I.F.F. (Identification Friend or Foe) System

By

Eric Meyers (emeyer7)

Noah Prince (nprince2)

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TA: Braedon Salz

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Contents

Acronyms & Pre-Requisite Information

- Infantry - branch of a military force that fights on foot.
- I.F.F. - Identification Friend or Foe
- PWM - Pulse Width Modulation
- PCB - Printed Circuit Board
- R.F. - Radio Frequency
- RTC - Real Time Clock

1 Introduction

There have been several friendly fire incidents in recorded military history, accounting for an estimated 2% to 20% of all casualties in battle[1]. Using attire to identify friend vs enemy is problematic in situations when both sides are clad in the same camouflage pattern, or are obscured by obstacles.

In order to reduce the amount of friendly fire accidents in modern combat, a Infantry I.F.F. (Identification Friend or Foe) will be designed and constructed which will notify a soldier bearing a weapon whether or not their target is friendly.

Several I.F.F. systems exist for aircraft, however not many reliable systems have been constructed to suit infantry.

The system will mount to the side of any weapon, send out queries, ask if a target is friendly, and upon receiving a successful (friendly) reply, will notify the operator.

This will be accomplished through a laser transmission system mounted to the rail (weaver mount) of a weapon. If the friendly personnel receives any of this signal (via phototransistors), it will respond with "acknowledgement" that it is friendly. Once the interrogator receives notice that the target is friendly, the dot sight will turn to a different color.

Encryption plays a large role in a system like this, and for this reason must be emphasized heavily in the design process. Pulse Width Modulation will be used to transmit a unique I.D. of the interrogator pointing their sights at a friendly target, and upon receiving this laser transmission, the target will respond with an RF signal. This RF Isotropic Signal will be encrypted with a passphrase that is generated using a method similar to a "Time-based one-time password" algorithm.

The benefit of a system like this are the following:

- Reduce number of friendly fire accidents during combat [2]
- Reduce number of misfires accidents during combat [2]
- Notify friendly personnel location of particular friendly target when aiming
- Other applications including but not limited to:
  - Paintball or Airsoft
  - Arcade Laser Tag

The cost of a system like this will be heavily emphasized throughout the design phase. The team has proposed a schedule dating from February 8th - May 2nd of this semester. This gives the team $\approx$ 3 weeks for design, $\approx$ 7 weeks to assemble, test, and refine, and $\approx$ 3 weeks to document. The cost and schedule are both expanded upon in Section 5 in this document.

2 Design

2.1 Block Diagram

The design of a system like this is very flexible and can be implemented in several ways. The team decided to break this up into two subsystems with individual sub-components. These will be referred to the "friendly interrogator system" and the "friendly target system".

1. Friendly Interrogator System
    - Laser Transmission (Transmit Query)
    - RF Receiver (Receive Acknowledgement)
2. Friendly Target System
    - Photoreceiver (Receive Query)
    - RF Transmitter (Transmit Acknowledgement)

Below is a block diagram containing all subsystems that will be designed and constructed this semester. The red dotted line is referring to the Laser Subsystem which is essentially a adjustable laser that will reach the desired distance along with a photodetector to detect these signals. The blue dotted line is the R.F. Subsystem which will serve as the "acknowledgement" to the laser signal to notify the interrogator that the target they are pointing their weapon at is friendly. The green dotted line is referring to the Friendly Interrogator and the Friendly Target Subsystem which will be expanded upon in the following pages.

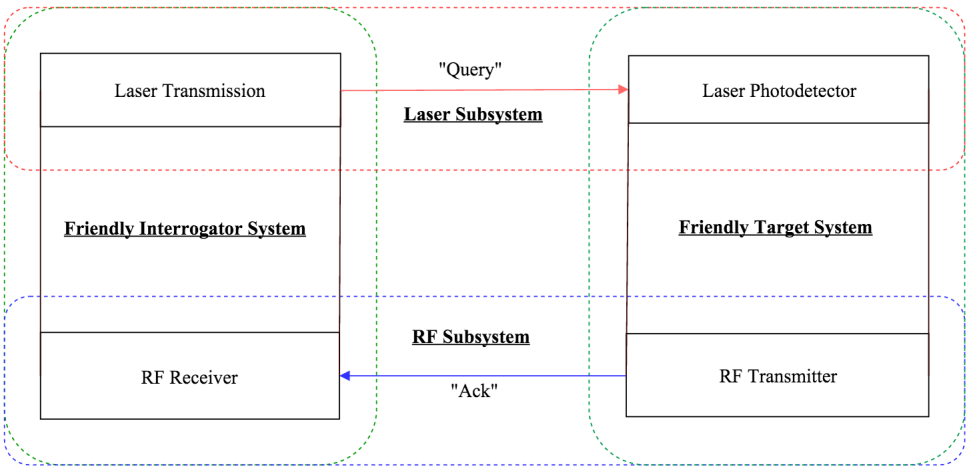

Figure 1: I.F.F. Subsystem Diagram

2.2 Block Descriptions

Friendly Interrogator System

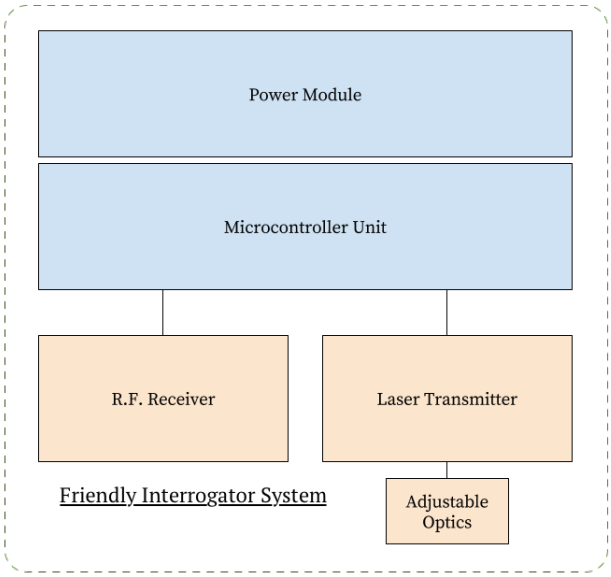

Figure 2: Interrogator System Diagram

Laser Transmission

- Optical adjustment to achieve:
  - Short Range (Close Quarters) : 0 - 50 m
  - Medium Range (Urban Setting) : 50 - 150 m
  - Long Range : 150 - 300 m
- P.W.M Signal to transmit signal attached with a unique I.D. of interrogator.
  - Ability to adjust duty cycle to transmit information
  - Preamble followed by unique I.D. of transmitter

R.F. Receiver

- Receives "acknowledgement" signal from friendly target
- Must have ability to verify passphrase with common clock (Real Time Clock - RTC)
- If successful (i.e. system identifies target as friendly), then indicator (LED) will change color from red to green.

Friendly Target System

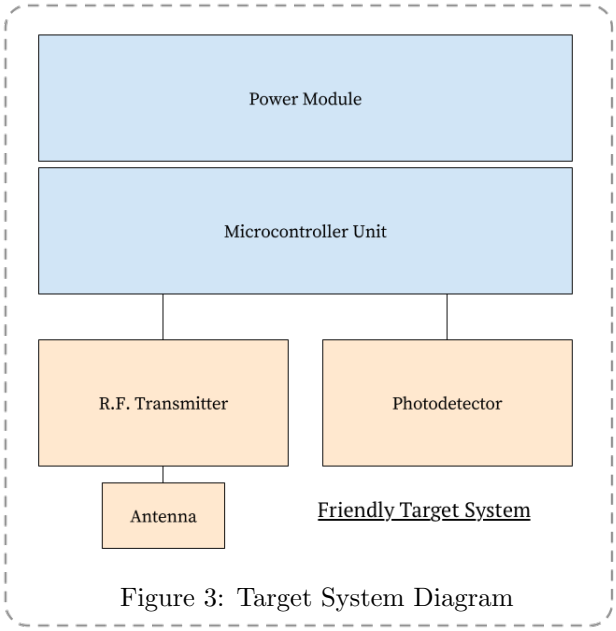

Figure 3: Target System Diagram

Laser Photodetector

- Couse staff and resources provided on Wiki will help narrow down options in the design phase.
  - https://courses.engr.illinois.edu/ece445/wiki/?n=Topics.LaserDiodeAndPhotodiodeIntroduction
- Photodiode that must be engineered to receive the wavelength and intensity of the laser transmission at maximum range.
- Photodiodes will be mounted on the wearer's helmet, gun, and/or chest to detect incoming transmissions.

R.F. Transmitter

- Isotropic R.F. Radiator to acknowledge query sent by laser on interrogator
- Ability to reach up to 300 m
- Encrypted Passphrase
  - Password generated based off of common clock (RTC)
  - Clocks will need to be synced with a common clock source periodically

2.3 Flow Chart

The below block diagram demonstrates the basic functionality of a system like this. First the

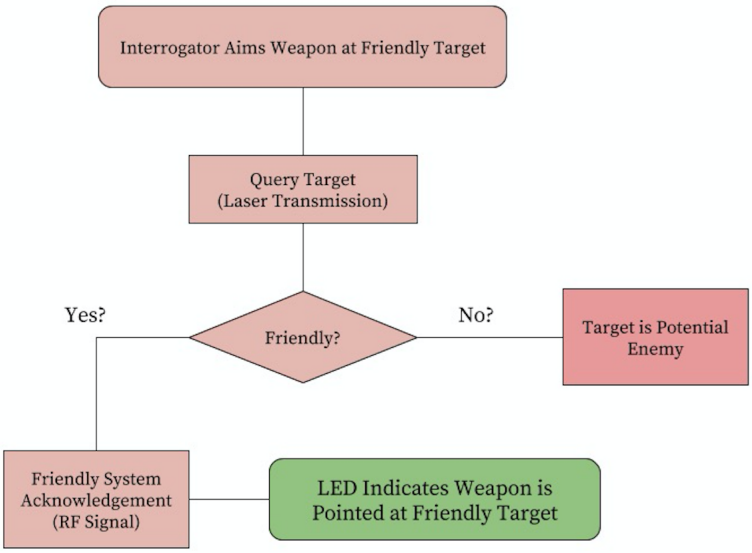

Figure 4: Block Diagram

3 Requirements and Verification

The requirements for this semester are as follows:

1. Power Module - must maintain a constant DC power source of 5.0V ± 2.0V.
2. Laser transmitter must transmit a PWM signal with a duty cycle of less than __¡insert numerical value here¿__ to transmit a unique integer I.D. of the interrogator.
3. Laser transmitter must be able to span a range that is equivelent to the width of a human chest (2-3 ft) at the following distances:
   - Short Range (0 - 50 m)
   - Medium Range (50 - 150 m)
   - Long Range (150 - 300 m)
4. Photoreceiver with the ability to detect a PWM signal up to ≈300 m of the same wavelength as the laser transmitter.
   - 90% ± 5% of packets must be detected by photodetector properly
5. Microcontroller Unit with ability to generate PWM signals through laser transmission and receive R.F. Acknowledgement and process the signal.
6. Isotropic R.F. signal with a range of ≤ 300 m (operating frequency to be determined later).

7. R.F. receiver with the ability to detect an R.F. signal of $\leq$ 300 m
8. Encryption - An R.F. signal being transmitted from a friendly target back to the interrogator must contain a clock that is within $\pm$ 10 seconds of the clock that is onboard the interrogator.
9. Speed - The average human reaction time for visual stimulii is 190 milliseconds [3]. A friendly target at 300 m should be marked friendly within 190 milliseconds so that, to a human user, it seems nearly instantaneous.
10. Laser transmitter accuracy - at 300 m, the beam makes contact with the aiming point of the rifle.

4 Tolerance Analysis

The signal transmission from the friendly interrogator to the friendly target will be a critical aspect of this project. The extremes of this transmission must be tested; ensuring that it has bot the range and signal span required.

Capturing these requirements, the team must transmit a signal to a photo-detector at the following ranges:

- Short Range (0 - 50 m)
- Medium Range (50 - 150 m)
- Long Range (150 - 300 m)

The team should then verify that the signal was received and processed by the MCU. Furthermore, the team should verify that the signal spans the width of a human chest. More concretely, that a sighted-in laser transmitter can be aimed at any point within 1-1.5 feet of the receiver and still register friendly.

The team must transmit a signal over a distance of 300 meters that has the ability to be accurately received by a photo-detector and processed by an MCU.

Test Procedure:

- Mount the receiver 300 m downrange of the transmitter
- Aim the laser transmitter directly at the receiver, using a mount (like a vice grip) to keep it stable.
- Verify the signal is received.
- Aim and verify the signal is also received when aiming 1.5ft to the right, top, and bottom of the receiver.
- Repeat these steps for 50 m and 150 m.

Accuracy can be captured by the likelihood of Type I and Type II errors for the system. That is, we can define a Type I error as incorrectly identifying something as friendly, when in fact it was either an inanimate object (or worse) an enemy. A Type II error, then, would mean that the system failed to mark a friendly target as friendly. Type I errors should be greatly mitigated by the encryption system; that is, if an acknowledgment

is received and valid, it is impossible that the acknowledgment occurred due to chance. The sources of Type II errors, then, would be a glitches in either the interrogator circuit or the acknowledgment broadcasting circuit. A Type II error, however, could happen for a number reasons; including the laser being interrupted before its identification could be transmitted to the photo-receiver. I don't know where this belongs but might be useful

5 Cost & Schedule

The schedule and budget of this project will be analyzed in the sections below.

5.1 Schedule

Please refer to Figure 5 for the brief timeline of this project highlighting the milestones and approximate duration of each phase. Refer to Figure 6 for an extended week-to-week description of what the team wishes to accomplish over the duration of the semester.

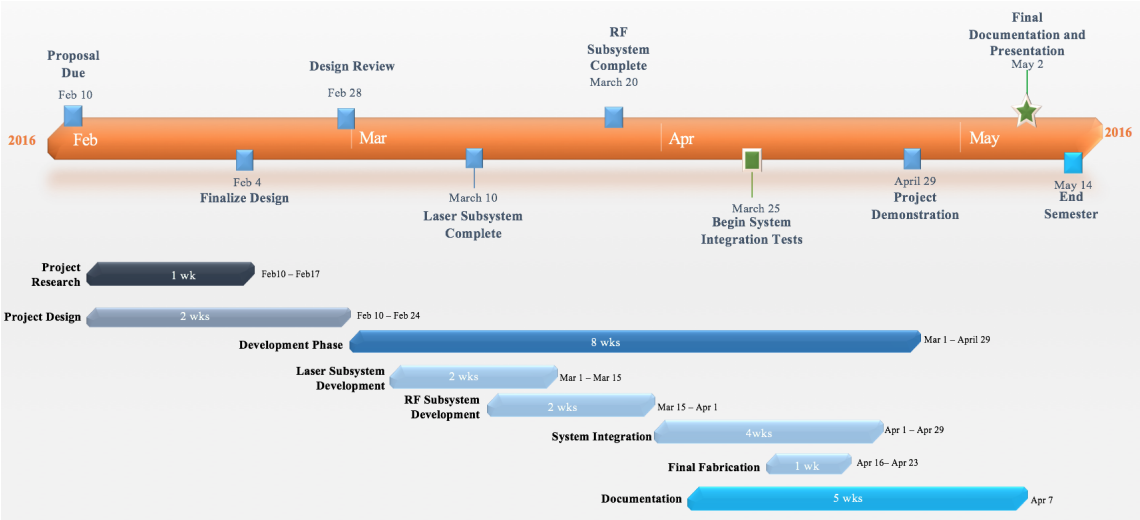

Figure 5: Timeline with Milestonesxx

Wk #	Week	Task	Responsibility
1	2/8	Finish and Submit Proposal	Team
		Research R.F. Transmitter and Receiver Modules	Eric
		Research Optical Adjustment Techniques/Theory	Noah
2	2/15	Research Laser Transmitter and Photodetector Modules	Team
		Research MCUs and Power Module	Team
		Develop encryption algorithm and communication protocol	Noah
3	2/22	Develop circuit for photodetector and R.F. Modules	Eric
		Select and Buy Parts/Sensors	Team
		Finalize Design Review Documentation	Team
4	2/29	Finish and Submit Design Review + Presentation	Team
		Construct basic laser transmission circuit with protoboard	Noah
		Construct basic R.F. circuit with protoboard	Eric
5	3/7	Establish communication between both Laser Transmitter and Photodetector	Team
		Establish communication between R.F Transmitter and R.F. Receiver	Eric
		Implement PWM with laser	Team
6	3/14	Implement RF Encryption Algorithms on MCU	Noah
		Test and Debug	Team
		Finalize Construction before Spring Break	Team
7	3/21	Spring Break (NO SCHOOL)	----
8	3/28	Assemble Friendly Interrogator System	Noah
		Assemble Friendly Target System	Eric
		Test and Debug	Team
9	4/4	System Integration Tests	Team
		Test Tolerance Analysis	Team
		Revisions for PCB	Team
10	4/11	Sign up for Presentations	Team
		Final Revision PCB	Team
		Field Test and Verify Requirements Met	Team
11	4/18	Test System Integration	Team
		Finalize Construction	Team
		Prepare Presentation and Demonstration	Team
12	4/25	Friendly Interrogator System Documentation	Noah
		Friendly Target System Documentation	Eric
		Finish Final Report/Documentation	Team
13	5/2	Prepare Presentation	Team
		Final Report/Presentation	Team
		Check-in Supplies	Team

Figure 6: Extended Schedule Week-by-Week

5.2 Cost

The following is a rough cost analysis of the project:

Eric, I'm gonna need help making a good table!

Industrial IR Laser - $13.26 http://www.ebay.com/itm/Industrial-Focusable-50mW-780nm-Infrared-IR-Laser-DOT-Diode-Module-Lazer-/110887862755?hash=item19d16e81e3:g:4akAAOSwxH1ULBEs

8-bit PIC MCU, x2 - Free, from lab?

PCB - At least 2 at $33 each

should we include estimates for photodiodes or just one big estimate for all sorts of parts like LEDs and stuff?

5.3 Labor

This appears to be a fairly demanding Senior Design project. The team has approximately 12 weeks to design, implement, and fabricate this project. Each member of the team will likely work at least 10 hours a week on the project. This means 120 hours per team member.

we need another chart. Each person worth$31 an hour, with 120 hours invested makes 120*$31*2.5 = $9300per person, makes $18600 in labor for the project.

References

[1] *Lieutenant Colonel Charles R. Shrader, Amicicide: The Problem of Friendly Fire in Modern War*, US Command & General Staff College Survey No.1, 1982.

[2] *Garrison, Webb B., Friendly Fire in the Civil War: More than 100 True Stories of Comrade Killing Comrade,* Rutledge Hill Press, Nashville, TN, 1999