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Jackson Schilling
ECE 445L

Lab 11 Report

YouTube Link: https://youtu.be/UbIlrk0mnuI

Objectives

a. Requirements Document

1. Overview

1.1. Objectives:

- Create a proposal and requirements document for the embedded system
- Design the embedded system at the schematic level
- Implement low-level software for each component of the system
- Collect components and implement a prototype of the embedded system on a breadboard
- Develop unit testing skills to evaluate the subsystems
- Demonstrate that the project is feasible.
- To lay out and route a PCB board.
- To perform integration testing to verify combined interoperability of a system.
- To develop a test plan for the final product.
- To write the main high-level application that implements the final objective of the embedded system

1.2. Roles and Responsibilities:

Name	Main Responsibility
Ben Endara	Software
Jack Schilling	PCB
Minseo Park	CAD
Tianfang Guo	CAD

1.3. Interactions with Existing Systems: We will be interfacing with the entire TM4C123 development board, as this will decrease time taken during debugging and will lead to easier development overall, as well as providing access to certain power rails. However, this will increase the size of our enclosure, which might be an issue.

2. Function Description

2.1. Functionality: What will the system do precisely?

Our embedded systems will perform as laser tag guns. Limit switch will act as a trigger, and IR receiver will receive the signal to deduct the points of getting shot. The electric buzzer will be used to make sound effects, and the LCD will display the stats and instruction. LEDs will be used to display team color and notify the user that the shot was made.

2.4. Performance: Define the metrics used to evaluate the performance of your system and describe how they will be measured.

The first measurement will be the distance the reliable shot can be made.
Reliable shot will be tested by checking if the sensor receives the shot more than 80% of the time.
There should not be any noticeable delay or lag after the shot being fired or received. We will test with and without lens attached.

2.5. Usability: Describe the interfaces. Be quantitative if possible.

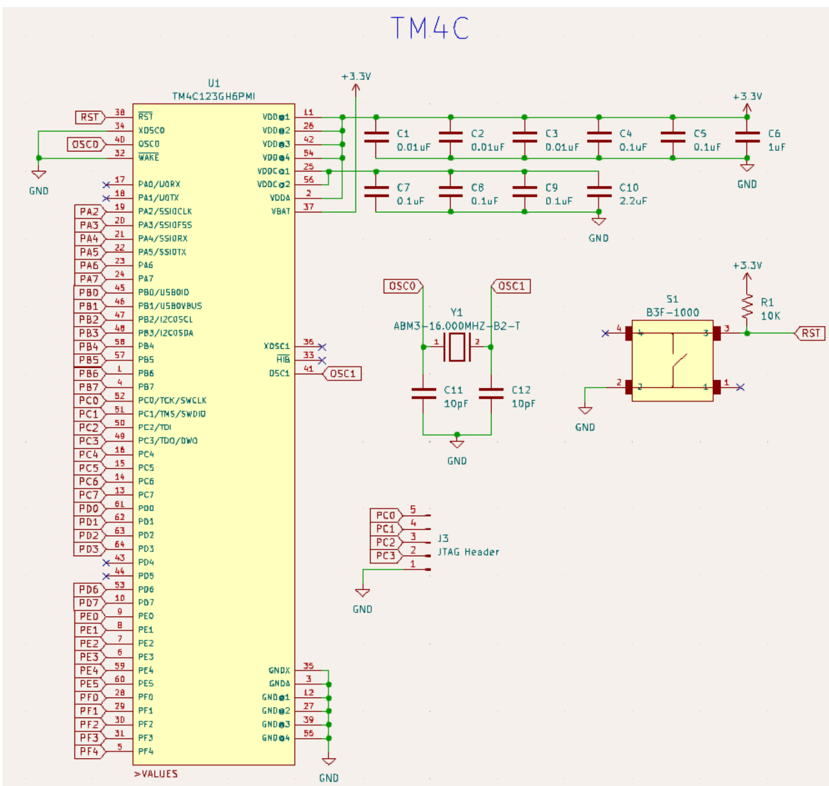
Triggers(switch) are used for shooting the shot. Screens are used for displaying the user data, remaining time, remaining shots, etc. LEDs are used to display the shot fired/received made. Electric buzzer will produce sound effects for making a shot, taking a shot, game start, timer, etc. IR transmitters and receivers send shot/player data to other player. After decoding and processing the shot received, receiving IR data will be shot back to the original shooter.

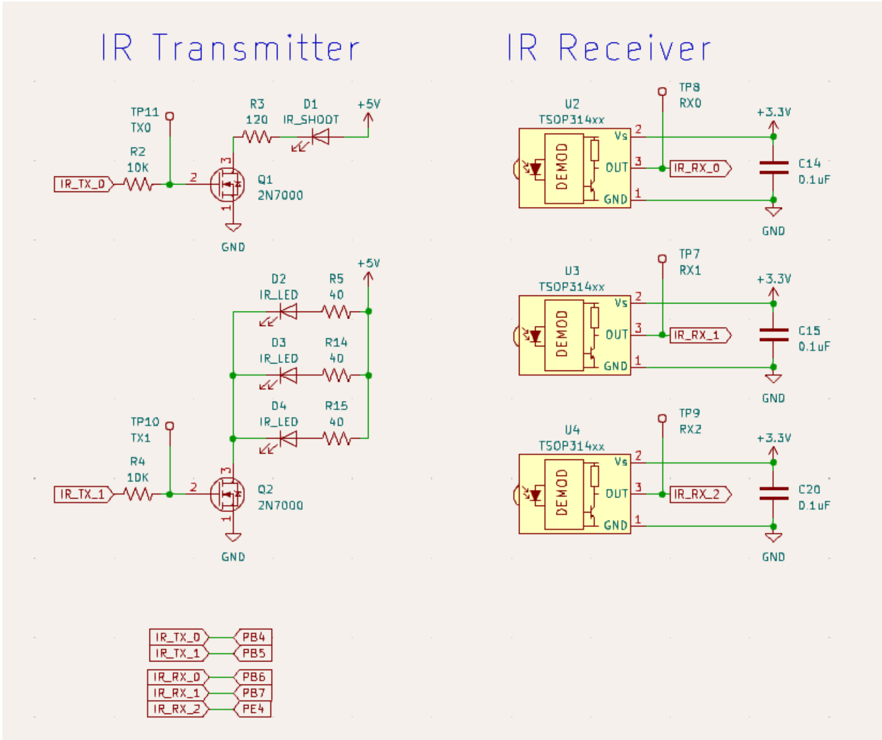
3. Deliverables

3.1. Reports: The reports for Labs 11 will be written at a future date.

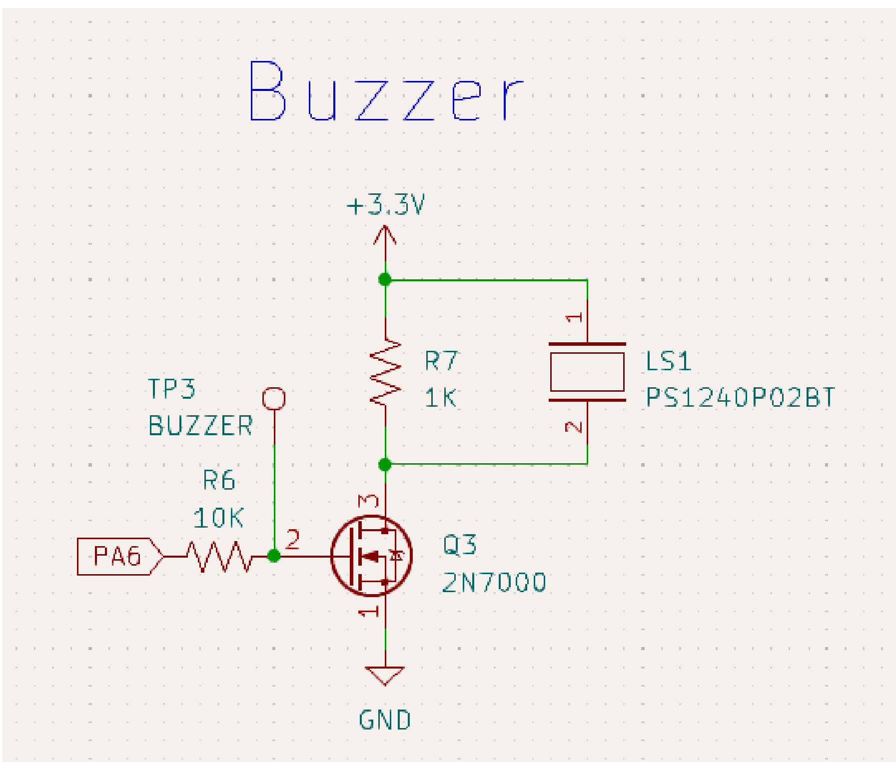
3.2. Outcomes: Lab 11 deliverables are as follows:

Hardware Design

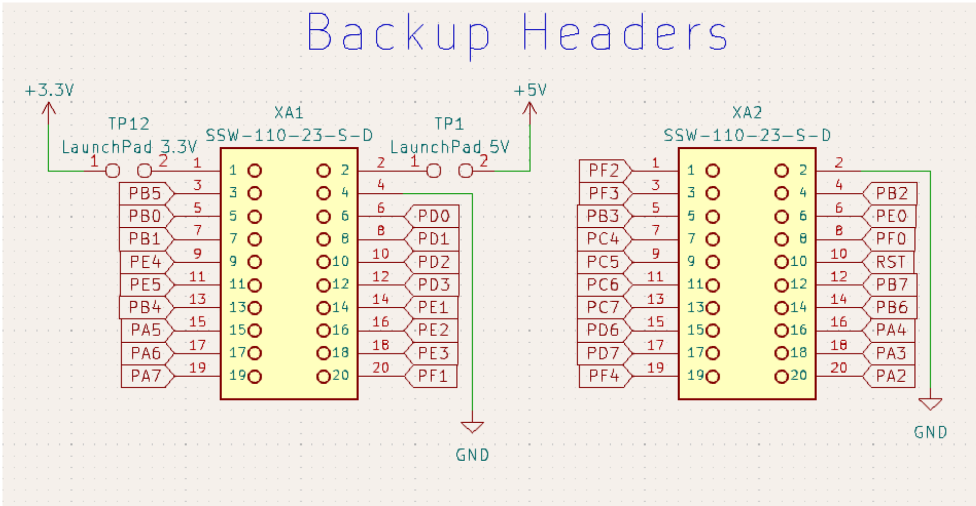
a. 


IR Transmitter
IR Receiver
TP11
TX0
R2
10K
IR_TX_0
R3
120
D1
IR_SHOOT
+5V
Q1
2N7000
GND
D2
IR_LED
R5
40
D3
IR_LED
R14
40
D4
IR_LED
R15
40
TP10
TX1
R4
10K
IR_TX_1
Q2
2N7000
U2
TSOP314xx
TP8
RX0
+3.3V
DEMOD
Vs
OUT
GND
IR_RX_0
C14
0.1uF
U3
TSOP314xx
TP7
RX1
IR_RX_1
C15
0.1uF
U4
TSOP314xx
TP9
RX2
IR_RX_2
C20
0.1uF
IR_TX_0
PB4
IR_TX_1
PB5
IR_RX_0
PB6
IR_RX_1
PB7
IR_RX_2
PE4

b.

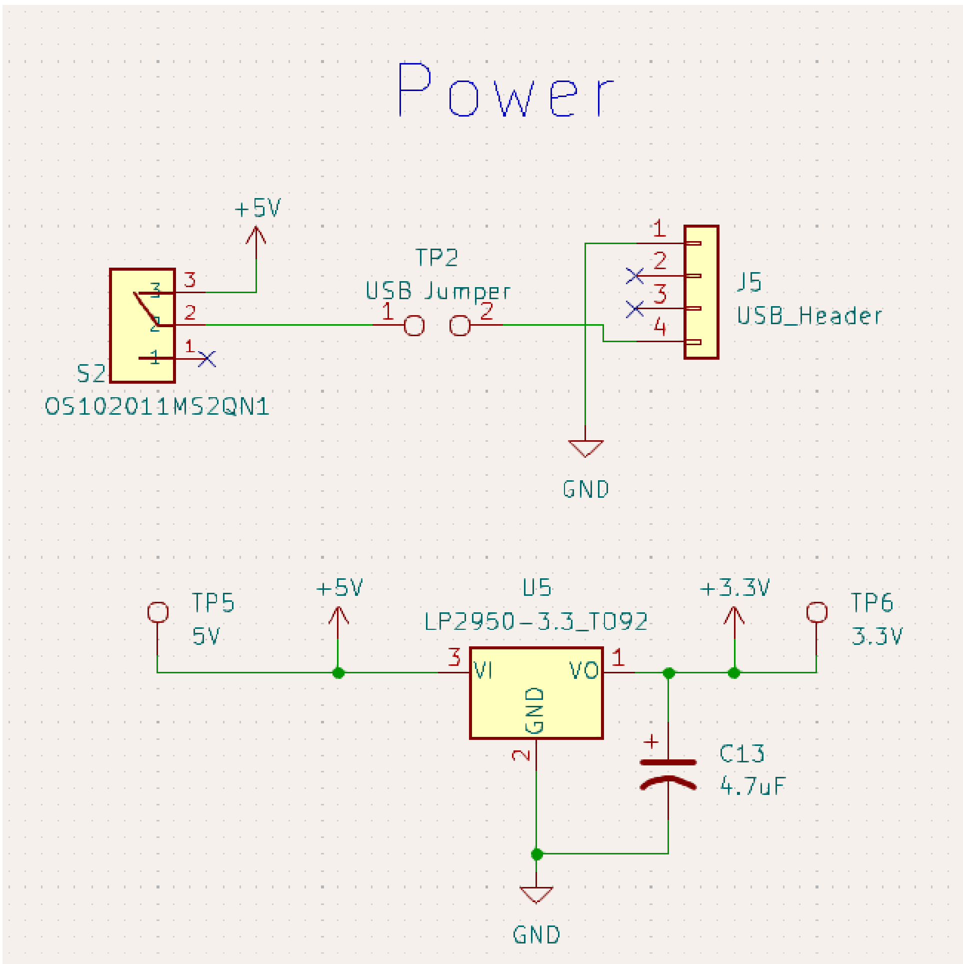

Buzzer
+3.3V
R7
1K
LS1
PS1240P02BT
TP3
BUZZER
R6
10K
PA6
Q3
2N7000
GND

c.



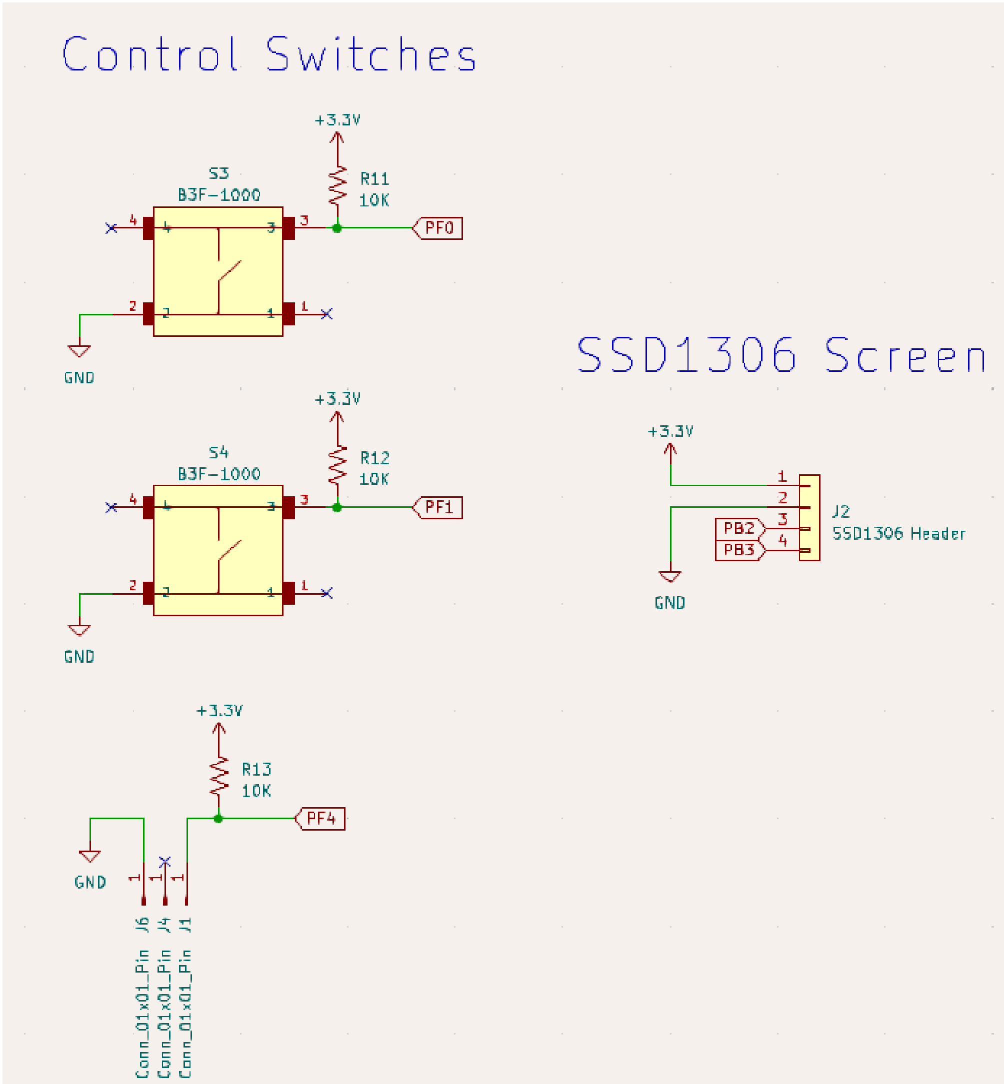
Backup Headers
+3.3V
TP12
LaunchPad 3.3V
XA1
SSW-110-23-S-D
TP1
LaunchPad 5V
+5V
XA2
SSW-110-23-S-D
PB5
PB0
PB1
PE4
PE5
PB4
PA5
PA6
PA7
PD0
PD1
PD2
PD3
PE1
PE2
PE3
PF1
GND
PF2
PF3
PB3
PC4
PC5
PC6
PC7
PD6
PD7
PF4
PB2
PE0
PF0
RST
PB7
PB6
PA4
PA3
PA2
GND

d.

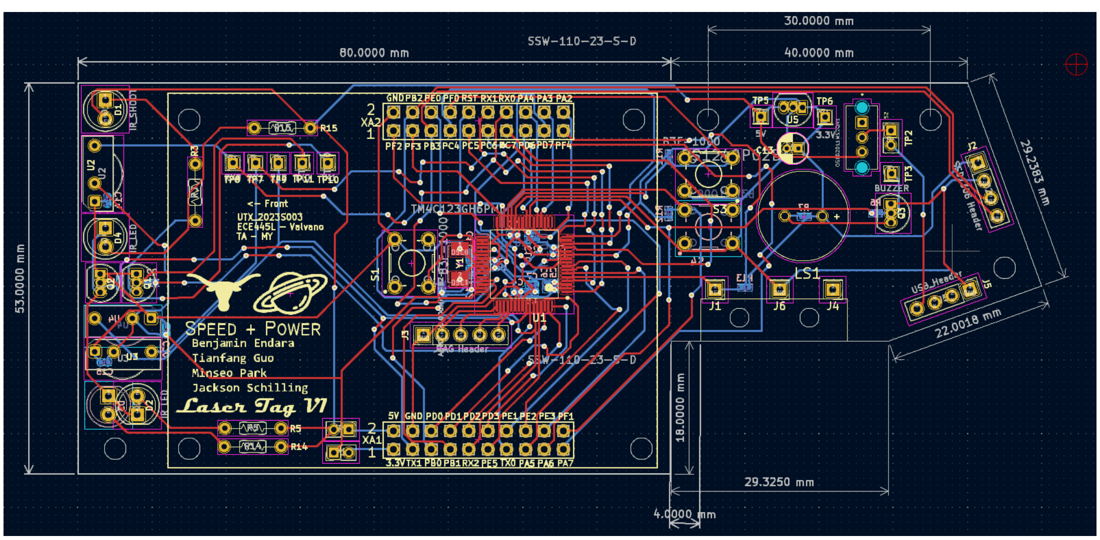


Power
+5V
TP2
USB Jumper
J5
USB_Header
S2
OS102011MS2QN1
GND
TP5
5V
+5V
U5
LP2950-3.3_TO92
VI
VO
GND
+3.3V
TP6
3.3V
C13
4.7uF
GND

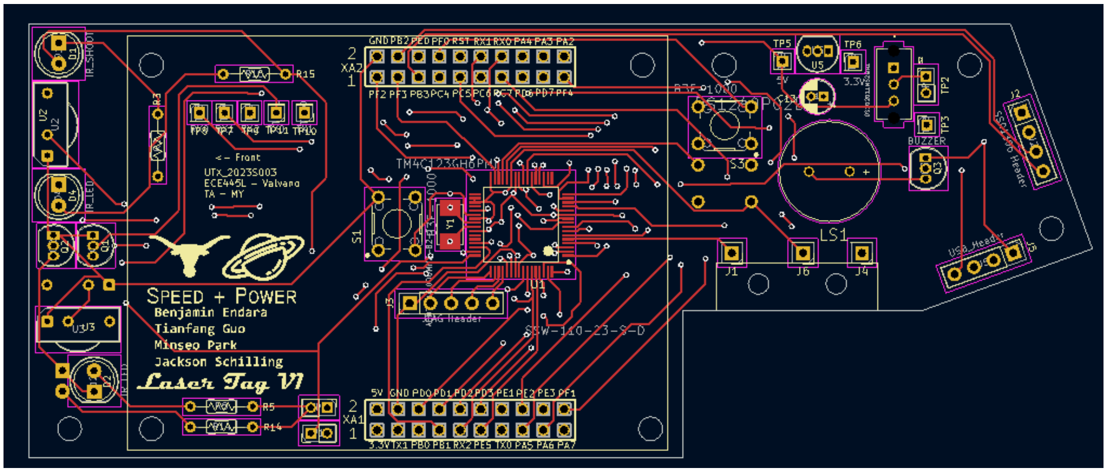
e.

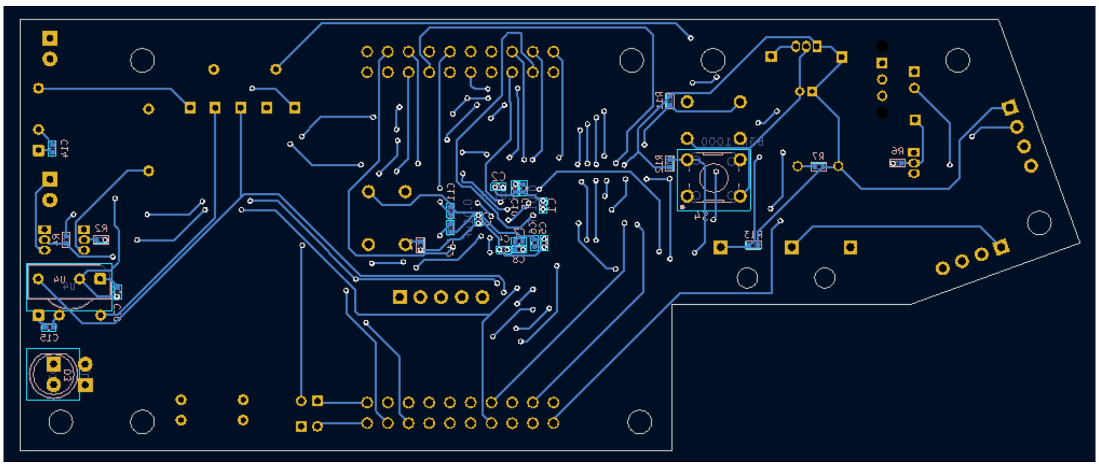

Control Switches
+3.3V
S3
B3F-1000
R11
10K
PF0
GND
+3.3V
S4
B3F-1000
R12
10K
PF1
GND
+3.3V
R13
10K
PF4
GND
J6
J4
J1
Conn_01x01_Pin
Conn_01x01_Pin
Conn_01x01_Pin
SSD1306 Screen
+3.3V
PB2
PB3
GND
J2
SSD1306 Header

f.


80.0000 mm
SSW-110-23-5-D
30.0000 mm
40.0000 mm
53.0000 mm
29.2383 mm
22.0018 mm
18.0000 mm
29.3250 mm
4.0000 mm
TM4C123GH6PM
<- Front
UTX_2023S003
ECE445L - Valvano
TA - MY
SPEED + POWER
Benjamin Endara
Tianfang Guo
Minseo Park
Jackson Schilling
Laser Tag V1

g.

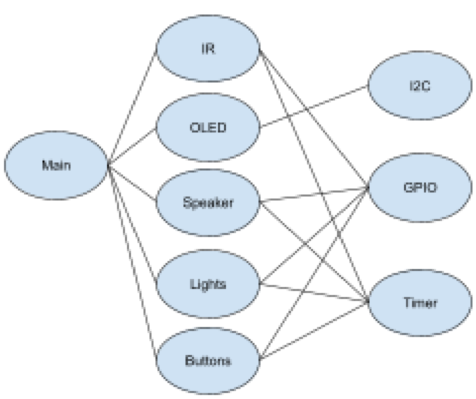
h. 

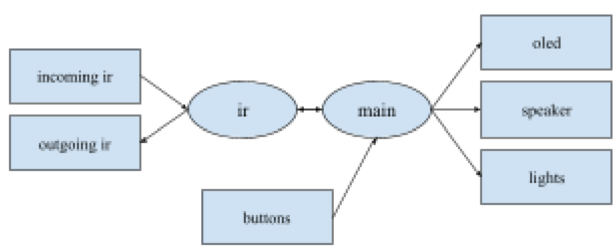
i. 

Software Design

a. Software call graph

b. Data flow diagram





Description of Software Design

The IR transponder code has both a transmitter module and a receiver module. Both the transmitter and receiver are finite state machines that change state at a fixed rate based on timer interrupts. The transmitter FSM updates at the baud rate of the IR transmission. The receiver FSM updates at a rate 8 times that of the baud rate to achieve asynchronous transmission via oversampling. The transmission protocol is fault tolerant and operates at a bit rate half that of the baud rate. The carrier frequency of the IR is 38 kHz, and each bit of the transmission consists of multiple pulses at 38 kHz. These pulses are generated using the PWM hardware on the TM4C, allowing the transmitter FSM to update at the baud rate and just switch the PWM on and off at the baud rate

Each bit of data is sent using two bits in the transmission. A data 0 is sent with 01, and a data 1 is sent with 10. This way there is never more than two bits in the transmission that are the same value. This prevents data loss if the transmission gets blocked partway through or the IR receivers are saturated by another signal transmitting at the same time. The start condition is 0000, which prevents small bursts of IR from inadvertently starting the receiver sequence. Using this protocol, the receiver is very unlikely to receive anything other than the intended data.

The other components are much simpler. Button debouncing is achieved using a single periodic interrupt which samples the buttons at a rate low enough to ignore bounces. The buzzer is operated with the PWM hardware and only outputs square waves. The display is updated as needed, so when a number needs to change on the display only that area of the screen is overwritten. This allows the display to update quickly despite the slow speed of the I2C connection.

Measurement Data

Testpoint 2 current measurement:

- without launchpad: 4.39mA
- With launchpad: 65mA

Mistakes and Near-Misses

a. The buzzer output pin is on PA6, which luckily just happened to be a PWM port, but we made the mistake of not double-checking ahead of time. We got lucky here.
b. Use of the LP2950-3.3 regulator was chosen in possible error, as its current output is only 100mA. However, we should have chosen the TPS73633DRBT (or a through hole equivalent) that is used on the TM4C Launchpad board, as it supplies 400mA at 3.3V. Explanation for why the LP2950-3.3 was used stems from its use in Lab 6.
c. All receiver and shoot pins should've all been on the same port. The third receiver was placed on PE4, when it should have been put on one of the PB ports instead with the rest of the IR interfaces. This mistake just makes it a little bit more of a pain to program, but will still work.
d. More thorough checks for shorts during soldering would have been helpful.
e. All pre-populated parts done by JLCPCB should've been placed on the same side as the TM4C chip so we could've used the oven. We ended up having a short when soldering by hand which basically bricked the whole board.
f. Place all of the adjacent test points with standardized offsets so we don't have to snip individual pins.

g. Didn’t add heartbeat LED on the PCB itself.
h. For case, didn’t add a hole for the power switch, but with the PCB design it can be placed to be accessible, but we forgot about that. This forced us to have to open the enclosure everytime we wanted to turn off the power, but that was still very easy.
i. The clip holding the battery could’ve been more precise.
j. The enclosure handle was a little too large for the battery, as well as not bolted together, so it was open on parts of it.