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Design Review 1

Subsystem Design:

Transmitter Subsystem

The transmitter subsystem begins when the user pulls the trigger which will press a button (PTS647SN50SMTR2 LFS) that indicates the user's desire to deliver an IR pulse. This signal will be delivered to an input pin of the microcontroller, which will then send an output signal to the emitter via a wired connection. The emitter to be used will depend on more testing, but the options are SFH 455 (1.4V at 100 mA) and VSLY5850 (1.65V at 100 mA) which have varying viewing angles. These emitters each have one anode and one cathode lead and have a small resistor in series to ensure the current does not exceed the amount it can pull from the microcontroller.

An additional requirement in the transmitter subsystem will be a delay in emission when continuous pressure is applied to the button. This will entail about 2 milliseconds of emission followed by 2 seconds of downtime. The ISR is currently designed to trigger on the rising edge of the button being pressed so that you cannot hold the button down. This subsystem will be demonstrated with the user interface subsystem on DR2, where a button press will lead to an IR emission, using either an ESP32 series microcontroller or an Arduino Uno.

Receiver Subsystem

The receiver subsystem will include several TSOP32233 (which seems to be better with noise suppression and sensitivity) or TSOP3238 which both rework on .35 mA at 3.3V. This subsystem may include several receivers that join together into one input pin or that each is individually connected to an input pin depending on future viewing angle testing. The TSOP3... families of receivers require a power lead, a ground lead, and a connection lead with the order determined by which of the receivers is used. This subsystem will be demonstrated with the Emission and User Interface subsystem on DR2. When the receiver receives an IR pulse, it triggers an ISR that causes the lights to turn on, the buzzer to buzz, and the sound to emit. The receiver subsystem and user interface will be demonstrated with an ESP32 microcontroller or Arduino Uno.

User Interface Subsystem

The user interface subsystem includes all inputs that the user can act on, and the resulting outputs result from these events. The input includes the trigger and the outputs include LED lights, a buzzer, and a speaker. The point of the user interface system is to give the user control over their blaster module and to give the user feedback alerting them to when certain events have happened.

Trigger - The trigger will be how the user activates their blaster and controls when it shoots. The trigger should be in a comfortable position in the blaster for the user to hold the blaster and reach the trigger without much difficulty. However, the trigger should have some resistance to it, so as to limit accidental misfires. The trigger will likely be a button that sends a signal back to the microcontroller when it has been pressed. The trigger will need to be connected to 5V and output to an interrupt pin.

LEDs - There will be LED lights on the exterior of the blaster that will provide visual feedback to the user as well as for aesthetic purposes. The visual feedback provided includes flashing lights when the player has been hit and the blasters will also be different colors to separate the teams. The aesthetic element is also important as many traditional laser tag blasters include LEDs and we would like to keep this familiar feel of the game in our at-home version. The LEDs will be mounted on the exterior of the blaster and will receive signals from the microcontroller to control the color and flashing. The LED will need to be connected to 5V and input from a data pin.

Buzzer - The buzzer will serve as another form of feedback for the user, this time haptic feedback. This type of feedback is already very common in many handheld devices such as cell phones and video game controllers, and we think it could be useful to incorporate in our design as well. The feedback will be accomplished by mounting a vibration motor on the inside of the handle of the blaster, and it will receive signals from the microcontroller to tell it when to activate, such as when the user has been hit by another player, or when shooting. The buzzer will simply be connected to an I/O pin.

Speaker and Amplifier - The speaker will provide audio feedback to the user, enhancing the interactive experience. It will be mounted on the outside of the blaster and will play different pre-recorded sounds in response to various events, such as shooting, hitting another player, or being hit. An SD card and adapter module will store the audio files, allowing for a variety of sound effects without using excessive onboard memory. To play the audio, the microcontroller will first read the .wav file from the SD card. The raw audio data will then be extracted from the file format, and the microcontroller will use pulse width modulation (PWM) to generate the sound. PWM will convert the raw audio data into an analog signal that can be sent to an amplifier (PAM8302A). The amplifier will then boost the signal to ensure the sound is loud and clear when played through the speaker. This setup ensures efficient audio playback with high-quality output that is suitable for gameplay while preserving onboard memory for other essential tasks. Both the amplifier and the SD card adapter module will need to be connected to 3.3V and GND. The SD card adapter will need to connect to CS, SCL, MOSI, MISO, power, and ground. The signal pin of the amplifier will be connected to a PWM-capable GPIO pin on the microcontroller board.

Microcontroller - The microcontroller is the most important component of the user interface subsystem, as it is the brain that controls all of the other components. As mentioned in the previous component descriptions, the microcontroller will take various input signals from components such as the trigger and IR receiver and will send output signals to other components such as the LEDs, vibration motors, speakers, and IR transmitters, responding to various in-game events. The microcontrollers will also have the additional duty of communicating with each other and with the web server, so as to keep track of things such as time remaining, game mode, score, player identification, shots remaining, and more. We chose the ESP32-S3-WROOM-1-N16R8 for the dual cores and maximum available flash and PSRAM since we don't know how much memory the audio will need. The microcontrollers will be powered by the subsystem as described below.

Questions - Will the playing of sound interrupt the other functions?

Power Subsystem

The power subsystem will be primarily run off of 3 AA batteries in series. This will supply a voltage of 4.5 V at full charge down to approximately 3 V when discharged. To account for this wide range of possible voltages, a boost converter will boost the supply voltage to 5 V, and then an LDO will convert down to 3.3 V for the components that need it. This will also provide the 5 V supply for the aiming laser and the LED strips. The boost converter chosen is the PAM2423. Although it comes with a slightly higher price and added circuit complexity versus some comparable options, it has a high efficiency at the high currents possible from the batteries and will be able to easily handle the approximately 1.5 A of load current. The 3.3 V LDO that will supply power to the other components is the AZ1117IH-3.3, which is in stock at the EIH. The batteries will be held in a custom battery holder built into the blaster. From the battery contacts, there will be wires soldered onto the circuit board.

It is noted that pulling about 2.4 A from AA alkaline batteries is pushing the limits of their output current. It will certainly negatively affect battery life, given the rather high internal resistance of many alkaline AA batteries. The 2.4 A number comes from the following math:

$$I_{3.3\ load} = 0.79\ A$$

$$I_{5\ load} = 0.76\ A$$

$$I_{buck\ load} = 0.76\ A + 0.786\ A = 1.55\ A$$

Since the efficiency of an LDO comes from the ratio of input voltage to output voltage, the input and output currents will remain equal. This means that there will be a total load of 1.55 A on the PAM2423. At the given operating conditions the datasheet indicated an efficiency of around 90%, which would give a 3.6 V (supposing 1.2 V avg battery voltage) current draw of 2.4 A.

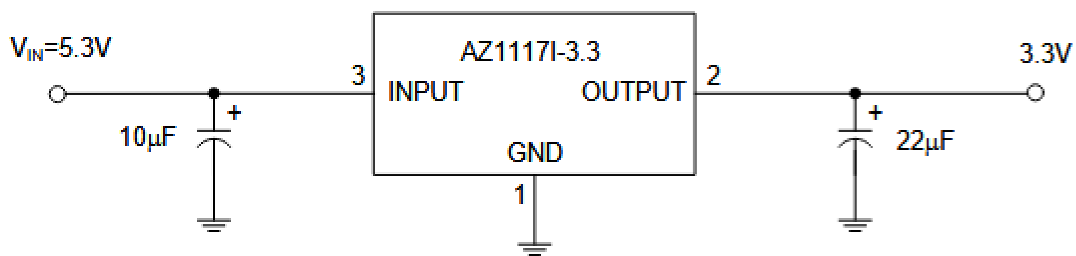
$$P_{boost\ load} = 1.55\ A * 5\ V = 7.75\ W$$

$$P_{boost\ input} = 7.75\ W\ / 0.9 = 8.6\ W$$

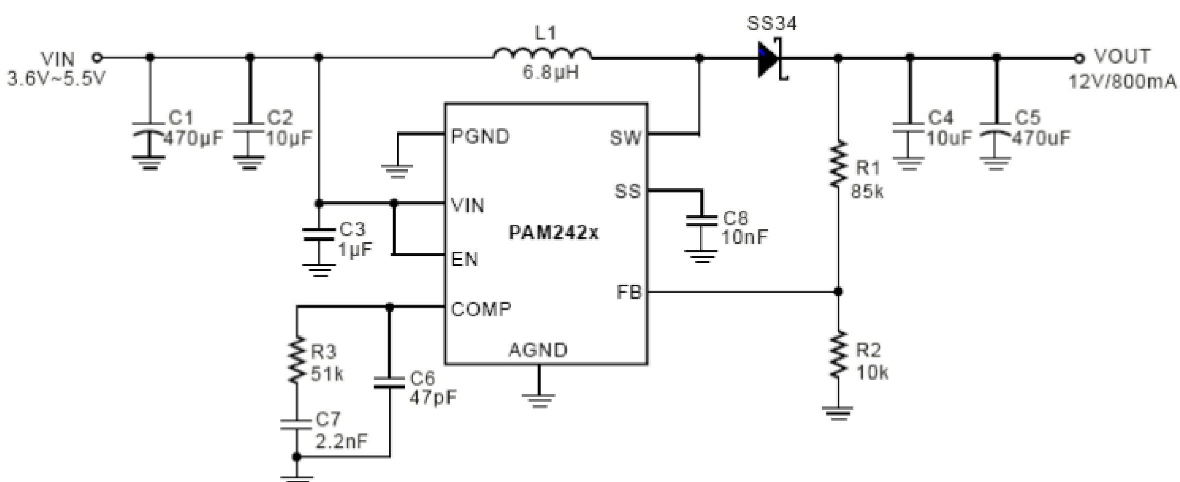
$$I_{boost\ input} = 8.6\,W\ /\ 3.6\,V\ = 2.4\,A$$

If this poses a problem, the simplest solution would be to use NiMH AA batteries, which are widely available as rechargeable alkaline alternatives. Their 1.2 V output would work with the existing setup, and they are able to supply higher currents with a much-lessened impact on battery life due to their lower internal resistance.

The connections necessary for the AZ1117IH-3.3 are detailed in the datasheet and consist of a V_{in} connection, which will be fed by the PAM2423, and a V_{out} connection, which will connect to the 3.3 V net. It also requires a 10 µF capacitor connected from V_{in} to ground and a 22 µF capacitor connected from V_{out} to ground. Both of these are in stock at the EIH.



The connections for the PAM2423 are more complicated, but also detailed in its datasheet.



The given configuration has the output set to 12V, however, so some modifications will need to be made. The output voltage can be set using the following equation from the datasheet.

$$R_1 = R_2 * (\frac{Vout}{V_{FB}} - 1)\ ,\ V_{FB}\ =\ 1.262\,V$$

Solving this equation for R1/R2 gives a value of 2.96. Using the 0805 E12 resistor kit in Stinson Remick 205, the best way to make this ratio is with R1 = 270 kΩ and R2 = 91 kΩ. Of the other components, the ones not in stock at the EIH are C1 and C5 (470 µF capacitors), C6 (47pF), C7

(2.2nF), C8 (10nf), the SS34 Schottky diode, and L1, the 6.8 μH inductor.Happily, C6, C7, and C8 are all available in 205 as well. The only special considerations to remember are that the inductor should be equipped to handle the current flowing through it and that all capacitors should be placed close to their pins. It is worth referencing similar boost converter PCB layouts when doing so on our board since there is not a recommended layout in the datasheet.

Questions - What is the best way to simulate load?

Web Server/Control Software Subsystem

The web server/control software subsystem will consist of a game server that can be loaded onto a computer or mobile device that acts as a "central hub" for gameplay. The game logic will include different modes, a log of the current game, and live user scores. With all modes, the game must start and set the timer and output game information to a screen as the game progresses. Signals need to be sent to all modules and communicate within a range of 20 feet using Bluetooth Low Energy (BLE). This subsystem should work with two microcontrollers simultaneously on a web server we have developed with rudimentary game mechanics.

Design Problems & Action Items:

We are looking into receiving distances, testing to see if the emitters will be powerful enough alone to be received at 40 ft away.

Simple tones and melodies can currently be played with the amplifier and speaker breakout board. There are some complications with formatting the SD card properly to be used with the microcontroller, but we will continue debugging this issue.

We will continue interfacing the IR subsystems with the user interface subsystems, focusing on the lights and sound. We will begin to interface Bluetooth with the receiver subsystem.