Lab 6: Introduction to PCB Design

Allen Pan & Paris Kaman

Requirements document

1. Overview

    1.1. Objectives: Why are we doing this project? What is the purpose?

        The objectives of this project are to design, build and test an alarm clock. Educationally, students are learning how to design and test modular software and how to perform switch/keypad input in the background.

    1.2. Process: How will the project be developed?

        The project will be developed using the TM4C123 board. There will be switches or a keypad. The system will be built on a solderless breadboard and run on the usual USB power. The system may use the on board switches and/or the on board LEDs. Alternatively, the system may include external switches. The speaker will be external. There will be at least four hardware/software modules: switch/keypad input, time management, LCD graphics, and sound output. The process will be to design and test each module independently from the other modules. After each module is tested, the system will be built and tested.

    1.3. Roles and Responsibilities: Who will do what? Who are the clients?

        EE445L students are the engineers and the TA is the client. Students are expected to modify this document to clarify exactly what they plan to build. Students are allowed to divide responsibilities of the project however they wish, but, at the time of demonstration, both students are expected to understand all aspects of the design.

    1.4. Interactions with Existing Systems: How will it fit in?

        The system will use the TM4C123 board, a ST7735 color LCD, a solderless breadboard, and be powered using the USB cable.

    1.5. Terminology: Define terms used in the document.

        Power budget- The allocation, within a system, of available electrical power, among the various functions that need to be performed

Device driver- device driver is a computer program that operates or controls a particular type of device that is attached to a computer

Critical section- a part of code where two (or more) pieces of your code might access the same variable at the same time, resulting in wrong values

Latency- amount of time between when a signal happens and when it is recognized

Time jitter- difference between the shortest and longest execution time of a interrupt service routine

Modular programming- keeping parts of the code partitioned into different files for different types of actions, different devices, etc.

1.6. Security: How will intellectual property be managed?

The system may include software from Tivaware and from the book. No software written for this project may be transmitted, viewed, or communicated with any other EE445L student past, present, or future (other than the lab partner of course). It is the responsibility of the team to keep its EE445L lab solutions secure.

2. Function Description

2.1. Functionality: What will the system do precisely?

1) It will display hours and minutes in both graphical and numeric forms on the LCD. The graphical output will include the 12 numbers around a circle, the hour hand, and the minute hand. The numerical output will be easy to read.

2) It will allow the operator to set the current time using switches.

3) It will allow the operator to set the alarm time.

4) It will make a sound at the alarm time.

5) It will allow the operator to stop the sound. An LED heartbeat will show when the system is running.

6) An ADC will be used on a knob potentiometer to allow quick time and clock setting in the menu interface.

2.2. Scope: List the phases and what will be delivered in each phase.

Phase 1 is the preparation; phase 2 is the demonstration; and phase 3 is the lab report. Details can be found in the lab manual.

2.3. Prototypes: How will intermediate progress be demonstrated?

A prototype system running on the TM4C123 board, ST7735 color LCD, and solderless breadboard will be demonstrated. Progress will be judged by the preparation, demonstration and lab report.

2.4. Performance: Define the measures and describe how they will be determined.

The system will be judged by three qualitative measures. First, the software modules must be easy to understand and well-organized. Second, the clock display should be beautiful and effective in telling time. Third, the operation of setting the time and alarm should be simple and intuitive.

The system does not have critical sections. The interrupt service routine used to maintain time completes in as short a time as possible. All LCD I/O occurs in the main program.

The while loop in main is the critical section. It updates the global variable time, alarm, curStage, stages array, etc... And it draws on the LCD, based on these global variables. All these operations are supposed to be atomic, therefore we disable the interrupt at the beginning of the while loop, and enable it upon exit. The two ISRs, systick and button press, will not be allowed to occur until it exits the critical section. But we made this critical section short enough so it doesn't affect the interrupt functionality.

Since we are only setting a flag in systick handler, then update the time in main, it does not affect the usage of time in the button ISR. And for the alarm flag, which is cleared in the button ISR and set in the systick ISR, we made it atomic when clear the alarm flag, so systick won't interrupt when we are at the processing of turning the alarm flag off. The situation here is, if systick tries to enable the alarm flag when we are just pressing the button to disable it. This happens when a user presses the alarm disabling button when the alarm isn't even on, and at that instant the alarm is required to sound. So that button press wouldn't disable the alarm. This is really rare.

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

There will be two switch inputs. In the main menu, the switches can be used to activate
1) set time;
2) set alarm;
3) turn off alarm; and
4) display mode.

The user should be able to set the time (hours, minutes) and be able to set the alarm (hour, minute). Exactly how the user interface works is up to you. After some amount of inactivity the system reverts to the main menu. The user should be about to control some aspects of the display configuring the look and feel of the device. The switches MUST be debounced, so only one action occurs when the operator touches a switch once. The LCD display shows the time using graphical display typical of a standard on the wall clock. The 12 numbers, the minute hand, and the hour hand are large and easy to see. The clock can also display the time in numeric mode using numbers. The alarm sound can be a simple square wave. The sound amplitude will be just loud enough for the TA to hear when within 3 feet.

The knob is in use in the scenes "Set Time" and "Set Alarm" when you select a section of the time. You can turn the knob to change the number and then hit the switch again to select the value.

2.6. Safety: Explain any safety requirements and how they will be measured.
The alarm sound will be VERY quiet in order to respect other people in the room during testing. Connecting or disconnecting wires on the protoboard while power is applied may damage the board.

3. Deliverables
3.1. Reports: How will the system be described?
The system uses 2 input switches, and 1 input ADC knob in order to navigate the menus. The menus allow the user to set the time and set an alarm time using said inputs. The system uses the systick timer to provide interrupts to keep track of the time on the clock. The time is then output to the ST7735 in a numerical display and in an analog format using trigonometric functions to gather an angle for the time. When the alarm time is reached, a flag is set that lets the systick interrupt reach a section of the handler that toggles a voltage on Port D that is hooked up to a speaker. This results in a square wave that ends up sounding the speaker. This is turned off by one of the switches in the main scene.

3.2. Audits: How will the clients evaluate progress?
The preparation is due at the beginning of the lab period on the date listed in the syllabus.

The preparation includes having each individual module of the project built, including time management, the alarm, the ST7735 display, and the input devices (buttons and ADC knob)

The application of these modules includes putting them together into an interface and providing any additional features to make the system coherent. For our system, this includes menus with navigation tied to the buttons and ADC knob.

3.3. Outcomes: What are the deliverables? How do we know when it is done?
There are three deliverables: preparation, demonstration, and report.

The preparation was submitted on canvas before the lab session, and we demonstrated our project features to our TA during the lab. The report will be finalized and submitted for review on Friday, 9/29

Hardware Design

Battery

UBBL20
Technical Datasheet

Features

- Off-the-shelf convenience
- Wire or connector terminals
- Full circuit protection
- Meets all UN transportation testing
- Long cycle life
- High energy density
- Wide operating temperature range
- Lightweight
- No memory effect

Applications

- Portable electronics
- Hand-held devices
- Medical equipment
- Back-up power

Accessories Optional

- UCH0037-S: Wall Wart charger (U.S.)
- UCH0037-I: Wall Wart charger (International)
- UCA0102-01: Interface cable for UBBL20-FL
- UCA0102-02: Interface cable for UBBL20-C1

Technical Specifications	
Part No.	UBBL20-FL or UBBL20-C1
Voltage Range	6.0 to 8.4V
Average Voltage	7.2V
Capacity	2.4Ah @ C/5 Rate @ 23°C±2°C
Max. Discharge	2.5A continuous
PTC	Rated for 2.6A Hold Current @ 20°C
Energy	17.3Wh
Energy Density	180Wh/kg, 450Wh/l
Weight	~100g
Cycle Life	> 300 cycles @ C/5 to 80% of inital capacity
Memory	No Memory Effect
Operating Temperature	-20°C to 60°C
Storage Temperature	-20°C to 50°C
Self-Discharge	< 10% per month
Exterior/Housing	PVC Shrink Wrap
Terminals/Connector	FL: 22 AWG wire leads Red (+), Black (-) C1: JST Connector VHR-2N
Safety	Material Safety Datasheet - MSDS041 Safety Guide UBI-5112
Transportation	Excepted from regulations for packages with gross mass of 10kg or less (see note.)
Protection Circuit Module and Fuses	Over Voltage Limit: 4.35±0.025V (per cell) Under Voltage Limit: 2.30±0.1V (per cell) Over Discharge Current Limit: 3.0 - 5.5A
Charging	Recommended charge rate is 466mA to 8.4V in a temperature range of 0°C to 45°C. Hold at 8.4V until current declines to 50mA. Maximum charge rate is 1.63A @ 23°C±2°C.
Note	A complete description of transportation regulations, lithium weights and transportation classifications is available on the Ultralife website.

Enclosure

TOP VIEW

112.40 [4.425]
102.10 [4.020]
50.50 [1.988]
60.50 [2.382]

SECTION A-A END VIEW

27.00 [1.063] INSIDE HEIGHT
55.45 [2.183] INSIDE WIDTH
31.00 [1.220]

SECTION B-B SIDE VIEW

6.00 [.236]
2.00 [.079]
27.00 [1.063]
2.00 [.079]
107.05 [4.215] INSIDE LENGTH

INSIDE BOX

4X 6-32 UNC ⤓ 11.00
⌴ Ø3.50 ⤓ 3.00
107.58 [4.235]
56.50 [2.224]
44.50 [1.752]
96.10 [3.783]
HAMMOND 1590B

INSIDE LID

102.10 [4.020]
4X Ø4.00 [.157]
4.19 [.165]
52.06 [2.050]
50.50 [1.988]
103.46 [4.073]

2.00 [.079]
4.00 [.157]

Enclosures can be Factory Modified (Milling, Drilling, Printing etc.)
Contact Factory   mjm@hammondmfg.com for quotes
Solid models of this enclosure available in STEP or IGES.
(Part number and text placement/orientation on our products are subject to change,
we do not recommend using them as a locating reference for modification purposes)

NOTE
Purchased assembly includes box, lid and 4 cover screws.
Box and lid are made from Diecast Aluminum Alloy.
Silicone Gasket supplied with liquid resistant enclosure.

Recommended Torque: 50-55 cN.m [71-78 ozf.in]
Recommended Torque with Gasket : 25-30 cN.m [36-43 ozf.in]

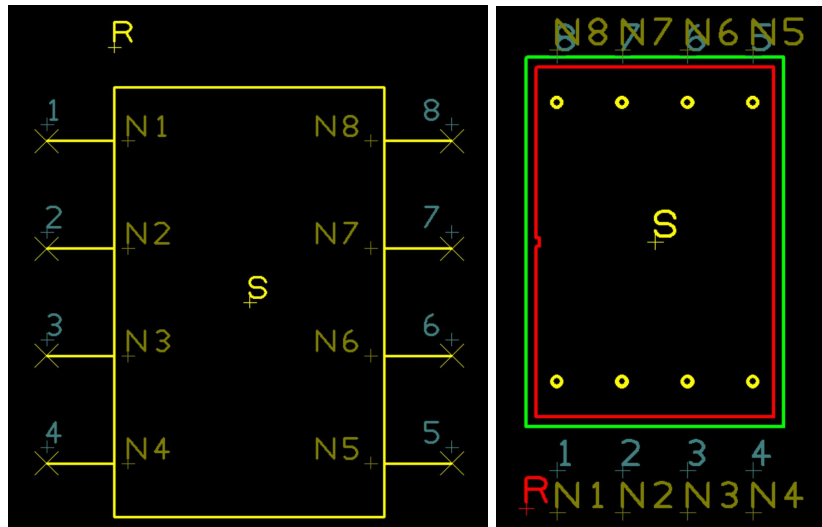| PART NUMBERS	
1590B Enclosure	
Natural Finish Enclosure	1590B
Black Textured Enclosure	1590BBK
1590B Liquid Resistant Enclosure (Silicone Gasket)	
Natural Finish Enclosure	1590WB
Black Textured Enclosure	1590WBBK
ACCESSORIES	
Liquid Resistant Cover Screws	
Stainless Steel Cover Screws (Pkg 100) [6-32 x 1/2" With O-Ring]	1590WMS100
Black Stainless Steel Cover Screws (Pkg 100) [6-32 x 1/2" With O-Ring]	1590WMS100BK
Standard Cover Screws	
Plated Cover Screws (Pkg 100) [6-32 x 1/2"]	1590MS100
Black Cover Screws (Pkg 100) [6-32 x 1/2"]	1590MS100BK

HAMMOND MANUFACTURING®
1590B

Dimensions:
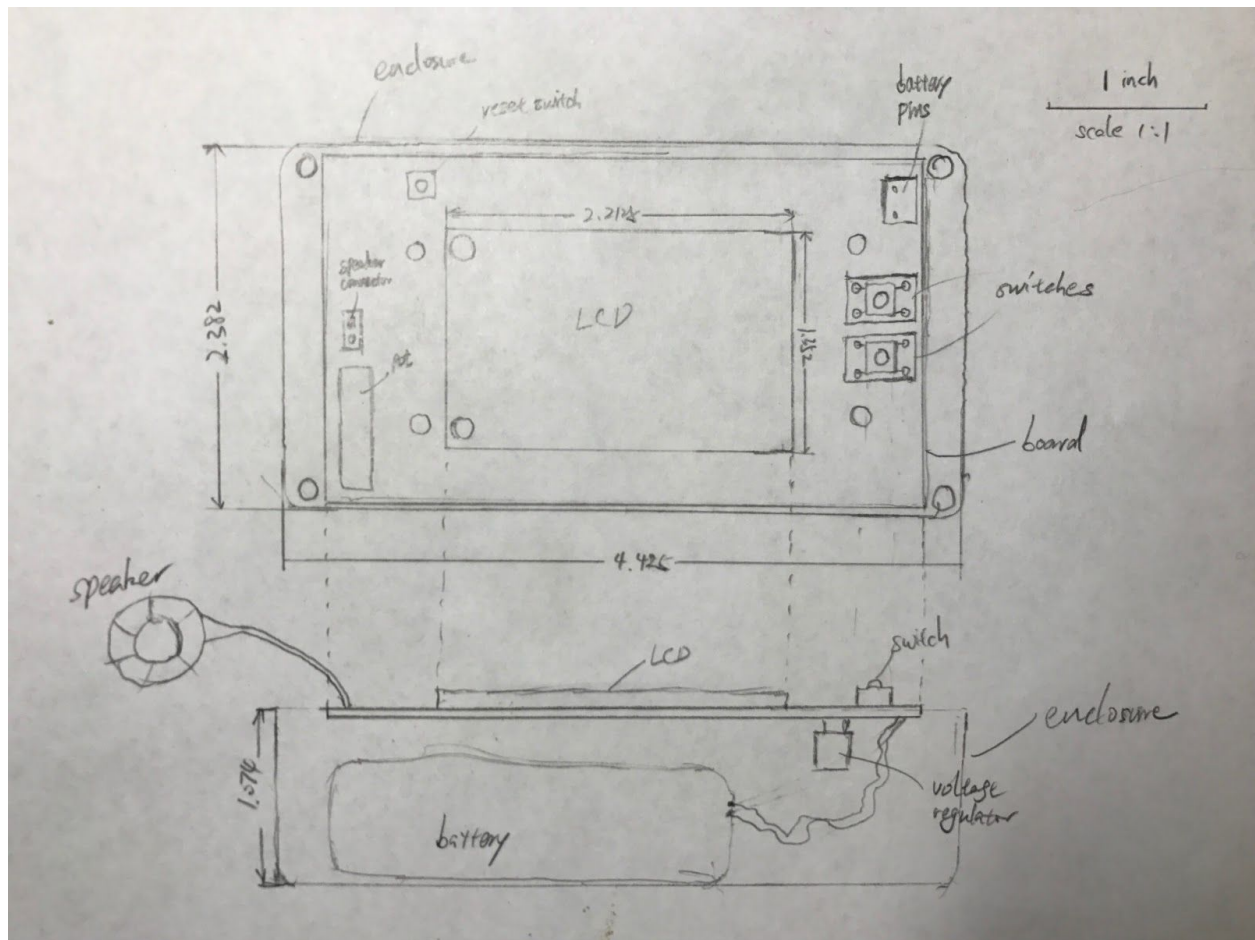mm
[inches]

www.hammondmfg.com

Created Part

This is TI TLV5618ACD, which is a dual 12-bit voltage output DAC. It allows two analog outputs, which can be used to create a dual channel stereo speaker.

Gate	Sch Symbol	Sch Symbol	Sch Terminal	Pcb Symbol	Component Pin	Net (Class)
Name	Name	Terminal Name	Number	Pad Number	Name/Number	Name
a	TLV5618ACD	Din	1	1	1	
		SCLK	2	2	2	
		CS	3	3	3	
		OUTA	4	4	4	
		AGND	5	5	5	
		REF	6	6	6	
		OUTB	7	7	7	
		VDD	8	8	8	

Component: C:\Users\Allen Pan\Desktop\PCBArtistLibrary\personal_lib.cml - TLV5618ACD - Untitled

Mechanical Drawing

In our system, the battery is placed at the bottom of the enclosure, and the PCB is placed on the top of it.
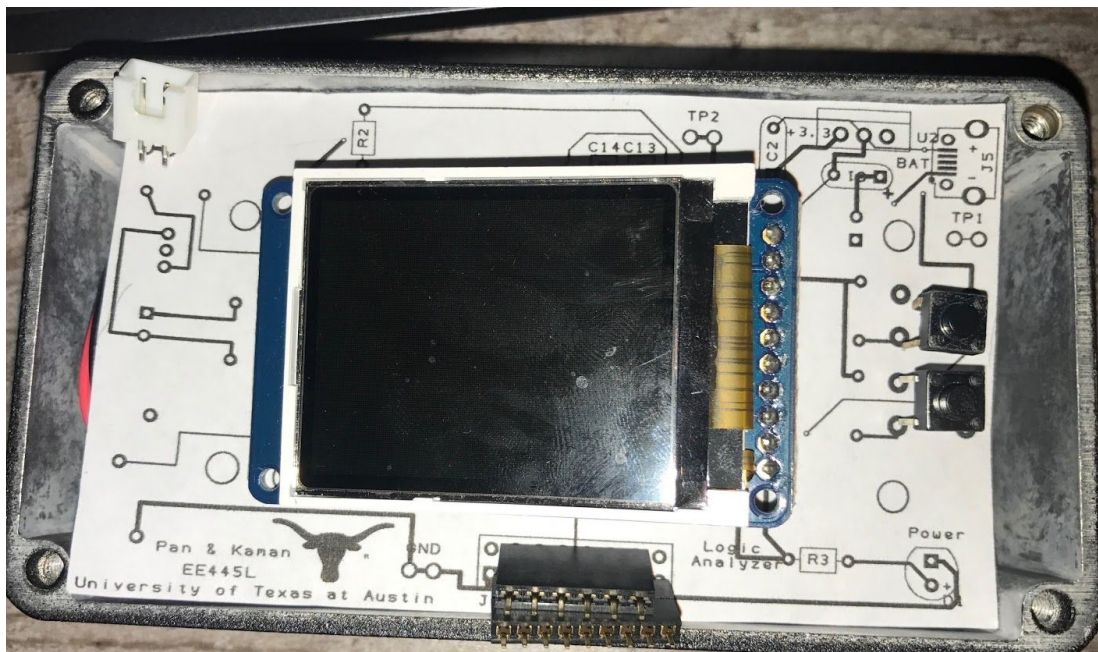
The LCD, switches, potentiometer and headers (user interface) sit on the top layer. The speaker will be placed outside of the enclosure.

In the drawing it seems like the PCB is floating above the battery, but actually since the components such as capacitors and resistors are sticking out toward the bottom, the space is filled.

Schematics
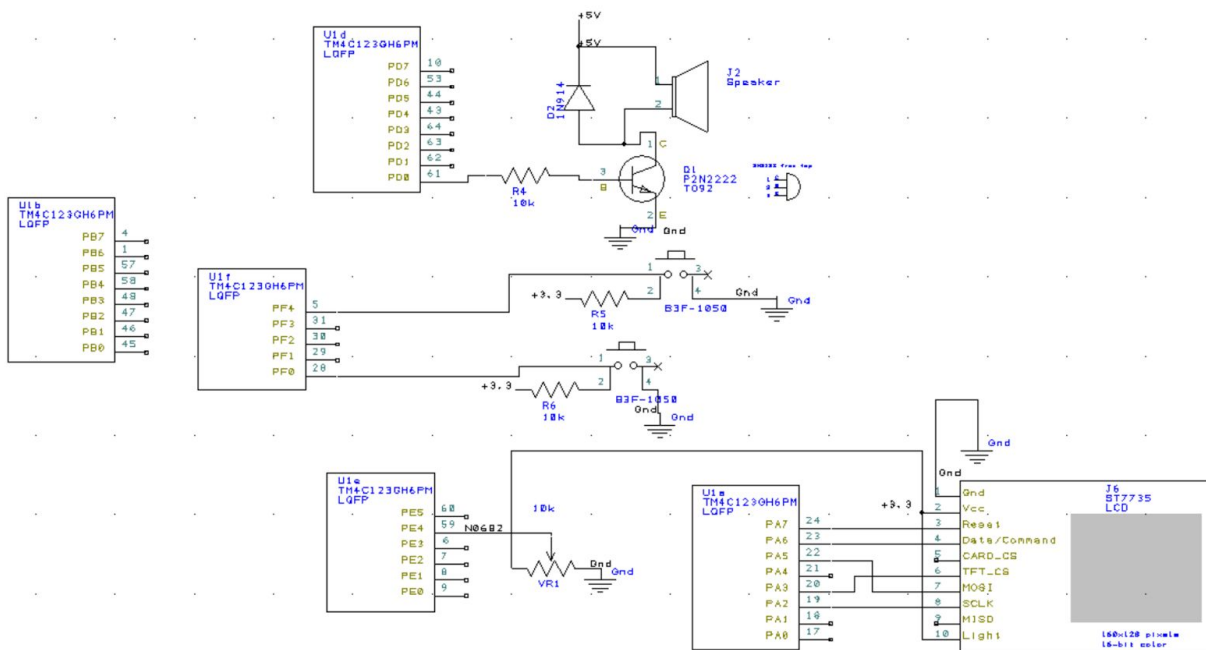
Cardboard Mockup

Here the battery is underneath the board. We only placed some of the components because it is hard to keep them in position. Also, we have not gotten some of the parts.

Measurement Data

1. The Bill of Materials

								$0.00				Package	Current	
1			SPEAKER 8OHM 300MW TOP PORT 92DB	CUI Inc.	CDM-20008	Digikey	102-2502-ND	$2.28	$2.28	Speaker		DIP	100 mA	
1			UBBL20 Battery, 7.2V, Connector	Ultralife	UBBL20-C1	Mouser		$46.36	$46.36				2.5A	
1			Enclosure Diecast Alum Black 4.4 x 2.38 x 1.06"	Hammond	1590BBK	Mouser		$8.98	$8.98					

Only showed the extra parts here since the list is too long. The entire xls file is uploaded on canvas.

2. Explain how you chose the battery.

We will need 5V voltage for the speaker, so the minimum voltage needed to be provided for the battery is 5V. And the measurement we had for the maximum current needed to drive the speaker was around 100mA. Since we need to run the system for 24 hours, the capacity will need to be around 2.4Ah.

So when selecting the battery, we need to meet following specifications:
1) Capacity at least 2.4Ah
2) Maximum discharge at least 100mA
3) Voltage at least 5V

Considering all three, we found that the battery shown above suits the best. But we will need to use voltage regulators to convert the voltage to 5V and 3.3V.

Analysis and Discussion

Explain the testing procedure you would suggest for the system

In order to test the system, we would load a program that produces a simple sine wave at the frequency of the lowest note we support (C1) we would hook the device up to the logic analyzer to check the wave. We would check the values of the sine wave with an expected value array at various test points in the wave. The program would then produce a sine wave with the highest frequency note (B8) and get tested in the same manner. We test the high frequency note to make sure the clock is running fast enough to produce the output that requires the quickest processing. To test individual signals within the system, we could hook up a small wire inside a via on the path of the signal and read that value specifically.

We would also have a program loaded that would simply test the actuation of the buttons and make sure each press of a button is registered within the machine. The program would be something like if a button is hit, toggle a certain bit. We would each bit corresponding to each button and make sure all buttons are functional.