POTD-Problem Based Alarm Clock

ECE 445 Design Document

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1. Introduction

1.1 Objective

Getting up on time has always been a problem for many people. The very basic alarm that only makes clangorous sound often fails to wake people up, and often lead to people turning it off half-awake and falling back to sleep, which may cause a delay to their days. Setting alarm clocks with cell phones also has certain drawbacks. Often, the cell phone battery dies in the middle of the night, and thus the alarm fails.

To address this issue, we propose a problem-based alarm clock that requires users to answer several multiple choice questions to turn it off. The alarm clock is connected with a mobile app via Bluetooth so that users can load their own questions and setup time to wake up. The questions can be of any subject and are typed manually. The flexibility of questions gives users opportunities to review certain things as they like. The app also records the time it takes for them to wake up each morning and the result of their quiz.

1.2 Background

The process of thinking can stimulate people's brains and help people fully wake up, not only physically, but also mentally, according to Peter Balyta, President of Education Technology at Texas Instruments [1].

While waking up in the morning can be hard for a lot of people, there are many applications that attend to address this issue with problem-based approach in the market, such as the Mathe Alarm. It has both Android and iOS app that is available for free. Using this app, users are able to choose the number of simple algebraic questions they want to answer in order to turn off the alarm. The users can also pick the level of the math problems. However, it does not support custom questions and only have algebraic ones.

Moreover, in the current market, there is no physical alarm that has the similar functionalities. While some people use phone apps as alarm, many people still prefer to use physical alarm. According to a survey from market research firm YouGov in 2011 [2], while 48 percent of respondents aged 16-34 said they used their phone as an alarm, another 38 percent said they use either a clock radio or an alarm clock.

1.3 Visual aid

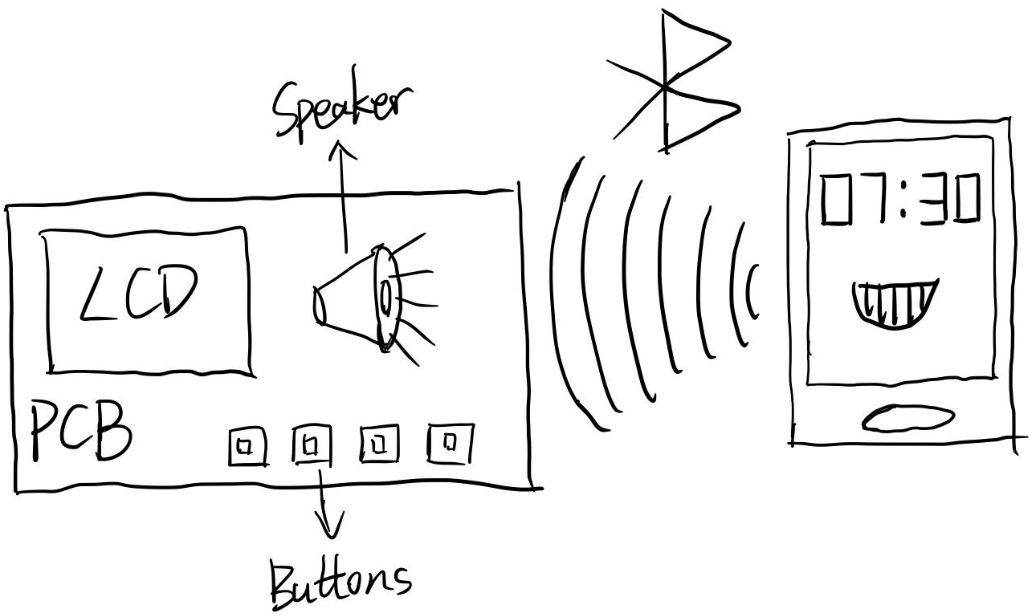

Figure 1. Visual Aid

1.4 High-level requirements

- The alarm device must be able to function as an actual alarm clock: display time, alarm at a preset time and turn off the alarm when a certain number of questions are correctly answered or a maximum number of questions are answered regardless of correctness.
- The alarm device must load correct number of questions, display questions on the LCD, record user answers to the questions when the alarm goes off.
- The alarm device must communicate with the Android app via Bluetooth. The Android app would set the alarm time and load questions into the alarm device; the alarm device would send recorded data back to the app.

2. Design

The project requires four sections of hardware and one section of software. The hardware contains power supply, control unit, user interface and an alarm.

The main power supply is an approximate 9V battery power, which is adjusted by a 5 volt voltage regulator for different components. The control unit consists of a microcontroller and a Bluetooth module. The user interface includes a microcontroller to control LCD, an LCD module, and physical buttons for users to press. The alarm consists of a speaker and a real time clock module. The software is an Android app that is used to set the alarm time and set questions to the control unit.

Normally, the control unit constantly receives time data from RTC and sends it to the microcontroller in the user interface to display current time on LCD module. When connected to the Bluetooth, the control unit receives question data and alarm time from software and send data of user's performance data to software. Then the control unit sends alarm time data to user interface again. When the alarm time matches the current time, the control unit triggers the alarm to go off and signals the user interface to display problems on the LCD module and records user input. After a certain number of questions are answered correctly or a maximum number of questions are answered, the control unit turns off the speaker and sends time data to user interface to display time again.

The whole system flow is shown in Figure 2.

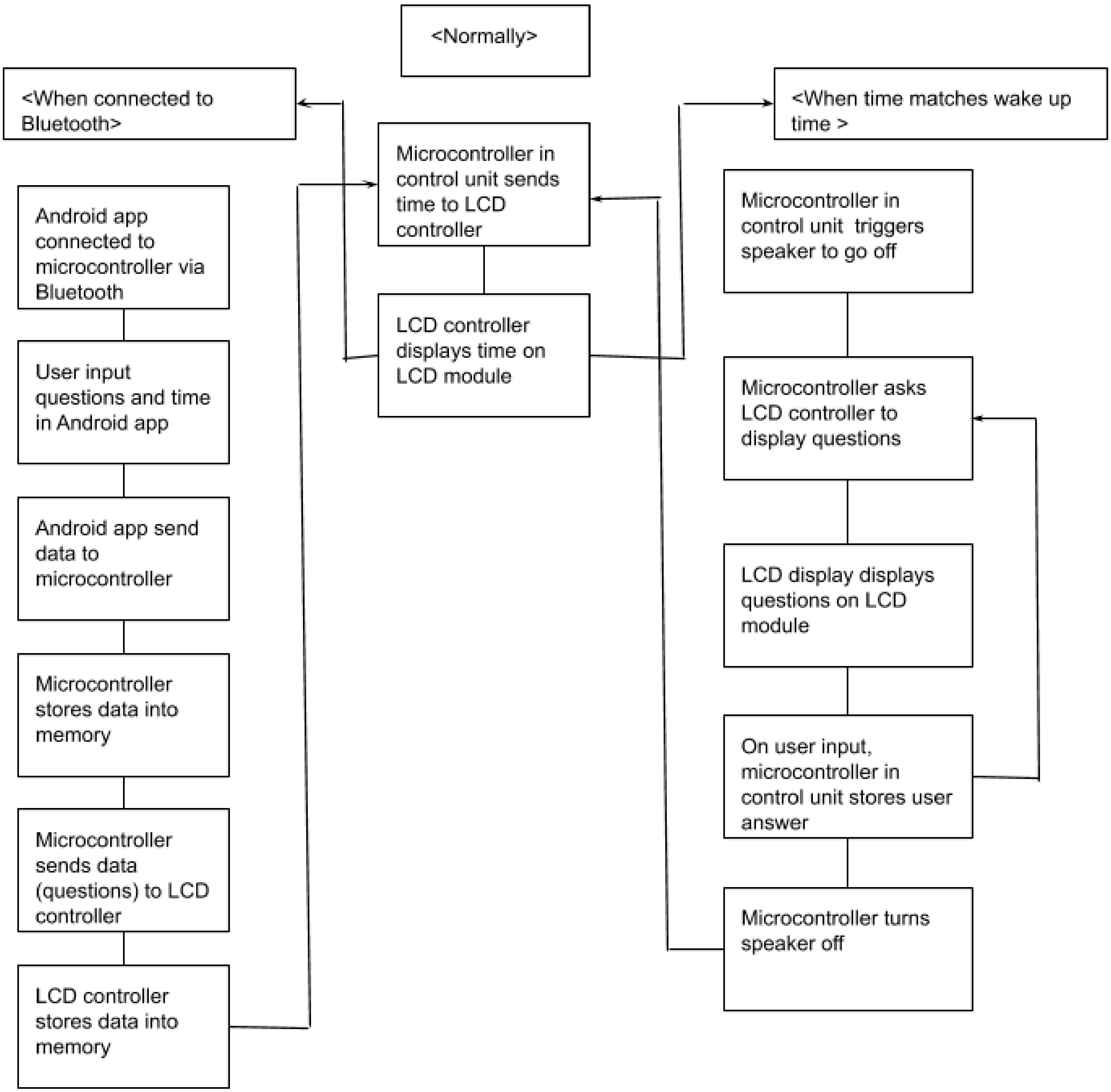

Figure 2. System flow

2.1 Block diagram

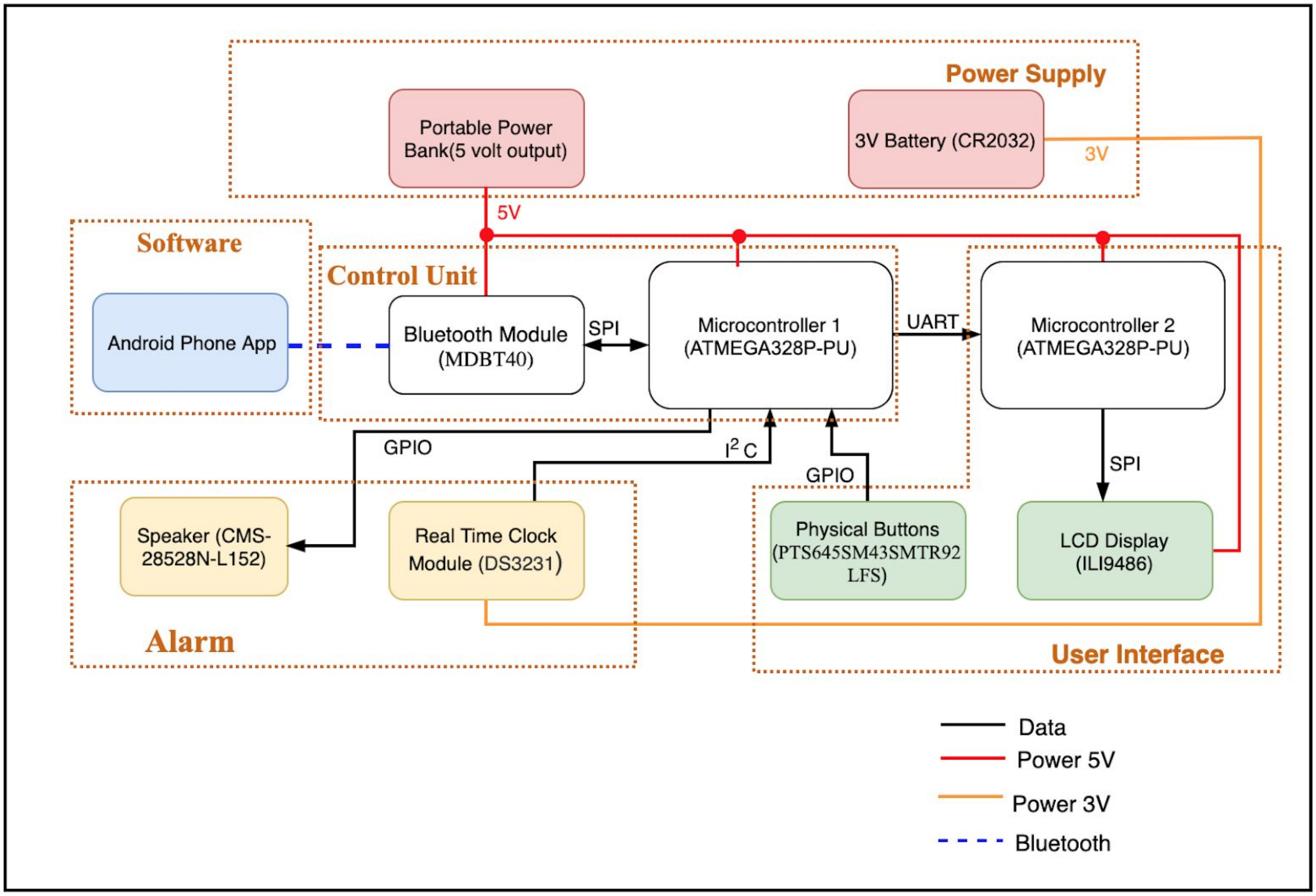

Figure 3. Block Diagram

2.2 Control Unit

A control unit is able to receive data from software (Android Phone App) as input, which provides information of questions, wake-up time, and the ring-tone choice. The control unit also receives data from physical buttons so it is able to receive user input and record their performance on the "daily questions" and these data will be sent back to the app through Bluetooth module for further data analysis. Moreover, control unit communicates with the microcontroller in the user interface to send time data and the questions that needs to be displayed for the day. The control unit is responsible for turning on/off the alarm's ringtone as well.

2.2.1 Microcontroller

The microcontroller (Atmega328P) handles input data received from Bluetooth module (MDBT40) via SPI , DS3231 real time clock via I2C, and physical button via GPIO. The microcontroller loads questions to the microcontroller in user interface via UART after the control unit receives question data from software. When the microcontroller is not sending question data to the microcontroller in the user interface, it constantly sends time data received from RTC to the microcontroller in the user interface. According to the data received from RTC module, microcontroller determines when to turn on the alarm's speaker; based on the user input, it determines when to turn off the alarm. The input data from the physical buttons is stored in the microcontroller and should be sent to Android phone app via Bluetooth module. Microcontroller's 32KB flash memory will be mainly used to store the question database(up to 30 questions), user's answer data (input data from physical buttons), and the different preset ringtone sounds.

Memory Requirement: *Maximum number of questions stored: 30*
Question length constraint: 200 char
Answer length constraints: 25 char
*Integer for time: 10 digit (4 bytes*10)*
Memory estimated:
30(200 + 4*25) byte + (10*4)byte +*
some space to store user answer data + several ring-tone music < 32kB

Requirements	**Verification**
1. Able to get time from RTC module 2. Able to get data from physical buttons 3. Able to send data to the microcontroller in user interface	1. Write a test program to have the microcontroller turn on LED based on RTC input 2. Write a test program to have the microcontroller turn on LED based on button input 3. Press the buttons to control the LED on the microcontroller in user interface

4. Able to send data to Bluetooth module and get data from Bluetooth module	4. a. Write a test program to have the microcontroller turn on LED based on Bluetooth module input b. Write a test program to have the Bluetooth module turn on LED based on microcontroller input

2.2.2 Bluetooth module

Bluetooth module Adafruit Bluefruit LE SPI Friend (MDBT40) is used to communicate between Android phone app and the microcontroller in the control unit. The users can load their questions into the microcontroller via Bluetooth module, as well as set the alarm time. The Bluetooth module is also used to send user answer data from microcontroller to the Android phone app when user's phone is connected to the alarm via Bluetooth.

Requirements	**Verification**
1. Able to connect to Android app 2. Able to receive data from Android app 3. Able to send data to Android app 4. Able to send data to microcontroller and able to receive data from microcontroller	1. Write an Android application to connect LED on microcontroller 2. Write an Android application to control the LED to light up on the microcontroller 3. Press buttons and display output on the Android app 4. a. Write a test program to have the microcontroller turn on LED based on Bluetooth module input b. Write a test program to have the Bluetooth module turn on LED based on microcontroller input

2.3 Power supply

The power supply for the whole device is mainly a 5V-1000mAh portable power bank. It is connected to the device via USB. The only separate battery power (button battery 3V CR2032) used is for real time clock.

Requirements	**Verification**
1. Provides 5V +/- 2% from the portable battery bank.	1. a. Measure the output voltage using an oscilloscope, make sure that the output voltage stays within 2% of 5V

2.4 User Interface

The user interface is used to receive time/question data from control unit, and outputs user answer data to the control unit. The user interface includes a microcontroller (ATMEGA328P), used solely to control the LCD module via SPI, an LCD (ILI9341) module, used to display problems, and four physical buttons for users to press to answer multiple choice questions.

2.4.1 Microcontroller

The microcontroller (ATMEGA328P) (referred later as the LCD controller) is solely used to control the LCD module via SPI. Normally, it constantly receives data from the microcontroller in the control unit to display time on the LCD module. When the control unit is connected to the Bluetooth, the LCD controller receives questions from the control unit's microcontroller and stores in its memory. When the alarm goes off, the microcontroller from the control unit tells the LCD controller which problem to display.

Requirements	**Verification**
1. Able to control the LCD display 2. Able to receive data from the microcoller in the control unit	1. Write a program for the LCD controller to display some text on the LCD display 2. Write a program to have the microcontroller in the control unit control the LED on the LCD controller

2.4.2 Physical Buttons

Users use four buttons (PTS645SM43SMTR92 LFS) to answer the multiple choice questions. They would send data to the microcontroller in the control unit via GPIO.

Requirements	**Verification**
1. Button pressed can be detected by the microcontroller over GPIO 2. Buttons can be easily pressed	1. Measure the output signal using an oscilloscope, make sure that the output correctly represents whether the button is pressed 2. Press Button and ensure that it can be done

2.4.3 LCD Module

The LCD (ILI9341) module is used to display time and questions. It is directly controlled by a separate microcontroller (referred later as the LCD controller) via SPI. The microcontroller in the control unit tells the LCD controller what to display and the LCD controller controls the LCD module to display them accordingly.

Requirements	**Verification**
1. LCD Display is able to receive data over SPI	1. Connect the LCD Display to the SPI port of the microcontroller and send random characters. The characters should be correctly displayed on LCD.

2.5 Alarm

2.5.1 Speaker

The purpose of CMS-28528N-L152 speaker is to produce audio output to wake people up. It is used with a sound filter chip (LM386 Low Voltage Audio Power Amplifier) to filter out some noises to have a better sound effect.

Requirements	**Verification**
1. Speaker is able to receive data over GPIO and produce audio output when signal is sent	1. Connect speaker with microcontroller, use microcontroller to input data to speaker and send signal, check if the speaker can produce correct music when signal is sent

2.5.2 Real Time Clock Module

The DS3231 Real Time Clock module is used to keep track of time and send its time data to the microcontroller in the control unit via I2C. DS3231 has its own battery-backup input for continuous timekeeping.

Requirements	**Verification**
1. RTC is able to keep track of real time 2. RTC is able to transmit over I2C to microcontroller	1. Current time of RTC is the same as real time after setting initial time for RTC 2. Time computed by RTC can be received by microcontroller and displayed on LCD

2.6 Software

2.6.1 Android application

An auxiliary Android app that communicates with the circuit via Bluetooth for users to type in their customized questions as well as set the alarm time. When it is connected to the alarm, users can add questions and set time. When submitted, these data are sent to the microcontroller via Bluetooth module. The app also includes the option to show past analysis for user performance on the problems they answered. The software would get the result of user answers as well as the time they took to wake up for the past couple of days from the microcontroller from the control unit, compute an average wake up time for users and display users' past performance and average wake up time for their reference.

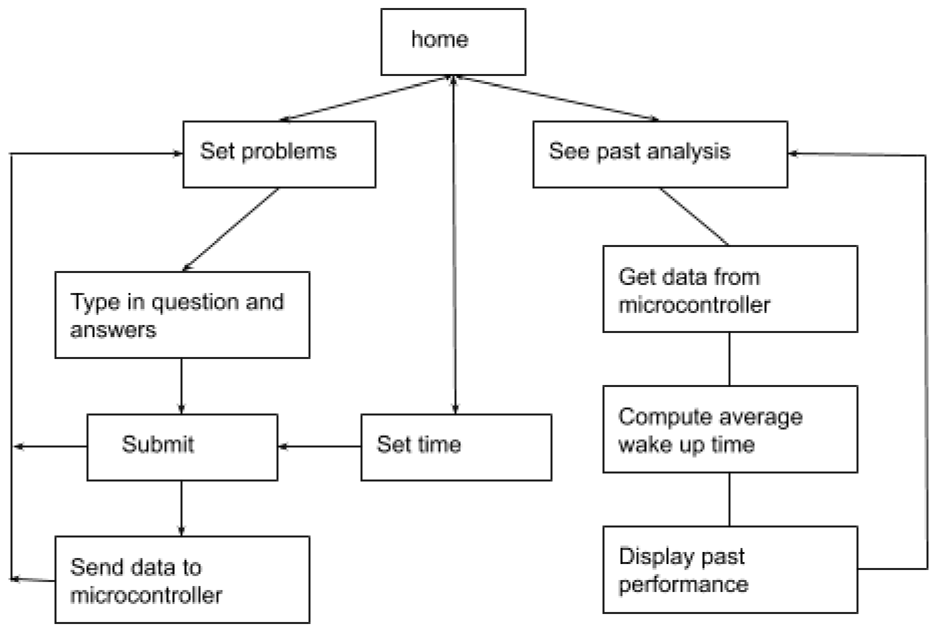

Figure 4. Software Flow

Requirements	**Verification**
1. Android app is able to connect to Bluetooth 2. User is able to use the Android app to send data to control unit 3. Android app is able to receive data sent from the control unit	1. Write an Android application to connect LED on microcontroller 2. Write an Android application to control LED to light up on microcontroller 3. a. Write a test program to have the microcontroller turn on LED based on Bluetooth module input b. Write a test program to have the Bluetooth module turn on LED based on microcontroller input

2.7 Schematic

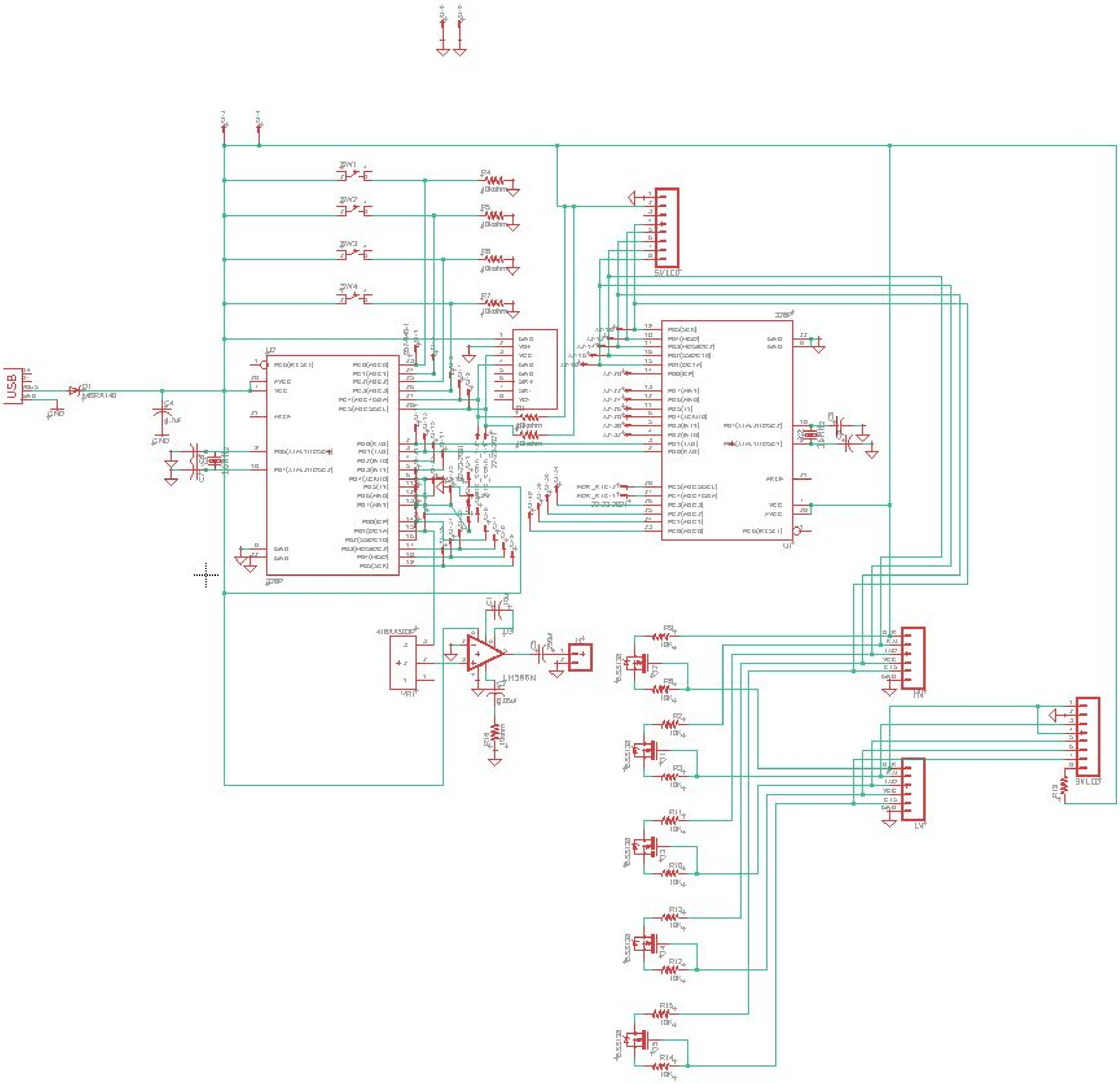

Figure 5. Schematic

2.8 Tolerance Analysis

2.8.1 LCD module transfer rate analysis

To achieve decent performance on LCD display, we choose SPI protocol. The minimum required transfer rate is

$$minimum\ required\ rate\ =\ pixels\ on\ the\ screen\ *\ sizeofPixel$$
$$resolution\ =\ height\ *\ weight\ (pixels)$$

LCD module screen resolution is 480 * 320, which need

$$480\ *\ 320\ *\ 8\ bits = 1228800\ bits \approx 1.17Mb$$

to refresh once. SPI does not define any speed limit; implementations often go over 10MBps,

$$10MB\ >\ 1.17\ Mb$$

and hence it can refresh about 10 times in one second, which would be sufficient for our purposes.

2.8.2 Power supply error range analysis

Additionally, one error source in the system is the power supply. In the power supply, the 5 volts portable power bank has a ± 2 % error.

$$maximum\ voltage:\ 5\ *\ (1.02)\ = 5.1\ volts$$
$$minimum\ voltage:\ 5\ *\ (0.98)\ =\ 4.9\ volts$$

That would range from 4.9 volts to 5.1 volts.
Since the maximum voltage the microcontroller could take is 5.5 volts;

$$5.1 < 5.5\ volts$$

And the maximum voltage the Bluetooth module could take is 16 volts,

$$5.1\ < 16\ volts$$

it would be acceptable at this range.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

Salary per hour is estimated to be $20/hour. Total hours to complete the project per person is estimated to be 165 hours (15 h/week *11 weeks). The total labor cost is estimated to be:

3 person * $20/hour * 165 hour/person *2.5 = $24,750

3.1.2 Parts

Part	**Cost(prototype)**
10000mAh Portable Power Bank (Amazon; Anker)	$27.99
3 volt Button Battery (Digikey; CR2032)	$0.35
5 volt voltage regulator (Digikey;LM2674)	$3.38
Microcontroller * 2 (Digikey; ATMEGA328P-PU)	$3.92
Physical Buttons * 4 (Digikey; PTS645SM43SMTR92 LFS)	$1.24
Bluetooth Module (Amazon; MDBT40)	$19.48
LCD Module (Adafruit; ILI9341)	$29.95
Speakers (Digikey; CMS-28528N-L152)	$3.59
Sound filter chip (Digikey; LM386N-4/NOPB)	$1.17
Real Time Clock (Digikey; 1528-1598-ND)	$13.95
Total	$105.02

4. Schedule

Week	Sherry Wu	Shirley Xu	Charlene Zheng
09/30/2019	Begin PCB design	Begin protocol design and programming for control unit	Begin Android app design
10/07/2019	PCB design first version	Continue, research data transmission protocols	Have Bluetooth module connected with control unit
10/14/2019	PCB design final version	Have microcontroller get time from RTC	Have Android app communicate with control unit via Bluetooth
10/21/2019	Power system done	Have microcontroller get data from buttons	Have Android app send questions to microcontroller
10/28/2019	Have microcontroller control LCD module	Have microcontroller trigger speakers, and load preset ringtone	Have Android app set alarm time to microcontroller
11/04/2019	Keep working on having microcontroller control LCD module	Test on control unit	Have control unit send user performance information to Android app and do analysis
11/11/2019	System integration; check the data transmission; prepare mock demo;	System integration; check the data transmission; prepare mock demo;	System integration; check the data transmission; prepare mock demo;
11/18/2019	Mock demo; Prepare demonstration	Mock demo; Prepare demonstration	Mock demo; Prepare demonstration
11/25/2019	Last check for final demo	Last check for final demo	Last check for final demo
12/02/2019	Prepare presentation, creating powerpoint slide; start final report	Prepare presentation, creating powerpoint slide; start final report	Prepare presentation, creating powerpoint slide; start final report
12/09/2019	Complete final report	Complete final report	Complete final report

5. Ethics and Safety

5.1 Safety

Lithium-ion batteries can explode if not handled properly (exposed to extreme temperature, overcharged etc). Also the voltage of the battery can be too high for sub components and can potentially cause damage to the circuit. Therefore, for user’s safety, the voltage regulator must be properly connected to various components and adjusted to different voltages based on the requirement of that piece of component.

5.2 Ethics

Privacy and security is a serious problem on the Internet. Information leaking is always the core issue of mobile applications. For instance, some apps track people's search history and send them advertisements based on that information. It is common to see some products searched yesterday pop up as a floating or static window.

Since we are collecting data from users on the mobile app, we must handle their information carefully. As the questions are manually created by users, they can potentially contain sensitive data, and thus the authentication of the application needs to be implemented properly. User information including account information and other relevant data will be stored in database in the server. Each user should have their own account with password and username and their information including question bank and the time it takes them to wake up each day are private data not be visible to other users. Therefore, we will not violate code 6 of IEEE Code of Ethics.

Our application should align with the IEEE Code of Ethics in section 7, "To accept responsibility.."[3] there could be potential risks that result from having access to private user data.

References

[1] Hess, A. (2019). *10 highly successful people who wake up before 6 a.m.*. [online] CNBC. Available at: https://www.cnbc.com/2018/05/17/10-highly-successful-people-who-wake-up-before-6-a-m.html [Accessed 14 Sep. 2019].

[2] M. Floyd, “Almost 60% of 16-34 year olds use a phone as their primary timepiece,” *YouGov*, 05-May-2011. [Online]. Available: https://today.yougov.com/topics/lifestyle/articles-reports/2011/05/05/brother-do-you-have-time. [Accessed: 14 Sep. 2019].

[3] Ieee.org, "IEEE IEEE Code of Ethics", IEEE policies section 7, 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed 14 Sep. 2019]