AN-FP-2101
Application Note Considerations: Op Amps

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Abstract

Topics such as Operational Amplifiers, Capacitators, B.J.T., and Diodes are important to electronics. They are just in various applications. For the final project, we decided to combine different oscillators (B.J.T. Phase Shift, Tone Drone, and A stable) onto a P.C.B. To keep everything packaged nicely, a box was 3-D printed to keep everything safe and to allow easy carrying.

On top of that we taught the class how to make a basic circuit in Altium, and made kits (PCB, parts and box) for every student within the two classes.

Introduction

Within the class, we discovered different oscillators and how they worked. The basic requirement for classic oscillator topologies is to produce a total 360° phase shift from output back through the circuit.

In basic terms, an oscillator is a circuit that takes in a single, unipolar, D.C. power input and causes it to oscillate it between two different points. The three used within this project are B.J.T. Phase Shift, Tone Drone, and A stable. They each used a single 12-volt power supply.

B.J.T. Phase Shift oscillator is an oscillator that takes advantage of a transistor to allow the oscillation. You can see the oscillation on the feedback network. For this B.J.T., 180° is contributed by the inverting gain of Q1 as shown in Fig. 1, then another 180° must be obtained from the cascaded C-R sections to produce the total phase shift of 360° that will result in oscillation.

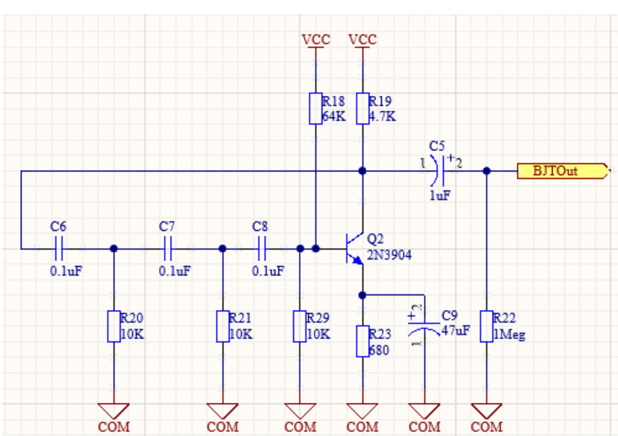

Figure 1: B.J.T Phase Shift schematic

For this oscillator, although it states 12 volts, we decided to only use 6 volts. This is due to the frequency of the output, which was extremely high.

The Astable oscillator takes advantage of an operational amplifier.

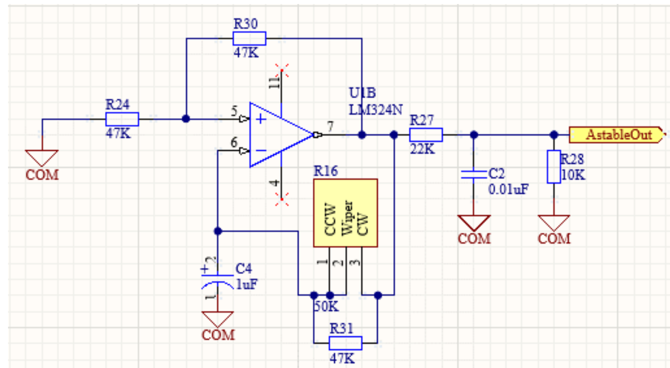

Figure 2: Astable Multivibrator Schematic

Since operational amplifiers needing bipolar input sources to power the device, a voltage divider was created. This causes a +6 volts, common ground and -6 volts from the original 12-volt input.

In addition to that, it is important to make sure that we have a voltage follower. This allows you to "clean up" the signal that is produced. The less noise that occurs within the voltage signal, the more accurate the output signal will be.

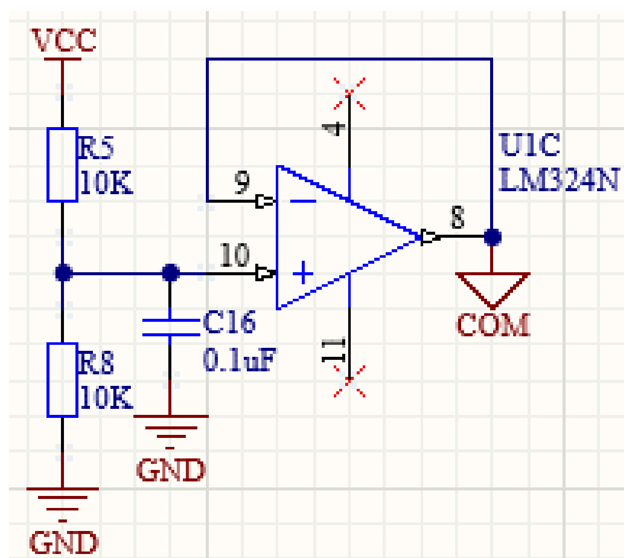

Figure 3: Voltage Divider with follower

Due to this being needed and the fact that the Astable oscillator has a higher output, the input voltage was 6 volts.

Tone Drone oscillator takes advantage of reverse avalanche breakdown of a transistor.

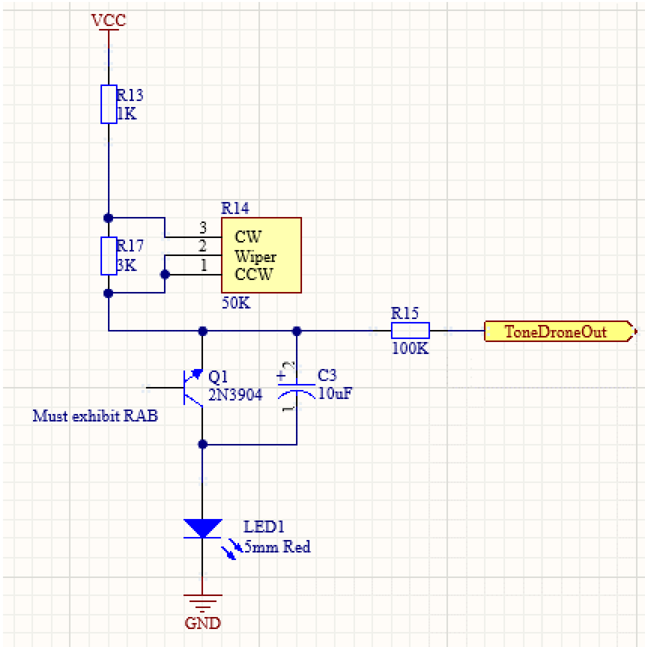

Figure 4: Tone Done Oscillator Schematic

The LED helps visualize the frequency of the output. The input for this oscillator is the total 12 volts.

All the outputs of the oscillators were put into the inputs a summing amplifier topology. The summing device takes in multiple inputs and outputs one final wave form.

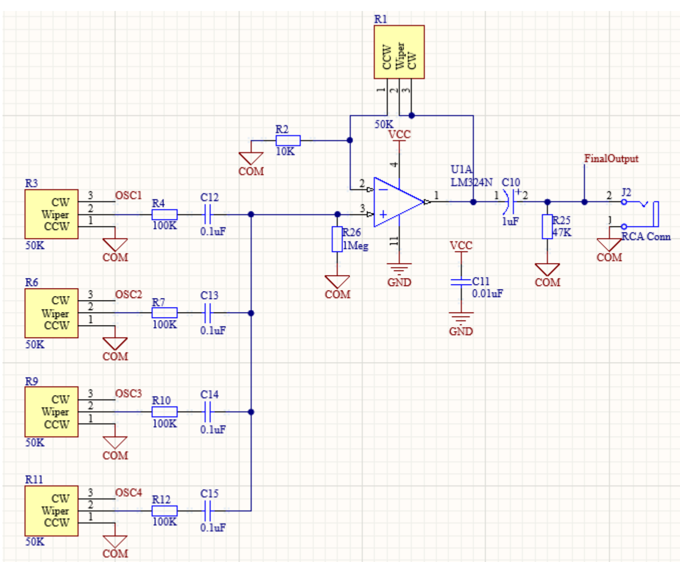

Figure 5: Summing Oscillator Schematic

Each different oscillator's input is running through each potentiometer on the left-hand side. A resistor and capacitor are used to smooth out the results on each of the oscillators.

Each circuit is provided with its own power so the only part in need of power is the quad op amp, which is fed +6 and -6 volts.

Circuit Analysis

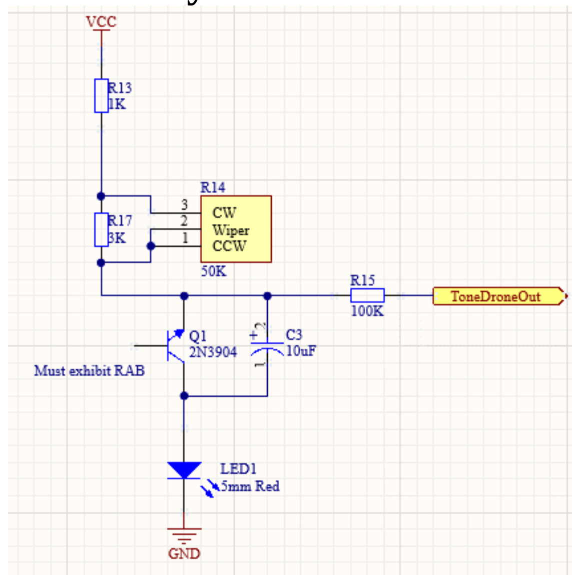

Figure 6: Tone Done Oscillator Schematic for analysis

When looking at the circuit starting at VCC, 12 volts, we can see that the power its being delivered to a voltage divider which cuts the power in half from the node in between R13 and R17. This then goes through the transistor which has reverse avalanche breakdown which allows for the oscillations. The capacitor in parallel is used to smoothing out the signal once it is produced. The LED going to ground is used to show the user the oscillation through it blinking.

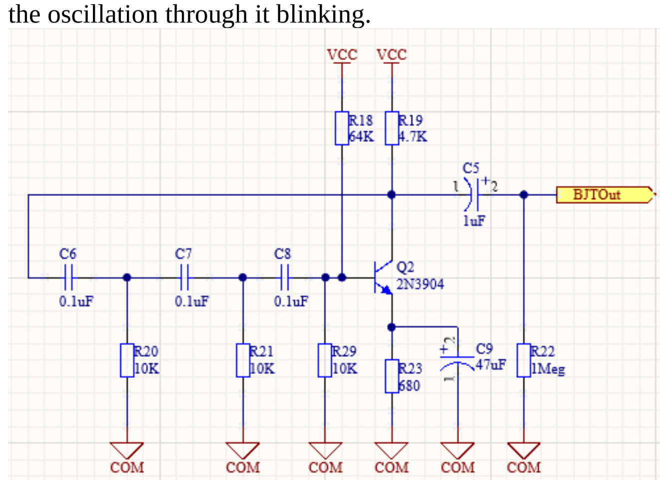

Figure 7: B.J.T Phase Shift schematic for analysis

For the BJT Phase Shift, a potentiometer was not able to be implemented into the circuit. Instead, we have to change the frequency coming out of the circuit by changing C6, C7, And C8 to a higher capacitance. This capacitance was a better fit for the intended output that we wanted.

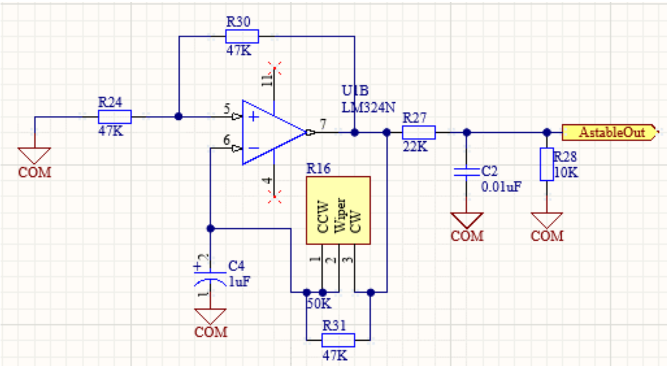

Figure 8: Astable Multivibrator Schematic

For the Astable Multivibrator, initially the potentiometer was in parallel to the feedback resistor. But when we tested the circuit out, we found that we would get better results if the feedback resistor was no variable. Thus, why the potentiometer is on the bottom portion of the circuit.

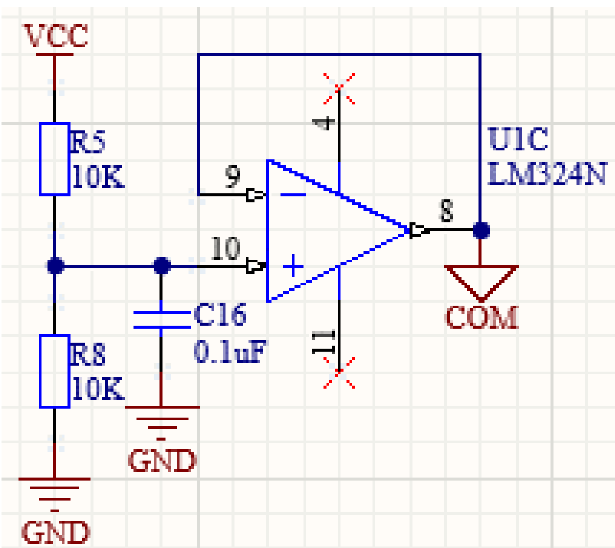

Figure 9: Voltage Divider with follower

A voltage follower was needed in order to get a few of the other oscillator's such as the astable multivibrator and the BJT Phase shift to work. It was needed to step down the voltage from its normally 12 volts to 6 volts. The reason this was intentionally done was because the rail-to-rail voltage on each oscillator was too high.

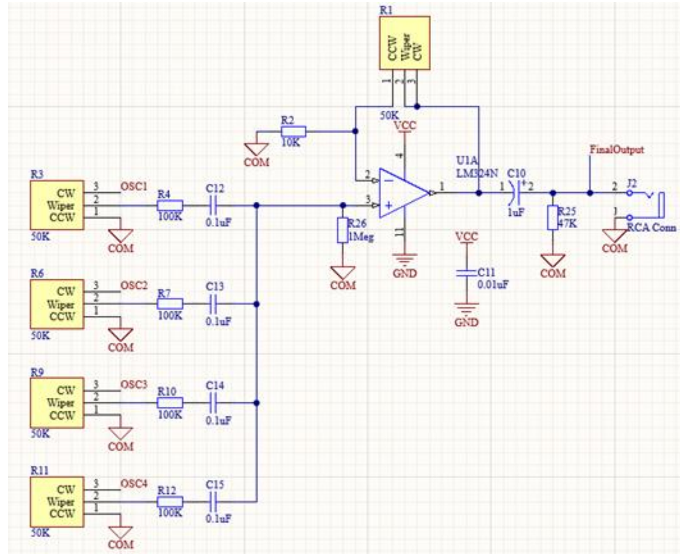

Figure 10: Summing Oscillator Schematic

The summing amplifier takes all of the three inputs from the oscillators and combined the audio signals into one signal. This was achieved by having resistor and capacitor in series in order to smooth out the signal before going into the operational amplifier. Once in the op- amp the signal was produced and outputted into an AC couple was inserted by a capacitor and resistor with a pulldown to virtual ground in order to ensure no noise was produced as well as to block any DC signal that was produced. A potentiometer was used as a feedback resistor in order to control the overall volume of the mixed signal.

Simulation

We used LTSpice for simulating all of our oscillators. We recreated the schematics above in the program and simulated as shown below.

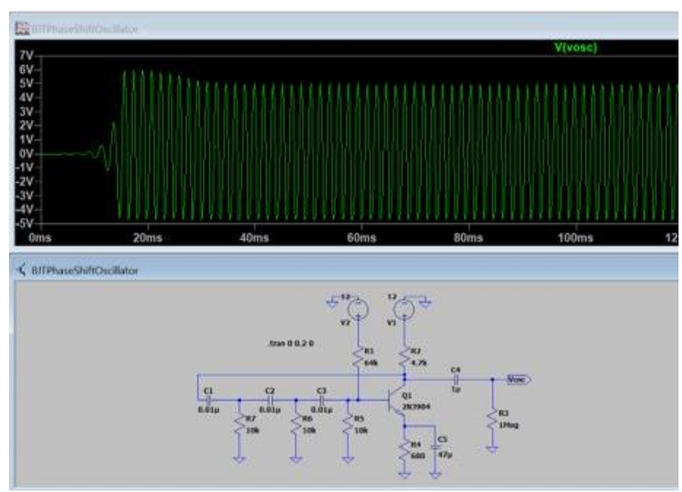

Figure 11: BJT Phase Shift Oscillator, Simulation Results

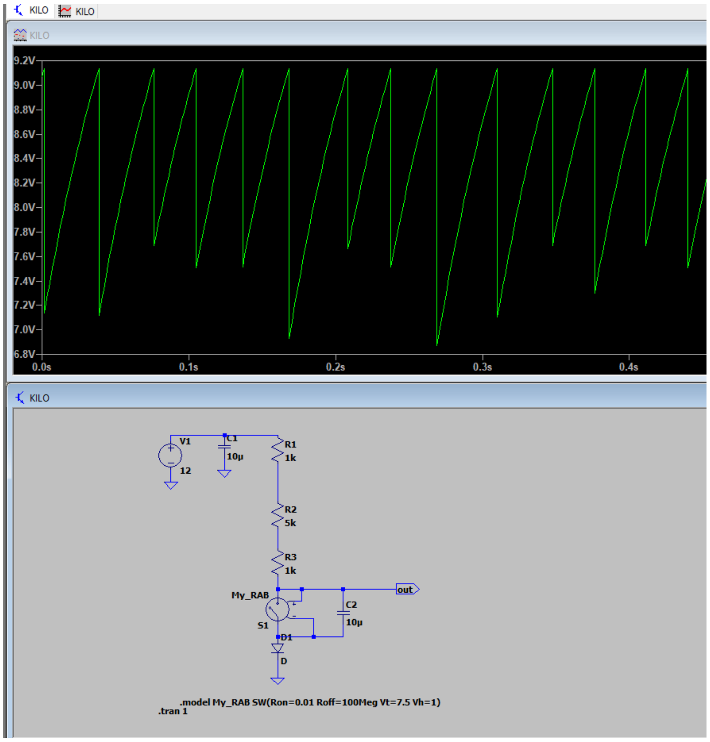

Figure 12: Tone Drone Oscillator, Simulation Results

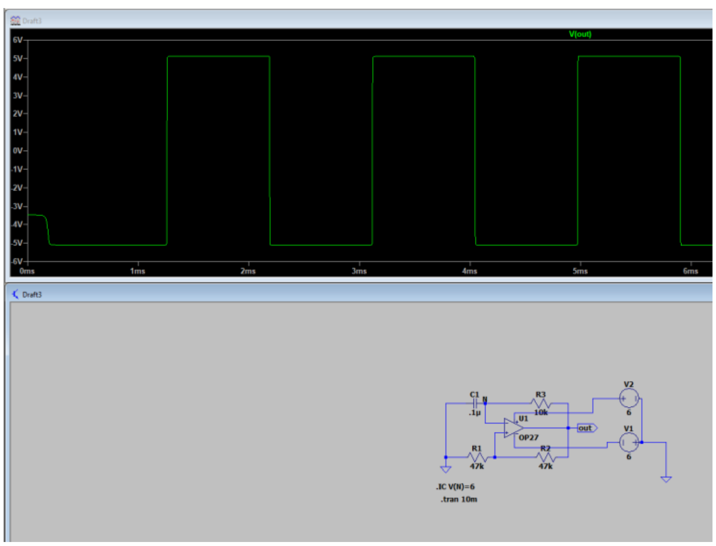

Figure 13: Astable Multivibrator, Simulation Results

PCB

Once we had all of the schematics done, we breadboarded it to make sure all the values that we calculated were correct.

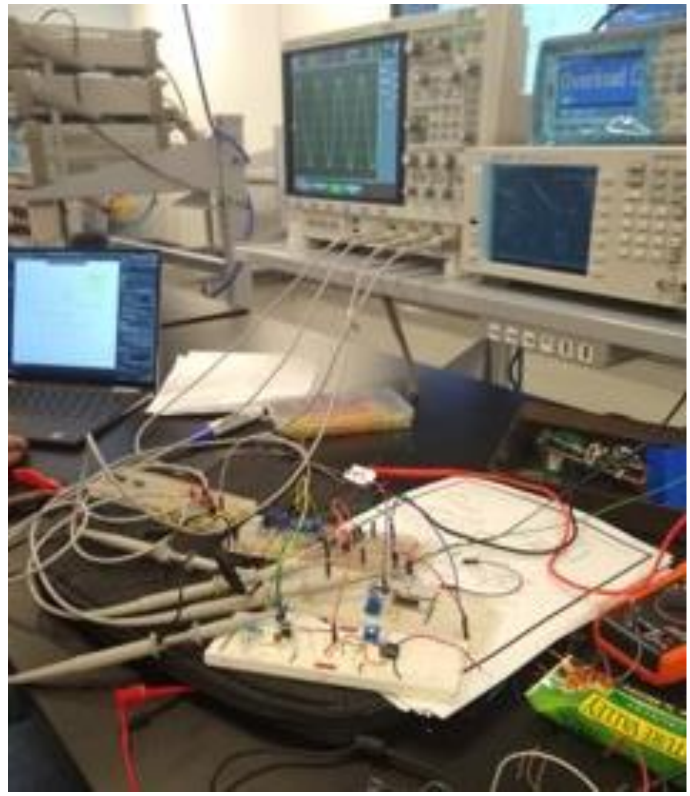

Figure 14: Breadboard of Entire Circuit

Once all the testing was concluded and the signals all were correct, it was time to transfer all the schematics to Altium so the PCB of it could be created.

We added a schematic per oscillator plus one more for the summing amplifier to tie it all together. This helped with organization of all the components/circuits.

After the schematics were all within Altium, we made it into a PCB. All the parts were imported, rearranged, and wired. In addition to all of the regular parts, test points were created to allow students to test each circuit individually.

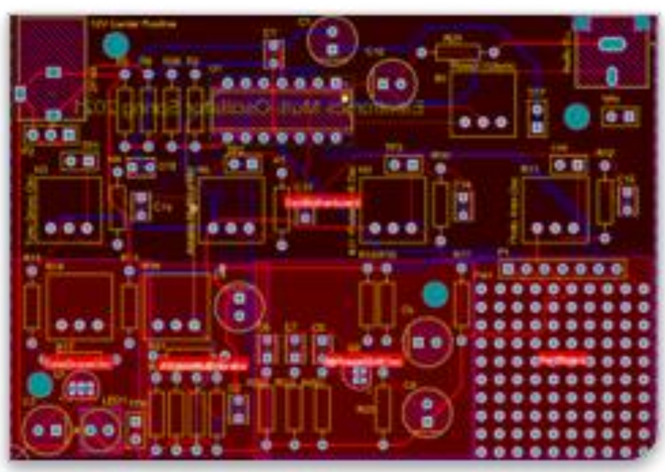

Figure 15: PCB layout within Altium

After that was all done, we cropped the board shape to the size we need. From there we could preview how the board would look when it was shipped.

Figure 16: PCB preview

Even though everything worked on the breadboard, we wanted to do one final check before shipping it out. To go this, we milled a prototype of the PCB.

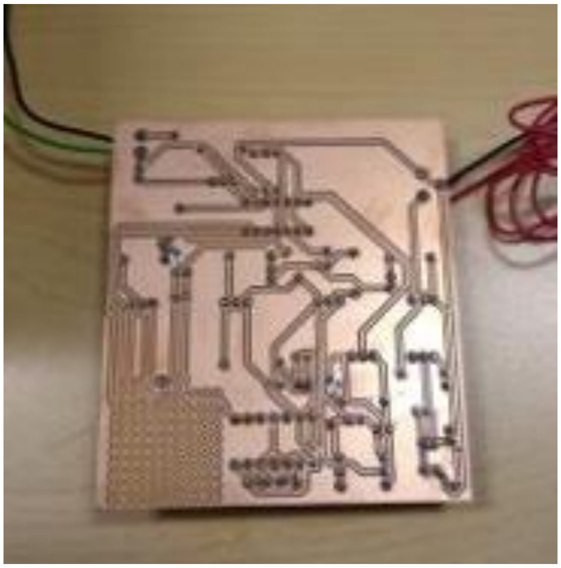

Figure 17: Milled PCB backside

Figure 18: Milled PCB front side with components

Once more testing on this was done, the boards were ordered and shipped out.

3-D Printed Box

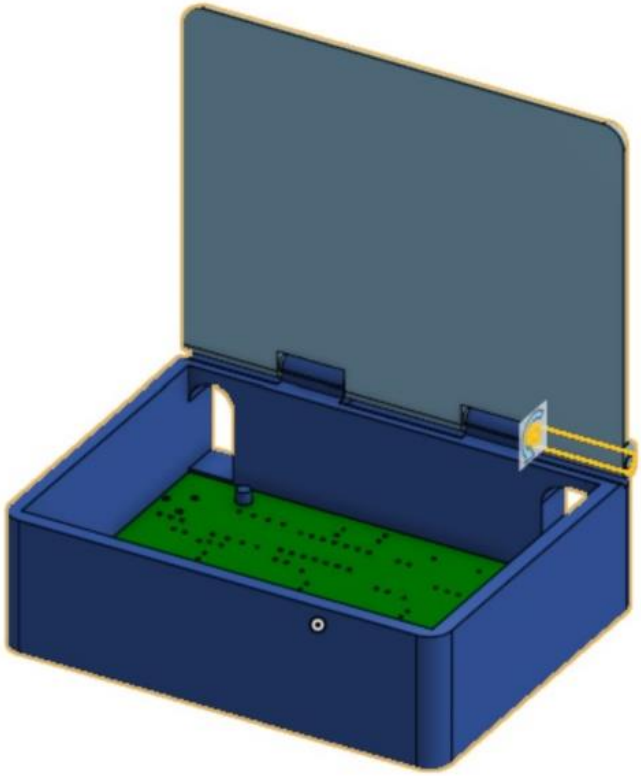

Figure 19: CAD model assembly of housing for Tri- Oscillator PCB

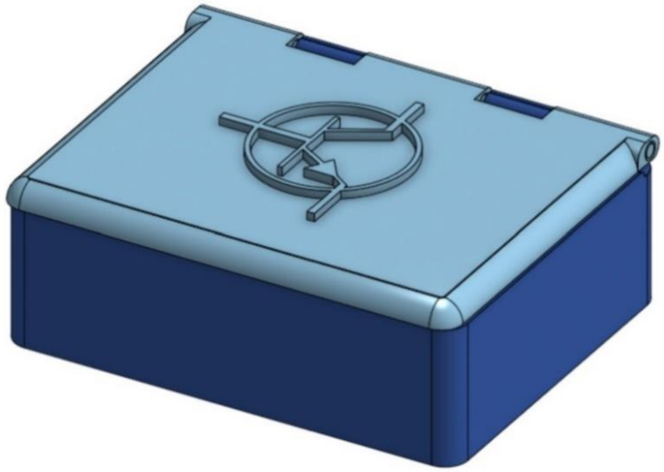

Figure 20: CAD model assembly of housing for Tri- Oscillator PCB

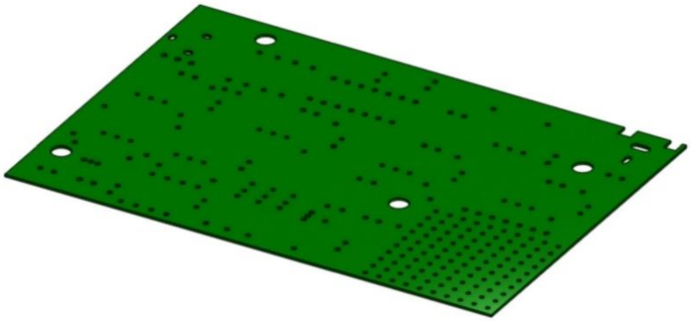

Figure 21: Imported PCB CAD model unzipped from STEP file from Altium Designer

In order to allow for the PCB to fit perfectly in the 3D printed box, a 3D model was generated from Altium Designer.

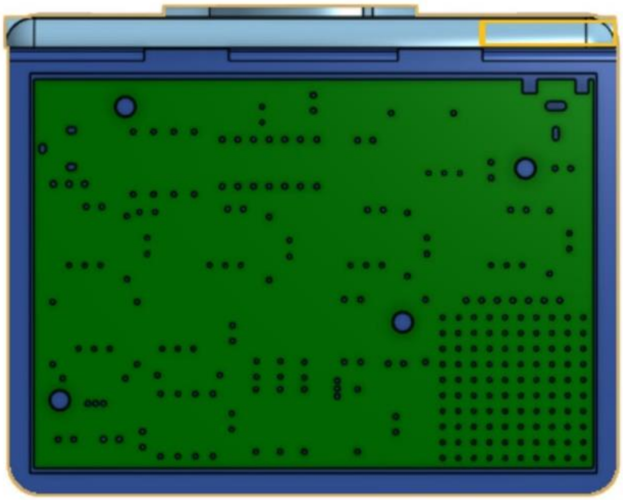

Figure 22: PCB location within housing

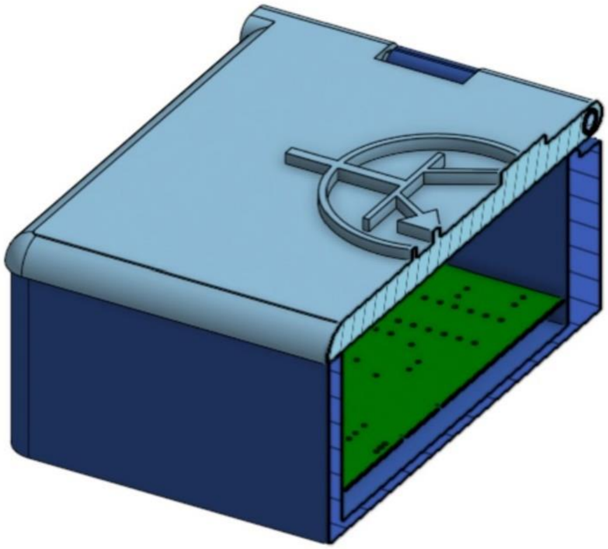

Figure 23: Section view of 3D model inner housing shown

This 3D PCB model was used as a reference point in ensuring that the box would have enough space for students to create solder joints at the bottom of the circuit board. Also, the holes made on the back portion of the box were intentionally made bigger in order to accommodate enough space for the RCA jack as well as the DC barrier jack.

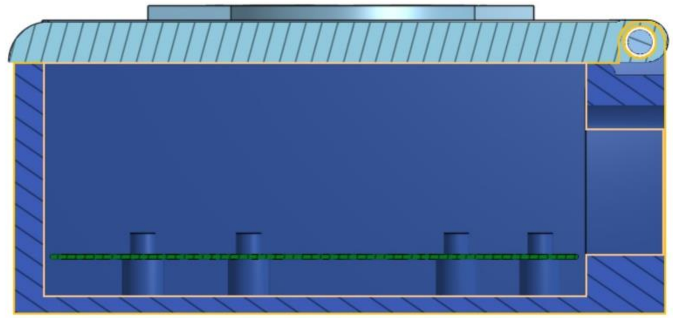

Figure 24: Section view of side portion of housing

As seen in Figure 24 above, roughly a 6mm clearance was left underneath the PCB board in order to allow for students to have enough room in case of solder mistakes. Since most of the students in this course have not had solder experience have the extra room helps the PCB still fit snug into the case without any problems.

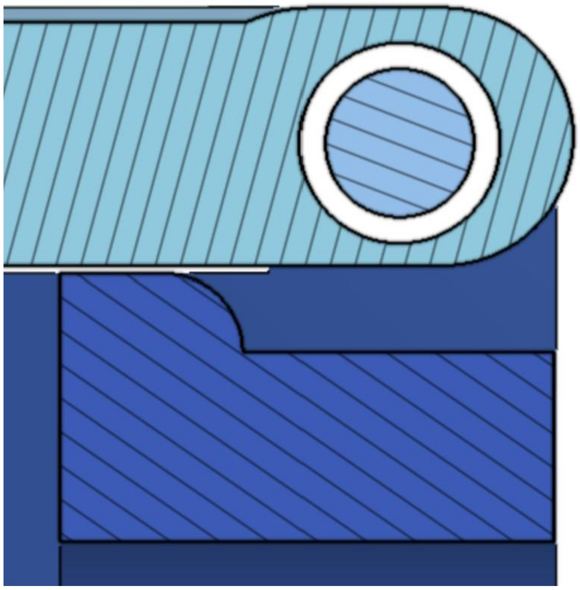

Figure 25: Section View of hinge mechanism, uses piece of 3D printing material, filament, to secure the top and bottom portion of the case in place

When designing the hinge mechanism different concepts came to mind for the design such as using screws, bolts, or paperclips. The concept that ended up making it into the final design was to incorporate a piece a filament, material used by the 3D printers, in order to secure the top portion of the case to the bottom. By using the same material as the box, seen in figure 16 it makes the overall cost of manufacturing decrease drastically.

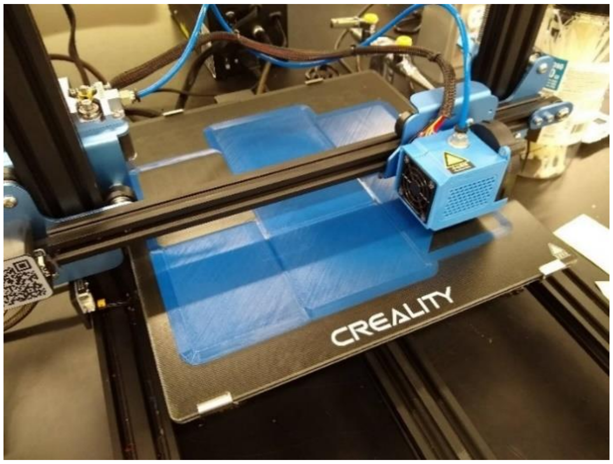

Figure 26: Depiction of housing model being printed on a Creality CR-10 V2

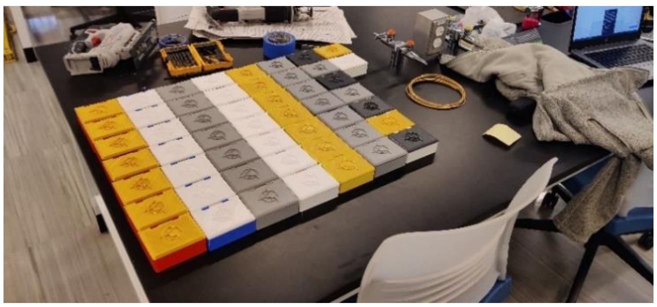

Figure 27: Fully assembled housing, 50 housing for two sections of Electronics I

Once the cases were fully assembled, they were distributed to each section of the class. The randomness of color was deliberately done to increase user variety.

Kits

To create the boards, there was going to be a lot of components. Rather than have the students hovering over the vidmars within the labs, our group decided to create parts kits that included everything that they would need to solder.

Figure 28: Parts kits for PCB

These were either handed out to each student during class or it was shipped to them with the PCB.

Lesson

Although we learned how to use Altium, not every student within our class knew how to. Since it is an important skill to have for an electrical engineer, we decided to teach the class.

For the process of teaching them, we chose to create the tone drone in both schematic and PCB form. This circuit included that the basics of Altium such as manufacturing parts, components, schematics, wiring, board shape etc.

Throughout teaching, there were people walking around helping students out who got stuck during certain parts. This helped progress the lesson without taking too much time on each part.

Conclusion

When the final prototype was built using the milled board, only the kilo-drone ended up working. this is because when soldering the components, a section of the board was short circuited. But from the simulations and the working bread board the schematics were still sent out to be printed for the entire class. Unfortunately, due to outside forces the boards did not come in time do solder them up in class, so the parts kits were made so we could send everyone the parts as well as the board when it does come in.

Instead of building the boards the last day of classes, a mixer was brought in to sum all the oscillators that were made by everyone in the class. The result was about 15 different oscillators summed up into one main mixer and outputted by an amp. From this demonstration everyone was able to hear the different frequency and how certain circuits were at much higher frequencies then others.

Finally, the topics such as Operational Amplifiers, Capacitators, B.J.T., and Diodes that were explored in order to get the results. For the project, a quad amp was found to be the best fit to condense the board as well as the part number. With the capacitors and resistors, each circuity had to be analyzed to fit a certain frequency. This mean each capacitor and resistor had to be picked appropriate to fit the range. For the phase shift oscillator, a B.J.T. had to be implemented appropriately in order to get the oscillator to function as expected. Lastly, a diode (LED) was used to check if the kilo-drone was working on the board.

References

[1] J. Schmalzel, Circuit Brief 2102, pp.1-3 https://docs.google.com/document/d/1F-MTieDkxlkg2H7RNSWmF5eA4z8TVrTY/edit

Appendix A. Bill of Materials

Comment	Description	Designator	Footprint	LibRef	Quantity
10uF	CAP ALUM 10UF 20% 100V THRU HOLE	C1, C3	FP-ESLE3-MFG	CMP-03015-000004-1	2
0.0082uF	Capacitor, Ceramic, 0.01 uF, +/- 10%, 100 V, X7R, -55 to 125 degC, 2-Pin THD, RoHS, Bulk	C2, C11, C14	KEMT-C315-THT-2	CMP-1664-00007-1	2
1uF	CAP ALUM 10UF 20% 100V THRU HOLE	C4, C5, C10	FP-ESLE3-MFG	CMP-03015-000004-1	3
0.1uF	Capacitor, Ceramic, 0.01 uF, +/- 10%, 100 V, X7R, -55 to 125 degC, 2-Pin THD, RoHS, Bulk	C6, C7, C8, C12, C13, C15, C16	KEMT-C315-THT-2	CMP-1664-00007-1	8
47uF	CAP ALUM 10UF 20% 100V THRU HOLE	C9	FP-ESLE3-MFG	CMP-03015-000004-1	1
PJ-102B	Through Hole Right Angle DC Power Jack, 2.5 A, 2.5 mm Center Pin, 3 Position, -25 to 85 degC, RoHS, Bulk	J1	CUI-PJ-102B_V	CMP-2000-06900-1	1
RCA Conn	Female RCJ Jack, 2 Position, Height 11.724 mm, Tail Length 4 mm, RoHS, Bulk	J2	CUI-RCJ-041_V	CMP-1692-00002-1	1
5mm Red	THT LED round mono-color color lens, WL-TMRW, Red	LED1	Type 5mm	CMP-1488-00008-1	1
OSC4 Connector	Header, 7-Pin	P1	HDR1X7	Header 7	1
Alternate Power	Header, 3-Pin	P2	HDR1X3	Header 3	1
2N3904	NPN General Purpose Amplifier	Q1, Q2	TO-92A	2N3904	2
50K		R1, R3, R6, R9, R11, R14, R16	TrimmerPot	TrimmerPot	7
10K	Resistor	R2, R5, R8, R20, R21, R28, R29	AXIAL-0.4	Res2	7
100K	Resistor	R4, R7, R10, R12, R15	AXIAL-0.4	Res2	5
1K	Resistor	R13	AXIAL-0.4	Res2	2
3K	Resistor	R17	AXIAL-0.4	Res2	1
64K	Resistor	R18	AXIAL-0.4	Res2	1
1Meg	Resistor	R22, R26	AXIAL-0.4	Res2	2
680	Resistor	R23	AXIAL-0.4	Res2	1
47K	Resistor	R24, R25, R30, R31	AXIAL-0.4	Res2	4
4.7K	Resistor	R19	AXIAL-0.4	Res2	1
22K	Resistor	R27	AXIAL-0.4	Res2	1
Test Point	Header, 2-Pin	TP1, TP2, TP3, TP4, TP5, TP6, TP7	HDR1X2	Header 2	7
LM324N	Low Power Quad Operational Amplifier, 14-pin MDIP	U1	N0014A	CMP-0055-00082-3	1