The Design of a LED Cube Audio Visualizer System

By Arnold Chand and Maurice Gaynor

Previous Semester...

Formulation and Statement

3D LED cubes can be built with relatively little skill if one has a soldering iron. We plan to design our LED cube with each layer of LEDs mounted on vertical PCB connectors for support. The PCB's will have connectors so the assembly of the PCB's can be done without soldering. The base PCB contains the Microprocessor (ATMega328) and power connectors.

Objectives

- Use 3 different frequency bands to control color of the LED.
- Use the sound level to control intensity of the LED.
- Design a LED cube structure.
- Control the LEDs with as few output pins as possible.
- Design a circuit to control the LEDs.

Abstract

The aim of this project was to design a visual medium through which sound could be displayed. The design would need to be able to read the different frequencies that are associated with different tones and melodies. We decided that we would use a 3D cube shape using RGB LEDs. These LEDs would then be controlled by an audio input, typically some kind of music. In our design and testing we found out that the design of our cube and board fits this aim, but were only able to partially test the design. The results gained from this project has proved that the design works, but we were only given a short amount to time to expand on this theory.

Deviations

- Battery changed to AC Adapter
- Inspired by cube design by Freetronics, but decided to use wider PCBs for ease of use
- Decided to use digital filters instead of analog filters
- 1.27 mm header changed to 2.53 mm header
- Changed LED plate width from 4 inches to 4.5 inches due to the number of components
- Putting APB and LCB layouts on a single board rather than have them separate
- Cube parts wider than previously calculated, so had to solder one side using wires rather than headers on both sides.

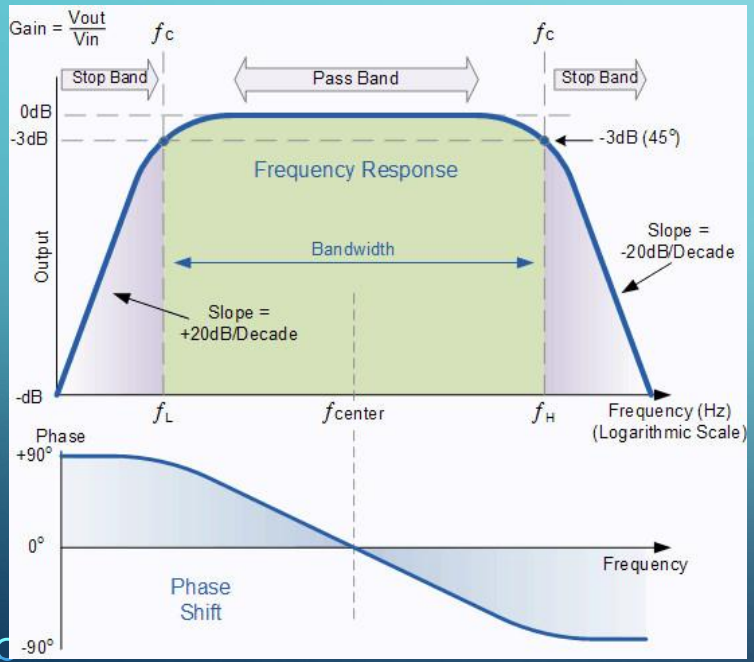
Design Constraints

- Cost for parts must be as close to $200 as possible.
- PCB layouts must fit specifications set by Advanced Circuits.
- Time to design and test the prototype.
- Filtering out frequencies using analog filters.
- Needed a precise stencil due to tiny parts.
- Power design must not exceed 4A.

Design Specifications

- Base Board: 5 inches by 5 inches
- Cube Size: 4 inches by 4 inches by 4 inches
- 2 ATMEGA328 Microprocessors (One for APB, one for LCB)
- # of RGB LEDs: 64 (192 individual LED colors)
- # of LED Plates: 16 (4 RGB LEDs per plate)
- # of Shift Registers: 8 (2 LED plates per shift register)
- # of 4-input AND gates: 96 (6 per LED plate)
- # of Dual NOT gates: 32 (2 per LED plate)
- # of Resistors: 203 (1 for each LED, rest for base board)
- AC Power Adapter (5V 4A)
- # of Audio Jacks: 2 (one for input, one for output)
- # of Bandpass Filters: 3

Theoretical Analysis (APB)



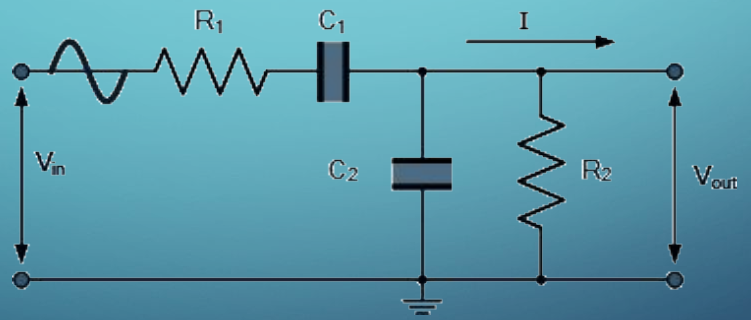
Three Bandpass Filters

Formula used to determine high and low pass filter:

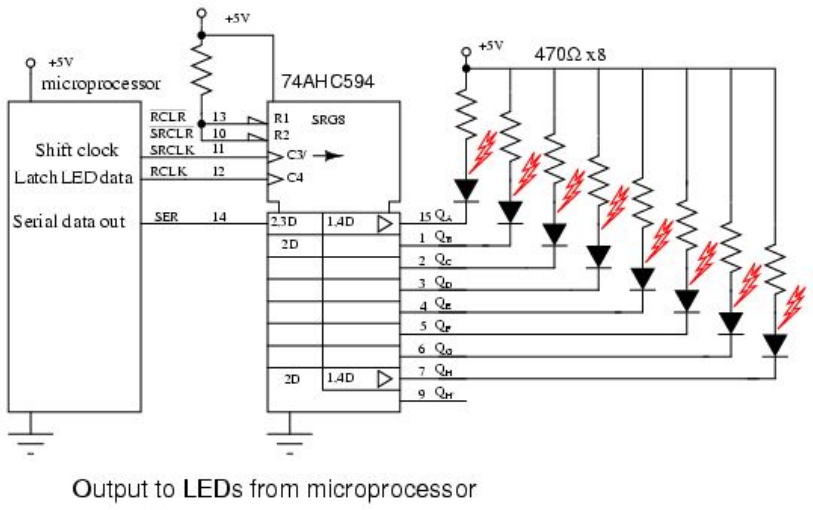
$$fc = \frac{1}{2\pi RC}\ Hz$$

Theoretical Analysis (APB) contd

Circuit Schematic for a Bandpass filter:



Theoretical Analysis (LCB & Cube)



Output to LEDs from microprocessor

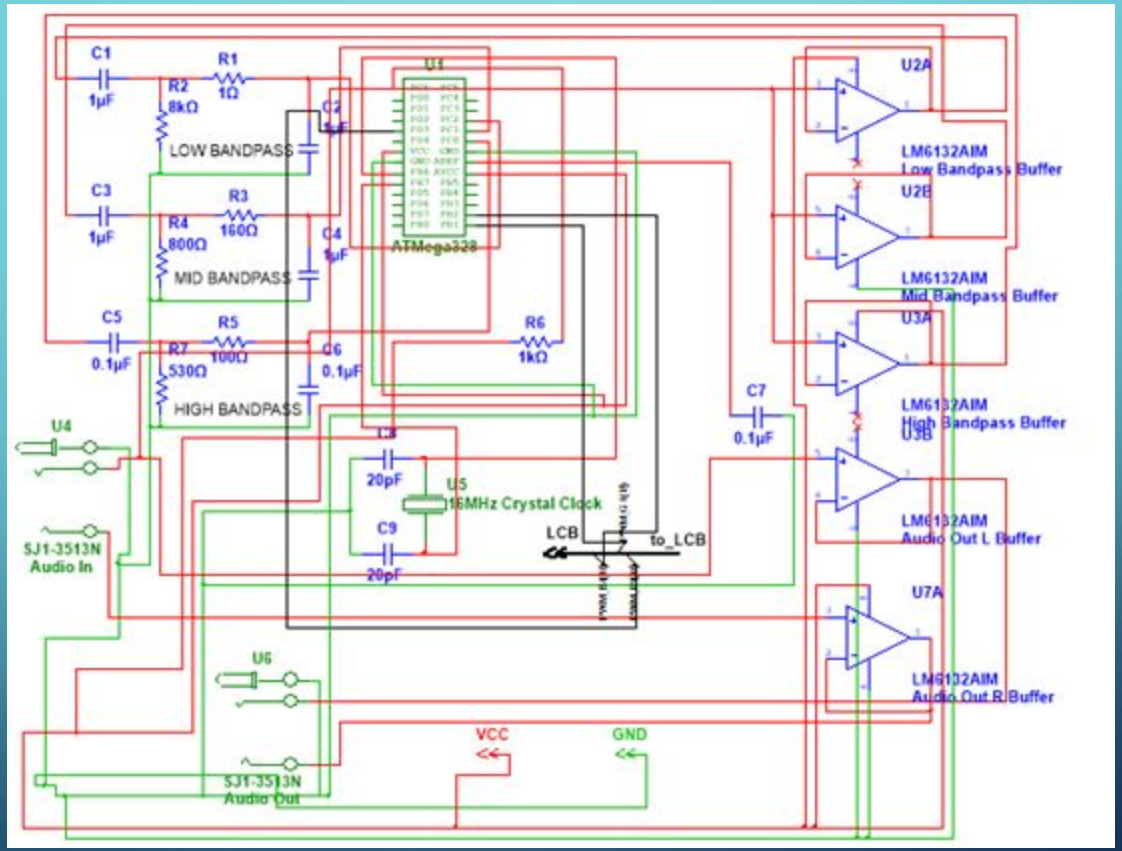
Microprocessor would load eight bits each to eight shift registers which would send four bits to each LED plate.

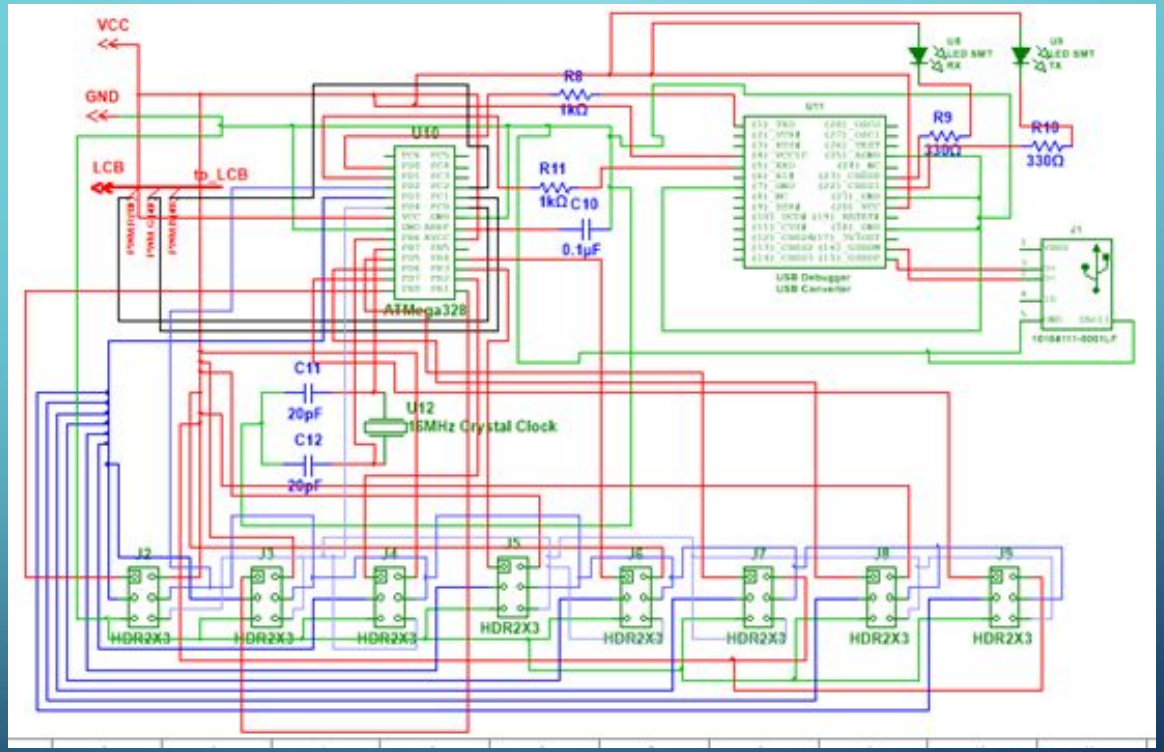
Theoretical Analysis (LCB & Cube)

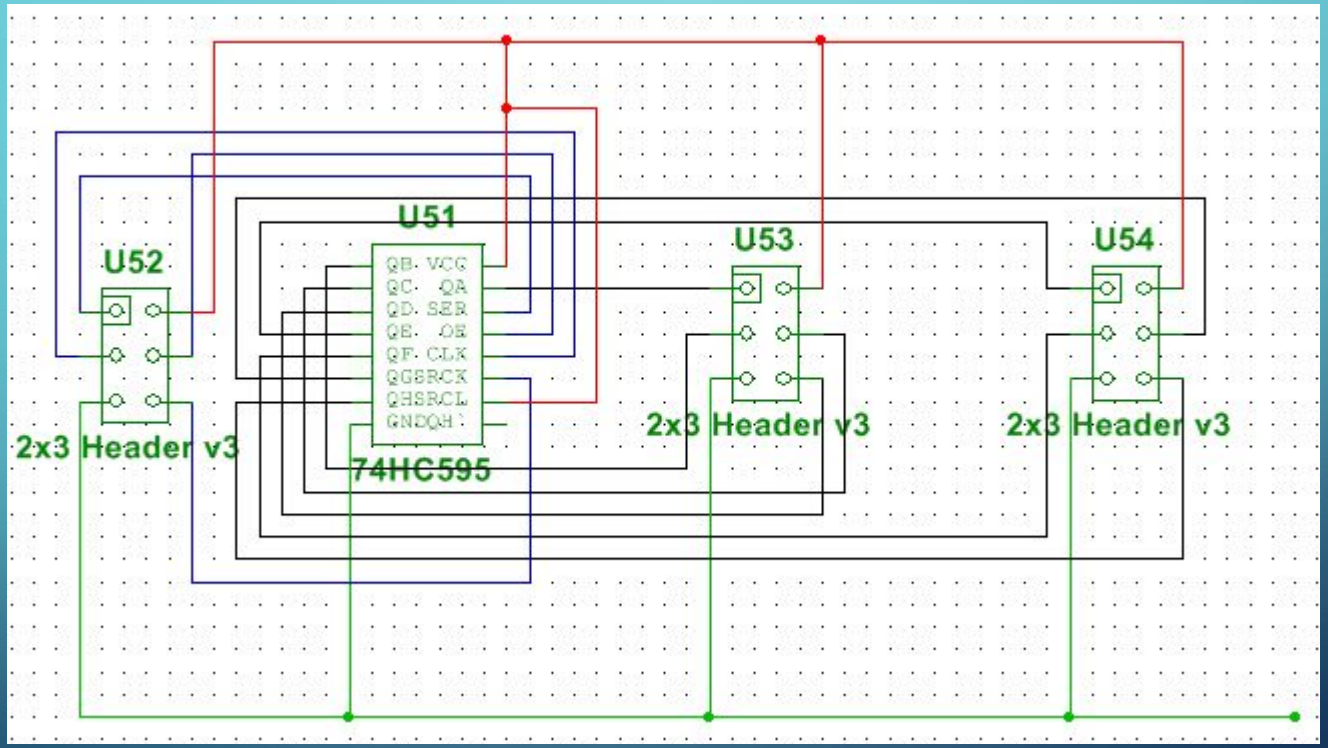
A	B	C	D		L	ML	MR	R		Color
1	1	1	1		1	-	-	-		Red
1	1	1	0		1	-	-	-		Green
1	1	0	1		1	-	-	-		Blue
1	1	0	0		-	1	-	-		Red
1	0	1	1		-	1	-	-		Green
1	0	1	0		-	1	-	-		Blue
1	0	0	1		-	-	1	-		Red
1	0	0	0		-	-	1	-		Green
0	1	1	1		-	-	1	-		Blue
0	1	1	0		-	-	-	1		Red
0	1	0	1		-	-	-	1		Green
0	1	0	0		-	-	-	1		Blue

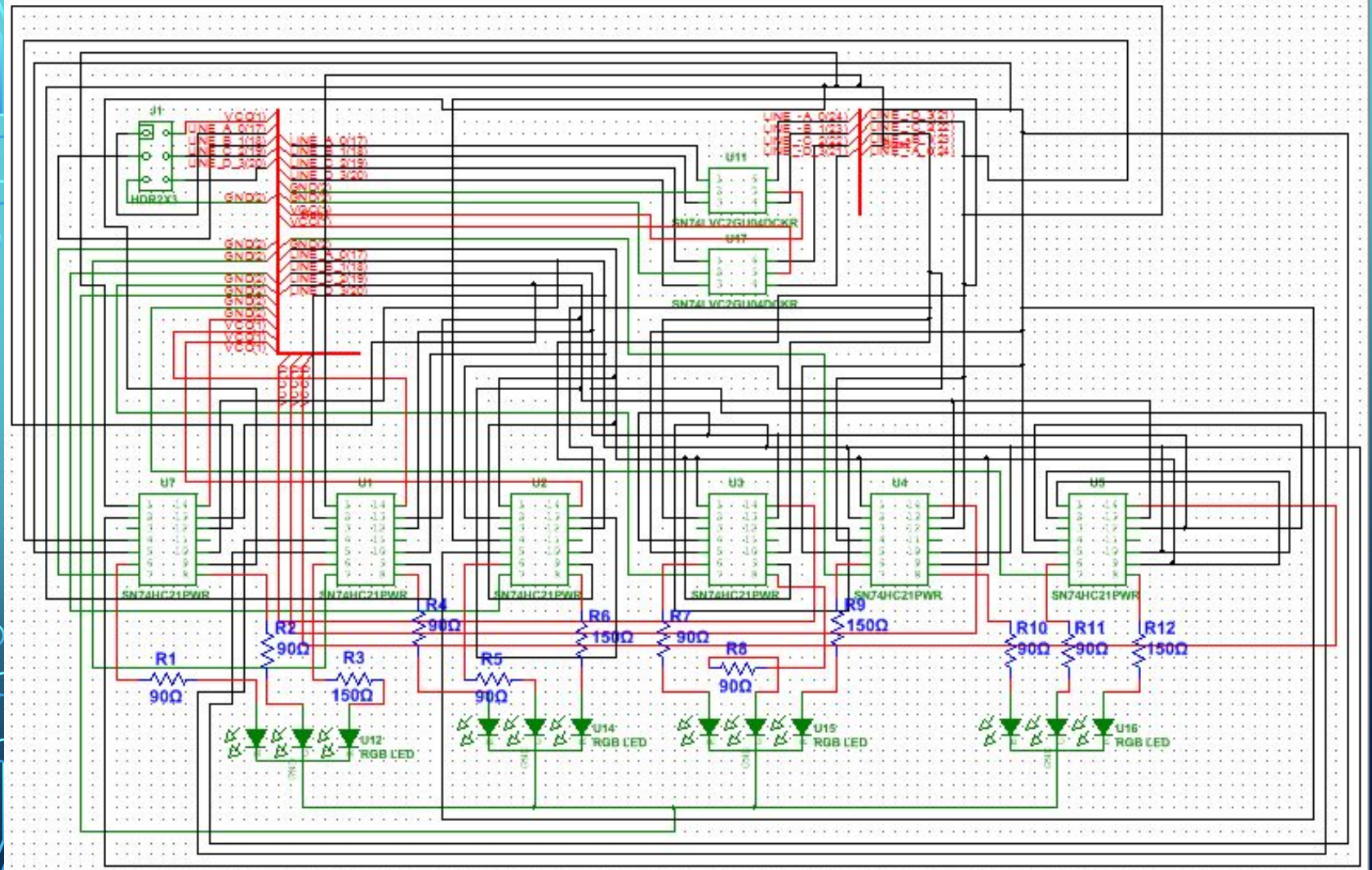
These are the bits that would be sent to each plate, and filtered through the 4-input AND & dual NOT gates. Here you can see the expected results.

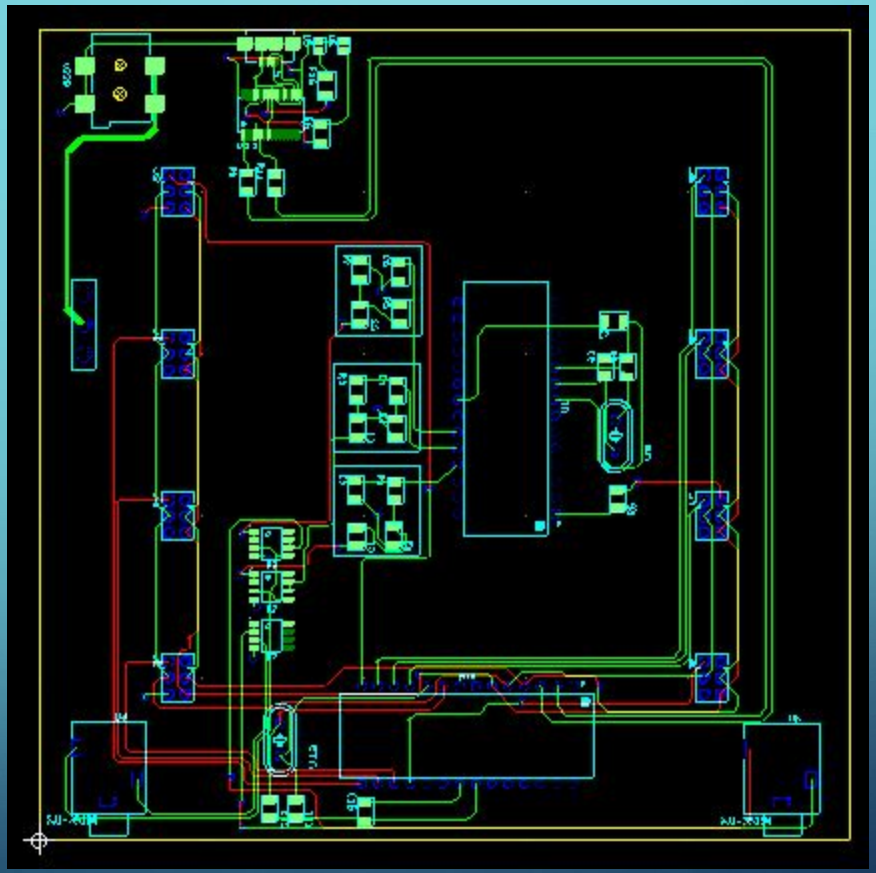
Schematics

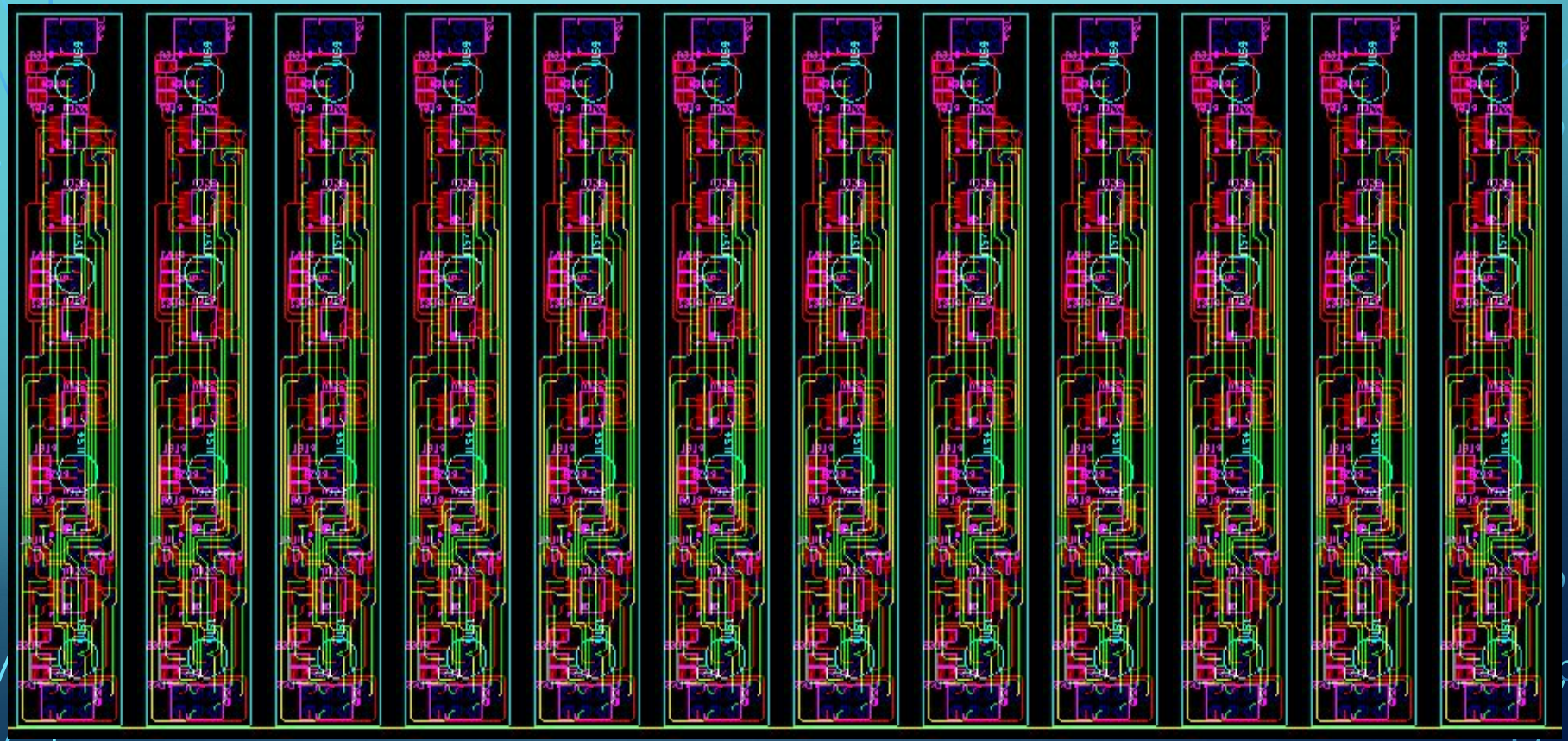

C1
1µF
R1
1Ω
R2
8kΩ
LOW BANDPASS
C2
1µF
C3
1µF
R3
160Ω
R4
800Ω
MID BANDPASS
C4
1µF
C5
0.1µF
R5
100Ω
R7
530Ω
HIGH BANDPASS
C6
0.1µF
U1
ATMega328
R6
1kΩ
C7
0.1µF
U2A
LM6132AIM
Low Bandpass Buffer
U2B
LM6132AIM
Mid Bandpass Buffer
U3A
LM6132AIM
High Bandpass Buffer
U3B
LM6132AIM
Audio Out L Buffer
U7A
LM6132AIM
Audio Out R Buffer
U4
SJ1-3513N
Audio In
C8
20pF
U5
16MHz Crystal Clock
C9
20pF
LCB
to_LCB
U6
SJ1-3513N
Audio Out
VCC
GND


VCC
GND
LCB
to_LCB
U10
ATMega328
R8
1kΩ
R11
1kΩ
C10
0.1µF
R9
330Ω
R10
330Ω
USB Debugger
USB Converter
C11
20pF
C12
20pF
U12
16MHz Crystal Clock
J2
J3
J4
J5
J6
J7
J8
J9
HDR2X3
HDR2X3
HDR2X3
HDR2X3
HDR2X3
HDR2X3
HDR2X3
HDR2X3

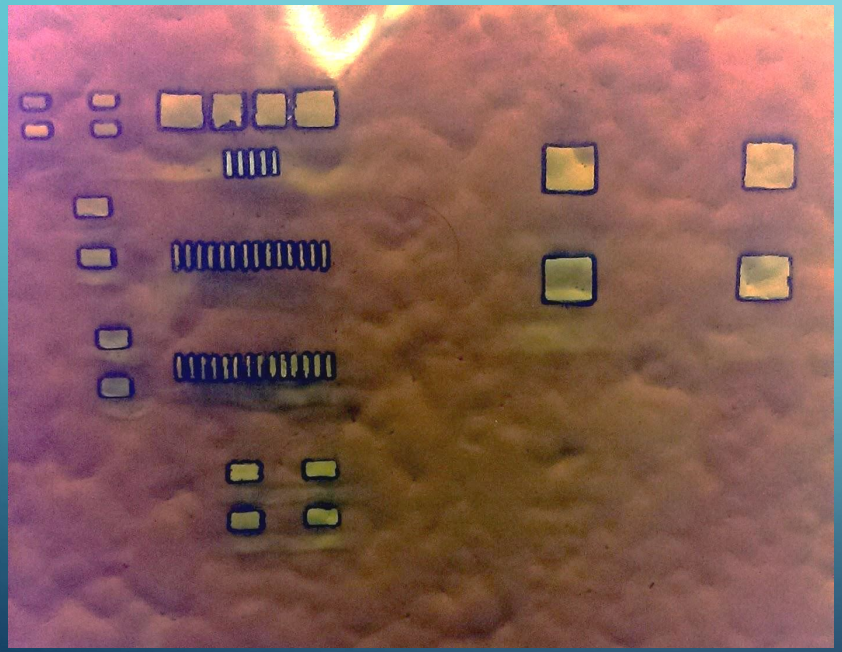

U51
U52
U53
U54
QB VCC
QC QA
QD SER
QE OE
QF CLK
QGSRCK
QHSRCL
GNDQH
74HC595
2x3 Header v3
2x3 Header v3
2x3 Header v3

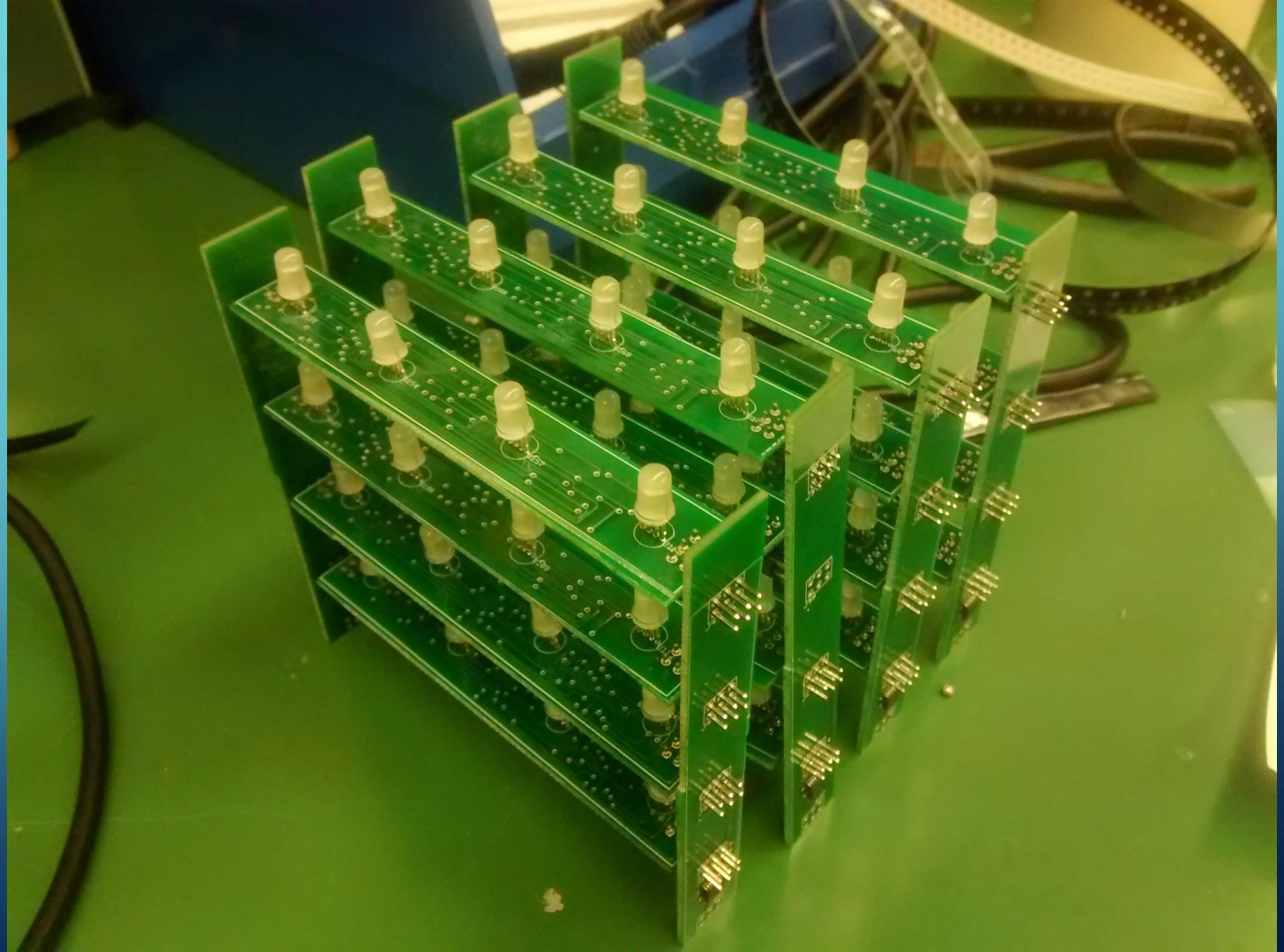

J1
HDR2X3
U11
SN74LVC2GU04DCKR
U47
SN74LVC2GU04DCKR
U7
U1
U2
U3
U4
U5
SN74HC21PWR
R1
90Ω
R2
90Ω
R3
150Ω
R4
90Ω
R5
90Ω
R6
150Ω
R7
90Ω
R8
90Ω
R9
150Ω
R10
90Ω
R11
90Ω
R12
150Ω
U12
RGB LED
U14
RGB LED
U15
RGB LED
U16
RGB LED



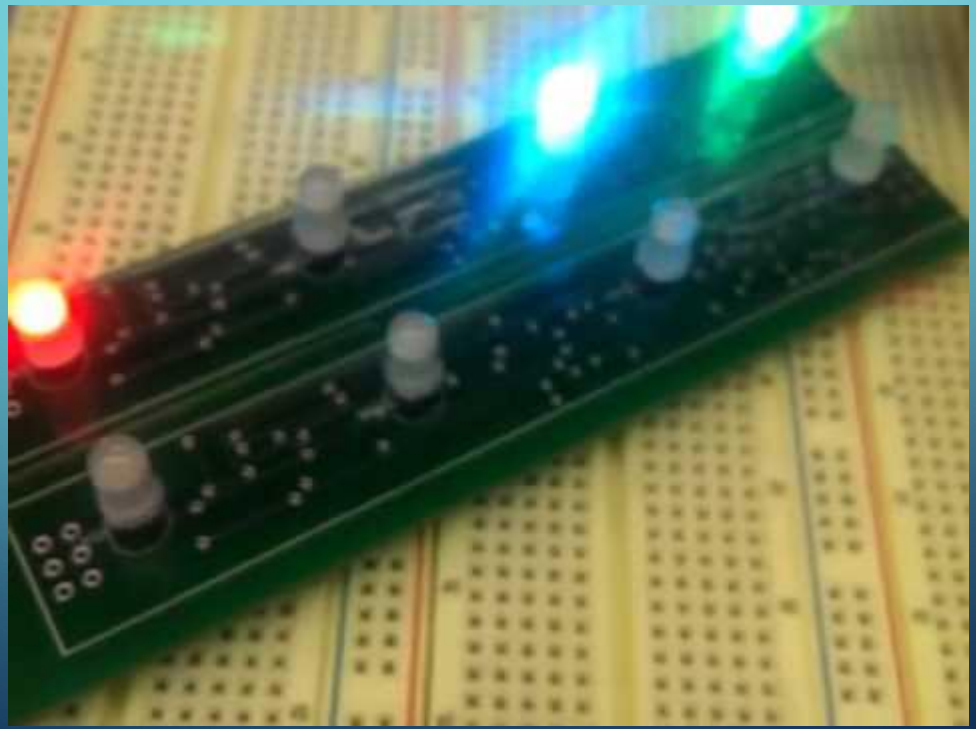


Stencil Results



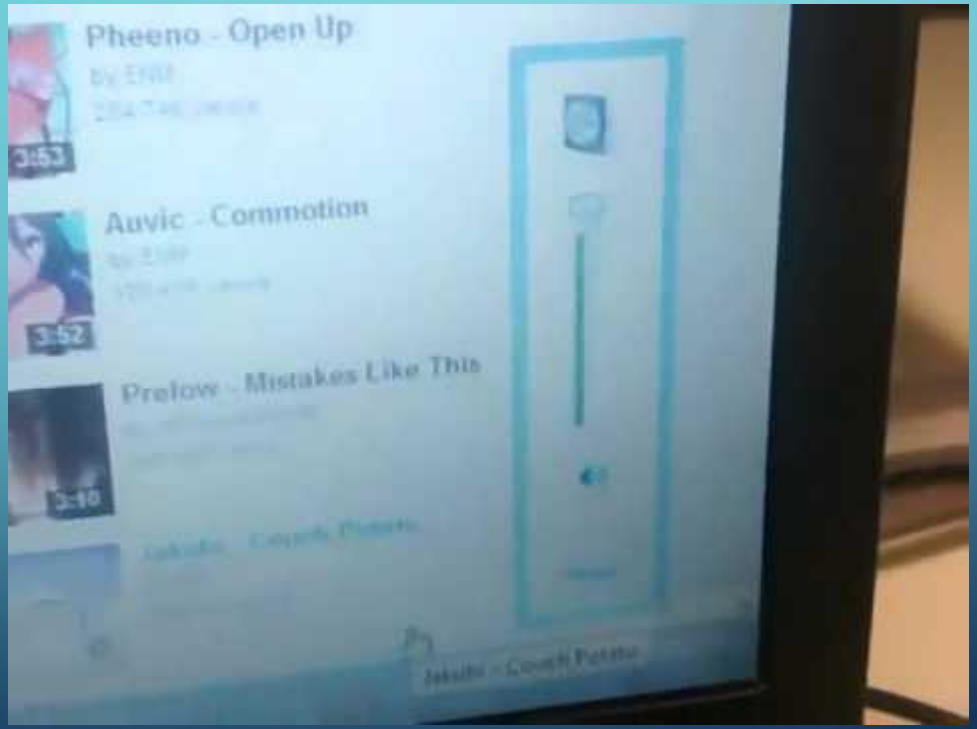


Testing LED Plate

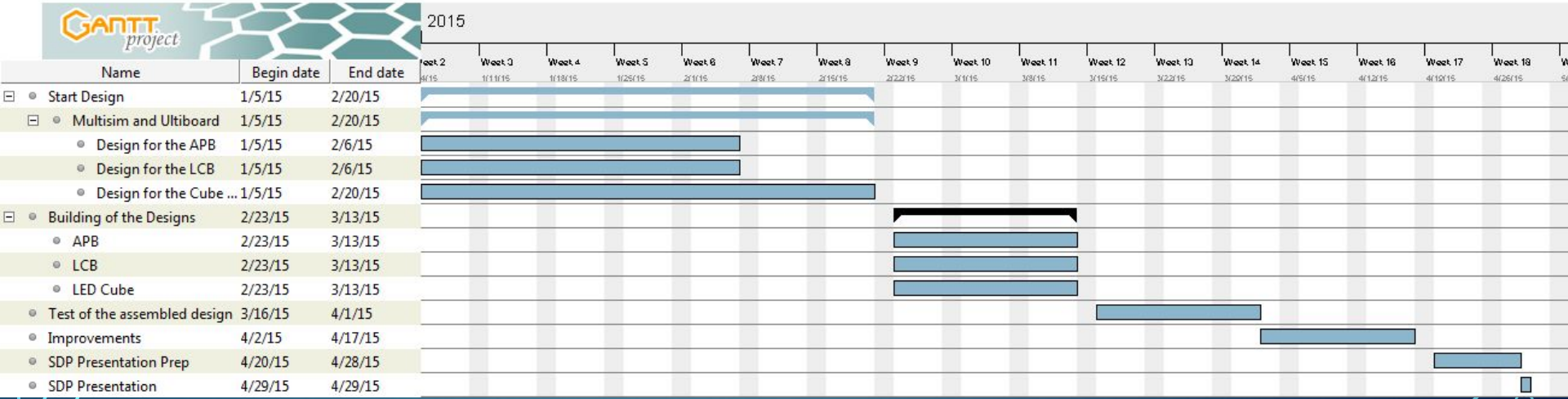


Testing Assembled Plates

Testing Concept (control of LED brightness with Audio)

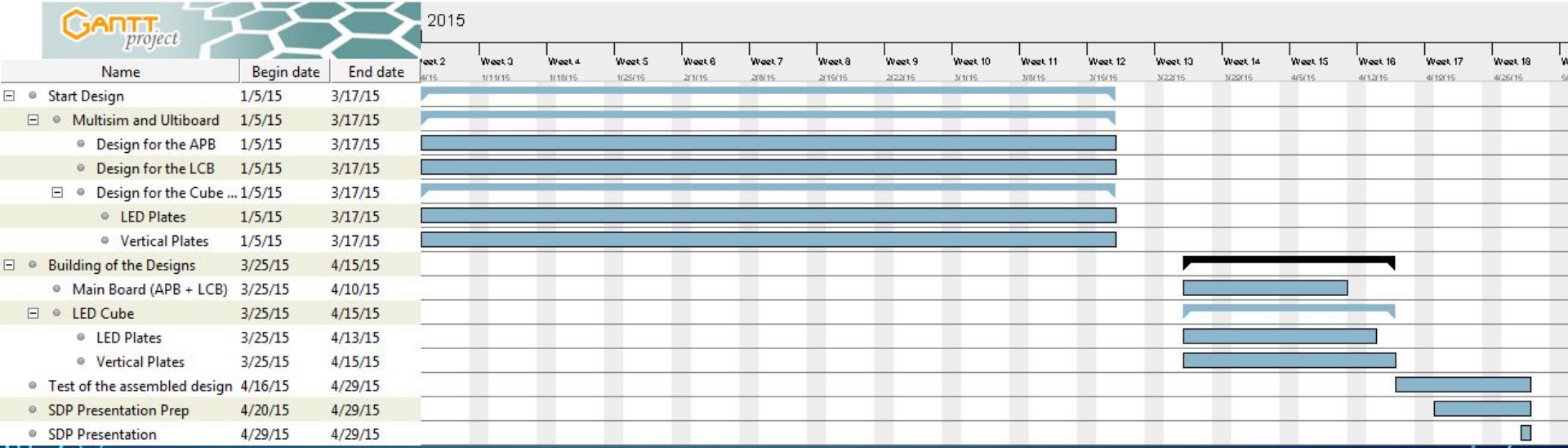


Gantt Chart (Predicted)



Name	Begin date	End date
Start Design	1/5/15	2/20/15
Multisim and Ultiboard	1/5/15	2/20/15
Design for the APB	1/5/15	2/6/15
Design for the LCB	1/5/15	2/6/15
Design for the Cube ...	1/5/15	2/20/15
Building of the Designs	2/23/15	3/13/15
APB	2/23/15	3/13/15
LCB	2/23/15	3/13/15
LED Cube	2/23/15	3/13/15
Test of the assembled design	3/16/15	4/1/15
Improvements	4/2/15	4/17/15
SDP Presentation Prep	4/20/15	4/28/15
SDP Presentation	4/29/15	4/29/15

Gantt Chart (Actual)



Name	Begin date	End date
Start Design	1/5/15	3/17/15
Multisim and Ultiboard	1/5/15	3/17/15
Design for the APB	1/5/15	3/17/15
Design for the LCB	1/5/15	3/17/15
Design for the Cube ...	1/5/15	3/17/15
LED Plates	1/5/15	3/17/15
Vertical Plates	1/5/15	3/17/15
Building of the Designs	3/25/15	4/15/15
Main Board (APB + LCB)	3/25/15	4/10/15
LED Cube	3/25/15	4/15/15
LED Plates	3/25/15	4/13/15
Vertical Plates	3/25/15	4/15/15
Test of the assembled design	4/16/15	4/29/15
SDP Presentation Prep	4/20/15	4/29/15
SDP Presentation	4/29/15	4/29/15

Budget

- PCB outsourcing: ~$119
- Components (Resistors, capacitors, ICs): $85
- Total: ~$205.00

Issues

- LED footprints too small.
- Audio Jack holes not corrected by Advanced Circuits.
- Microprocessor wrong footprint. (Row spacing too wide)
- NOT gate wrong footprint, the spacing was too small.
- USB Debugger not functioning properly.
- Short circuit on the LED plates.
- Too much noise detected on the Main board for audio.
- Had to hard wire the communication wires from the APB and the LCB microprocessors.
- Went a little over the budget.

Ways to Improve

- Accurate footprints for the design.
- Unless a machine is assembling, use larger parts.
- Fix USB debugger interface for ease of programming.
- Make PCBs thinner so LEDs are easier to see.
- Possibly find a better multiplexing method.
- Another alternative for controlling the LEDs.

What We Learned

- Check your footprints thoroughly
- PCBs are expensive
- Mistakes will cost you both time and money
- Small parts are hard to work with
- Calculations are important

Acknowledgements

- Dr. George Agoki - Coordinator
- Dr. Gunnar Lovhoiden - Advisor
- Advanced Circuits - PCB Fabrication
- Dr. William Greenley - Laser Cutter
- Professor Brendan Cross - Solderpaste and Reflow Oven
- The Internet - Research and Concepts
- Friends, Family, and most importantly God - Encouragment, advice, and keeping us through the project

References

- ENGR275 – Electronics I
- ENGR325 – Electronics II
- ENGR335 – Logic Circuit Design
- ENGR385 – Microprocessor Systems
- YouTube Videos
- Arduino Forums
- https://learn.adafruit.com/adafruit-arduino-lesson-4-eight-leds/overview
- http://www.electronics-tutorials.ws/filter/filter_4.html
- http://www.arduino.cc/en/Tutorial/SecretsOfArduinoPWM
- http://www.arduino.cc/en/uploads/Main/ArduinoNano30Schematic.pdf