

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

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Acronyms & Pre-Requisite Information

- MCU - Microcontroller Unit
- R.F. - Radio Frequency
- T.I. - Texas Instruments
- PPM - Parts Per Million - used to designate accuracy of crystal oscillator

1 Introduction

This document is a "Mock Design Review" in preparation for the Design Review occurring during the week of February 29th, 2016. This will outline the preliminary design for one block of the entire system. The system the team decided upon was the Laser Transmission Subsystem on board the Friendly Interrogator Unit.

2 Block Diagram

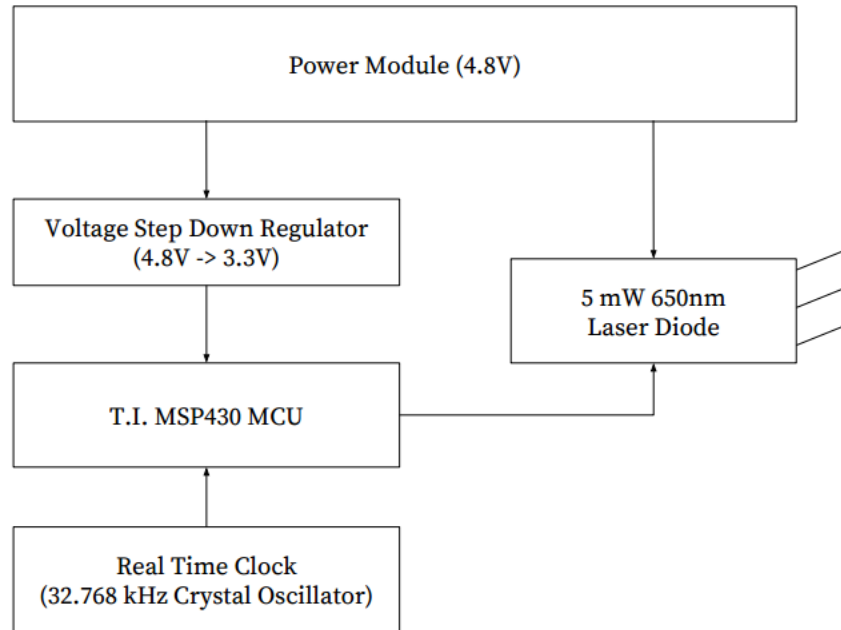


Figure 1: Block Diagram of Laser Transmitter

3 Block Description

The subsystem of the Laser Transmitter will be broken down into 5 primary modules:

1. Power Module
2. Voltage Step Down Regulator
3. Microcontroller
4. Real Time Clock
5. Laser Diode

Power Module

The Power Module will consist of four standard rechargeable 1.2V AA NiMH batteries. This will provide an output voltage of 4.8V when placed in series in a battery pack. Depending on the manufacture chosen and the

battery model, the batteries will hold a capacity of 1000 mAh to 3000mAh. For budgetary purposes the team will choose the ladder (a battery with a smaller capacity) because this will easily satisfy the requirements of powering the module for minimum of 8 hours. The friendly interrogator unit will not be drawing much current however there are restraints placed on the current drawn from this battery in order to satisfy the time requirement. A 1000mAh battery will supply a circuit with 125 mA for 8 hours, therefore this unit must not draw more than 125 mA, which will be achievable.

The team decided to use four standard AA 1.2V NiMH rechargeable batteries instead of any other standard batteries (such as disposable AAA or AA or a 9V battery) for several reasons. For one, the laser diode (as discussed later on) operates on a voltage from 4.5 - 5.5 voltage and this will satisfy this requirement. Also, the capacity is much higher for AA rechargeable batteries than 9V batteries so therefore the team went with the obvious option of choosing the AA batteries.

Voltage Step Down Regulator

The LD1117V33 Voltage Step-Down Regulator^[1] will take the 4.8V supply input and step it down to 3.3V to supply the MSP430 MCU. The voltage regulator will supply a maximum of 900 mA of current which will be significantly less than this circuit draws.

Microcontroller

The team chose to work with an T.I. MSP430F2274 Microcontroller Unit ^[2] due to its compiler simplicity, its availability in the ECE445 Senior Design Labs (inventory) and the number of GPIO Pins on board (compared to other options, this model had several I/O pins and was the most inexpensive). Compared to many other MCUs on the market, the MSP430 is relatively well documented and there exist several support forums on the internet to assist the team throughout the duration of the project.

Real Time Clock

The Real Time Clock is not entirely necessary for the operation of the Laser Transmitter Subsystem, however it will be necessary for the operation of the R.F. Receiver and thus must be included in the MCU circuit. It will operate using a 32.768 kHz Crystal Oscillator (as recommended by T.I. ^[3]) with an accuracy of +/- 20 PPM (deviates between 32.7673 kHz and 32.7687 kHz).

Laser Diode

The 5mW laser diode will operate on 3.3V at 25mA so a 1.3kΩ resistor is necessary to drop the current being supplied to the diode down to this threshold.

Due to safety and ethical considerations, the requirements have changed for the divergence of the beam. The proposal stated a requirement of a 5-6 ft diameter beam at 50, 150, and 300 m (with optical adjustments allowed).

With some tolerance, the PIN photodiode can register an irradiance of $9 \frac{W}{m^2}$. The laser required to achieve this irradiance is a function of the laser power and the radius of the beam. With relatively short distances of 0-300 m, atmospheric deflection of light is negligible.

Using trigonometry, the power as a function of radius is given by $P = \pi r^2 E_{req}$, where r is the radius (in

meters) and E_{req} is the required irradiance of $9 \frac{W}{m^2}$.

For a diameter equal to the one stated in the proposal ($\approx 1.6764m$), a $\pi(0.8382)^2(9) \approx 20mW$ laser is needed. A $20mW$ laser is a Class 3B laser, and is considered dangerous. For the scope of this senior design project, a $5mW$ laser will be used instead.

The radius achieved using a $5mW$ laser is given by $\sqrt{\frac{P}{E_{req}\pi}} = 0.420522m$. This is approximately a $2.75ft$ diameter beam, which is still the size of a person's chest.

4 Circuit Schematic

The circuit schematic is for the Laser Transmission Subsystem on the Friendly Interrogator Unit.

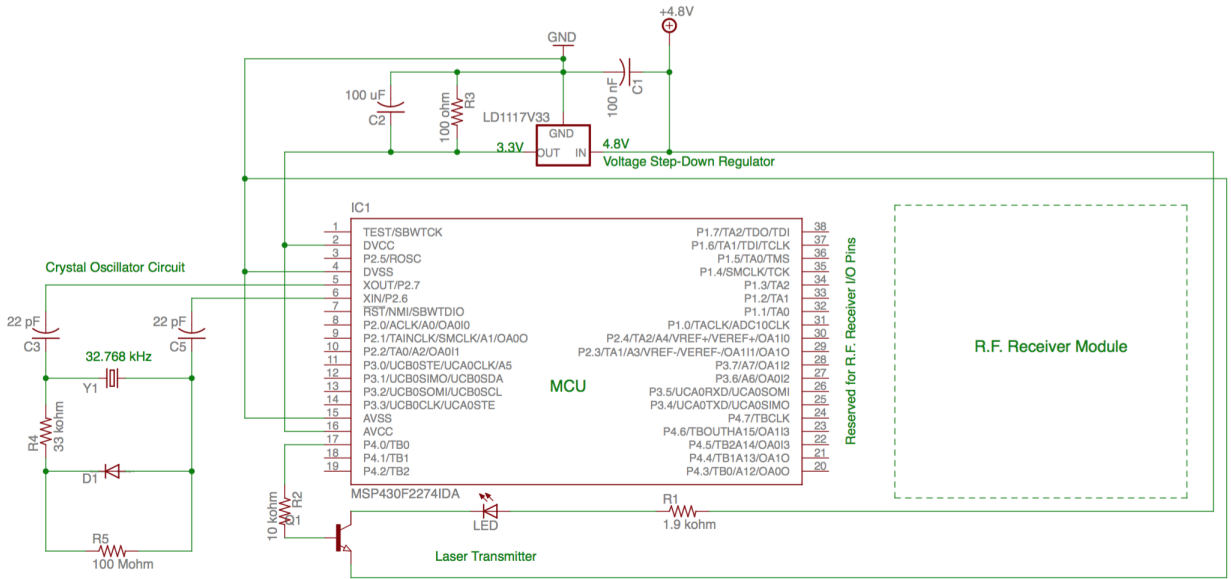


Figure 2: Circuit Schematic of Laser Transmitter

5 Plot

Figure 3 depicts the Nominal Ocular Hazard Distance (NOHD) vs the power of the laser diode on a 50% duty cycle. See 8 for more details on this calculation and what it means.

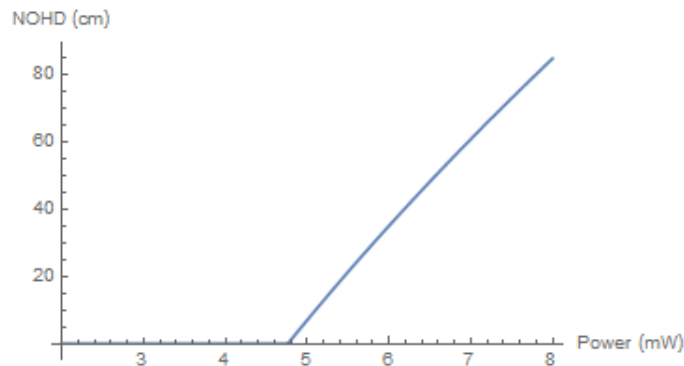


Figure 3: NOHD vs Power for Laser Diode

6 Calculation

Please reference Section 8 for calculations regarding the safety of the laser transmitter.

7 Requirements and Verification

Block/Subsystem	Module	Requirement	Verification
Friendly Interrogator System: Laser Transmitter	Laser Diode	Must be able to achieve 5 mW of power at source with a wavelength in the visible light spectrum from 620–750 nm (red). Light from the beam must span a range of 10-15 inches at the following distances, with optical adjustments allowed: - Short Range (50 m) - Medium Range (150 m) - Long Range (300 m)	Verify with multimeter that the laser is producing 5 mW at source. Verify the laser is in the visible light spectrum from 620-750nm using a Field Test - Verify laser transmission at distances for three ranges.
	Power Module	Must maintain a constant DC power source of $4.8V \pm 5\%$. Must be able to supply 4.8V for a period of 8 hours $\pm 5\%$.	Attach power module to digital multimeter in parallel and measure output voltage with and without load components attached. Attach power module to digital multimeter in parallel and measure output voltage over a period of time.
	Voltage Regulator	Must be able to output a constant voltage of 3.3V with $\pm 0.3V$ deviation (i.e. $3.27V < V_{out} < 3.33V$), with a current supply of max 75mA.	Attach power module to digital multimeter in parallel and measure output voltage with and without load components attached.
	Real Time Clock (RTC)	Must oscillate at a frequency of 32.768 kHz with a precision of ± 20 PPM.	Attach oscilloscope to outputs of crystal oscillator circuit and measure frequency
	Microcontroller (MCU)	Ability to control laser transmitter to send digital data at a frequency of at least 30 kHz.	Verify using oscilloscope connected to output generated by MCU and measuring period time in μs .
		Must maintain its own internal clock to a precision of ± 10 minutes $\pm 10\%$.	Sample packets sent to microcontroller and verify time with that of a local known source.

Figure 4: Requirements/Verification for Laser Transmitter System

8 Safety & Ethical Considerations

The proposal requirements would have required a 20mW IR laser. However, in the State of Illinois, a 20mW laser is considered a Class 3B laser and must be registered with the Division of Nuclear Safety in the Illinois

Emergency Management Agency. This would have required the team to file the correct paperwork and pay a registration fee of \$50. This paperwork would have likely caused delays in receiving parts and construction of this project. A 20 mW laser would have also needed much more pre-caution and safety mitigations than a much less powerful laser.

For the reasons stated above, the team will instead use a 5mW visible red laser. 5mW visible lasers have a low chance of injuring the eye, as the blinking reflex will save a victim from permanent damage; as opposed to IR lasers which can go unnoticed for several seconds.

The following is a calculation for the nominal ocular hazard distance (NOHD) of our laser, as defined by the ANSI Standard [4].

The maximum permissible exposure (MPE), as defined by the ANSI Standard [4] is the highest power or energy density of a light source that is considered safe, i.e. that has a negligible probability for creating damage. This MPE for a pulsing laser is calculated as the minimum of the following three rules:

1. Any single pulse in the train must not exceed the MPE for the pulse exposure time.
2. The exposure from any group of pulses delivered in time T must not exceed the MPE for time T, where T is 0.25 seconds (from the blinking reflex), for a visible laser.
3. For thermal injury, the exposure for any single pulse within a group of pulses must not exceed the single-pulse MPE multiplied by a multiple-pulse correction factor

The laser will pulse at a rate of 40 kHz. Assuming at most a 50% duty cycle, each pulse will be of max length $1.25 * 10^{-5} s$. The divergence of the beam is smallest for the longest range; a lower divergence is more restrictive in terms of safety, so this calculation uses 300m. The divergence of the beam for 300m is 2.79 mrad and the beam waist is approximately 4mm.

Following the ANSI Standard [4], the Rule 1 calculation is

$$5 * 10^{-3} * \left(\frac{2.79}{1.5}\right) = 0.0093 \frac{J}{m^2}$$

The Rule 2 calculation is

$$\frac{18(.25^{0.75})\left(\frac{2.79}{1.5}\right)}{.25 * 40000} = 0.0011837 \frac{J}{m^2}$$

The Rule 3 calculation is

$$(.25 * 40000)^{0.25} * 5 * 10^{-3} * \left(\frac{2.79}{1.5}\right) = 0.093 \frac{J}{m^2}$$

The most restrictive of all the rules is Rule 2, which gives us an MPE of $0.0011837 \frac{J}{m^2}$.

At 5mW with a pulse width of $1.25 * 10^{-5}$, the power of the laser is $6.25 * 10^{-8} J$.

The NOHD is defined as

$$\frac{\sqrt{\frac{4*P}{\pi*MPE}}-2w}{\theta}$$

Where P is the power of the beam ($6.25 * 10^{-8} J$) and w is the waist of the beam ($1mm$). This gives an NOHD of

$$\frac{\sqrt{\frac{4*6.25*10^{-8}}{\pi*0.0011837}}-2(0.004)}{0.00279} = 0.0713m$$

The team will avoid eye damage by not working with their eyes inside of 8 cm from the laser. If it is necessary to get this close to the laser, the team will wear eye protection or simply power off the laser.

References

- [1] “Adjustable and fixed low drop positive voltage regulator,” Web, ST Life Augmented, accessed February 2016. [Online]. Available: <https://www.adafruit.com/images/product-files/2165/LD1117.pdf>
- [2] “Mixed Signal Microcontroller MSP430F22x4,” Web, Texas Instruments, accessed February 2016. [Online]. Available: <http://www.ti.com/lit/ds/symlink/msp430f2274.pdf>
- [3] “Using the Real-Time Clock Library,” Web, Texas Instruments, accessed February 2016. [Online]. Available: <http://www.ti.com/lit/an/slaa076a/slaa076a.pdf>
- [4] “American National Standard for Safe Use of Lasers,” ANSI Z136.1-2000.