User Manual
Project 6: Laser Communication

20/20 Vision (Group 24):

Denzel Delnawaz: 490424744

James Young: 490402708

Rocco Liu: 490503016

Bhavesh Balaji: 490400667

MTRX3700 Mechatronics 3

School of Aerospace, Mechanical and Mechatronic Engineering

The University of Sydney

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Contents

Chapter 1

Introduction

1.1 Document Identification

This document describes the use of a proof-of-concept free-space laser communication mechanism. This document is prepared by 20/20 Vision (Group 24) for assessment in MTRX3700 in 2021.

1.2 System Overview

Project 6, Long Distance Optical Communication was chosen from a list of possible project ideas. The project centres around the idea of using a laser for free-space communication, sent and received by different devices and allowing the transmission of various forms of data.

The transmission side of the system will offer a user interface to select and input data which is converted into pulses of a laser signal over a chosen protocol.

The receiver side will receive these pulses through air and convert them back into digital logic which is then output in an appropriate form.

1.3 Document Overview

This document provides a simple, concise and non-technical explanation of the laser communication system that has been developed and how to use it.

Included are sections on how to connect or interface various components of the system, how to use the system in various different scenarios and safety cautions for using the system.

If a more detailed technical explanation of components or the system is required, please see the Technical Manual in the Reference Documents, Section 1.4.

1.4 Reference Documents

The present document is prepared on the basis of the following reference documents, and should be read in conjunction with them.

- "Technical Manual". 20/20 Vision, November 2021.

Chapter 2

System Configuration Options

2.1 Configurations

For this communication mechanism, there are a variety of configurations explored each with distinct benefits, with all possibilities seen below.

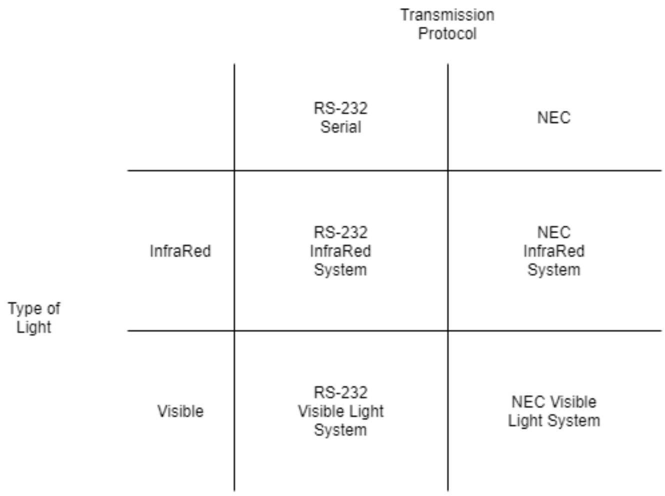


Figure 2.1 – System Configuration Options

2.2 Basic Decision Tree

When using this laser communication mechanism, it is important to know which of the options we have explored is best for you. The following diagram shows each of the options we have developed, and the basic decisions required to choose a configuration. Further details can be found in the Technical Manual in the Reference Documents, Section 1.4.

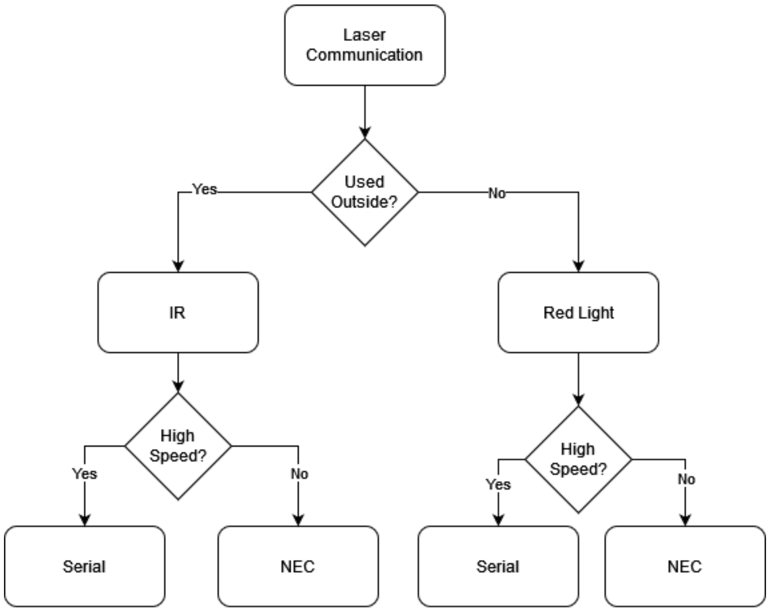


Figure 2.2 – Configuration Decision Tree

Chapter 3

System Setup and Operation

3.1 Hardware

The entire system will be primarily based on two Microcontrollers for the purpose of laser communication - any Arduino board and a PIC18. These two controllers will largely remain configured and connected the same across the different transmission protocols.

3.1.1 Arduino Configuration

The Arduino will be connected to both the PC which contains the GUI via a USB Type-A to Type-B cable. This multipurpose cable will be used to load the correct transmission code and serve as both serial communication for the transmission of data to the laser/IR transmitter and as the power source for the Arduino.

Upon successful connection of the USB Type-A to Type-B cable, the ON LED should turn on.

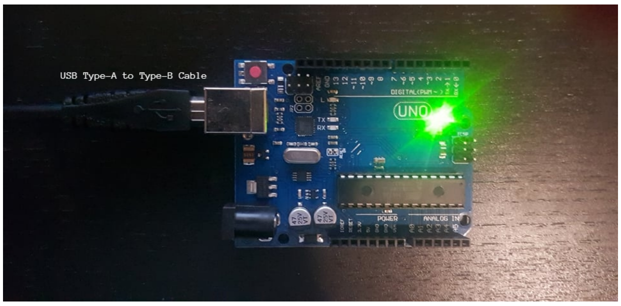


Figure 3.1 – Arduino and Cable Connection

Specific pin configuration for each transmitter will be detailed below.

3.1.2 PIC18 Configuration

The PIC18 is more complex, requiring: The MPLAB ICD3/4 Debugger and its respective cabling, a RS232 IC, a Male RS232 to USB Type-A Cable and a 9V Power Source. Both the ICD and the RS232 cable will be connected to the PC. Respectively, the components are for loading software, enabling serial transmission to the PC, serial transmission to PC and powering the PIC18.

The order of connection is also important. 1: RS232 IC, 2: 9V Power Supply, 3: ICD3/4 Debugger, 4: RS232 to USB Type-A cable. When disassembling the system, it is also important that these steps are followed in reverse order as well.

Upon successful connection of all the cabling, the a green LED on the PIC18 will turn on. The ICD will also have LED's which indicate its current status, differing between the ICD3/4.

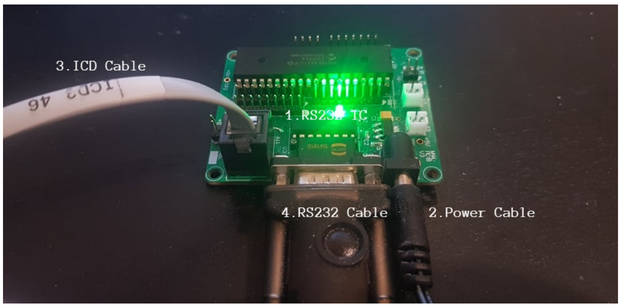


Figure 3.2 – PIC18 and Cable Connections

Specific pin configuration for each receiver will be detailed below.

3.1.3 Transmitter & Receiver Configuration

Specific pin configuration for each form of transmitter and receiver are necessary with only minor changes. Both electromagnetic transmission frequencies can transmit in Serial or NEC protocols given the appropriate receivers and transmitters. Primarily, the transmitters determine the type of light used and the receivers + software determine the protocol used. These can and should be altered and configured depending on the use case of the system.

Visible Light - Laser Diode Setup

The Laser Diode employed was a 5mW, XC4490 Arduino Compatible Red Laser Diode Module which requires a 5V power source. To connect it to the Arduino, two male to female pin connectors are required. Connect labeled pin S on the Laser Module to the Digital pin 2 on the Arduino. Then connect labeled pin - on the Laser Module to any Ground.

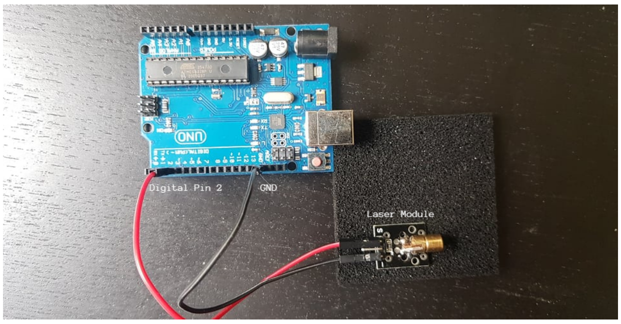


Figure 3.3 – Arduino and Laser Module

Photo-diode Serial Receiver Setup

The Serial Receiver module currently involves a photo-diode in series with an op amp circuit which is connected to the micro controller. First, connect up 5V and GND to the power bus on the receiver module from the PIC18 X2 or X9 terminals. Then, connect the output from the op amp (IC pin 1) to pin RX/RC<7> on the PIC18.

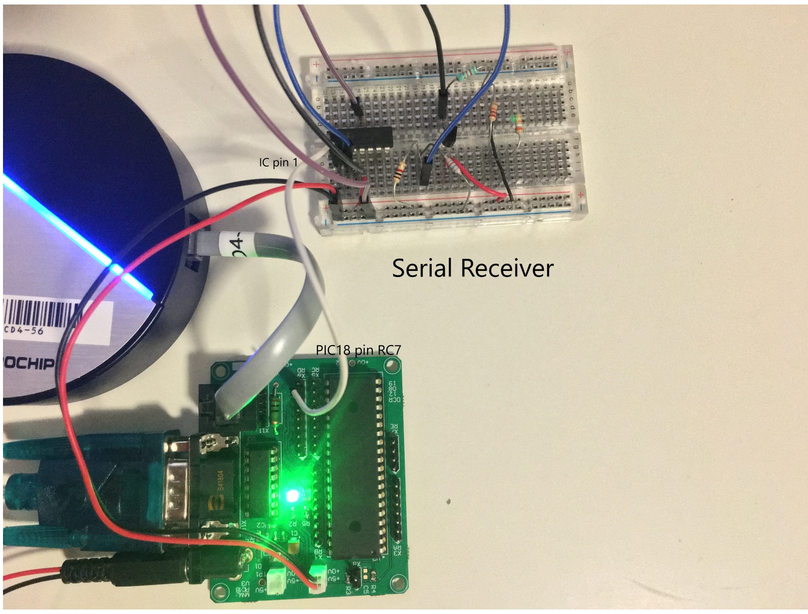


Figure 3.4 – PIC18 and Serial Receiver Module

Infrared Light - IR LED Setup

The IR transmitter consists of a XC4426 Arduino Compatible Infrared Transmitter Module connected to the PIC18. Use two male to female pin connectors, connecting labelled pin - on the IR module to GND on the Arduino and labelled pin S on the IR module to pin 2 of the Arduino for Serial, or Pin 3 for NEC.

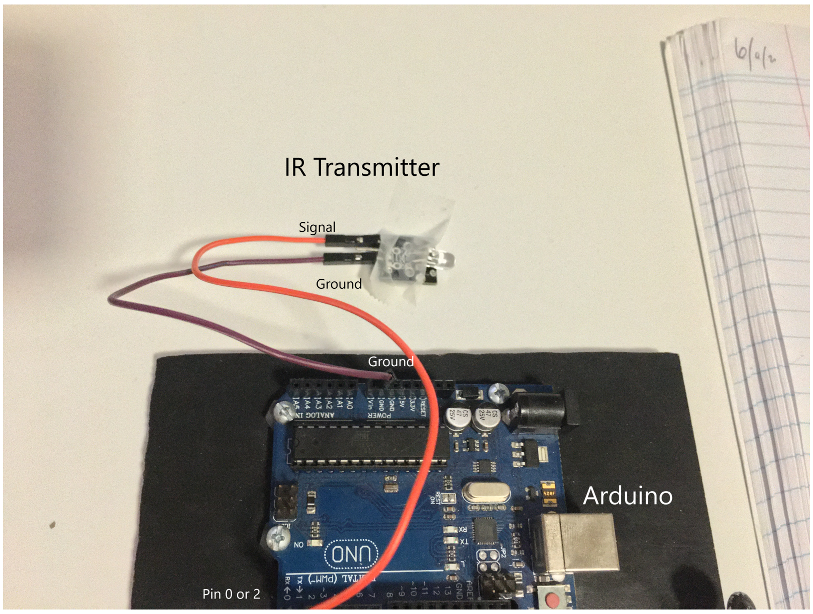


Figure 3.5 – Arduino and IR LED Module

NEC Receiver Setup

The IR NEC Receiver used was a XC4583 Linker Infrared Receiver Module for Arduino which requires a 5V power source. To connect it to the PIC18, 3 female to female pin connectors are required. First connect up the VCC Pin on the IR Receiver to a 5V power supply, then connect the GND Pin on the IR Receiver to ground. Finally connect the OUT pin on the IR Receiver to RB<4> on the PIC18.

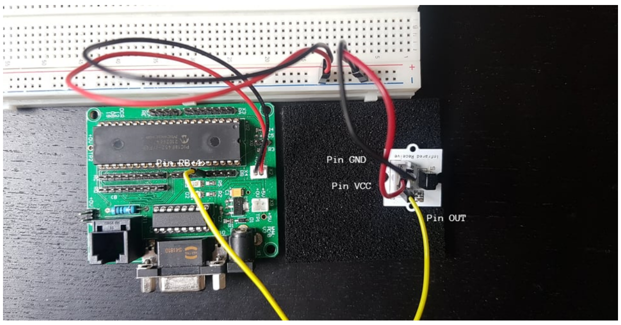


Figure 3.6 – PIC18 and NEC Receive Module

3.2 Software

There are 4 main pieces of software required for this system to operate.

1. A GUI is ran from the transmission sided PC which allows selection of transmission data, E.g. ID, String, Image or Sound. This software will be used live during operation of the system.

2. The transmission sided Arduino require it's associated software, also called Arduino to load the relevant projects. As we can transmit via both Serial and NEC protocols, two different projects are required. The Arduino software can preload the Arduino with the desired code.

3. The receiver sided PIC18 requires it's associated software, MPLAB X to load the relevant projects. Once again, a separate project and code will be required for either Serial receive or NEC receive. The MPLAB X can preload the PIC18 with the desired code.

4. PuTTY, a serial communication software will be ran on the receiver sided PC which displays the data received via laser communication. This software will be used live during operation of the system.

3.2.1 Arduino

For the Arduino, the relevant software is called Arduino. Begin by connecting the USB Type-A to Type-B cable from a device to the Arduino. Next select the relevant transmission project, either *laser_serial_out* or *laser_NEC_GUI* for either Serial or NEC communication respectively by clicking the . Once the correct project is loaded, click Verify and then Upload to program the Arduino.

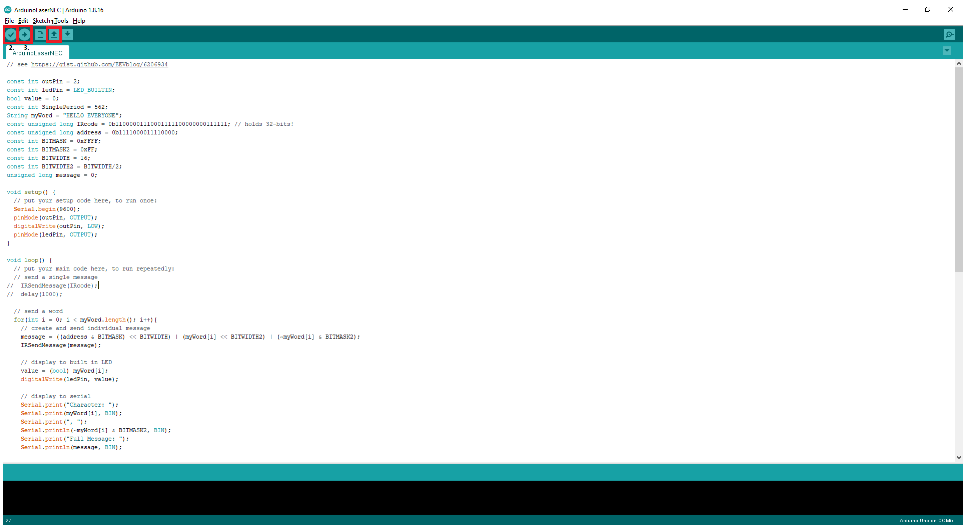


Figure 3.7 – Arduino Software

3.2.2 PIC18

For the PIC18, the relevant software is called MPLAB X. Begin by setting up the PIC18 following the instructions in the PIC18 Hardware section. Once the ICD is connected and the PIC18 is powered. Go to MPLAB X and right click the relevant project under the Projects tab and set it as main project, either *serial_receive* or *NEC_receive* for the two transmission types.

Once the desired project has been set as main, first click Clean and Build and then click Make and Program Device Main Project to download the program to the PIC18.

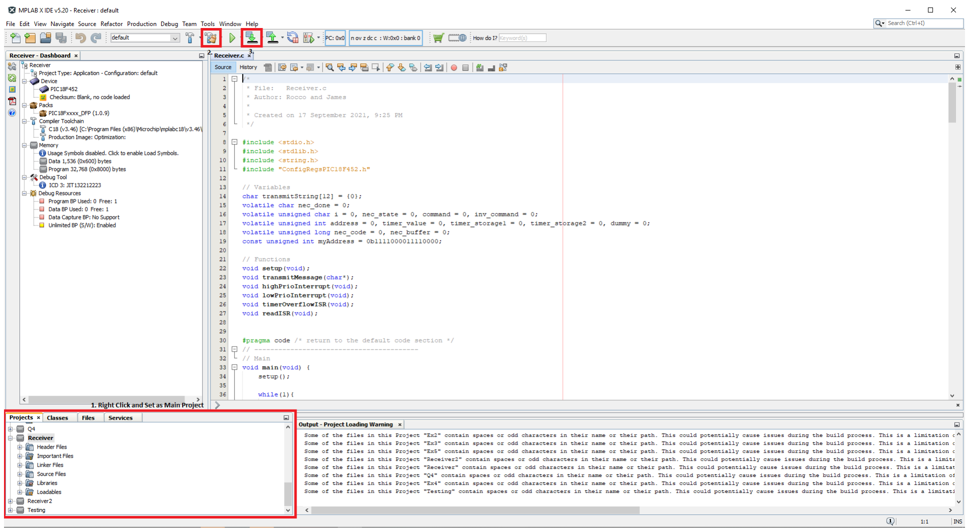


Figure 3.8 – Arduino Software

3.2.3 PuTTY

PuTTY will be opened on the receiver sided PC during operation after following the instructions for setting up the PIC18. The user may first need to identify which COM port the RS232 Cable is connected to. This can be done using Device Manager on Windows.

Once the correct COM port is identified, open PuTTY. On the Session, select Serial as the connection type. Change the Serial Line to the correct COM port and set the speed to 9600.

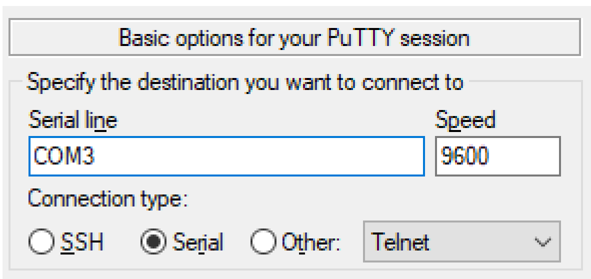
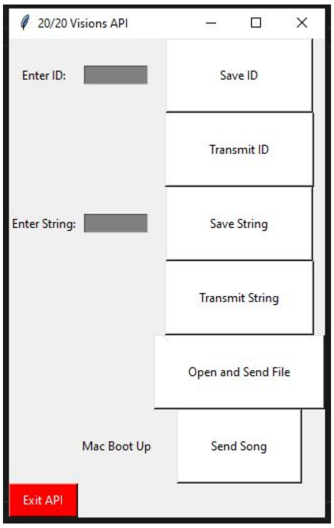


Figure 3.9 – PuTTY Settings

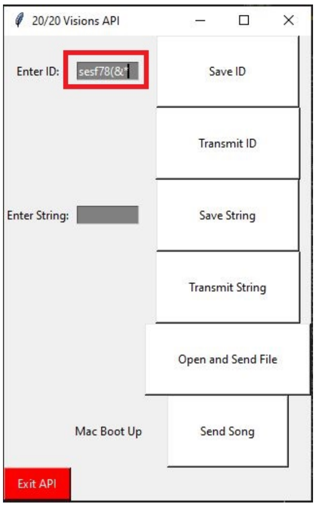
3.2.4 GUI

The way the user control's the transmission is through the Graphical User Interface (GUI), the GUI will allow the user to enter text, select files and subsequently transmit them. The GUI is simple, labeled, and relatively self-explanatory. Below is a step by step guide on how to navigate and use the GUI, the steps will teach the user to use all functionality of the GUI.

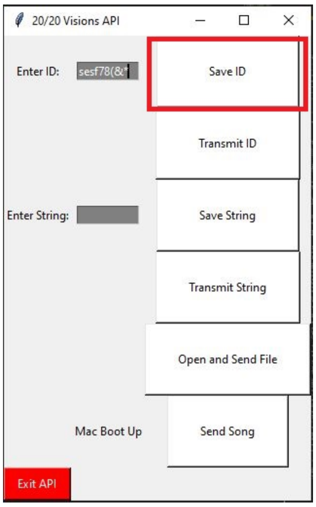


3.2.5 ID

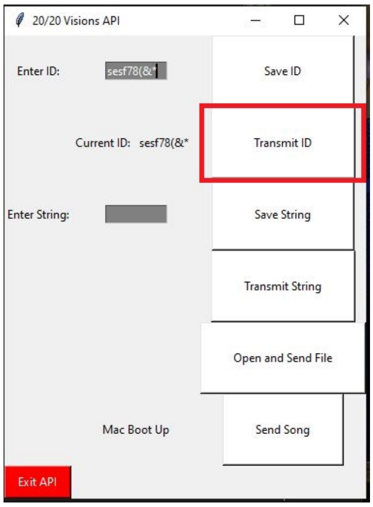
If a user wants to save and send an ID the following steps must take place:



(a) Enter ID into text box



(b) Save the ID entered

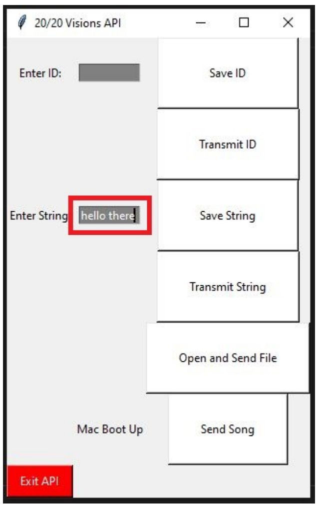


(c) Transmit the Saved ID

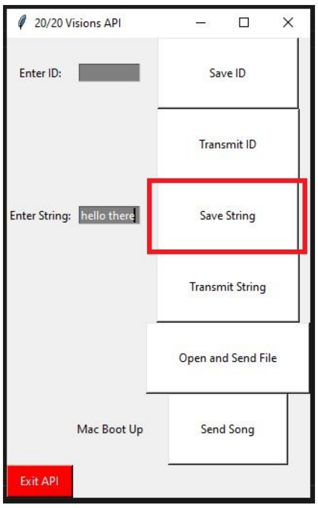
These steps are to be followed in the order of a) -> b) -> c), to successfully enter, save and transmit an ID.

3.2.6 String

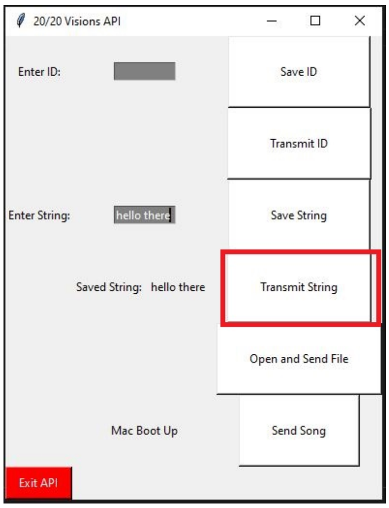
If a user wants to save and send a String the following steps must take place:



(a) Enter String into text box



(b) Save the String entered

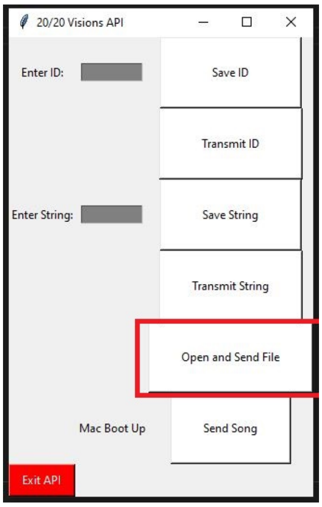


(c) Transmit the Saved String

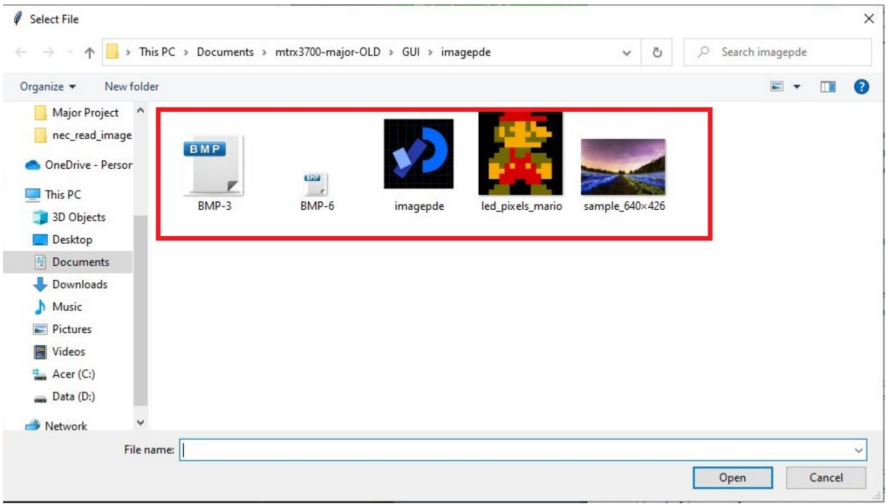
These steps are to be followed in the order of a) -> b) -> c), to successfully enter, save and transmit a String.

3.2.7 Images

If a user wants to save and send an image the following steps must take place:



(a) Press button to prompt image select



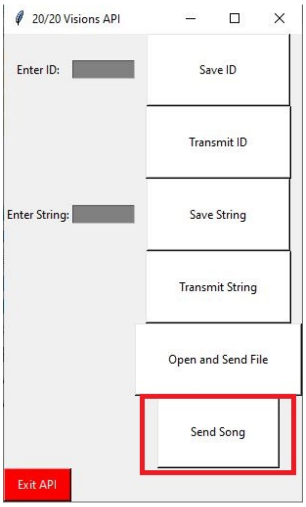
(b) Select desired BMP image

Figure 3.13 – **(c)** Image path send to GUI to indicate the image has been selected

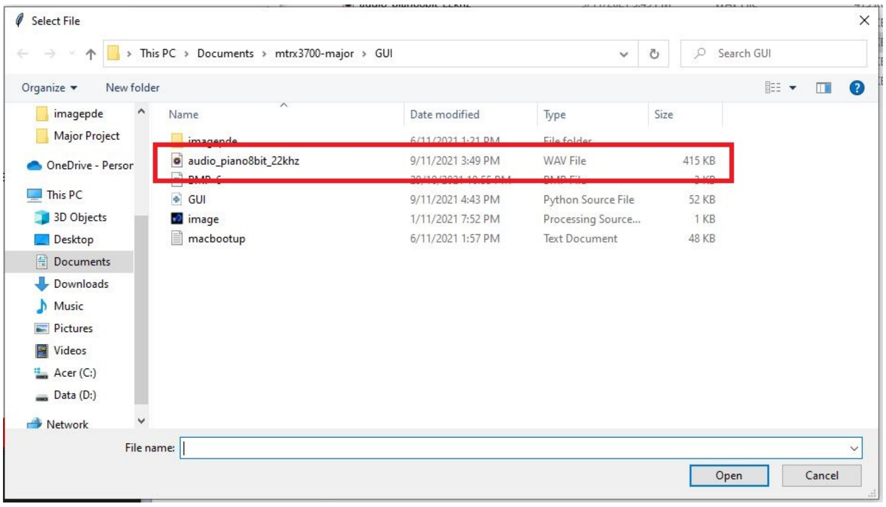
These steps are to be followed in the order of a) -> b) -> c), to successfully enter, save and transmit an Image.

3.2.8 Song

If a user wants to send a saved audio file the following step must take place:



(a) Press button to prompt song select



(b) Select desired WAV file

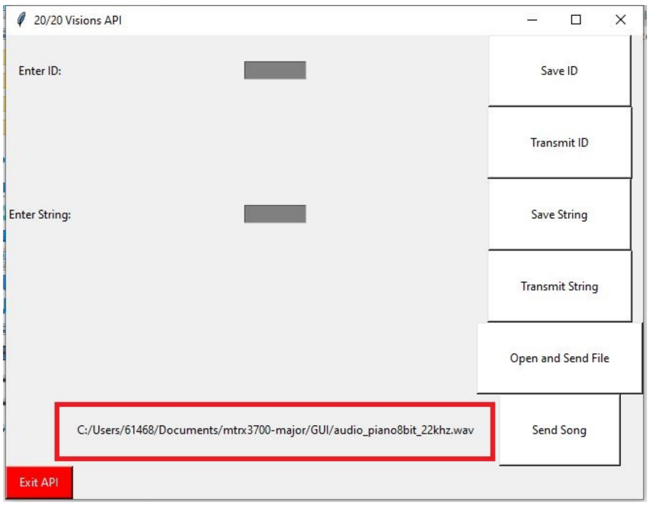


Figure 3.15 – **(c)** Song path send to GUI to indicate the song has been selected

These steps are to be followed in the order of a) -> b) -> c), to successfully enter, save and transmit an song.

3.2.9 System Operation

Serial Transmission

Upon set-up of the Serial Transmission hardware and the downloading of the software to all devices, the user needs to enter the form of transmission as detailed above within the GUI section.

The laser diode should then turn on. Proceed to carefully align the laser module and the receiver such that the laser light directly lands on the receiver module. The effective range of the laser is dependant on light conditions. Under a well lit room, it should reach around 15m - 20m. At night time in the dark, the laser is capable of reaching about 50m.

The user should then see their chosen media appearing on the receiver sided PC.

NEC Transmission

Upon set-up of the NEC Transmission hardware and the downloading of the software to all devices, the user needs to enter the form of transmission as detailed above within the GUI section. NEC transmission will limit the user to Number or String inputs only.

Once user input is complete, place the IR LED transmitter within 10m of the IR receiver, pointing it roughly in the direction of the receiver.

The user should then see their Number or String message appearing on the receiver sided PC.

Chapter 4

Use Cases

4.1 Operational Scenarios

4.1.1 Serial Transmission

The major operational scenario which demands Serial Transmission over NEC Transmission is high speed communication.

Based on our calculations, RS-232 can transfer at rates of up to 500,000 bits per second (with reduced accuracy), whereas NEC can only transmit approximately 300 bits per second due to necessary timing and delays. This makes it much more desirable for large amounts of data or where speed is critical, such as in image or sound transmission.

Within our system, optics such as focal lens may also be employed to further increase the range, but at the cost of reliability. On testing, the upper limits of the current laser range is around 50m, however this number will drastically change depending on light conditions if using visible light and the Serial protocol which is susceptible to light pollution.

Serial - Potential Avenues for Failure and Consequences

As the current operating system lacks an enclosure, manual alignment of the directional laser transmitter and laser receiver is required. This is also the main source of error for incorrect transmission. If this occurs, the receiver side will miss portions of the transmitted message, resulting in an incomplete image or audio file.

Serial protocol is also inherently much less robust due to large amounts of transmitted data and no acknowledge or checksum mechanism. There may be the occasional mismatch in messages transmitted although likelihood is fairly low. The transmission process most likely needs to be restarted in the event of failure.

4.1.2 NEC Transmission

NEC Transmission is primarily used for short range transmission where speed is not as important. NEC protocol is much more robust compared to Serial Transmission, leading to a very low possibility of and errors in transmission occurring. The usage in our case of an Infrared receiver and IR LED transmitter, both of which are omni-directional also drastically reduces the chance for alignment errors to occur. The trade-off is speed and range.

As a result the primary use case of NEC Transmission is for short range, small messages where stability and robustness are a high priority. For this system, it it primarily employed to transmit numbers and strings.

NEC - Potential Avenues for Failure and Consequences

Chances for failure with the NEC Transmission setup is extremely low if operated correctly within the range limits. If an incorrect message is transmitted, the receiver side will automatically reset and wait for a new message. The user does not need to do anything to fix transmission errors unless it is hardware based. NEC must be operated at 38 kHz with a transmitter that can modulate a signal with minimal parasitic capacitance to slow down signal oscillation of 38kHz and similarly have a receiver chip that is able to demodulate a 38 kHz signal. Further, an address is used in the message to ensure that only one transmitter and receiver are communicating with each other correspondingly.

Therefore, light pollution and other invading signals will have minimal to no effect based on our tests.

4.2 Real World Application

Below is a section of the theoretical uses cases that this system could be employed in. If further refinement is made on the system, we aim to develop the project in one of these directions.

4.2.1 COVID ID Scanner

The COVID ID Scanner would primarily employ the NEC Protocol with Infrared transmission. This is due to its very high robustness with varying light conditions and its maturity with use in TV remotes, with only short distances and relatively slow speed necessary. Upon turning on the ID Scanner, a mobile phone would send out IR Waves. An Infrared receiver should be able to pick up and distinguish each individual unique ID for phone.

In this use case, upon set-up of the receiver, users would only need to open an app and click a button on their phone to start transmission. The receiver would automatically pick and up distinguish unique ID's through NEC protocol.

4.2.2 Braille Replacement with Speaker

It's envisioned that this operational system could be used as a Braille Replacement. This is done by replacing Braille with a laser transmitter which can be picked up by a speaker or hearing aid for those with a disability. In such a case, high speed data communication with minimal visual interference is desired, hence the Infrared Serial transmission is chosen. An Infrared Serial transmitter could be implemented within museums/cultural sites at different displays or elevators and road crossings. As a user walks past with the appropriate receiver, it would automatically broadcast the audio.

In this use case, upon set-up of the transmitter, users would need the corresponding receiver, potentially embedded within a bracelet or a headset. No further procedures for operation are necessary for the user.

4.2.3 Transferring Images

Included within the functionality is the the ability to transfer images. Due to the large amount of data, Serial is required for its higher speed transmission. A potential real-world application would be the image transfer to an LCD screen, live updating of the LCD image could be performed through Serial laser or IR transmission allowing for long range in-air communication.

In this use case, a pair of laser transmitters and receivers could be arranged in a stationary fixture. The user would then operate the system as defined above in the Hardware - Laser Communication section to transmit a series of images to an LCD screen.

Chapter 5

Safety Implications

5.1 Eye Safety

It is a legal requirement in Australia for lasers to be labelled according to their particular hazard. This information includes the class of the laser, the power output and the wavelength. All laser pointers that are available to the Australian public must have a radiant power output of less than 1 milliwatt.

Diodes we used:

- Red light wavelength = 700nm
- Infrared light wavelength between 780 nm and 1 mm
- Both diodes have power output less then 1 milliwatt.

Laser diodes are focused beams of light which can be detrimental to the human eye if directly exposed, which can cause damage after only 10 seconds of exposure, causing injuries.

Methods to mitigate the exposure:

- Wear Eye Protection - Safety glasses designed to protect from light.
- Coordination - During trial runs, we coordinate specific the firing of the diodes to ensure no one was in way of the laser. One man was on watch to ensure no members of the general public walked into the way.
- Aversion Response - A human instinct which involves a blinking reflex when a laser beam shines onto the eye to protect itself.

Dangers and Injuries resulting laser beams include:

- If pointed up a laser can hit a plane and become very dangerous.
- Permanent damage - Loss of vision.
- Temporary damage - Eye irritation, spots, or headache.