ECEG 301:
Firefly PCB Design and Fabrication
Project Report

Iteration 2

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Introduction:

The firefly circuit board incorporates with 555 timer is a circuit that blinks an LED. The LED is an UV LED which blinking period and frequency is controlled by the 555 timer. At the individual level, each firefly flashes under its own frequency but when putting several of them onto the same power supply. They blink roughly at a same rate results by synchronization.

Functional Description of the Firefly Circuit:

The circuit layout are shown in Figure 1. In the implementation, three IR sensor, three IR LED, one 555 timer, three, capacitors, six resistors and one RGB LED are used. The core of the firefly project is the 555 Timer. In this project, the 555 timer is running under astable mode. The astable mode can be viewed as: charging the capacitor and discharging the capacitor and this process is repeated cyclically. The resistors are used to charge the capacitor and the transistors are used to discharge the capacitor. The repeated cycle is accomplished by switching the capacitor to either Vcc or ground. By using three resistors (U3, R3 and R4) we can divide the voltage of Vcc by some factor 1/x. The idea is to charge the capacitor until it reaches (1 - 1/x)*Vcc, then close the switch causing capacitor to discharge until the voltage of capacitor reaches 1/x*Vcc. Then repeated the process by open and close the switch back and forth. The selection of color is accomplished by choosing the appropriate value of the three resistors (R1, R2, R5) attached to the RGB LED. The functioning block diagram is shown in Figure 2.

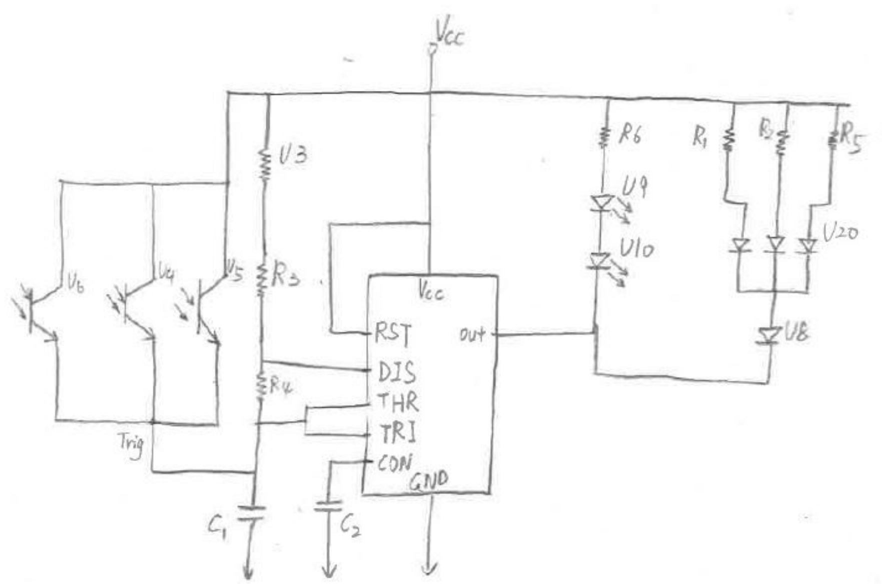


Figure 1. Components layout of firefly circuit

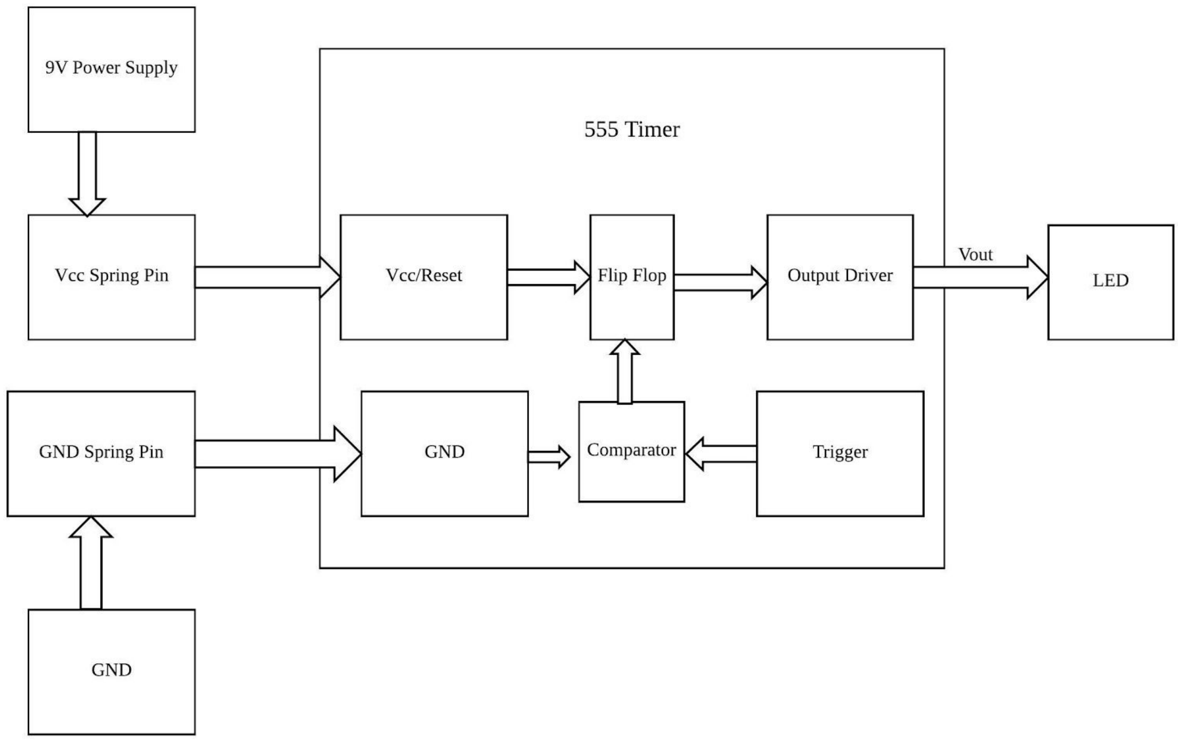


Figure 2. Block Diagram of Firefly system

Test Plan:

Criteria	Test Method	Passing Condition	Not passing criteria
Connection Test 1: Connection between traces. 2: Connection between via and traces. 3: Connection between vias and components.	1: Using two pins of multimeter to touch the vias that are connected through traces. (As Figure 3. Shown) 2: Using two pins of multimeter to touch via and the trace it is connected with. Also use two pins of multimeter to touch the back and front side of the vias. 3: Using two pins of multimeter to touch pins of the components and the vias that are connected.	A "beep" sound suggests a good connection.	No "beep" sound from multimeter.
Placement Test	Comparing the existing board with the Multisim Ultiboard layout. Checking each component especially the 555 timer and RGB LED in the correct places with correct	Every components is in the desired	1: Not in the correct place. 2: In the correct place

	orientation.	place.	with wrong orientation
Touch Test	Using tweezer to slightly touch the components.	The components are sticking to the surface firmly.	The components moved and not attaching to the surface pins.
Short Circuit Test	Short circuit often happened where the solder was added. Using two pins of multimeter to touch the surrounding copper board and the solder to test the connection.	No “Beep” sound suggests no short circuit.	A “beep” sound suggests short circuit.
Test Point Test	1: Vcc Test Point. Powering the firefly with external power supply. Then using oscilloscope to graph the signal from Vcc Test Point. 2: GND Test Point. Powering the firefly with external power supply. Then using oscilloscope to graph the signal from GND Test Point. 3. Trigger Test Point. Powering the firefly with external power supply. Then using oscilloscope to graph the signal from Trigger Test Point. 4: Vout Test Point. Powering the firefly with external power supply. Then using oscilloscope to graph the signal from Vout Test Point.	1: The graph appears to be a constant 9V. 2. The graph appears to be constant 0V. 3: The graph has charging and discharging curve. 4: The graph with constant 9V and 9V pulse in between.	1: The graph doesn’t have constant 9V. 2: The graph doesn’t have constant 0V. 3: The graph doesn’t have charging and discharging curve. 4: The graph doesn’t have constant 9V signal or doesn’t have signal pulse.
Light Test	Putting the board onto the copper wall outside of the Maker E.	LED lights up and blinks.	LED does not light up
Functional Potentiometer Test	Putting the board onto the copper wall and adjusting the Potentiometer.	The blink rate changed after the adjustment.	The blink rate does not change.
Precise Potentiometer Test	Connecting the firefly circuit with the 9V power supply and using oscilloscope to measure the Vout pin of both firefly test point.	Please see Figure 4 and Figure 5 below.	Not change in pulse frequency or amplitude observed.

Synchronization	Putting the board next to a functioning board to check if the both LED blinks at the same rate.	Both LED blinks at the same rate	LED does not blink at the same rate
Synchronization Test	Connecting the firefly circuit and the other functional board with a same power supply. Using the oscilloscope to measure the Vout pin of both firefly test point.	Both graphs have the constant 9 V with the pulse at the mostly the same time.	Graphs do not have the pulse at the same time.

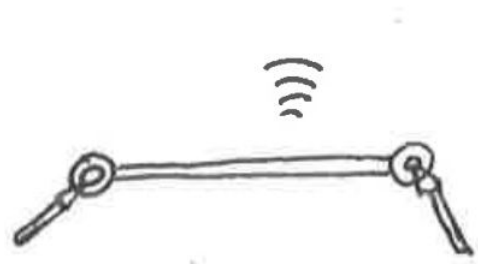


Figure 3. Demonstration of the connection test

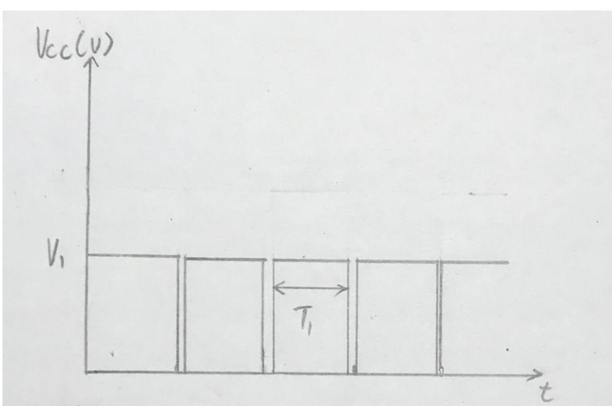


Figure 4: Oscilloscope Display of Vout with Small Potentiometer Input

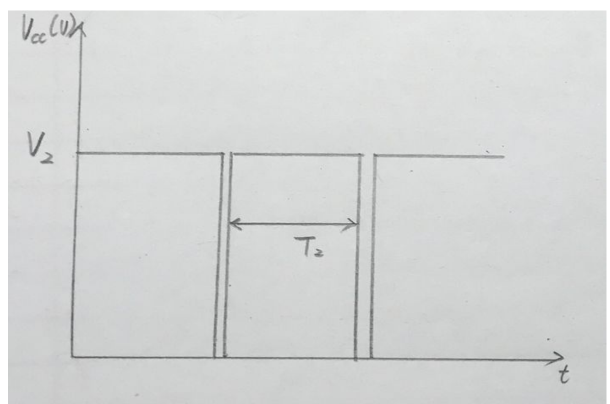


Figure 5: Oscilloscope Display of Vout with Big Potentiometer Input

Procedure Inspection and Reflection:

Milling Process:

Our design of ultiboard followed the dozuki instruction. The layout was more organized due to utilization of power plane. The components that connected to 555 Timer should be organized around the 555 Timer which will reduces the number of vias.

One of the problem we found during the process was that the milling traces were not carved deep enough, which results in poor connection or open circuit. We had a good result in the first milled test, the milled test channel had proper width and depth. But the first board we got from the milling machine didn’t provide consistent clear traces as the one we had during the milling channel test. During our second try, we not only went through the milled test and we also changed the desired channel width from 0.2mm to 0.27mm. Increasing the desired channel width ensured that we will have deep and wide traces. However, the drawback might be that the traces might overlap with each other if the traces are too wide and they are really close to each other. (See Figure 6(b).) In Figure 6(a), there is isolation between two traces. In Figure 6(b), there is no isolation at some places because the traces are too wide and this causes short in the circuit. Fortunately our board connection turned out to be good.

Figure 6. Demonstration of how channel width affect the circuit.

Pick and Place:

We followed dozuki for our pasting process and the outcome looks good to us. We flipped the board and dropped some components after we finished the first pick and place process. So we took off all the components and wiped out all the paste on the board with clean tissue.

Then we redo the process. We made sure all the components were correctly placed and all the pins of the components are right on the board pins that they should be connected. We did a solid work on the overall process.

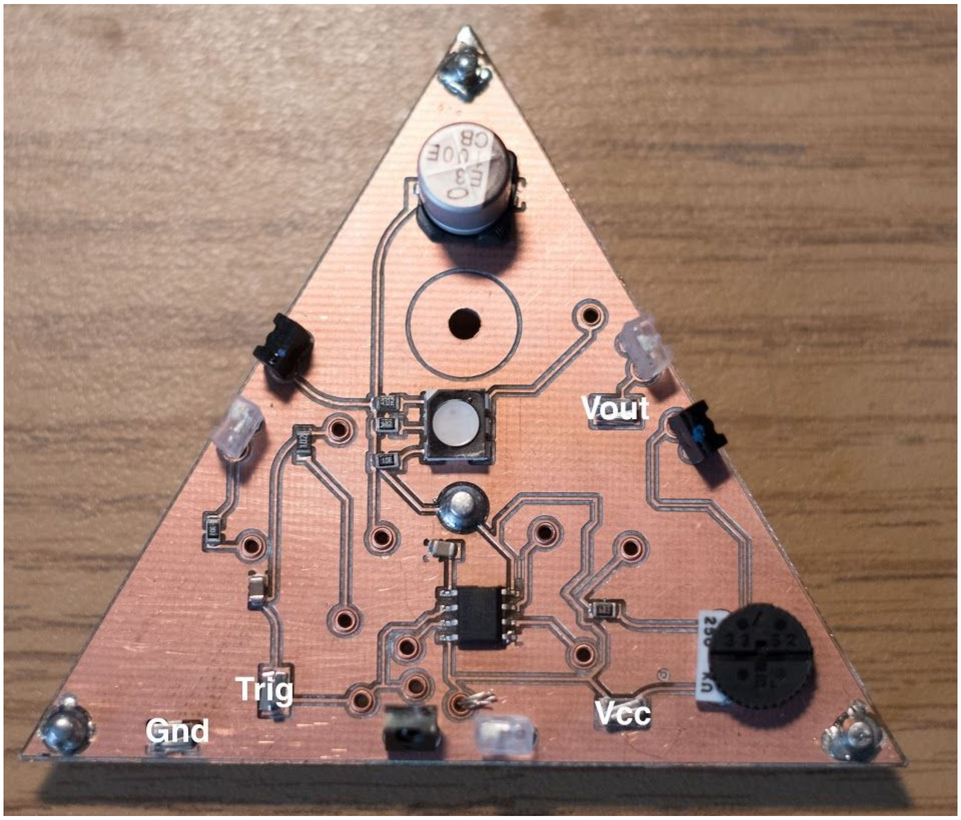


Figure 7. Finished PCB Board

Soldering:

We followed the dozuki tutorial for the soldering part. The outcome is not very good because the solder was really hard to control and was easy to cause short on the circuit board. However after several times of desoldering and fixation, we finished the soldering process.

The gaps between the hole (traces) and the copper were relatively thin and the solder could easily flowed between traces which causes short. Sometimes the components were not soldered with the board when we tried to avoid putting too much solder onto the hole. One of the biggest issues in iteration 1 we had was that we put too much solder onto the hole when we are soldering the spring loaded pins in the middle. Looking back to the procedure, we established two ways we used to avoid short and produced accurate soldering and utilized them in the power plane firefly project. One of them is enlarging the traces by using knives to scrap the copper surface as figure below shown:

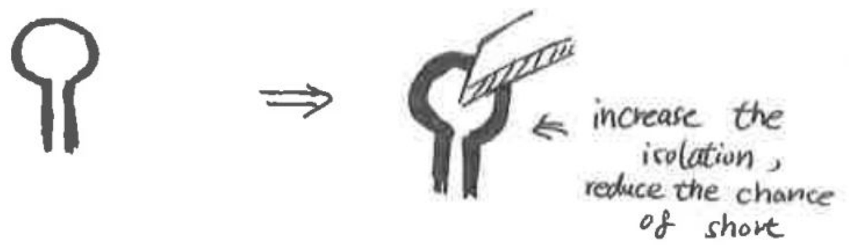


Figure 8. Demonstration of how to enlarge the isolation

Another way is to use the solder iron to heat the wire connected to the component we want to solder on the board. Then touch the solder stick with the wire and the heat transfer from the solder iron though wire into the solder stick and melt them. The process is shown in the figure below:

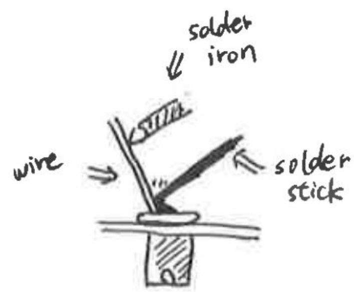


Figure 9. Demonstration of how to do accurate soldering

Debugging:

Debugging:

Stages	Procedures	Possible Issues	Possible Solutions
After Milling	Using multimeter to check connection.	1: Traces not connecting. 2: Short Circuit.	1: Adding a small wire between the two points without connection. 2: Do the milling again.
After Pick and place	1: Comparing the existing board with the ultiboard layout 2: Visual check to make sure every place has decent	1: Components in wrong orientation. 2: Too much solder paste causes short circuit.	1: Removing the components and placing it again. 2: Swiping the extra solder paste.

	amount of solder paste.		
After Reflow Oven	Touching the components on the board to check if they were firmly pasted.	The heavy components such as the big capacitor was not firmly pasted.	Remove the paste and redo the pick and place step.
After Soldering	Using multimeter to check connection.	1: Short circuit between copper board and traces 2: Not connecting	1: Removing the solder using the desolder tape or using knife to cut the solder. 2: Removing the solder using the desoler and placing more solder into the vias.
Functional Test	Stick the firefly board to the big board outside of the Maker E.	1: Not lighting up 2: Cannot be adjusted by Potentiometer 3: Cannot synchronization	1: Connecting the board with the power source and measuring the 4 test points. 2: Check the connection between traces and potentiometer.

Referencing back to the attachment, all of the test points had the desired responses. Attachment 1 is the ground pin, it has 0 volt. Attachment 2 is the Vcc pin, the firefly circuit has input voltage of 9 volt which is consistent with the oscilloscope measurement. Attachment 3 is the trigger test point. Trigger in the 555 timer circuit is dependent on capacitor charge and discharge.

$$V\,trig = V\,c \;=\; V\,cc\,(1 - \; e^{-t/RC}) \qquad \text{Equation (1)}$$

Constant pulses with a difference about 4 volt suggests the trigger point of the 555 timer was functional. Attachment 4 is the Vout pin. It has a constant voltage with a interval of about 3 seconds. This suggests that the RGB LED blinks at roughly 3 seconds.

Conclusion:

This is our second time working on a PCB project and there are a lot space to improve. Since we are not familiar with the functioning and the building process of the board when we start working on it, we made a lot of mistakes during the procedure. There are several points we need to be aware of:

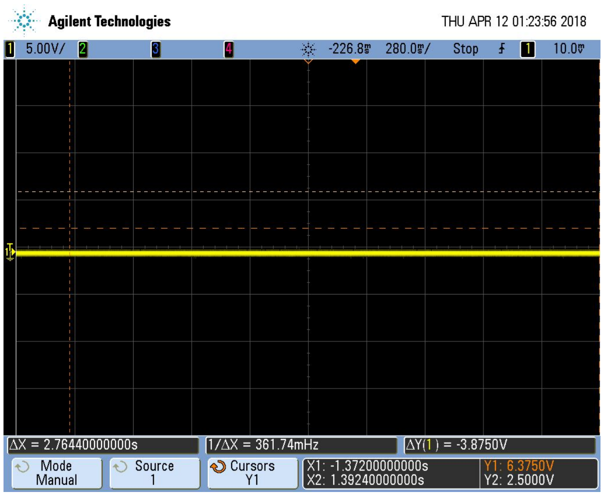
1) Organize the ultiboard layout in a neat way and reduce the amount of vias in the board. This can help to reduce any potential break in the circuit board during milling and help us to avoid making short circuit during soldering process.
2) More precise soldering technique needs to be applied next time when we are working with PCB. We made some short that forced us to resolder and cut the copper. These repairs could help to improve the board performance but also can lead to even severe issues if we couldn't fix the problems.
3) More organized and systematic test and debugging plan should be conducted at each stage of the process. With the limited knowledge on how IR sensor and IR LED, our circuit failure may caused by the misbehave of those two components.

We applied what we have learned from iteration 1 to iteration 2. We reduced more than 15 vias than we have in iteration 1. And the whole fabrication process is a lot more efficient in iteration. However, there are still a lot to improve. For instance, we can even reduce how vias and wires. We made reflection about things that we need to improve and concluded some techniques that could help us to finish our next team project in a neat and efficient way. The most important thing is to criticize and reflect our performances on this class and applied the useful experience onto our senior design.

Reference:

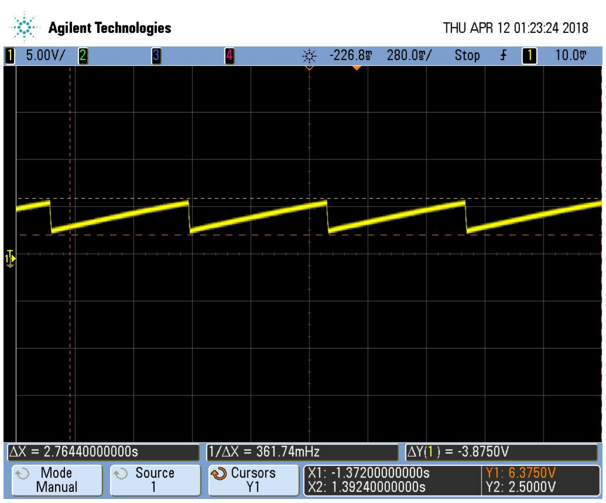
1. Texas Instruments, "LM555 Timer," SNAS548D datasheet, Feb. 2000 [Revised Jan. 2015].
2. Bucknellmakers.dozuki.com. (2018). *CAS – Central Authentication Service*.
3. YouTube. (2018). *Beginner how to Solder*.

Attachments:

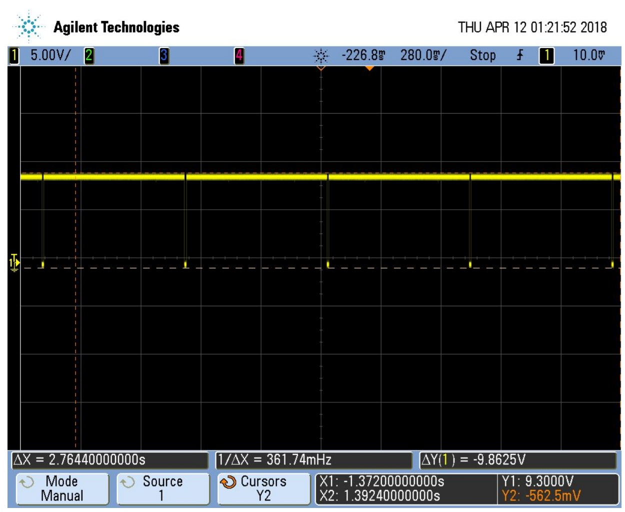


Attachment 1: Oscilloscope Display for GND(U11)

Attachment 2: Oscilloscope Display for Vcc(U12)



Attachment 3: Oscilloscope Display Trigger(U14)



Attachment 4: Oscilloscope Display for for Vout(U13)