. This would be difficult since the microcontroller would have to be able to independently sense it's environment and position itself over a detected mine in order to mark it.

Another future addition would be a digital copy of the locations of the mines, creating a map for future reference. This would require significant programming to accurately track the relative location of the robot and the location of the mines.

5 Low Level Design

5.1 Detection System

The metal detector announces the location of metal using an LED and an internal buzzer. These will be removed, and the leads connected directly to the robot microcontroller. The controller will look for a high signal, which will trigger an interrupt and indicate the location of a mine. The microcontroller will then send a signal to the robot remote control to light the LED indicating a mine has been found.

Testing Plan:

The detection system should consistently detect a mine or mine substitute when it is underneath the detector. To test this, a metal disc similar in size to a landmine will be placed under the detector. A corresponding LED on the controller should turn on if the system is working correctly.

5.2 Marking System

The spray paint can will be mounted above the metal detector, but high enough so it is outside of detection range (approximately 10 cm). To activate the marking system, a button will be depressed on the remote controller. This will send an interrupt signal to the robot microcontroller, which will turn on a MOSFET switch, powering the solenoid. The solenoid will extend, depressing the nozzle of the spray paint can and marking the mine.

Testing Plan:

The marking system must deploy paint onto the mine. When the corresponding button is pressed on the controller, the solenoid extends and depresses the top of the spray paint can, painting the ground.

5.3 Motor Control

Using built-in functionality, the robot microcontroller will generate the PWM signals for both the left and right motor H-bridge drivers, as well as a directional bit, all based upon input received from the joysticks. The PWM signals and direction signal will be sent to the Allegro A3941 H-Bridge driver chip which will generate the signals and voltages necessary to drive a full H-bridge of power MOSFETs that will control the current to the motor (as seen below).

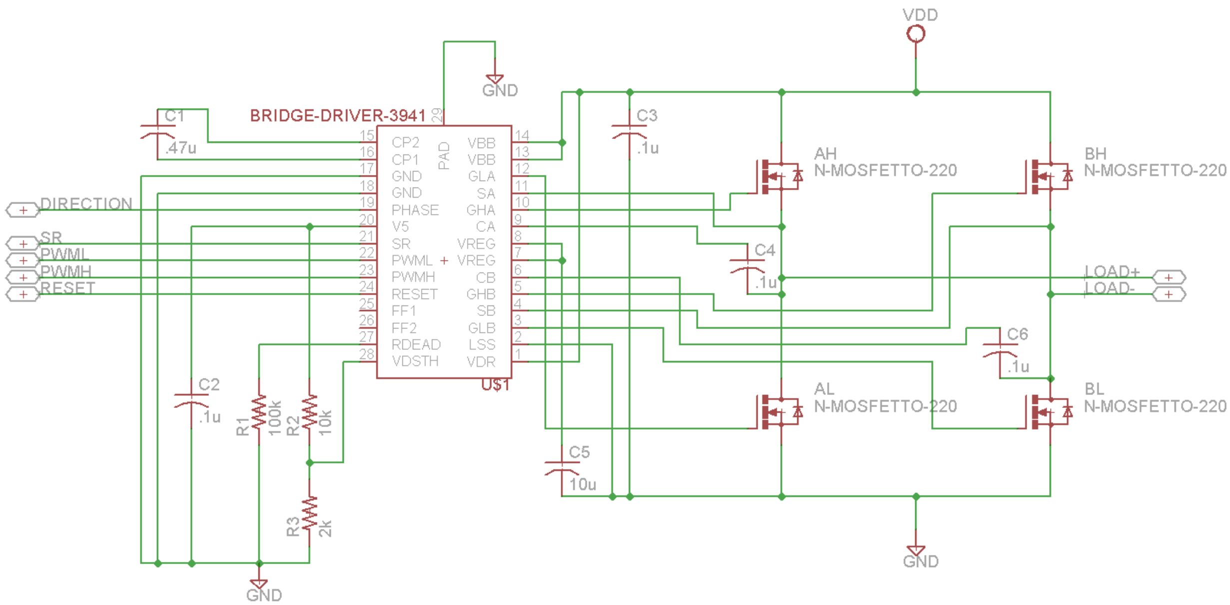

Figure 3. Schematic of H-bridge Driver

Testing Plan:

The robot microcontroller must generate the PWM signals that correlate to the speed indicated by the position of the joysticks. The system will be functioning properly if the motors spin at a speed that correlates to the duty cycle of the PWM signal and by extension, the joystick position information. The left motor should spin according to the left joystick, both forward and reverse direction, and the same for the right side as well.

Psuedo Code:

```
Initialize PWM generator;

Main(){
        while(1){
          Take information from wireless connection about joystick position;
          if(left_joystick > neutral_value)
                  left_direction = forward;
          else
                  left_direction = reverse;
          if(right_joystick > neutral_value)
                  right_direction = forward;
          else
                  right_direction = reverse;
          left_pwm = left_joystick;   //Normalized to range of %DC and joystick position
          right_pwm = right_joystick;        //Normalized to range of %DC and joystick
position
        }
}
```

5.4 Wireless Connection

In order to wirelessly connect the remote controller to the microcontroller on the robot, we will use the 802.15.4 standard that is the basis for radio frequency (RF) ZigBee communication. The part chosen to interface between the controllers is the ATMEL part AT86RF231. The ATMEL part will connect to the microcontroller through a standard SPI interface. This part provides a power output of 3 dBm, which would not be enough power to send a signal a distance of 50 meters. However, through the use of an external antenna, the signal range can be substantially extended. The Zigbee circuit that we will use was designed by Professor Michael Schafer, and a schematic of the circuit can be seen in the following diagram.

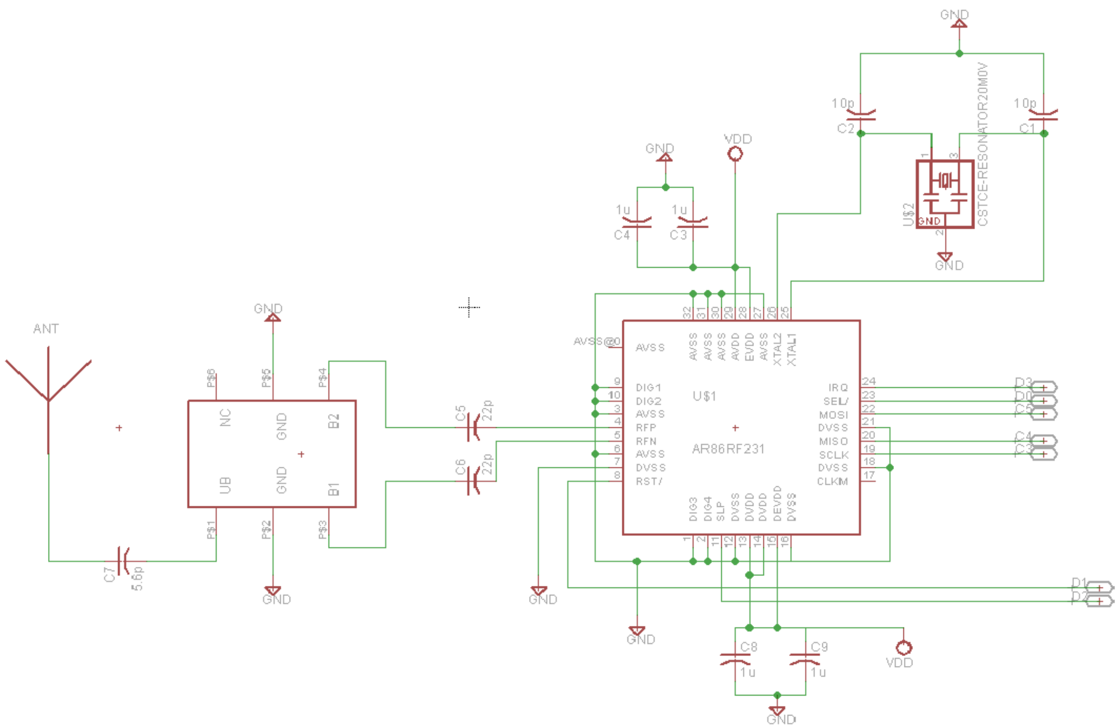

Figure 4. Schematic of Wireless Transceiver

Testing Plan:

To test the wireless connection, packet senders and packet sniffers will be utilized. The setup for the reception of packets will be tested with the packet sender, which will send packets to our receiving module that is connected to a laptop. If the module successfully receives the packets that the packet sender has transmitted, then the software for the reception of packets will be successful. The ability to send packets will be tested in a similar way, except our sending module will send the packets to the packet sniffer, and if packet sniffer receives the packets that our module has sent, then the sending software will be adequately tested. The next portion of the testing plan is to use our sending and receiving modules together to be sure that they are compatible. Once the two systems work together, we will take our system outside and run tests to see how far messages can be transmitted. With the use of the external antenna, our modules should be able to send and receive packets at a distance of at least 50 meters.

Wireless Software Design

WIRELESS SOFTWARE DESIGN - ROBOT
Every 10 seconds attempt to establish a connection with the remote wireless chip
Every .1 seconds, send a new pack to the remote containing information about the state of the metal detector I/O pins
When a packet is received from the robot, call an interrupt
In the robot interrupt routine, read the joystick and button position information and store them in global variables
Set PWM values based on joystick position information from the remote. (see motor control section)
Toggle solenoid switch based on button press information from the remote

WIRELESS SOFTWARE DESIGN - REMOTE
Every 10 seconds attempt to establish connection with robot wireless chip
Every .1 seconds, send a new packet to the robot containing joystick (potentiometer) positions and button information
When a packet is received from the robot, call an interrupt
In the interrupt routine, process the metal detector information and store them in global variables. Also, reset the interrupt flag
Toggle LEDs through the I/O pins corresponding to the information about metal detectors

5.5 Microcontroller

After calculating the number of I/O pins required for both the robot and remote microcontrollers and accounting for extra pins for future enhancements, we decided that 36 total I/O pins would be enough to suit our needs for the robot and remote microcontrollers. We also wanted to make sure that the microcontroller would be able to generate 2 separate PWM signals to drive both bridge drivers. The chip we selected is the Microchip PIC18f4321 (see references). It has 36 total I/0 pins on a 44 pin package. It has SPI interface capabilities for communicating with wireless chip as well as serial

RS-323 interface for communicating with a serial terminal if necessary. This microcontroller will be more than suitable for both the robot and remote systems.

5.6 Frame and Body

The design of the robot will be determined by the size of the motors and gearboxes it needs to house, as well as the battery and other electronic components which we do not have at this time. The design will probably be a rectangular prism, made out of Lexan, which is similar to Plexiglas. It is durable and tap-able , but most importantly it is lightweight to reduce the probability of an accidental detonation. To move the robot, treads on a track system will be mounted on each side. The metal detectors will be attached to the top, and extend over the front and both sides of the robot.

5.7 Robot Power Management

The motors need to run off a 12V battery supply. Since the maximum current draw of the motors is 4 A, a battery like the closed cell Tempest Power Security Battery with a rating of 7.5 Ah would allow the robot to run for at least 30 minutes. This would be sufficient because the current draw of the non-motor circuits is negligible compared to the current draw of the motors. The other circuits would use a voltage regulator in order to bring down the voltage to 3.3V, the level at which the microcontroller runs. When the robot is not running, a battery like this one would provide the required power to run for at least 2 hours. We will also use a 20 amp auto-resetting circuit breaker in between the battery and the motor to prevent an over-surge of current resulting from a motor stall or short circuit. The motor we plan on using (RS545, in the motor control section) has a stall current of 21 amps so the 20 amp breaker will limit us just before we run into problems?

5.8 Remote Power Management

Battery choice for the remote power system will be significantly different than the robot battery choice because it does not have to drive any motors, which are the largest consumer of power in the entire system by a great deal. A simple RC-car style battery pack that runs around 4-7 volts will be sufficient to supply enough power for the microcontroller for the time specified in the requirements section. The power consumption of the remote board will only be determined by the power required to: read information from the joysticks, power the LED’s, power the microcontroller as well as power the wireless transceiver.

6 Bill of Materials

See attached spreadsheet.

Note: Generic components such as surface mount resistors and capacitors and transitors have been included for completeness. They do not necessarily need to be ordered as there is a good chance we can find them from either Dr. Schafer or from the engineering department.

7 Conclusions

The complete system will contain several complex systems, each of which we have outlined here. Each requires a different approach, from the wireless system coding to modifying the metal detectors. The coding for our microcontroller is particularly important, as this is what will integrate the individual systems. Other systems, such as the marking system, are primarily mechanical and will determine the final frame design. All will require significant work from our team, but we believe our plan is sound and are ready to move forward with construction.

8 References

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5. Pic18F4321 Microcontroller -
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6. RS545 Motor from BaneBots
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7. P60 Gearbox from BaneBots
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