subject: **Senior Project II: System/Customer Requirement (Final Repot) -Portable Linux Terminal – Draft 1.0**

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Memorandum

This document provides Architecture/Interface level requirements for the Portable Troubleshooting Terminal

Introduction

Brendan: The Portable Linux Terminal is a compact, battery-powered device designed around a Raspberry Pi 4. The overall architecture can be divided into the main console and its discrete wireless keyboard.

Chibuike: The keyboard will be fully wireless and communicate through the medium of visible light using a technique called color shift keying (CSK) to modulate the signal.

Esteban: The CWPT will provide power to the main device. More specifically, the battery charger on the main device.

Main Console

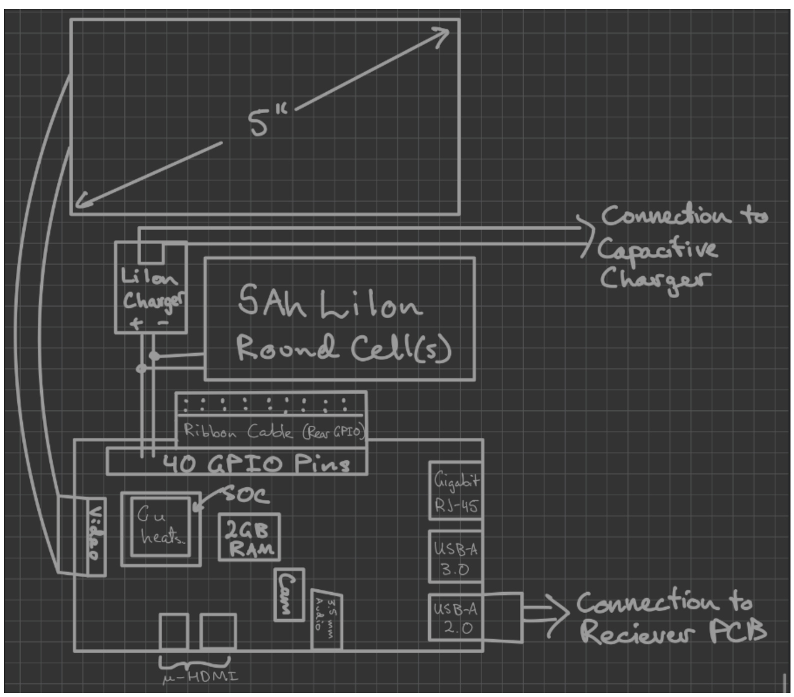


Figure 1. Main Console Architecture

Brendan: The main console is centered around a Raspberry Pi 4 single-board computer.
The Pi 4 is directly connected to a 5” TFT-LCD screen with capacitive touch. This LCD screen was chosen for its relatively low cost and its utilization of a DSI ribbon connector. A screen connected via DSI, rather than micro-HDMI or GPIO, can be integrated inside the device’s case without compromising external port access.
The Pi 4’s GPIO pins are connected to a lithium battery and an off the shelf charging regulator. The remaining GPIO pins are connected to the rear of the device through a 40-pin ribbon cable, enabling external GPIO access.

Detachable Secondary Board

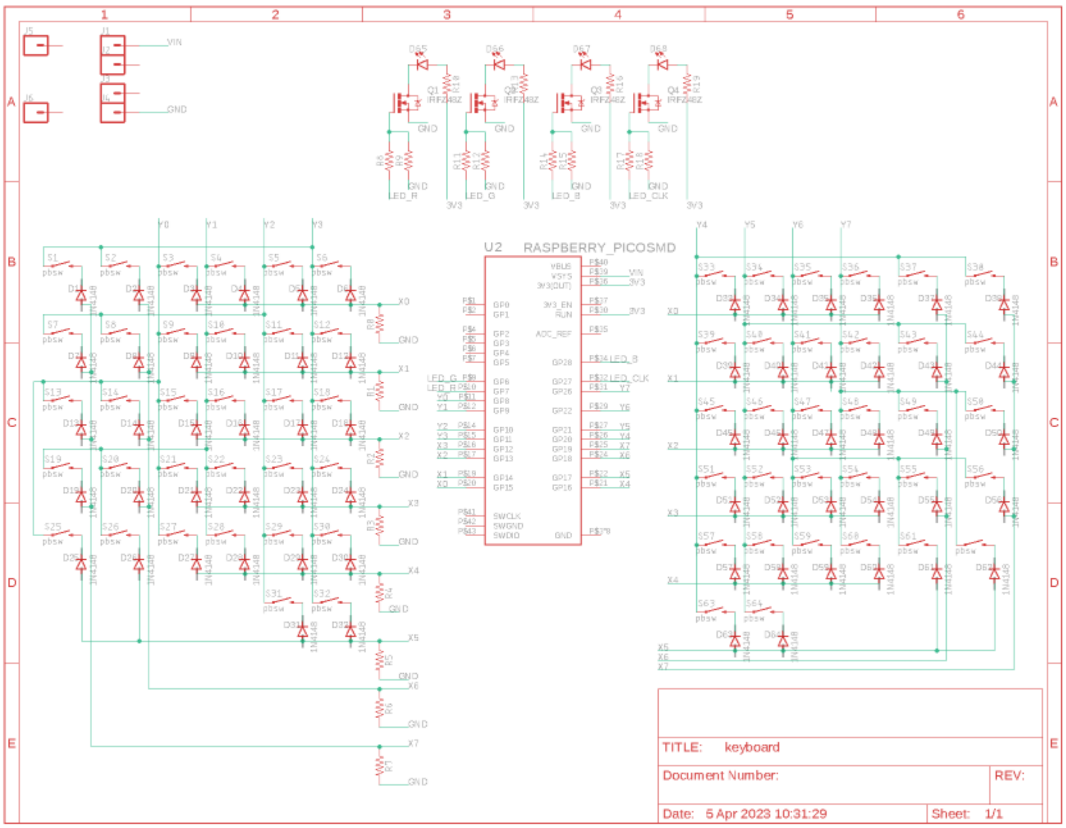


Figure 2. Detachable keyboard PCB schematic.

Brendan: The detachable keyboard comprises a battery and its charging circuit, a Raspberry Pi Pico microcontroller, a 64-switch keyboard, and an LED transmitter.
Battery
The battery and charging circuit supply power to the Pico. The 3.8V battery connects to the VSYS line of the Pico, which accepts input voltages ranging from 1.8V-5.5V. The charging module’s USB-C port may be connected to the main console or another source.
Switch Array
Sixteen of the Pico’s GPIO pins are connected to a switch array, consisting of 64 switches organized into rows and columns (X_0 to X_7 and Y_0 to Y_7). The 1N4148 diodes associated with each switch direct the current through the array to prevent ghosting. The $3k\Omega$ pull-down resistors filter noise and protect the diodes from excessive current by limiting the current to

approximately $\frac{3.3V-0.7V}{3k\Omega} = 867\mu A$. C code running on the Pico polls the active-high array, provides software debouncing, and encodes the output for the LED transmitter.

Encoding

The actuated switch is encoded as a binary value between 0 and 63. The binary value is transmitted via a composite of PWM pulses emitted from the red, green, and blue LEDs. Duty cycles ranging from 0% to 75% encode a 2-bit binary value ranging from 0 to 3 on each of the three colored LED, enabling each PWM pulse to transmit 6 bits of data. Modifier keys including ctrl, alt, and shift are added to a given transmission with additional PWM codes before the terminating clock pulse.

Duty Cycle	**Binary**
0%	00
25%	01
50%	10
75%	11

Clock Synchronization

Synchronization with the receiver is achieved using two pulses from the white LED, each with a 50% duty cycle. The first pulse is used to wake the receiver and synchronize the receiver's clock with the transmitter. The second clock pulse indicates the end of the transmission. The white LED was chosen for this purpose because it was observed that it is the least susceptible to ambient light interference.

Visible Light Communication Transmitter Circuit

The increased efficiency and low cost of n-channel IRFZ48Z MOSFETs make them an obvious choice for this portable application. The use of n-channel MOSFETs also makes driving the gate simpler since the source can be connected directly to ground, so any voltage above the LED's threshold will open the gate. The white LED is likely to have the highest forward voltage, estimated at ~3V.

Each MOSFET source is connected in series with a colored LED and a current-limiting resistor. Each current-limiting resistor value was determined based on the specific current requirement for the given LED. For example, R_{19} is used to control current through the white LED. Since the white LED requires $\sim 20mA$, $R_{19} = \frac{3.3V-3V}{20mA} = 15\Omega$.

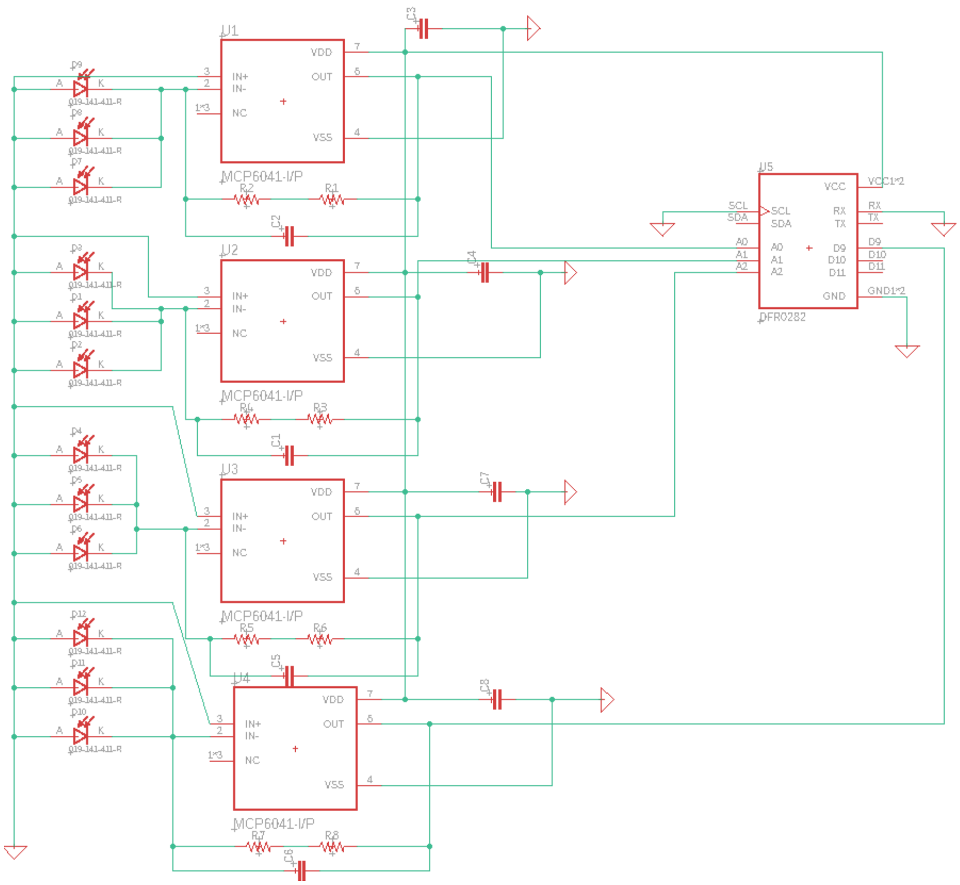
Each of the four IRFZ48Z MOSFET gate resistors connect to their respective GPIO pins in parallel with a pull-down resistor. The gate resistors must be high enough to limit current draw from the GPIO pins and low enough to allow the MOSFET to quickly change states. To find an appropriate range for the gate resistor:

1. The RC time constant and gate-source capacitance may be used to approximate an upper bound for the gate resistance. Since the gate-drain capacitance is approximately equal to the reverse transfer (or Miller) capacitance, the datasheet values may be used to approximate the gate-source capacitance as $C_{gs} = C_{iss} - C_{rss} = 1720pF - 160pF = 1560pF$. A common rule of thumb is that the charging time should be less than 10% of the PWM period (50ms). So, the capacitor must reach 99% charge after $5\tau = \frac{1}{10*20Hz} = 5ms \rightarrow \tau = \frac{5ms}{5} = 1ms$. Solving for RC time constant formula for R therefore gives an upper bound for this resistor value: $R < \frac{1ms}{1560pF} = 641k\Omega$.
2. According to the datasheet for Pico's RP2040, the maximum drive current for the GPIO pins is 12mA. Using Ohm's Law gives a lower bound of $R > \frac{3.3V}{12mA} = 275\Omega$.
3. Since this range is so large, to approximate a gate resistor value the 99% charging time for the gate was instead set to 0.1% of the period. This gives, $\tau = \frac{1}{1000*5*20Hz} = 10\mu s \rightarrow$

$R = \frac{10\mu s}{1560pF} = 6.41k\Omega$. As such, a $6.5k\Omega$ gate resistor was chosen, limiting current draw from the GPIO pin to $I = \frac{3.3V}{6.5k\Omega} = 508\mu A$.

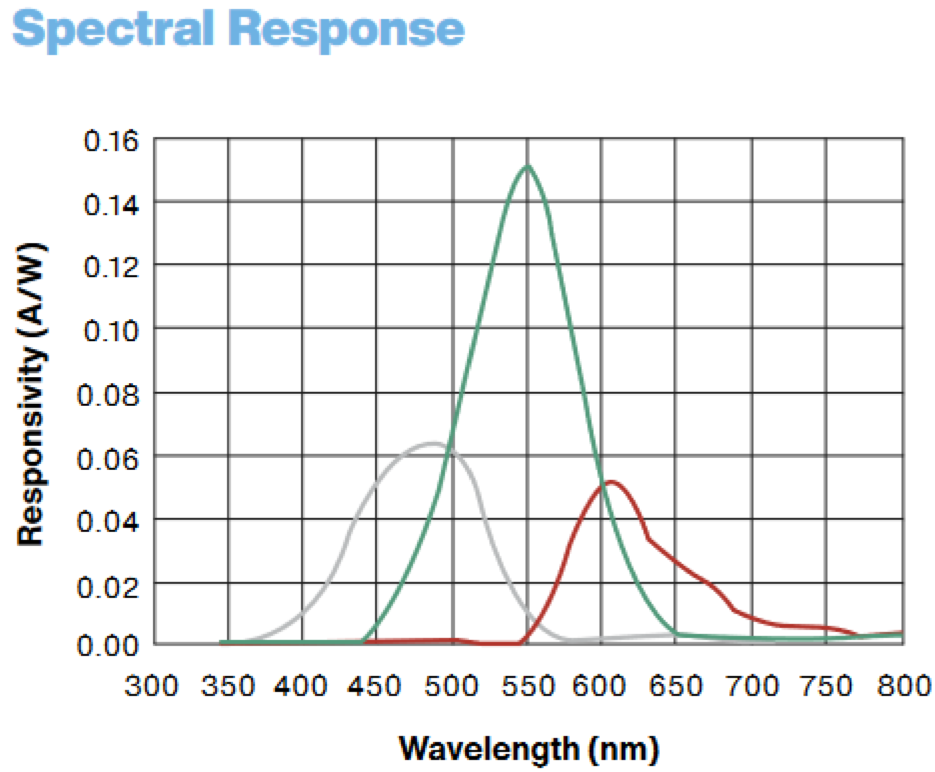
The primary purpose of the pull-down resistors is to drain the gate to prevent accidental MOSFET activation. Since this is a battery-powered device, it is advantageous to use a pull-down resistor with a greater resistance than that of the gate resistor. This approach minimizes power dissipation through the pull-down resistor when the gate is driven high, resulting in greater efficiency. A $120k\Omega$ resistor was chosen due availability. Thus, the power dissipation can be estimated as $P = \frac{3.3V^2}{120k\Omega} = 90.8\mu W$.

Receiver Board



Chibuike: The receiver used enhanced light photodiodes to convert incident light into a reverse current. That current is then sent through a transimpedance amplifier to convert it from a current source to a voltage source that can be read by a microcontroller and converted to an integer corresponding to the position of the key pressed and ultimately to an ASCII character to be send to the main board in the form of a keyboard input.

The photodiodes used for this are the 019-141-411 series photodiodes as what we needed was enhanced photodiodes with distinct enough spectral response curves that their response to ambient light would be muted in comparison their response to the intended light source at close range and they needed to generate enough current without using too large of a number of them in our design.



https://www.advancedphotonix.com/wp-content/uploads/2022/03/DS-SD019-141-411-X.pdf
For our choice of an operational amplifier, as we were working with current values in the nanoamps, with a low supply current requirement and a high sensitivity to lower the number of photodiodes we needed to use in unison. In the end we settled on the MCP6041 as it matched our needs.

Providing power to main Device

Esteban: Figure 3 below shows the top-level diagram of the WCPT model. This shows the circuit that is made, through the transmitter and receiving plates, which are connected to the receiver unit and the transmitter unit. In this model, the output is internal, which is further discussed in the following section.

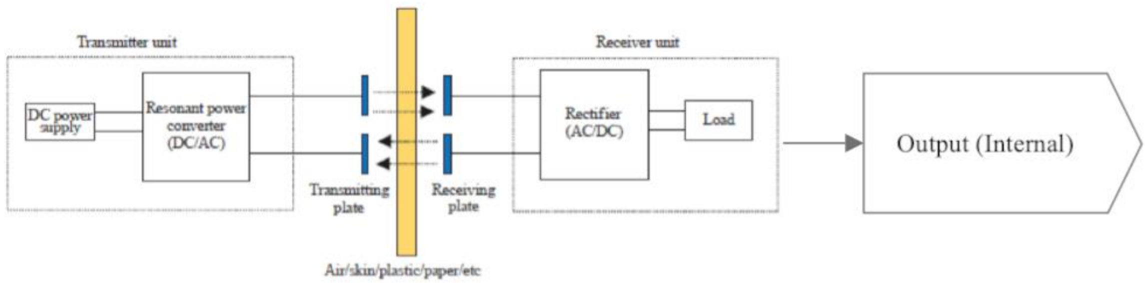


Figure 3. Transmitter and Receiver connected by plate interaction.

Figure 4 below shows the outlet which will provide voltage through the DC barrel of the PCB which contains the receiver side of the circuit. This will be connected to the highly conductive 1100 aluminum plates which will all be enclosed in a 3d printed plastic frame. This shows how a complete circuit is created when the main device is placed on top of the transmitter base where the other two rounded aluminum plates will be used as the receiving plates. These plates are connected to the rectifier pcb which will provide power to the battery charger on the main device. Careful attention will need to be placed on this distance between the transmitter base and the main device as the energy efficiency is decreased as the distance between the plates is increased. Also, the electric field emissions will need to be accounted for and be reduced as much as possible through some form of insulation. Electric field strength may be lower than 614 V/m at 1 MHz for human safety according to IEEE C95.1 standard. Other safety concerns will need to be addressed such as high voltage stress on the metal plates and foreign object impact.

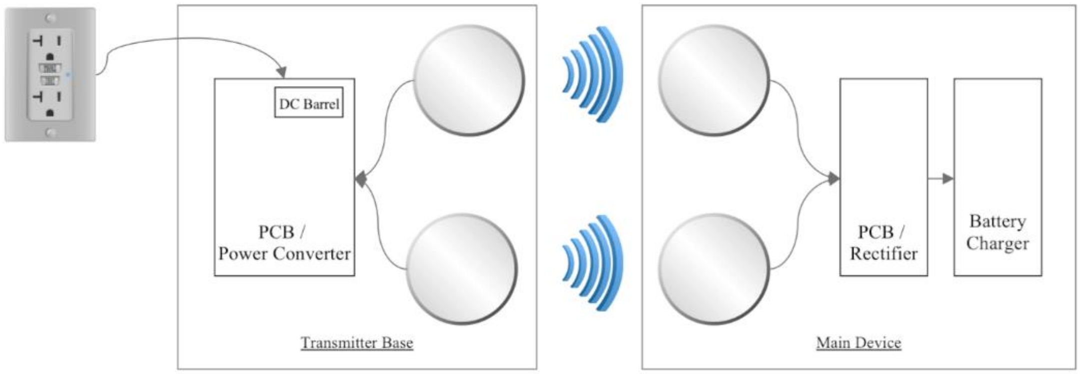


Figure 4. Transmitter and Receiver connected by plate interaction.

Systems Requirements (Tier 2)

Primary Device

Requirement: T2-0010
Summary: Terminal connections
Description: Connections shall have the following dimensions, the geometry should follow the diagram in Figure 1
End of Req. T2-0010

Requirement: T2-0020
Summary: Programmable main console
Description: Raspberry Pi with programable I/O
End of Req. T2-0020

Document Revision History

Version	Date	Description
0.1	12/09/22	Preliminary versions
1.0	04/07/23	Updated architecture

MSU-SD22023-COBGEH-1.0-COBGEH

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