Automatic Volume Control

Design Review

February 26, 2013

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1.0 Introduction

1.1 Statement of Purpose

A common problem that anyone who loves music runs into is when they are listening to a song on their stereo in one room, but they need to walk to another room for a moment. What do you do to avoid this problem? Some turn up their stereo really loud so that they can hear it from further away, and some grimace and hurry so that they only miss 20 seconds of the song. But what if there was a way to automatically adjust the volume of the stereo based on the distance that the listener is from it? That is exactly what our senior project addresses. With our Automatic Volume Control system, the volume of any sound system can be adjusted simply by the distance that the listener is from it so that no matter what distance they are from it, they hear the same volume level. This system will also be able to function with different speakers in different rooms, so that the closer speakers play the music as you move from one room to the other. By carrying an active device like a smart phone, the listener's position will always be known relative to the speakers in order for this system to function.

1.2 Objectives

1.2.1 Goals

The goals of this project are to create an automatic volume control system that will adjust the volume of the speakers based on the distance that the listener is from it to maintain a constant volume level. This system will also allow for multiple speaker systems, so that when the listener walks from one room to another, the speakers in the previous room will turn off and the new speakers turn on.

1.2.2 Functions

This will all be accomplished through a portable active device that the listener would carry, such as a smart phone. The phone will send information using Bluetooth technology to other Bluetooth sensors placed at the speakers so that the distance between the devices can be known. With that information, the volume level of each individual speakers would be adjusted, thanks to a logic circuit and microprocessor which adjusts the control of the amplifier circuit for each speaker.

1.2.3 Benefits

- Move within room while maintaining a constant volume level
- Transition from room to room with a constant volume level

1.2.4 Product Features

- Multiple volume controlled speakers that can be in different rooms
- Any phone that supports Bluetooth can be used with this system

2.0 Design

2.1 Block Diagrams

Figure 1: High Level Block Diagram

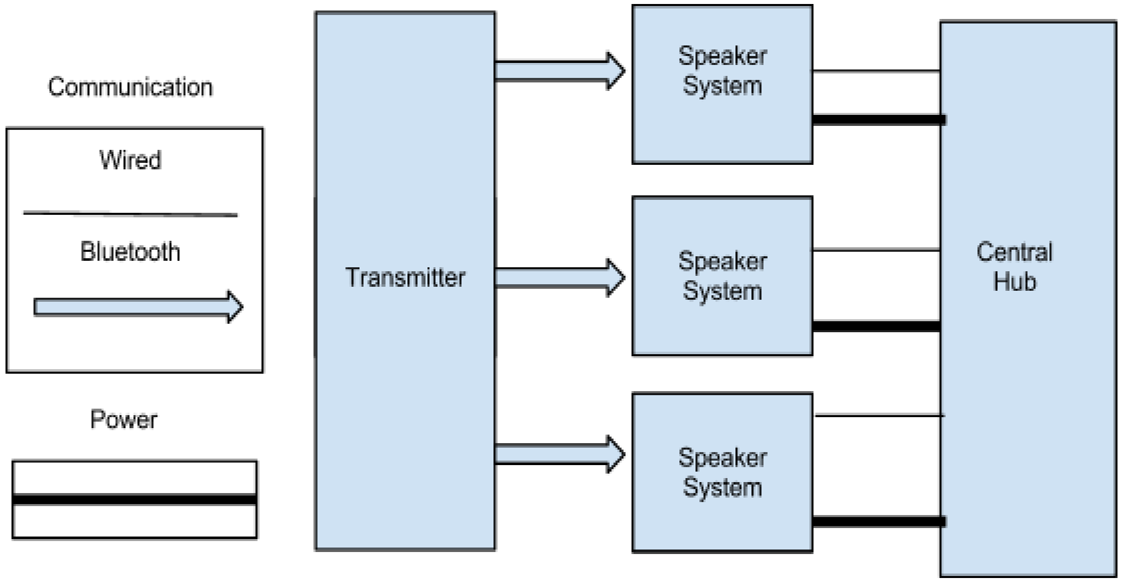

Figure 2: Central Hub Diagram

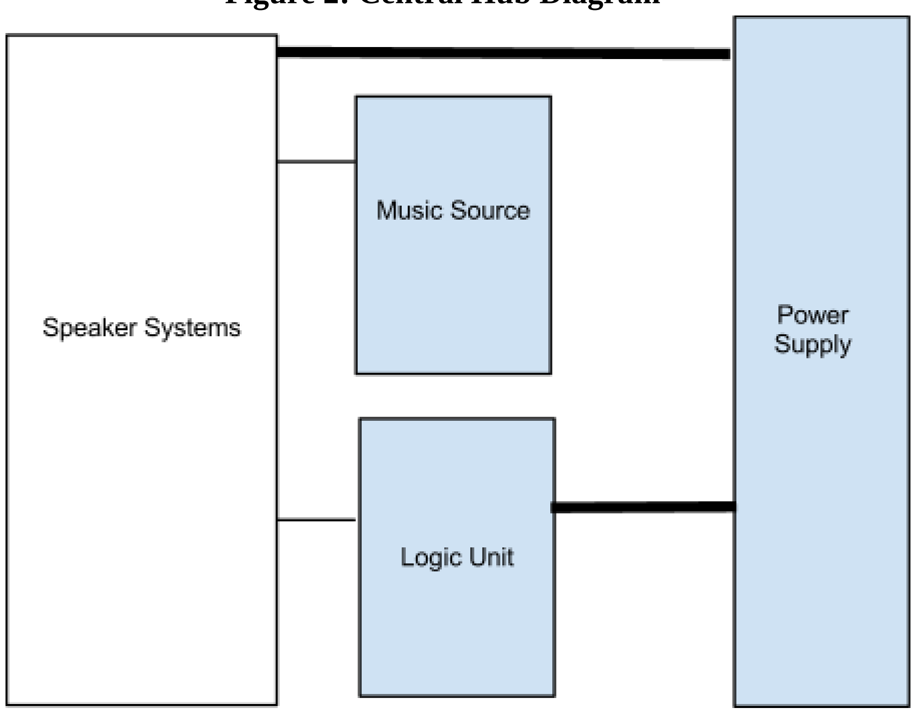

Figure 3: Speaker System Diagram

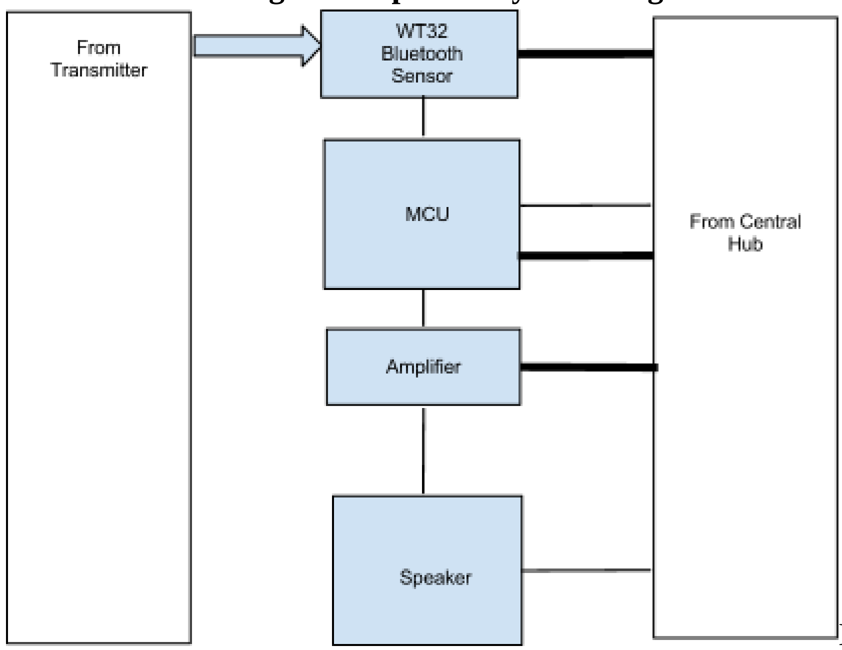

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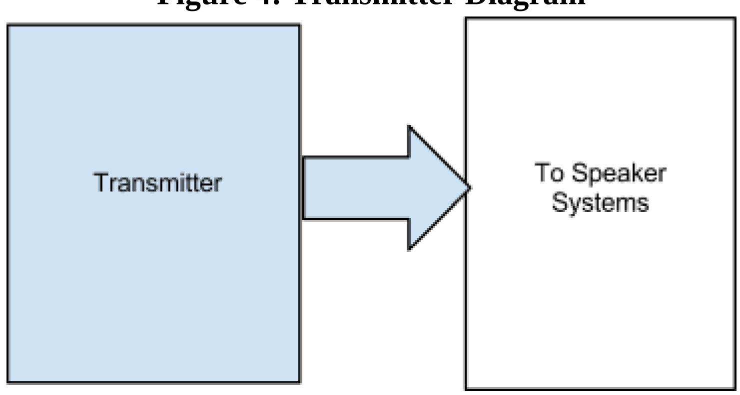
Figure 4: Transmitter Diagram



2.2 Block Descriptions

2.2.1 Central Hub

Overall Summary:

The purpose of this component is to dock the music source (ie. a mp3 player, a cd player, etc.), send the music to the speakers, and to decide which speaker will be on. It receives and sends information from the speaker system. The information it receives from each speaker is the distance the person is from that respective speaker, while the information it sends to each speaker is a binary signal telling each speaker whether it should be on or off. The subsystems of the central hub are the music source and the logic unit that sends out the on/off signals.

Case Design:

The Central Hub will consist of a music source and a logic unit. The music source, such as a portable laptop or stereo, will be powered by a battery charger. The portable logic unit will be powered by the music source as well.

Power Supply:

Input: The input to the power supply will be the 120V, 60Hz AC power supplied by a wall outlet.

Output: The following are the power needs for different devices in our system:

- 1.8-3.6V DC for the WT32 bluetooth sensors
- 1.7-5.5V DC for speaker system switches
- 3.3 or 5V DC for inverters
- 3.3 or 5V DC for NAND gates
- 5V DC for comparators
- 5V DC @ 1A for digital to analog converter
- 5V DC for amplifier
- 4.5-5.5V for microcontroller

Therefore, the power supply will output 3V DC and 5V DC, which will cover all of the different components.

Description: The central hub will contain the main power supply, which will be fed to the logic unit in the central hub as well as to the *Speaker Systems*.

Music Source:

Input: The music source will have an attachment for a wall outlet if necessary. It will have music files to play.

Output: The music source will send the music file signal to the microcontroller.

Description: The music source will consist of a laptop or stereo that will take a sound file (MP3, .wav,itunes, windows media player) as the desired music to be played and will then send this information to the speakers via audio cables.

Logic Unit:

Input: One analog voltage signal transmitted from each speaker. Each voltage signal will be inversely proportional to the distance between the speaker sending the signal and the user.

Output: One discrete, binary signal to each speaker. They correspond to an on/off signal, and at anytime only one of these signals will correspond to an "on". This will ensure that only one speaker will be on at a time.

Description: The logic unit is the subsystem of the central hub that will send an on/off signal to each speakers. The input of the logic unit will be analog voltage signals from each speaker system that are inversely proportional to the distance, which means that the speaker closest to the user will input the highest voltage to the logic unit. To generate the on/off signals that will be sent to the speakers, a demux will be used. To generate a selection signal that the demux can use, additional comparators and TTL logic will also be added to the logic unit.

2.2.2 Speaker System

Overall Summary:

The purpose of this component is to play the music at a normal volume. It is composed of four parts: WT32 Bluetooth Sensor, MCU, Amplifier, and Speaker.

Case Design:

This component will consist of a case to be set on top of the speakers. Inside the case will be the bluetooth sensor, MCU, and opamp. The case and speakers are powered by cables coming from the *Central Hub* unit. The case will be connected to the speakers such that it will tell the speakers what to play and the volume to be played at.

Microcontroller Unit:

Input: Data received from the WT32 Bluetooth sensor via UART communication. The data received corresponds to RSSI (Received Signal Strength Indicator), which will correspond to the distance the user is from the stereo. The MCU will also receive a binary signal from the Central Hub, which corresponds to whether or not the speaker should be on.

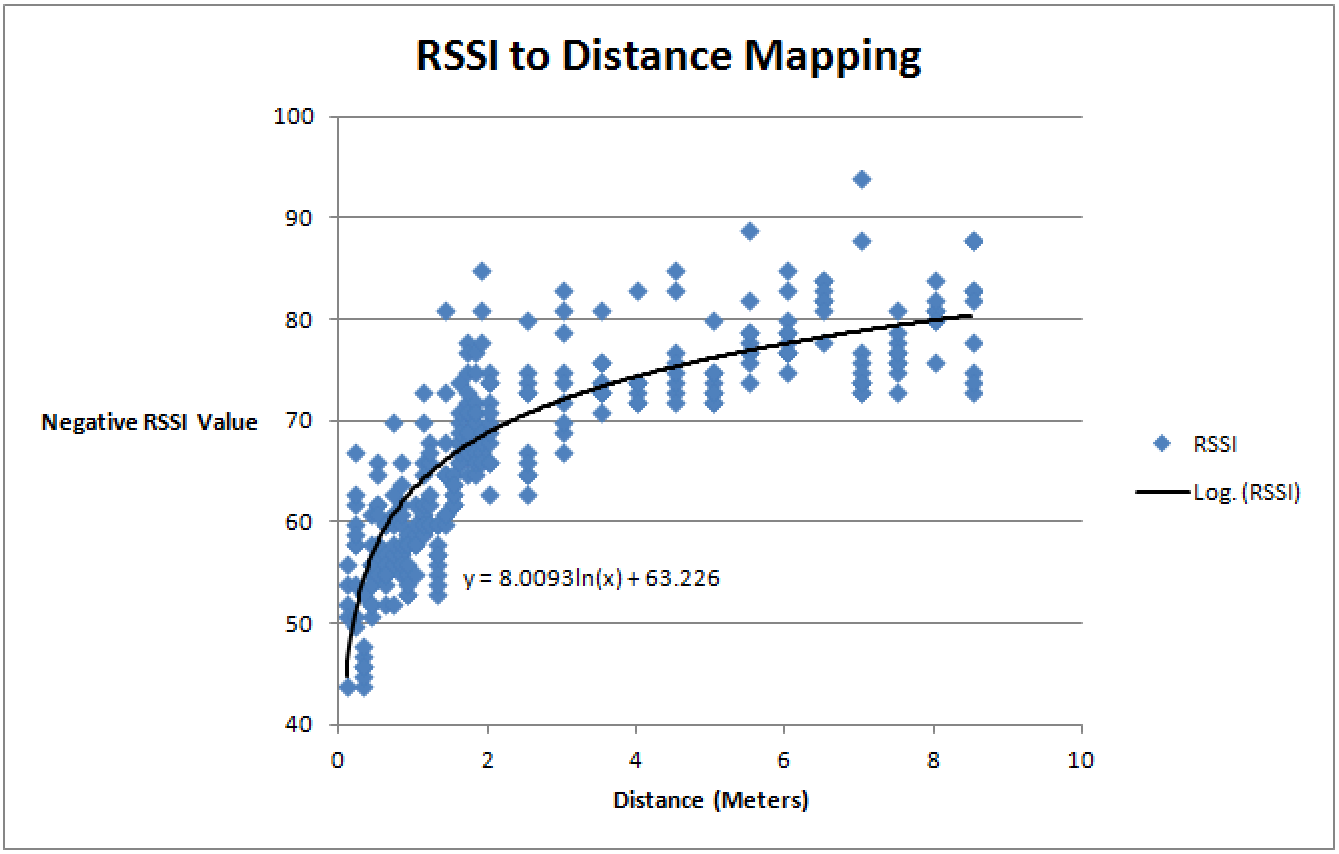
Output: A digital signal that will be sent to a digital-to-analog converter, then amplified so that it can be used by the speaker. This signal will control the volume of the speaker.

Description: The microcontroller unit is what controls the volume of the speaker. Since the objective of the system is to provide constant volume across multiple rooms, the speaker should raise the volume as the user moves away from it. To tell how far away the the user is from the microcontroller, the microcontroller will extract the RSSI value from the WT32 Bluetooth sensor via UART communication. Mapping the RSSI value to a predetermined relationship, a distance value can be determined. To come up with this relationship we empirically recorded the RSSI values from 0.1m to 8.5m. Our empirical results showed lots of scattering, however we were able to determine a logarithmic relationship.

$$|\mathrm{RSSI}| = 8.0093 \times \ln(\mathrm{Distance}) + 63.226$$

or

$$\text{Distance} = e^{\frac{|RSSI|-63.226}{8.0093}}$$



This distance value is valuable since the sound pressure (which determines volume), is related to distance by the distance law:

$$p \propto \frac{1}{r}$$

$$\frac{p_2}{p_1} = \frac{r_1}{r_2}$$

$$p_2 = p_1 \frac{r_1}{r_2}$$

So any change in distance requires the same change in sound pressure. For example, if the user moves away double the distance from the speaker, the volume should also be doubled. Using this relationship, an appropriate output can be determined to change the volume of the speaker.

WT32 Bluetooth Sensor
Input: PCM data received from the Transmitter
Output: UART communication to the MCU.
Description:

This block is a WT32 bluetooth sensor. Its purpose is to communicate with the transmitter to receive an Received Signal Strength (RSSI) value. The RSSI value will then be sent to the MCU to correlate that value into a distance unit. The RSSI values will range from -128 to 20. We will empirically determine what RSSI values correspond to what distances. See MCU section for more details.

The WT32 bluetooth sensor will communicate with the transmitter via an antenna using the Simple Secure Path (SSP) protocol. The messaging will be done with iwrap4,an embedded firmware running on the RISC processor. Iwrap4 will be interfaced with Universal Asynchronous Receiver Transmitter (UART) using ASCII commands that Iwrap4 supports.

To set up a SSP the following code must be implemented using iwrap4 syntax:

	syntax	example
Command	SET BT AUTH * {password}	SET BT AUTH * 0000 sets the authentication password to 0000
Command	SET BT SSP {option}{option}	SET BT SSP 3 0 sets up SSP with 3 = none 0 = man in the middle protection disabled.

To initiate an SSP connection the following syntax is used:

	syntax	example
Command	CALL {address} {option} A2DP	CALL 00:07:80:80:52:27 19 A2DP connects to address of transmitter with option 19 =A2DP option enabled
Response	CALL {linkid}	CALL 0returns linkid of transmitter
Command	CONNECT {linkid}	CONNECT 0 connects to linkid 0, the transmitter is now connected
Response	CONNECT {linkid} A2DP 25	CONNECT 0 A2DP 25 connects to linkid0 with an A2DP connection

Once a SSP connection is set up between the WT32 bluetooth sensor and the transmitter, the WT32 sensor can request the receiver signal strength indicator (RSSI) with the following command:

	syntax	example
Command	RSSI {linkid}	RSSI 0, linkid 0 = transmitter
Response	RSSI {address} {rssi value}	RSSI 00:07:80:80:52:27 -10, this is the RSSI value -10 coming from the transmitter

The RSSI value is a signed 7 bit number ranging from -128 to 20, corresponding to the signal strength coming from the transmitter. This value is then sent to the WT32 sensor on the Central Hub.

The WT32 sensor communicates with the MCU using the UART interface. See the MCU section for more details. The UART and the MCU must have a consistent Baud rate which is found with the following equation.

$$\text{Baud rate} = \frac{\text{PSKEY\_UART\_ABUD\_RATE}}{0.004096}$$

$$\text{Percent error} = \frac{\text{floor(Baud rate)}}{\text{Baud rate}}$$

With 3775 Persist store values x0EBF the Baud rate desired is 921600 with 0.00348% error.

Amplifier:

The amplifier receives the signal from the microcontroller and steps up the voltage of the signal at a constant rate before the speaker receives it.

Speakers:

The speakers receive the music signal from the amplifier and convert the electrical signal to sound.

2.2.3 Transmitter

Overall Summary:

The purpose of this component is to identify where the person,who is hearing the audio from the speakers, is in the room in relation to the speaker locations. It will communicate with the other WT32 Bluetooth sensors via Bluetooth using SSP, described in the bluetooth sensor section of the speaker system.

Case Design:

The Transmitter is a Galaxy S II, Model SPH-D710, Hardware Version D710.10, Android Version 4.0.4. with Bluetooth v3.0 + HS.

Transmitter:

Power Supply: 3.7 Volt, Lithium Ion, 1800mAh battery inside phone

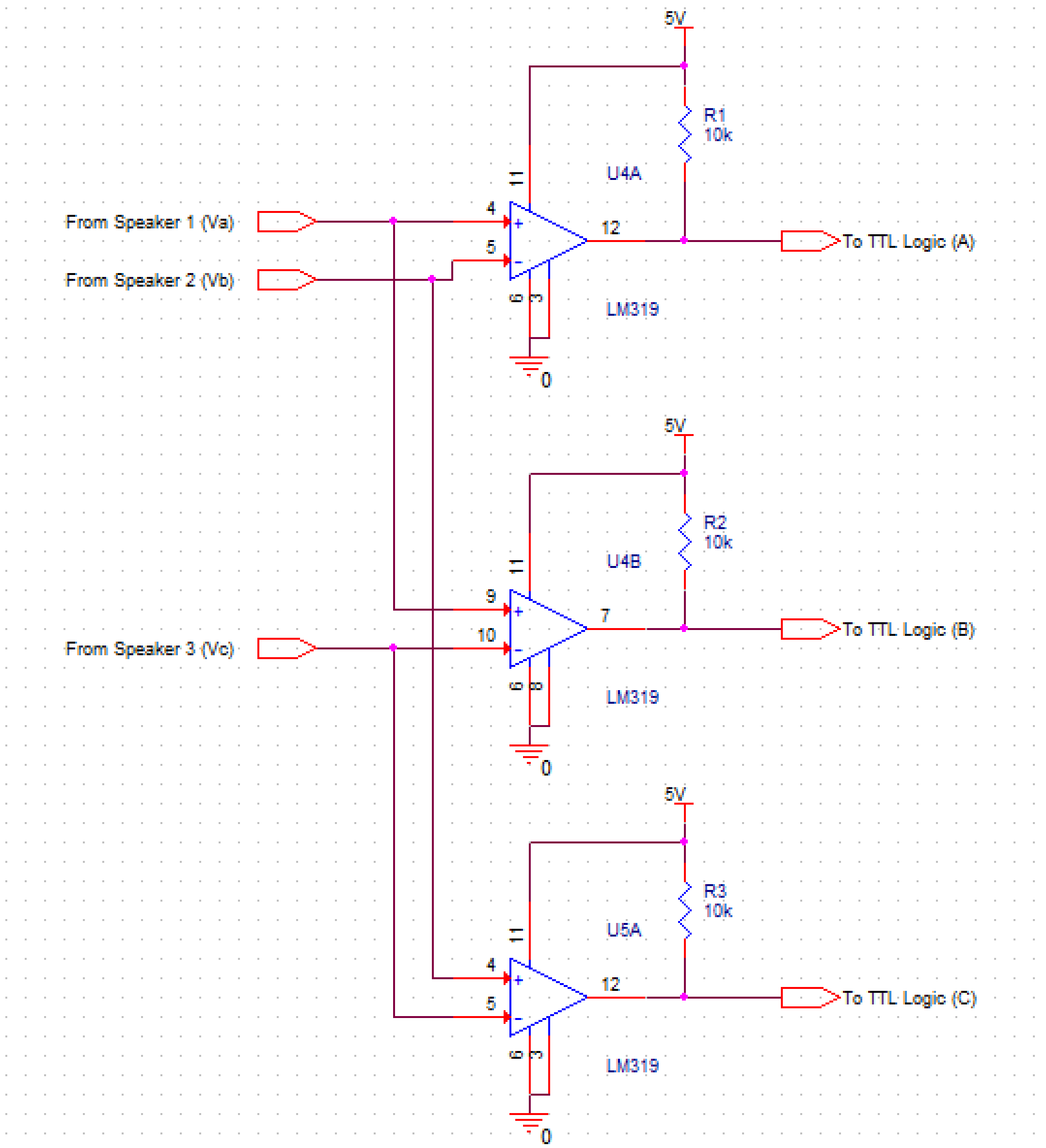
Output: Bluetooth v3.0 + HS inside phone

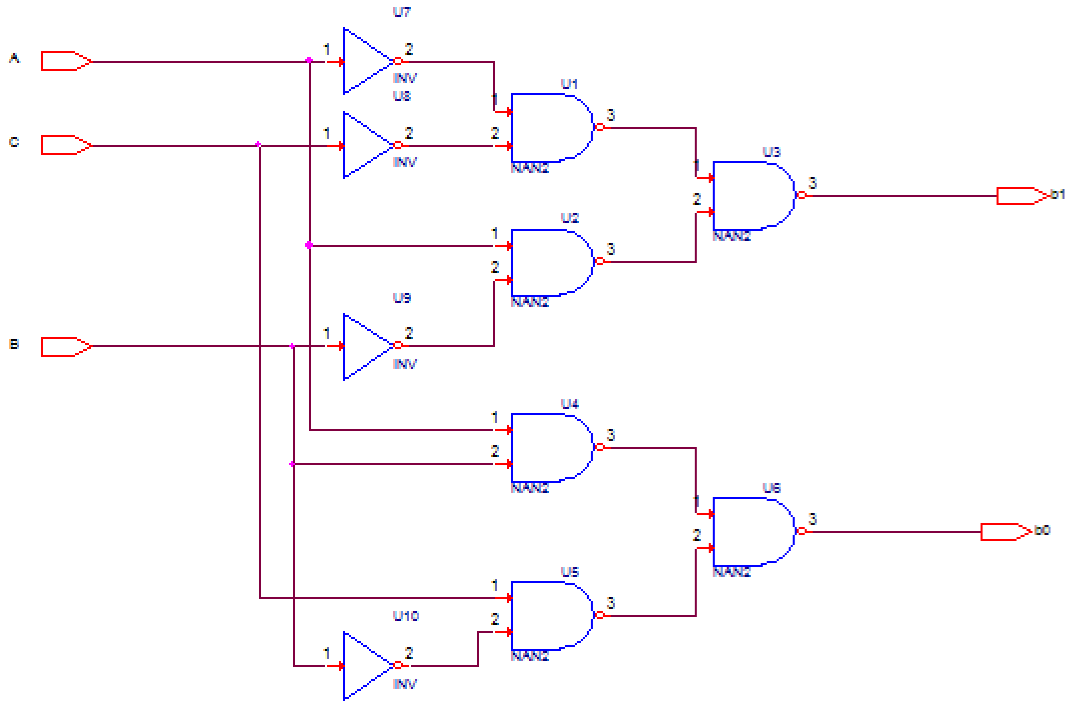
Description:

The Transmitter will be using Bluetooth to communicate with the other WT32 Bluetooth Sensors on the Speaker Systems and Central Hub. The Speaker Systems will request pairing as well as the RSSI value of the transmitter using the messaging protocols found in the *Speaker Systems* section.

2.3 Schematics of Overall System

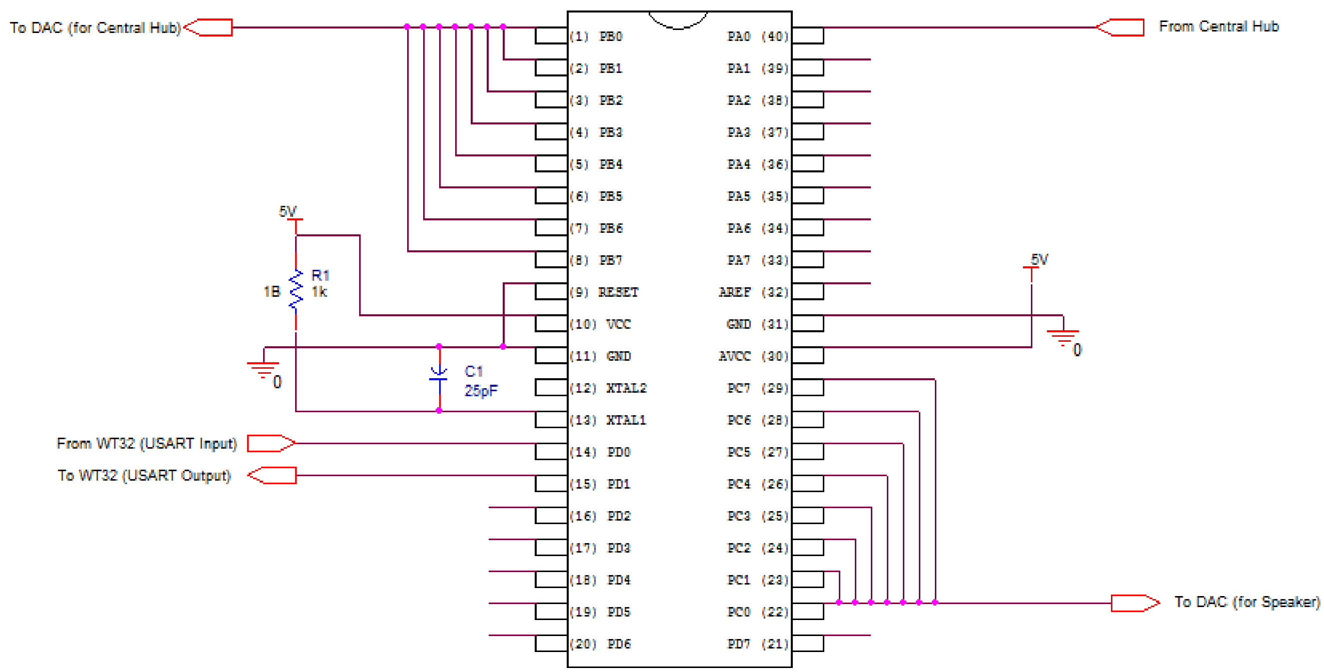
The following schematics outline the logic unit that will go inside the Central Hub. The input to the logic unit will be the voltages sent from the speakers. These voltage signals are inversely proportional to the distance the speaker is from the user, so the highest voltage corresponds to the speaker closest to the user.


5V
R1
10k
U4A
From Speaker 1 (Va)
From Speaker 2 (Vb)
To TTL Logic (A)
LM319
0
5V
R2
10k
U4B
From Speaker 3 (Vc)
To TTL Logic (B)
LM319
0
5V
R3
10k
U5A
To TTL Logic (C)
LM319
0

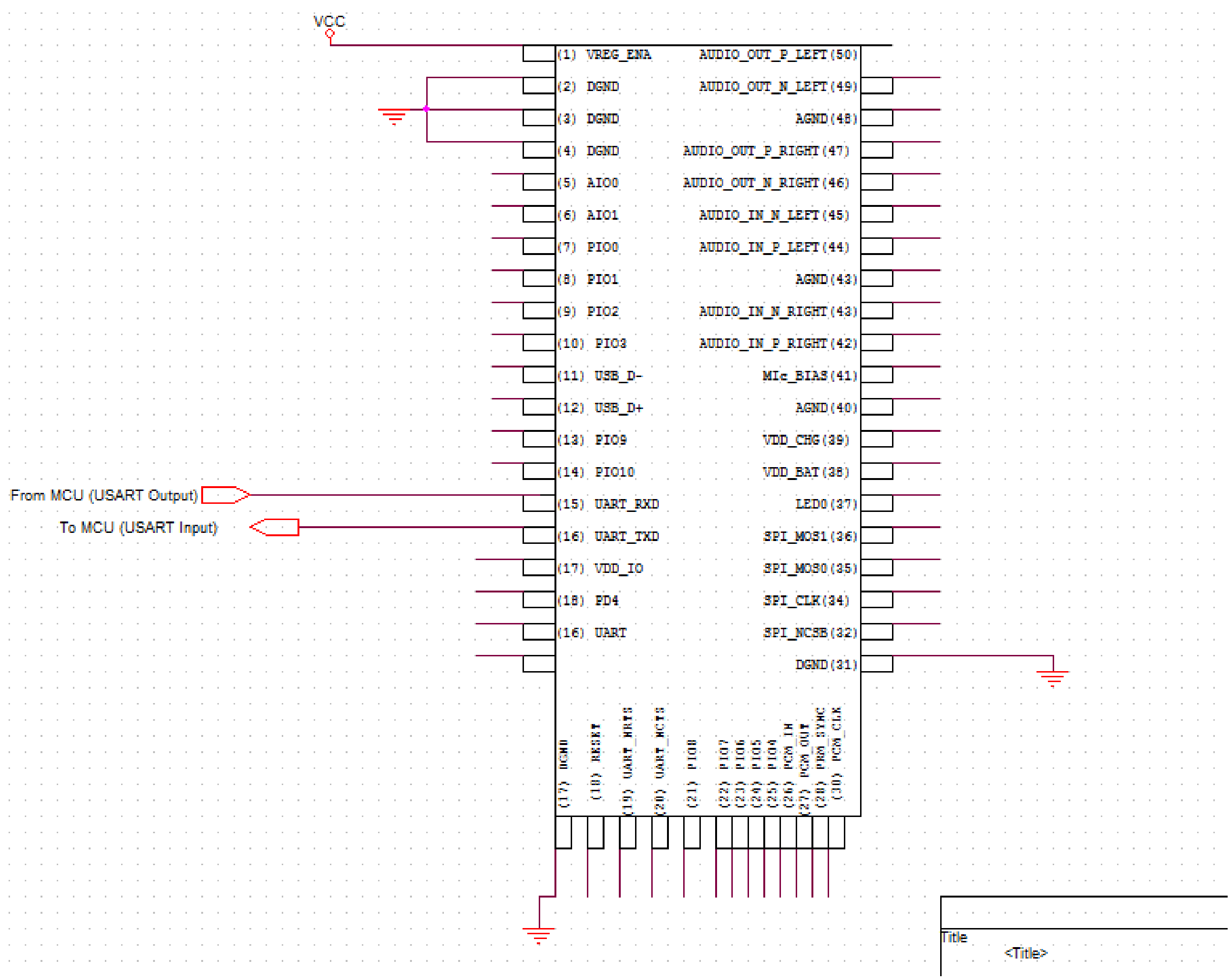


A
C
B
U7
INV
U8
INV
U9
INV
U10
INV
U1
NAN2
U2
NAN2
U3
NAN2
U4
NAN2
U5
NAN2
U6
NAN2
b1
b0

The following schematic is for the Microcontroller Unit. The input to the microcontroller is the UART signal coming from the Bluetooth unit. It outputs two 8-bit signals that will each go to a DAC. One of the signals will go to the Central Hub as the voltage signals that will be the input to the logic unit. The other output will serve as the input to the speakers that will control the volume.



WT32 Bluetooth Unit



2.4 Calculations

Distance vs. Sound Pressure Calculations:

The sound pressure, is related to distance by the distance law:

$$p \propto \frac{1}{r}$$

$$\frac{p_2}{p_1} = \frac{r_1}{r_2}$$

$$p_2 = p_1 \frac{r_1}{r_2}$$

So if the user increases his or her distance by a factor of K, the sound pressure at the sound source (ie. the speakers) must increase by the same factor K in order to keep the sound pressure the same from the perspective of the user.

Baud Rate Formulas and Calculations:

The baud rate is the number of distinct symbol changes made to the transmission per second. The number 0.004096 was empirically found and is used in the WT32 Bluetooth Sensor. The PSKEY UART ABUD RATE is the persist key to be used in UART.

The baud rate for the WT32 Bluetooth Sensor is dictated by the equations below.

$$\text{Baud rate} = \frac{\text{PSKEY\_UART\_ABUD\_RATE}}{0.004096} = \frac{3775}{0.004096} = 921630.859375 = 921600 \text{ is closest}$$

$$\text{Percent error} = \frac{(\text{Baud rate})}{\text{floor}(\text{Baud rate})} = \frac{921630.859375\text{-}921600}{921600} = 0.00348\%$$

The baud rate for the Atmel ATmega32 microcontroller is dictated by the relationship below. f_{OSC} is the system oscillator clock frequency and UBRR is the value in the UBRRH and the UBRRL registers.

$$\text{Baud Rate} = \frac{f_{OSC}}{16(\text{UBRR} + 1)}$$

Distance to RSSI Calculations:

Our distance to RSSI calculation was developed empirically by testing a bluetooth device against another bluetooth device. We found a logarithmic relationship between Distance and |RSSI| from the equation below.

$$\text{Distance} = e^{\frac{|\text{RSSI}| - 63.226}{8.0093}}$$

This means the farther we get away from the speaker the less our |RSSI| value will change.

3.0 REQUIREMENTS AND VERIFICATION

3.1 Requirements and Verification

This section lists the requirements and verification methods for each major component in the High level block diagram (see figure 1 “High Level Block Diagram”).

3.1.1 Requirements Summary

The first main goal for this project is to create a system that will adjust the volume of the speakers based on the distance of the listener. The second main goal for this project is for the music to follow the listener from speaker set to speaker set so that the closest speakers are used.

3.1.2 Central Hub

Requirements:	Verification:
1.Music Source:	
1. The speaker receives the signal from the music source a) The music source has an amplitude > 0.05 ± 0.01V	1a) Measure the voltage that the speaker receives ● Use voltmeter in AC setting to probe the differential between the received signal and ground ● The signal has an amplitude > 0.05 ± 0.1V
2. Logic Unit	
1. Logic Unit must receive correct power a) Vcc pins in Comparators, TTL logic, and Demux receives 5VDC ± 0.25VDC b) GND pins in Comparators, TTL logic, and Demux receive 0VDC ± 0.25VDC	1a) ● Make sure Comparator Vcc pins are connected to their source voltage ● Power on multimeter and set it to measure DC voltage ● Probe each Vcc pin with the multimeter, and record the reading on the multimeter ● Repeat for TTL logic and Demux 1b) ● Make sure Comparator GND pins are connected to digital ground ● Power on multimeter and set it to measure DC voltage ● Probe each GND pin with the multimeter, and record the reading on the multimeter ● Repeat for TTL logic and Demux
2. Comparators must have correct response to given inputs a) Comparator output must be 5V ± 0.25V when the non-inverting input is higher than	2a) ● Connect the non-inverting input of the comparator to a 5V source and the inverting input to digital ground ● Power on DMM and set it to measure DC

inverting input b) Comparator output must be 0V ± 0.25V when the inverting input is higher than the non-inverting input c) Comparator must transition correctly; comparator must correctly output 5V ± 0.25V or 0V ± 0.25V as input difference gets closer to 0.01 V	voltage ● Probe the output of the comparator and record the multimeter reading 2b) ● Connect the inverting input of the comparator to a 5V source and the non-inverting input to digital ground ● Power on DMM and set it to measure DC voltage ● Probe the output of the comparator and record the multimeter reading 2c) ● Power on the oscilloscope and connect probes to channel X and Y ● Power on the waveform generator and set it to the triangle waveform (0 - 10V) ● Connect the non-inverting input to the waveform generator and connect the inverting input to a 5V source ● Probe the non-inverting input with channel X and probe the output with channel Y ● Measure the output for two periods, then stop the oscilloscope ● Record the reading in channel Y at the times that the waveform input is at 4.99V and 5.01V
3. Logic Unit time delay must be small a) Comparator transition delay must be less than 1 µs b) Time delay for TTL logic in logic unit must be less than 0.1 µs	3a) ● Power on the oscilloscope and connect probes to channel X and Y ● Power on the waveform generator and set it to the triangle waveform (0 - 10V) ● Connect the non-inverting input to the waveform generator and connect the inverting input to a 5V source ● Probe the non-inverting input with channel X and probe the output with channel Y ● Measure the output for one period, then stop the oscilloscope ● Observe the time the reading of channel X crosses 5V; the time of the crossing should correspond to a transition in the output read by channel Y ● Measure the transition time 3b) ● Power on the oscilloscope and connect probes to channel X and channel Y ● Probe output 1 (b_0) and output 2 (b_1) of the TTL logic circuit ● Utilizing a 5V source and digital ground, generate an input state of 001; this should generate an output state of 01 ● Change the input state to 101 to generate an output state of 11 ● Find the point of transition in the oscilloscope reading and measure the transition time

3. Power Supply	
1. The Power Supply has output feeds according to the needs of the rest of the system a) Logic Unit receives 3V ± 10% and 5V ± 10% DC b) WT32 Bluetooth Sensors receive between 1.8-3.6V DC c) Amplifier receives 5V ± 10% DC d) MCU receives 5V ± 10% DC	1a) Test the voltage of the output to the logic unit ● Test the voltage on both wires that go from the power supply to the logic unit using a voltmeter in the DC setting, from the wire to ground. ● One wire reads 3V ± 10% DC and the other reads 5V ± 10% DC 1b) Test the voltage of the output to the Bluetooth sensors ● Use voltmeter in DC setting to probe the difference in voltage between the output from the power supply to the bluetooth sensors and ground ● Verify it is at 1.8-3.6V DC 1c) Test the voltage of the output to the amplifier ● Use voltmeter in DC setting to probe the difference in voltage between the Vcc wire that goes to the amplifier from the power supply and ground ● Verify that it is 5V ± 10% DC 1d) Test the voltage of the output ● Use voltmeter in DC setting to probe the difference in voltage between the microprocessor power input and ground ● Verify that it is between 5V ± 10% DC

3.1.3 Speaker System

Requirements:	Verification:
1. WT32 Bluetooth Sensor	
1. Range a)Bluetooth sensor connects to Transmitter within 0.10m ± 0.01m from speaker. b) Bluetooth sensor connects to the Transmitter within 10m ± 0.01m 2. Latency a)One way Latency between bluetooth and MCU is 1μs ± 0.5μs	1a) Test close range visibility ● Program MCU to detect nearby devices and display on the SPI bus. ● Use SPI packet watching software to detect information on SPI bus when 0.10m ± 0.01m from speaker. 1b) Test far range visibility ● Program MCU to detect nearby devices and display on the SPI bus. ● Use SPI packet watching software to detect information on SPI bus when 10m ± 0.01m from speaker. 2a) Send data packet from bluetooth to MCU ● Program MCU to detect packets and display on the SPI bus. ● Analyze SPI packet data and verify packets

3. Power Requirements a)Bluetooth sensor has -0.5µA ± 0.1µA when not transmitting b) Bluetooth sensor has -5µA ± 0.1µA when transmitting	are arriving within 1µs ± 0.5µs 3a) Check power from bluetooth when not transmitting ● Measure output pin 16 (UART TXD) using Multimeter and verify the current is -0.5µA ± 0.1µA when not transmitting 3b) Check power from bluetooth when transmitting ● Transmit signal from bluetooth sensor to MCU ● Measure output pin 16 (UART TXD) using Multimeter and verify the current is -5µA ± 0.1µA when transmitting
2. Microcontroller Unit	
1. MCU must receive the correct power a) Vcc pins receives 5VDC ± 0.25VDC b) GND pins receive 0VDC ± 0.25VDC	1a) ● Make sure Vcc pins are connected to their source voltage ● Power on multimeter and set it to measure DC voltage ● Probe each Vcc pin with the multimeter, and record the reading on the multimeter 1b) ● Make sure GND pins are connected to digital ground ● Power on multimeter and set it to measure DC voltage ● Probe each GND pin with the multimeter, and record the reading on the multimeter
2. Incoming RSSI signal should be mapped to the correct distance value a) For an incoming RSSI signal, the distance value that is sent to the Central Hub should match the predetermined mapped value by ±10%	2a) ● Wire the Bluetooth unit to the USART input of the MCU ● Wire the distance output (PB0 - PB7) to the DAC ● Power on the oscilloscope and connect a probe to channel X ● Power on the transmitter and hold the transmitter 1 meter from the speaker system ● Probe the output of the DAC using the oscilloscope ● Run the trial for 10 seconds, and record the oscilloscope reading ● Repeat the above procedures for successive trials, changing the distance between the transmitter and the speaker system to 2m, 4m, 8m, and 10m

3. MCU turns off speaker when the input from the Control Hub is low a) For a Control Hub input of binary 0, output to speaker should be 0 VDC ± 0.01VDC b) Latency of transition from on to off and off to on should be no greater than 1 μs	3a) ● Connect input from Central Hub (PA0) to digital ground ● Connect output to speaker (PC0 - PC7) to DAC ● Power on multimeter and set it to measure DC voltage ● Probe the output of the DAC and record the multimeter reading 3b) ● Connect output to speaker (PC0 - PC7) to DAC ● Connect the USART input (PD0) to the Bluetooth unit ● Power on the transmitter and hold the transmitter 1 m from the speaker system ● Power on the oscilloscope and connect a probe to channel X ● Power on the waveform generator and set it the square wave function (0 - 5 V) ● Connect the waveform generator to the input from the Central Hub (PA0) ● Probe the output of the DAC using the oscilloscope ● Record the oscilloscope reading and measure the time delay between the change of output states
3. Amplifier	
1. Amplifier steps up the signal from the microcontroller by a linear factor a)Amplifier increases input signal from microcontroller by a linear factor independent of the value of the input signal for a voltage level of -10V to 10V	1a) Measure the voltage ratio of input to output by doing a voltage sweep ● Feed a voltage ramp (-10 - 10V) signal into the amplifier ● Measure the input voltage and the derivative of the output voltage from the amplifier using an oscilloscope ● The slope reading from the oscilloscope must be 0 ± 0.3V/s
4. Speaker	
1. Speakers emit a steady volume at the user's location a) Volume level only varies by ± 3 decibels when the user stands still b) Volume level only varies by ± 3 decibels when measured by a user walking around the room	1a) Measure the volume level at user's location ● Use sound meter app to measure the sound level with the speakers playing music 1ft from the speakers ● The sound varies by no more than ± 3 decibels while remaining still 1b) Measure the volume level at user's location ● Start with phone in one location ● Measure the volume of the stereo using sound meter app ● As you walk around the room at 2 meter

	intervals, the volume changes by no more than ± 3 dB as read from your location
c) When speaker volume is changed, sound pressure at the transmitter should be within 10% of the desired change.	1c) MCU correctly interfaces with the volume control ● Use Sound Meter app to Measure the sound pressure .3 ± 0.1 meters from the speaker ● Move the transmitter to 2 ± 0.2 meters ● Sound pressure should be within 10% of the desired change
2. The closest speaker is the only one emitting music a) Only one speaker is on at a time	2a) Check switch voltages as user moves around room ● Move to 1 ± .2 meters directly in front of each speaker ● Use a voltmeter in DC settings to read the voltage out of each switch ● Only 1 switch must have a voltage greater than .3V ● Verify by listening and only hearing sound from one speaker
b) The closest speaker is the only speaker on	2b) Check that only the closest speaker is on ● User with phone begins close to one speaker ● Only the closer speaker is playing ● Check that that RSSI value for that speaker is the largest of all three RSSI values ● User walks closer to a different speaker ● When the user is ± 1 meter of the mid point between the two speakers, the old speaker turns off and the new speaker turns on ● Only the new speaker remains playing ● The current speaker has the largest RSSI value of all of the speakers
3. Adjusting the volume that the user hears is possible by adjusting the volume at the music source, and that volume is constant as the user walks around again a) The volume that the user hears changes as the music source's volume is changed	3a) Monitor the volume level at the user's location ● User with phone 1 ± 0.2 meters from music source remains still ● The volume of the music source is adjusted ● The volume measured by the sound meter on the user's phone changes according to the adjustment of the volume at the music source
b) The volume level of the user still remains within ± 3 decibels of the new level when the volume of the music source is adjusted	3b) Monitor the volume level at the user's location ● The user measures the volume at their location using the sound meter on their phone ● When the user moves around the room again, it remains within ± 3 decibels of the original volume measured before walking around

3.1.4 Transmitter

Requirements:	Verification:
1. Transmitter	
1. Multiple Devices a) Transmitter connects to all three WT32 Bluetooth sensors when within 10m ± 0.01m of an edge speaker	1a). Test bluetooth visibility ● Program MCU to detect nearby devices and display on the SPI bus. ● Use SPI packet watching software to detect information on SPI bus ● verify all devices have connections when 10m ± 0.01m from an edge speaker.
2. Latency a) One way Latency between bluetooth and transmitter is 10ms ± 5ms	2a). Send data packet to bluetooth unit ● Program MCU to detect packets and display on the SPI bus. ● Analyze SPI packet data and verify packets are arriving within 10ms ± 5ms
3. Power a)Device must not lose more than 10% ± 1% of power in 30 minutes.	3a). Check device power ● Use battery trace app to record power level with bluetooth on. ● Verify battery does not lose more than 10% ± 1% of power in 30mins.

3.2 Tolerance Analysis

The system must distinguish distances very accurately in order to cleanly transition from one speaker set to another, especially since the listener might be walking fast from one room to another. When between two speakers, the transition should take place within 2 feet of the midpoint between the two speakers. The speakers should also turn on and off quickly, within 100ms.

The system must distinguish distances very accurately in order to change the volume smoothly and consistently with distance. The volume heard at the user's end must only vary within plus or minus 3 decibels from the original volume that they heard when they started moving.

3.3 Contingency Plan

- If PCB is late, we will use a breadboard to attach all the components together.
- If bluetooth communication doesn't work, ultrasonic communication system will be used.
- If only 1 speaker is working. We will test the volume control of our project on that one speaker.
- If a teammate gets sick and cannot work, the other two will pick up the slack on the deadlines that were due for the sick teammate.
- If something is wrong with the project and we do not know the solution, we will ask a professor who specializes in that area for help.

4. Ethical Issues

Specific guidelines from the IEEE code of ethics follow, with our explanation of how we intend to abide by them.

3. *"[To] be honest and realistic in stating claims or estimates based on available data;"*

Throughout our work we will carefully document every test and simulation done to ensure no false or inaccurate data is reported.

5. *"[To] improve the understanding of technology; its appropriate application, and potential consequences;"*

Learning how volume is changed in a speaker and bluetooth communication are the important technology aspects of our project. We are learning these technologies, and will be able to explain them to others who are interested in our project.

6. *"[To] maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;"*

Throughout this project we will be improving our creative thinking, research, designing, debugging, and presentation skills. Through research we will learn how each of our components work, their limitations, and the safety hazards involved.

7. *"[To] seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;"*

Our project will go through a comprehensive investigation starting with a project proposal, design review, project demo, and final presentation. The University of Illinois faculty and staff of ECE 445 will check and observe the designs and demos to ensure that to the best of their knowledge, our project is free of major flaws and safety hazards, and that it is unique and properly gives credit to the work of others.

9. *"[To] avoid injuring others, their property, reputation, or employment by false or malicious action;"*

Following the guidelines by the FCC in radio transmission we will ensure our communication does not interfere with other objects.

10. *"[To] assist colleagues and co-workers in their professional development and to support them in following this code of ethics."*

By documenting our work through several academic papers and presentations such as a project proposal, design review, presentation, and final paper we will be demonstrating our understanding of this code of ethics. And by reviewing other design reviews as well as critiquing each members work, we will ensure that we are developing and supporting each other in following these standards.

5.0 Cost and Schedule

5.1 Cost Analysis

5.1.1 Labor Costs

Name	Hourly Rate ($)	Total Invested Hours	Total = Hourly Rate x 2.5 x Total Hours Invested
Eric Davila	42	150	15750
Chris Goulet	42	150	15750
Roland Legrand	42	150	15750

Total Hours: 450 hrs
Total Labor Cost: $47250.00

5.1.2 Parts Cost

Item	Quantity	Cost/Unit ($)	Total Cost ($)
A520S V7 Speakers	3	7.24	21.72
WT32-A-AI4 Bluetooth Transmitter/Receiver	3	29.50	88.50
PCBs	4	15.00	60.00
Atmel ATmega32 Microcontroller	4	2.88	11.52
TI CSD18531Q5A MOSFETs	10	1.62	16.20
Resistors	20	0.09	1.80
Capacitors	20	0.08	1.60

Inductors	20	0.39	7.80
TTL Logic	2	0.41	0.82
Logic Inverters	10	0.74	7.40
LM319 Comparators	2	1.08	2.16

Total Parts Cost: $219.52

5.1.3 Grand Total

Section	**Total**
Labor	$47250.00
Parts	$219.52
Total	**$47,471.52**

5.2 Schedule

Week Of	**Task**	**Person Responsible**
Feb 4	Prepare introduction for proposal	Chris Goulet
	Prepare block diagram and design overview for proposal	Roland Le Grand
	Prepare cost and scheduling for proposal	Eric Davila
	Finalize proposal	Roland Le Grand
Feb 11	Design logic unit for hub	Eric Davila
	Research and design power supply for speakers and hub	Chris Goulet
	Research and design transmitter and receiver	Roland Le Grand
Feb 18	Design control scheme for speakers	Eric Davila
	Research the dynamics of the speaker	Chris Goulet
	Simulate logic unit and power	Roland Le Grand

	supply using PSpice	
	Sign up for Design Review	Chris Goulet
Feb 25	Learn software for PIC microcontroller	Eric Davila
	Prepare presentation for Design Review	Chris Goulet
	Layout PCB for hub and speakers	Roland Le Grand
Mar 4	Adjust design using suggestions from Design Review	Roland Le Grand
	Program PIC microcontroller	Eric Davila
	Order parts from parts list	Chris Goulet
Mar 11	Prepare individual progress report, verify microcontroller design, layout PCB design	Eric Davila
	Prepare individual progress report, test bluetooth sensors and microcontroller	Roland Le Grand
	Prepare individual progress report, assemble power supply, amplifier to speaker connection, test all of these components	Chris Goulet
Mar 18	*Spring Break*	
Mar 25	Connect and test power supply lines to all components of system	Chris Goulet
	Prepare presentation for mock presentation, order PCB	Eric Davila
	Assemble hub and set up system for testing	Roland Le Grand
April 1	Make sure that the logic unit is correctly interpreting the data from the bluetooth sensors	Roland Le Grand
	Perform initial tolerance analysis, sauder components to PCBs	Chris Goulet

	Adjust presentation using suggestions from mock presentation	Eric Davila
April 8	Test assembled system	Roland Le Grand
	Debug remaining issues facing system	Eric Davila
	Perform remaining tolerance analysis	Chris Goulet
April 15	Verify specifications and fix any remaining bugs	Eric Davila
	Prepare presentation, using suggestions from mock presentation	Roland Le Grand
	Outline Final Paper	Chris Goulet
April 22	Demo and Presentation	Roland Le Grand
	Final Paper write-up	Chris Goulet
April 29	Final Presentation and Check-in	Eric Davila

6.0 SAFETY

This section lists all potential safety considerations when operating our Automatic Volume Control System. Each major component lists potential safety hazards and procedures to limit and respond to those hazards.

Speaker System

The speakers must not emit a volume exceeding 91 decibels, since permanent ear damage can occur within 2 hours at that level.

Transmitter

The transmitter is a Samsung Galaxy S II smart phone. In addition to the normal safety requirements of smart phones, the following safety considerations are relevant for using this device in our system. The transmitted signal from the device must be in FCC's class B for radio frequencies 2400-2483.5 MHz. FCC Section 15.249 also says the fundamental frequency field strength must be in the range of 50 - 500 uV/m. These requirements ensure that the device is not interfering with other objects in the radio spectrum. Since bluetooth is already configured on the device, the user will not be able to adjust the transmitted signal, thus ensuring the signal stays within the FCC ranges.

Because the device will be running bluetooth, the device may heat up more often than normal non-bluetooth use. If the device overheats remove from pocket or away from close contact with skin and wait until device cools before inserting back into pocket.

Control Hub

All electronic components must be contained in a closed container with no loose or exposed wires. Do not expose to water or connect to other circuits other than those specified in our design. All components that need to be grounded must be properly grounded. Never work or tinker on any part of the system if there is live power running through it.

Power Supply

The conductors must not be exposed, there should be in insulator over all conductive materials that could potentially shock someone. All components that need to be grounded must be properly grounded. Never work or tinker on any part of the system if there is live power running through it.

7.0 REFERENCES

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