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*Research Article*

# Intelligent Weapon System to Minimize Friendly Fire

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### *Abstract*

*Friendly fire is an attack by a military force on friendly forces while attempting to attack the enemy, either by misidentifying the target as hostile, or due to errors or inaccuracy. Such attacks often cause injury or death. The aim of this project is to develop a non-invasive system, which can be mounted on the guns to prevent friendly fire from happening. The technology developed here aims to reduce friendly fire at the instant it is about to happen. This technology makes use light dependent resistors (LDR) and Lasers.*

***Keywords:*** *Friendly fire, signal conditioning, light dependent resistor, lasers.*

## 1. Introduction

Friendly fire is often seen as an inescapable result of combat, and because it only accounts for a small percentage of casualties, can often be dismissed as irrelevant to the outcome of a battle. The effects of friendly fire, however, are not just material. Troops expect to be targeted by the enemy, but being hit by their own forces has a huge negative impact on morale. Forces doubt the competence of their command, and it's prevalence make commanders more cautious in the field. The goal of this project is to minimize the occurrence of friendly fire. Friendly fire arises from the confusion inherent in warfare. The three main contributing factors to friendly fire are:

- Error in Position occurs when the fire aimed at enemy forces may accidently hit our own. This happens during close combat situations.
- Error in Identification occurs when the fire is accidently aimed at our own forces on account of judgemental error. This may be due to poor external conditions (like lack of light). This error may also arise due to miscommunication between soldiers. It is more prevalent when allied troops are fighting with language is barriers to overcome.

## 2. Proposed Solution and Block Diagram

The proposed solution can be divided into two subsystems: 1. Gun Subsystem 2. Vest Subsystem. The block diagram of the proposed solution can be seen in Fig 1.

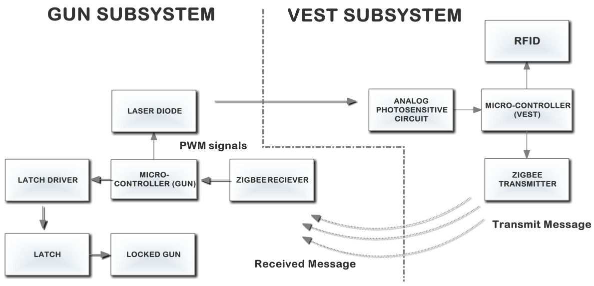


**Fig.1:** Block Diagram of proposed solution

The block diagram depicts the functioning of the vest circuitry. The functionality is as follows:

- The microcontroller monitors for two primary occurrences, that is, the presence of the RFID tag and also the aberration in the analog value from the junction of the potential divider.
- The system becomes active only if the RFID Tag is detected, or else, it does not proceed further in the execution of the functioning algorithm. This is a demonstration of the solution to the problem occurring if an enemy obtains possession of a vest used to protect allies.
- Once a laser impinges on the photosensitive circuit, the resistance circuit changes. This causes the output of the signal conditioning circuit which could consist of a linearization circuit or a potential divider circuit explained in the subsequent sections.
- Once this happens the analog value read by the microcontroller is drastically different from the expected value. A threshold is used keeping this in mind and the message to freeze the trigger is sent according to whether or not this aberration in expected readings is detected.

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The functionality of the gun circuitry is as follows:

- The microcontroller waits for the message that the laser has impinged on the vest.
- Once received it immediately signals an electromagnetic push-pull latch to activate via a high current latch driver with an adequately powerful power supply.
- When not in reception of the "I am friendly message", It signals for the latch to be retracted.

### 3. Hardware Implementation

This section provides a detailed description of the hardware used implement the prototype. As mentioned in the previous section, the proposed solution is divided into two subsystems.

*Gun Subsystem:* This subsystem has the following components.

1. **Micro-controller**: For prototyping sake we used an Arduino Uno (ATMEL 328P) micro-controller. This is because it is easy to interface external peripheral devices to it and it has an on board voltage regulator to supply 5V (DC) voltage.
2. **ZigBee Receiver**: This component enables wireless communication between the vest and the gun. The model used here is ZigBee Series2 transreceiver having a range of 200m at a frequency of 2.4Ghz.The transreceiver here has been configured to receive appropriate messages.
3. **Laser**: The laser is mounted on the gun. It is a standard 650nm (red) laser with a power rating of 10mW. The brightness of the laser impinging on the vest is controlled by PWM signals from the micro-controller.
   **Latch Driver**: This is basically a high current motor driver coupled with a half bridge IC. This IC has been used to drive our latch system.
4. **Latch**: It is an electromagnetic device that acts as an actuator in this system. It has a retractable piston which is capable of locking the trigger of the gun.

*Vest Subsystem:* This subsystem has the following components.

1. **Micro-controller**: For prototyping sake we used an Arduino Uno (ATMEL 328P) micro-controller. This is because it is easy to interface external peripheral devices to it and it has an on board voltage regulator to supply 5V (DC) voltage.
2. **ZigBee Transmitter**: This component enables wireless communication between the vest and the gun. The model used here is ZigBee Series2 transreceiver having a range of 200m at a frequency of 2.4Ghz.The transreceiver here has been configured to transmit appropriate messages.
3. **RFID Reader**: The module used here is a mifare RFID reader. It is interfaced to the micro-controller via the SPI. The passive tags have to be in close proximity with the reader for the system to work.
4. **Analog Photosensitive Circuit and signal conditioning**: This module forms the heart of the vest subsystem. It consists of a custom made photosensitive unit which is made by connecting LDRs in parallel (to form a matrix). Each row of the LDR in the matrix can be represented as single equivalent of the LDRs as shown in Fig.2. A multiplexer is present to scan each row of the LDR matrix at regular intervals of time.

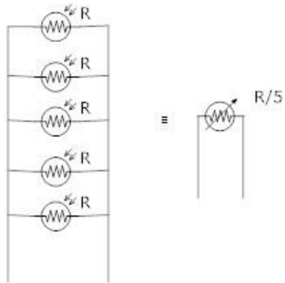


**Fig.2:** Effective LDR

To effectively obtain values from the vest circuitry, we can adopt any one of two signal conditioning techniques.

*Potential Divider Approach*: The first one makes use of a potential divider arrangement where the effective LDR forms the lower half of the potential divider and a suitable resistance with resistance comparable to the effective LDR's range of resistances forms the upper half of it. The junction between the effective LDR and the fixed resistance is connected to the inputs of a multiplexer. This is done for all the effective LDRs. The microcontroller constantly monitors the input from various junctions by giving the right digital values to the select lines of the multiplexer to choose to read from each junction and take the analog reading. The circuit can be understood more clearly from Fig.3 below.

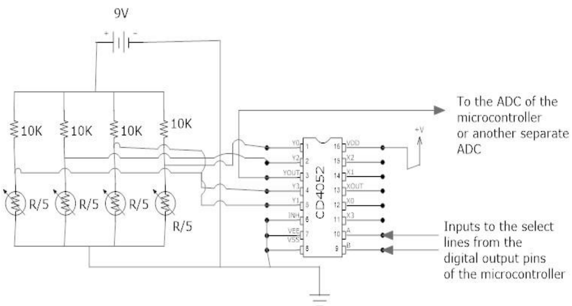


**Fig.3:** Wiring Diagram of the Potential Divider Approach

*Linearization Approach:* This approach is mainly used when the potential divider approach cannot give feasible enough results to be accommodated by the microcontroller's ADC. To make the most out of the signal and optimize it to the ADC being used whether internal or external this method can be applied.

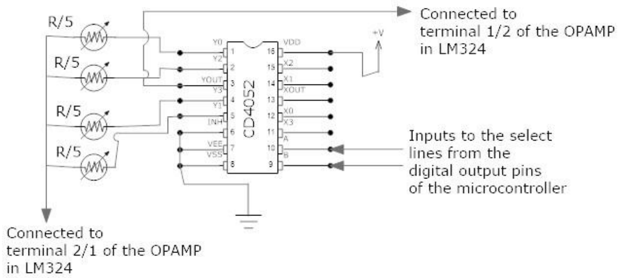


**Fig.4:** Wiring Diagram of the Linearization Approach

The circuit essentially attempts to completely linearize the signal obtained from the LDR. The figure above explains the general connection and multiplexing action of the effective LDRs. This is supplemented by Fig.5 which shows the circuit schematic.

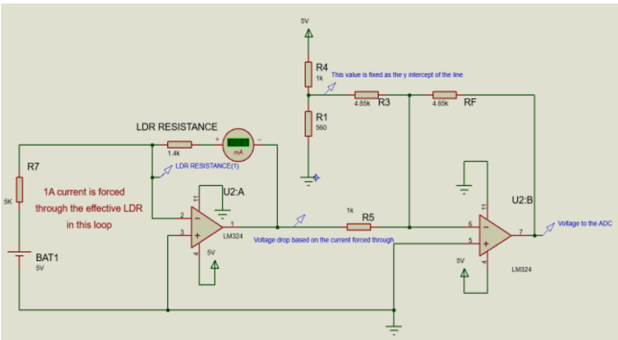


**Fig.5:** Circuit Implementation of the Linearization Approach

The Rationale and Design of the circuit is as follows:

The output of the effective LDRs must be in a form that is perfect for the ADC. And we define 'perfect' by converting the change in resistance of the effective LDRs to a voltage change spanning over the range of acceptable voltages by the ADC from minimum to maximum. In our case, let us assume the in built ADc of the Atmega328p. We require the output to be a linear signal from 0V to 5V. We linearize the non-linear response of the effective LDRs by trying to fit it in to the following equation:-

$$Vout= Rs*m + Vo \quad (1)$$

Here, Vout is on the y axis and it is the voltage being fed to the ADC. Rs is the resistance of the effective LDR multiplexed into the feedback network of the first OPAMP in the LM324 IC as shown in Fig.4. m is the slope of the line and Vo is the y intercept or the default voltage in the expression.

We substitute the extreme cases with ambient lighting saturating the ADC with 5V and the laser impinging on the vest with 100% duty cycle as 0V. The readings with a multimeter showed that Rs was 1.4k Ohm with ambient lighting in daylight and 370 Ohm with the laser impinging on the vest with 100% duty cycle. Hence we use the two extremes in the equation (1) to obtain the following two equations:-

$$5= 1400*m + Vo \quad (2)$$

$$0= 370*m +Vo \quad (3)$$

On Solving (2) and (3) we obtain:
m=0.00485 and Vo= -1.79611 V

Plugging in the values of m and Vo into equation (1) we obtain:-

$$Vout= 0.00485*Rs - 1.79611 \quad (4)$$

The Signal conditioning circuit has been designed to obtain the expression given by equation (4).

The $I^2R$ power loss through the effective LDRs can be minimized by ensuring that only a small amount of current is driven through it. For convenience sake we set this current value to 1mA.

With that in mind the individual terms of equation (4) are realized in our case as follows:

We use a 5V source from the VCC pin of the microcontroller or through a 7805 voltage regulator and a 5k resistor to force 1mA of current through the OPAMP feedback resistance. This takes place as I=V/R and that yields 1mA and since no current flows into the terminals of an OPAMP, all the current flows through he resistance. Thus the voltage drop across the effective LDRs manifest at the output terminal of the OPAMP as -0.001*Rs. But what we need according to equation (4) is 0.00485*Rs and a positive voltage. Hence we use the second OPAMP as an inverting summing amplifier to invert the voltage and provide a gain of 4.85 to which multiplies with the -0.001*Rs voltage to give 0.00485*Rs as one of the terms.

The additional y intercept term is obtained by simply using a potential divider circuit with the same 5V source as the other term to obtain the fixed positive voltage of 1.79611 V. In our case we need it inverted and unchanged in magnitude and hence we put a resistor in series with the potential divider junction whose magnitude is the same and the feedback resistance of the inverting summing amplifier to add the negative fixed y intercept voltage to the end expression.

## 4. Software Implementation

The software used to program the micro-controllers for the prototype is Arduino IDE. The main parameters which were configured have been listed below:

1. Gun Subsystem

- The PWM signal sent to the laser from the micro-controller. This forms a vital part, as the this signal adjusts the brightness of the impinging laser. With variation in the brightness of the laser, different soldiers (guns) can be identified by the vest subsystem, so that appropriate messages to cease fire (i.e. correct message to the correct gun) can be sent by the ZigBee transmitter of the vest.

- The baud rate of communication between the ZigBee RF modules was adjusted to 9600bps.
- The speed of the latch locking the trigger of the gun was also adjusted with the help of the motor driver.

2. Vest Subsystem

  - The micro-controller was configured to continue working only if it had a high output from the RFID reader.
  - The baud rate of communication between the ZigBee RF modules was adjusted to 9600bps.
  - The select lines of the multiplexer were toggled using digital output from the micro-controller.

To sum up the flow charts on how both the micro-controllers function is included in fig.5.

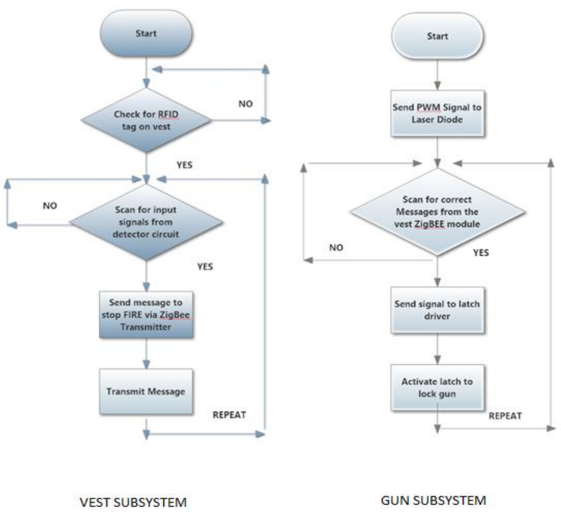


**Fig.6:** Flow chart of the programmed micro-controller

### 5. Advantages of the Proposed Solution

The following are the advantages of the Intelligent Weapon System

- The proposed solution helps reduce the number of causalities from friendly fire.
- If the enemy retrieves your weapon, they will not be able to use it against us.
- The laser is capable of travelling long distances without loss of intensity.
- The proposed solution requires little modification to the guns.
- The proposed solution is also a cost effective solution.
- The mechanism is also very durable and rugged.

### 6. Results

The results of the different signal conditioning methods are as follows:

*Potential Divider method:*

The below table shows the red colored text as regular analog readings without the laser impinging on the LDRs. The green text shows the values given at the10 bit ADC of the microcontroller, with 5V reference voltage, when the laser was impinging on any one of the LDRs in each parallel string.

**Table 1:** 10 bit ADC value output of the microcontroller

| LDR Column 1 | LDR Column 2 | LDR Column 3 | LDR Column 4 |
|---|---|---|---|
| 760 | 772 | 782 | 769 |
| 752 | 789 | 779 | 788 |
| 764 | 761 | 767 | 777 |
| 77 | 63 | 72 | 66 |
| 83 | 71 | 79 | 70 |
| 64 | 88 | 84 | 87 |

The graphs obtained from the LDR matrix for different cases are shown below(one column was taken into consideration):

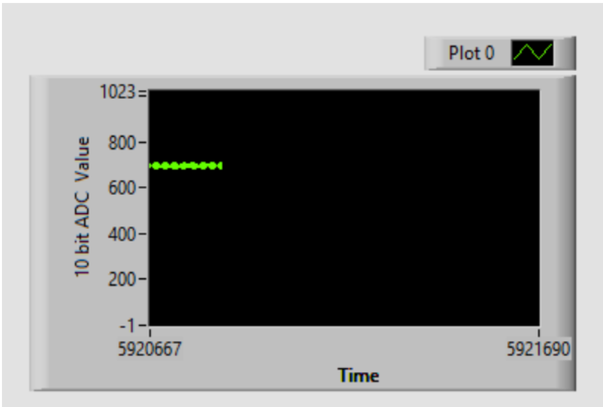


**Fig.7:** Graph obtained at ambient lighting

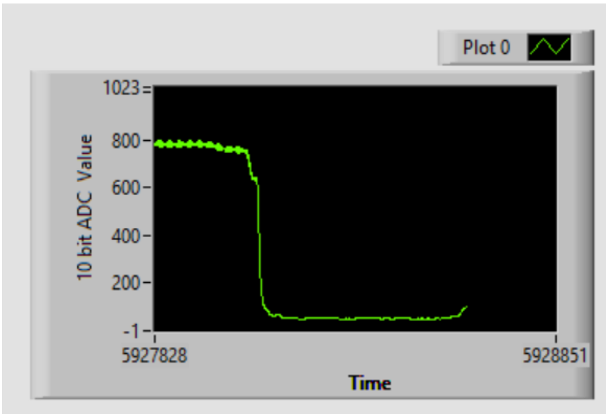


**Fig.8:** Graph obtained when laser was impinged on the LDR vest

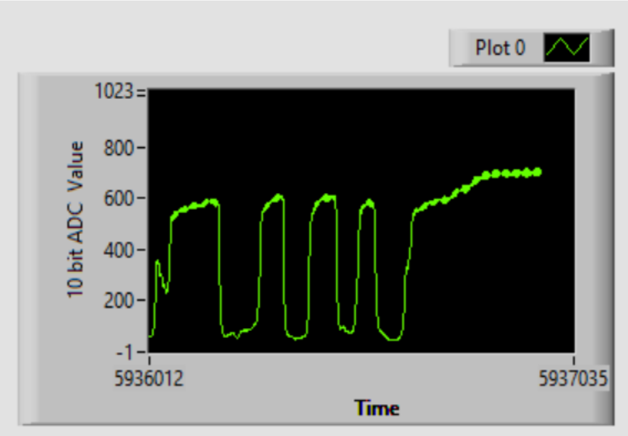


**Fig.9:** Graph obtained when laser was impinging and not impinging in a successive fashion to test speed of response

*Linearization Method:*

The simulation results were obtained keeping in mind the resistance values to be considered when our effective LDRs were in ambient lighting conditions without the laser impinging on them and with the laser light impinging on them. The resistance in the feedback of the first OPAMP of the LM324 were varied according to the extremes and midpoint value. The simulation results for the effective LDR resistances as 370 Ohm, 865 Ohm and 1.4k Ohm are shown in Fig.10, Fig.11 and Fig.12 respectively below:-

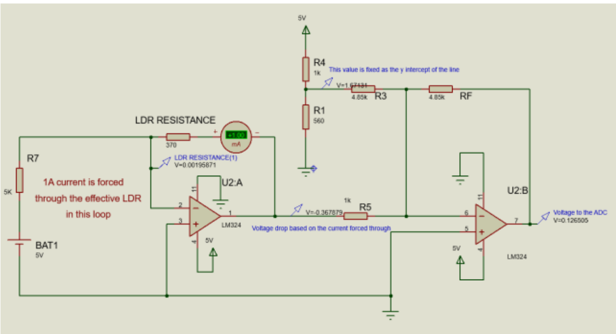


**Fig.10:** Simulation Result with effective LDR resistance as 370 Ohm

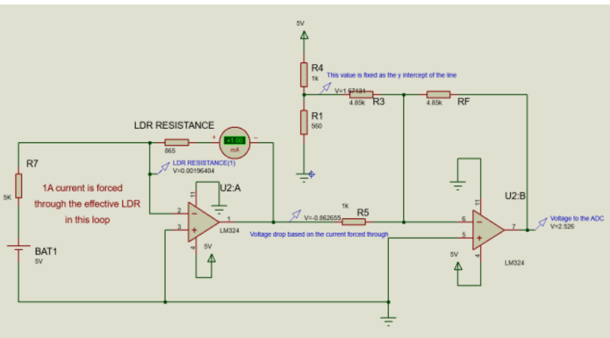


**Fig.11:** Simulation Result with effective LDR resistance as 865 Ohm

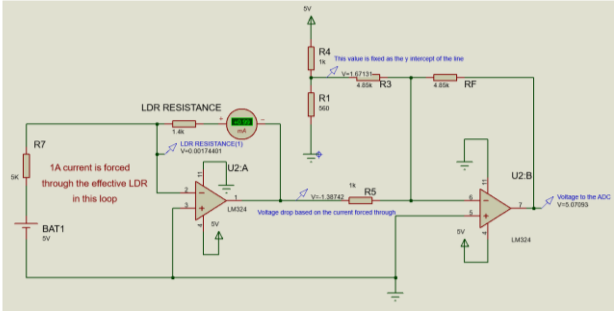


**Fig.12:** Simulation Result with effective LDR resistance as 1.4k Ohm

*Prototype Setup:*

The images of the prototype have been attached below. The basic functionality and concept remains the same but the prototype can be improved upon before a market ready product can be established.

**Fig 13:** Laser mounted on the gun and poised along the line of fire

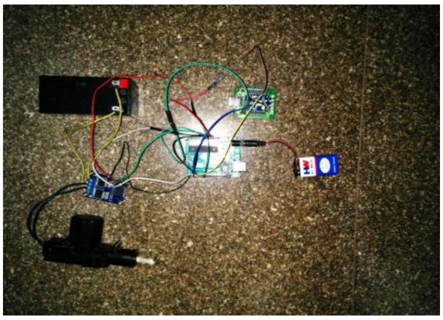

**Fig 14:** Physical implementation of gun subsystem

**Fig.15:** Latch mounted on the gun

**Fig.16:** Physical implementation of vest subsystem

**Fig.17:** Complete setup of the prototype (gun and vest subsystems)

## Conclusion

The proposed solution can be used for reducing the fratricide and Blue on Blue thus reducing the lives lost in the battlefield. This setup can be used in training of soldiers by giving them real time feedback about their movements in combat areas. The system can be later improved upon by using colored lasers and by implementing the military grade security encryptions to messages transferred between the two subsystems (gun and vest).

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