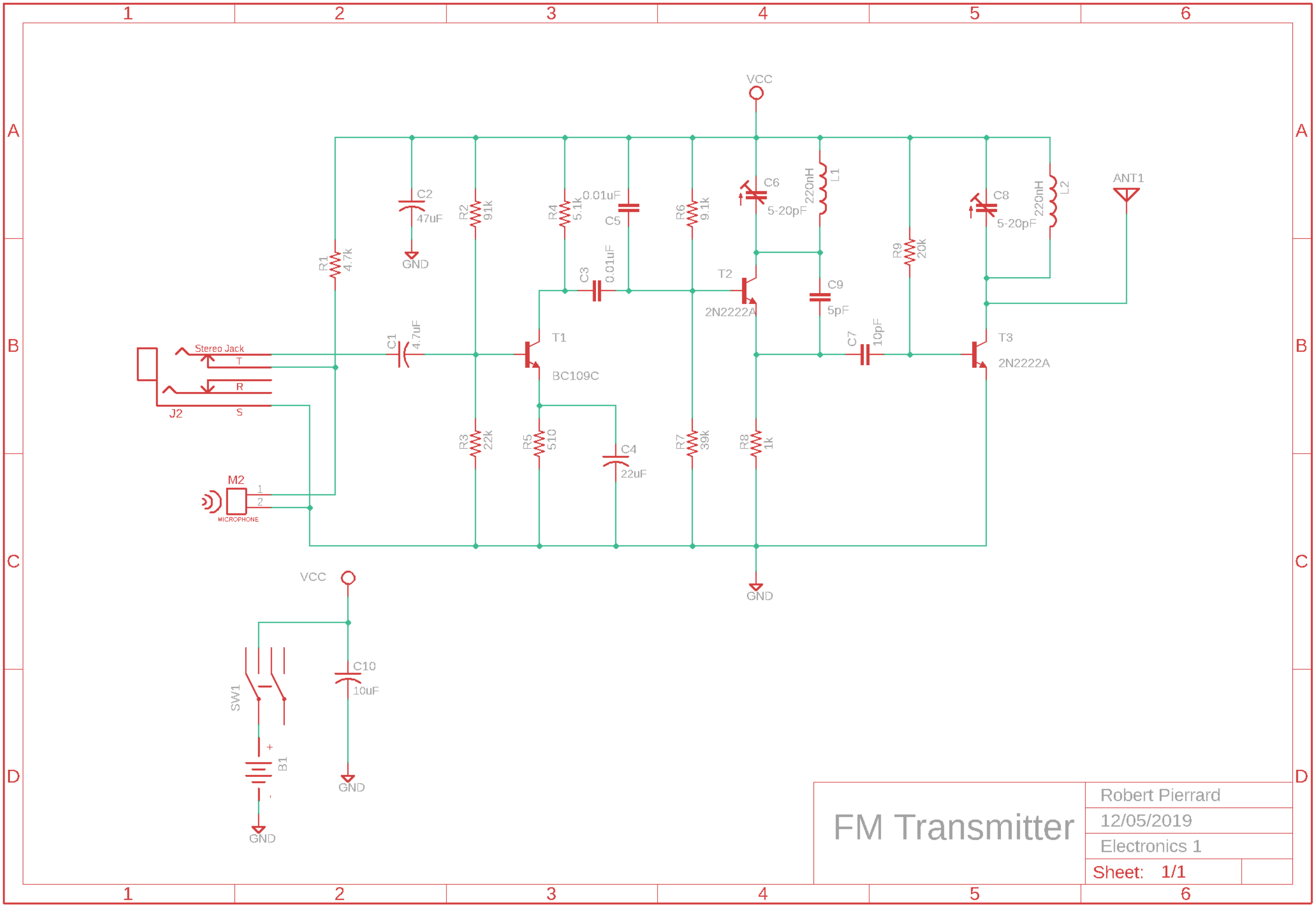
FM Transmitter

Electronics 1 Project

Robert Pierrard


VCC
C2
47uF
GND
R2
91k
R4
5.1k
0.01uF
C5
R6
9.1k
C6
5-20pF
220nH
L1
C8
5-20pF
220nH
L2
ANT1
R1
4.7k
C3
0.01uF
T2
2N2222A
C9
5pF
R9
20k
C1
4.7uF
T1
BC109C
C7
10pF
T3
2N2222A
Stereo Jack
T
R
S
J2
R3
22k
R5
510
C4
22uF
R7
39k
R8
1k
M2
1
2
MICROPHONE
GND
VCC
SW1
C10
10uF
B1
+
-
GND
GND
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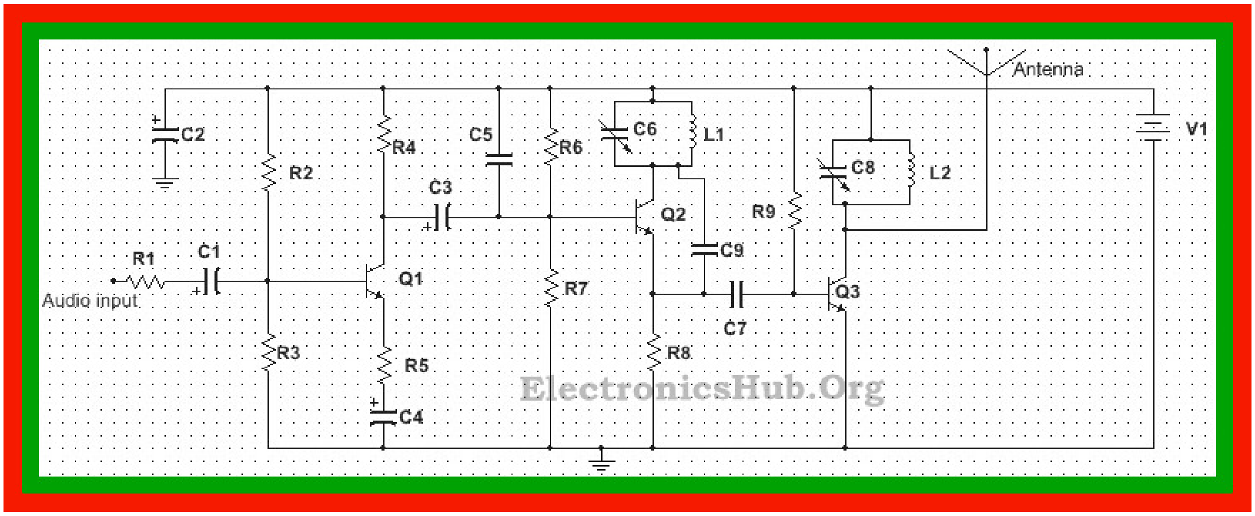
Source:

The design for this circuit was sourced online at electronicshub.org. The link for their FM transmitter is as follows:

https://www.electronicshub.org/fm-transmitter-circuit/#Selection_of_Antenna

On their page your will find a similar circuit schematic to the one above. Their writing serves as a good reference for general design choices and for how the circuit works. The schematic found on their page is included below.



Functional Description:

The overall purpose of this circuit is to take an audio input signal and transmit it over the radio frequencies so that a receiver can detect the transmission and convert it back to the original audio signal. In this circuit, the audio input comes from a standard 3.5mm audio jack and the antenna is routed as a winding circle on the PCB itself. In order to confirm its successful operation, a radio must be used, as will be discussed later.

Initial Power Amplifier:

There is a great problem with transmitting the input audio signal as is, it is a very low-level signal. As such, the signal must first be amplified. This is done using an NPN bipolar transistor in a basic common emitter configuration, as illustrated below. Resistors 2-5 are all DC bias resistors that produce the desired quiescent operating point voltages for T1. In this circuit, we are aiming for DC collector current of about 1mA. Further, we are setting the collector voltage to be around 4.5V. Therefore, the collector resistor can be calculated as follows:

$$I_c = 1mA$$

$$\frac{V_{cc}-V_c}{I_c} = R_c = R_4 = 4.5$$

Resistors 2 and 3 work together to serve as a voltage divider, setting the base voltage of T1. Using a PN junction voltage of 0.7V and setting the emitter voltage to be 1V, the base voltage is therefore 1.7V.

Further, approximating the current the bias current through resistors 2 and 3 to be ten times the base current, we can calculate R2 and R3:

$$V_b = V_E + V_{PN} = 1.7V$$

$$I_b = \frac{I_c}{h_{FE}} = \frac{1mA}{125} = 0.008mA \qquad I_{bias} = 10I_b = 0.08mA$$

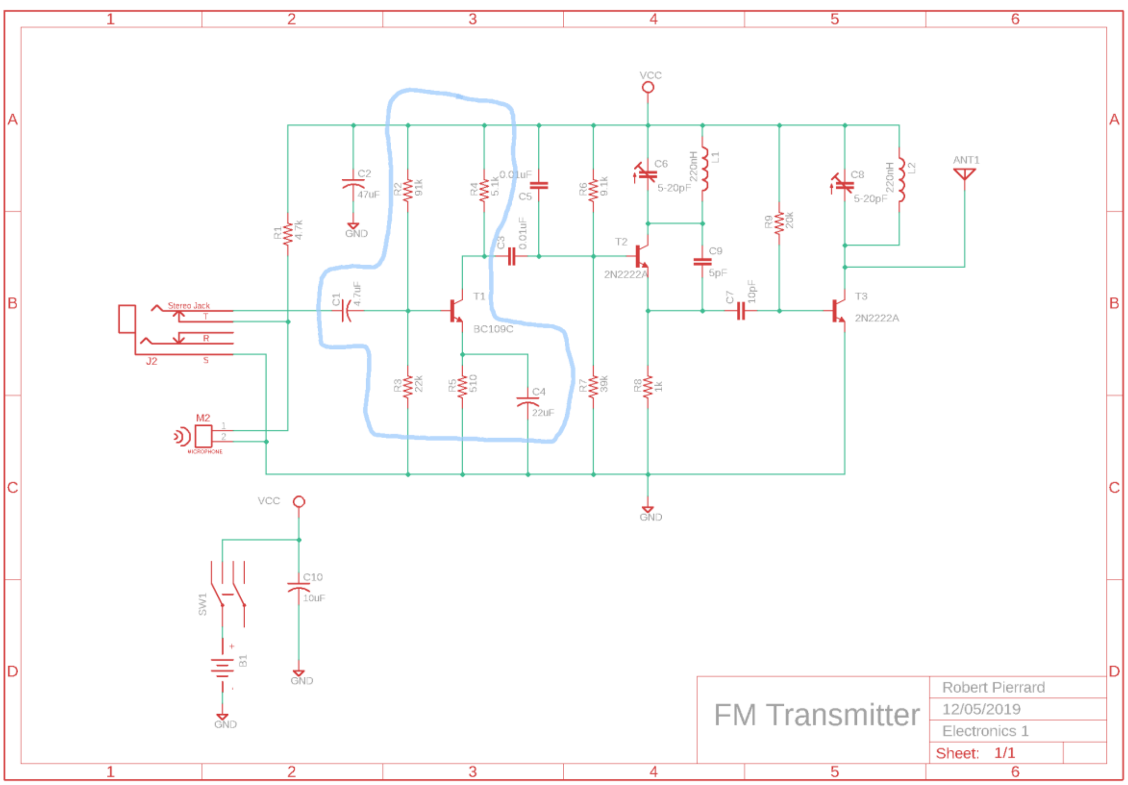
$$R_2 = \frac{V_b}{I_{bias}} = \frac{1.7V}{0.08mA} = 22.25k \qquad R_3 = \frac{V_{cc}-V_b}{I_{bias}} = 90.1k$$

The value for resistor 5 is simply such that the collector current is equal to the emitter current.

$$R_5 = 540\Omega$$

Capacitor 1 is used to add frequency dependence to the input signal. Higher capacitor values will permit low frequencies better than high frequencies, and vice versa. Therefore, a midrange value of 4.7uF was used. This capacitor also serves as a DC barrier between the audio input and the circuit.

Capacitor 4 is added so that high frequency signals, such as the audio input, can bypass resistor 5 with very low impedance.



Oscillator Circuit:

The second part of this circuit is to generate a carrier frequency that the signal will be transmitted on. This carrier signal is the radio frequency that a radio would tune to in order to receive the signal. This generated frequency should be completely stable; however, when combined with the audio input signal it becomes a frequency modulated signal which transmits information.

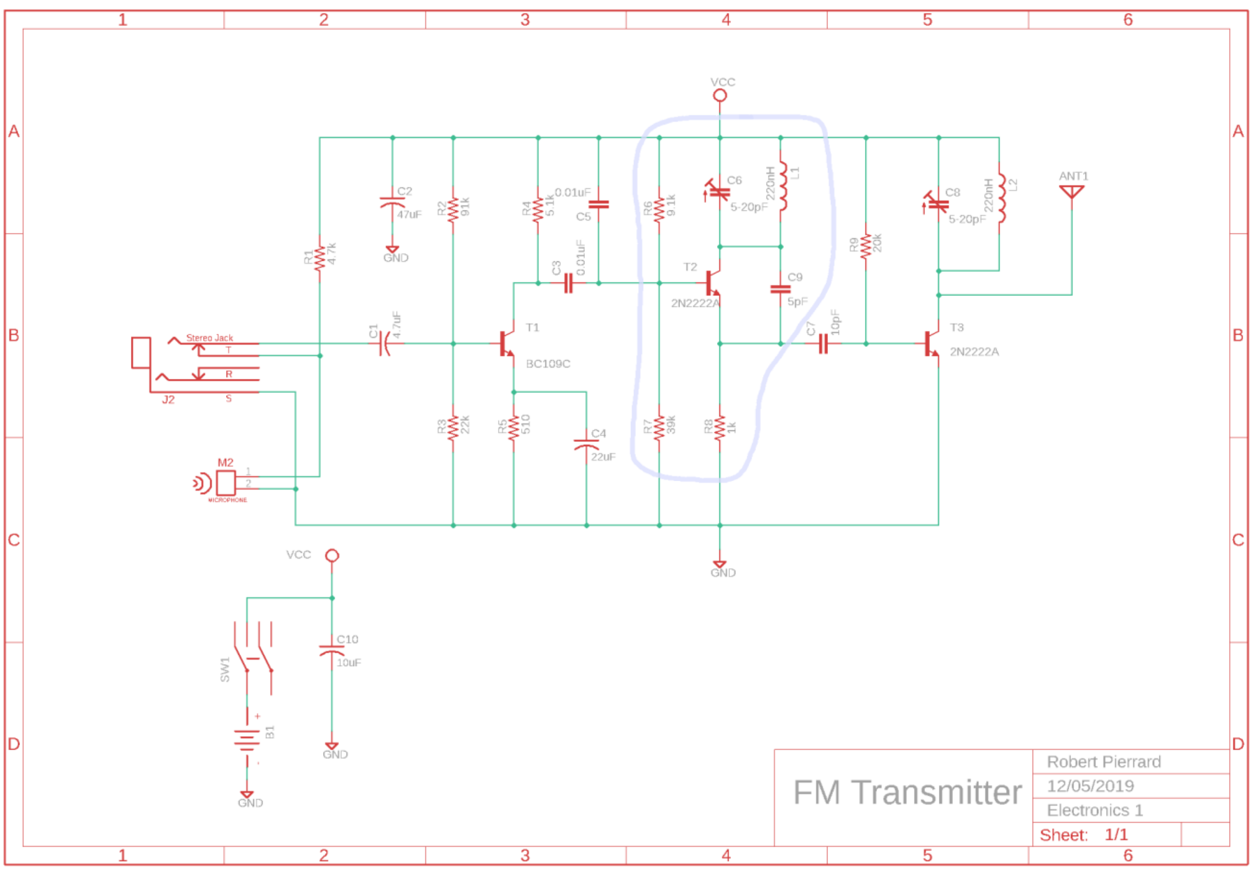
For the tank circuit components inductor 1 and capacitor 6, we know the frequency at which they will oscillate is given by the formula:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

If we decide to use a 0.2uH inductor, capacitor 6 must be around 12pF. Therefore, we will use a variable capacitor between 5 and 20pF.

Capacitor 9 function to keep the circuit vibrating. Its desired value for a tank circuit is dependent on the transistor being used. Since we are using a 2N222, we will set it to 5pF.

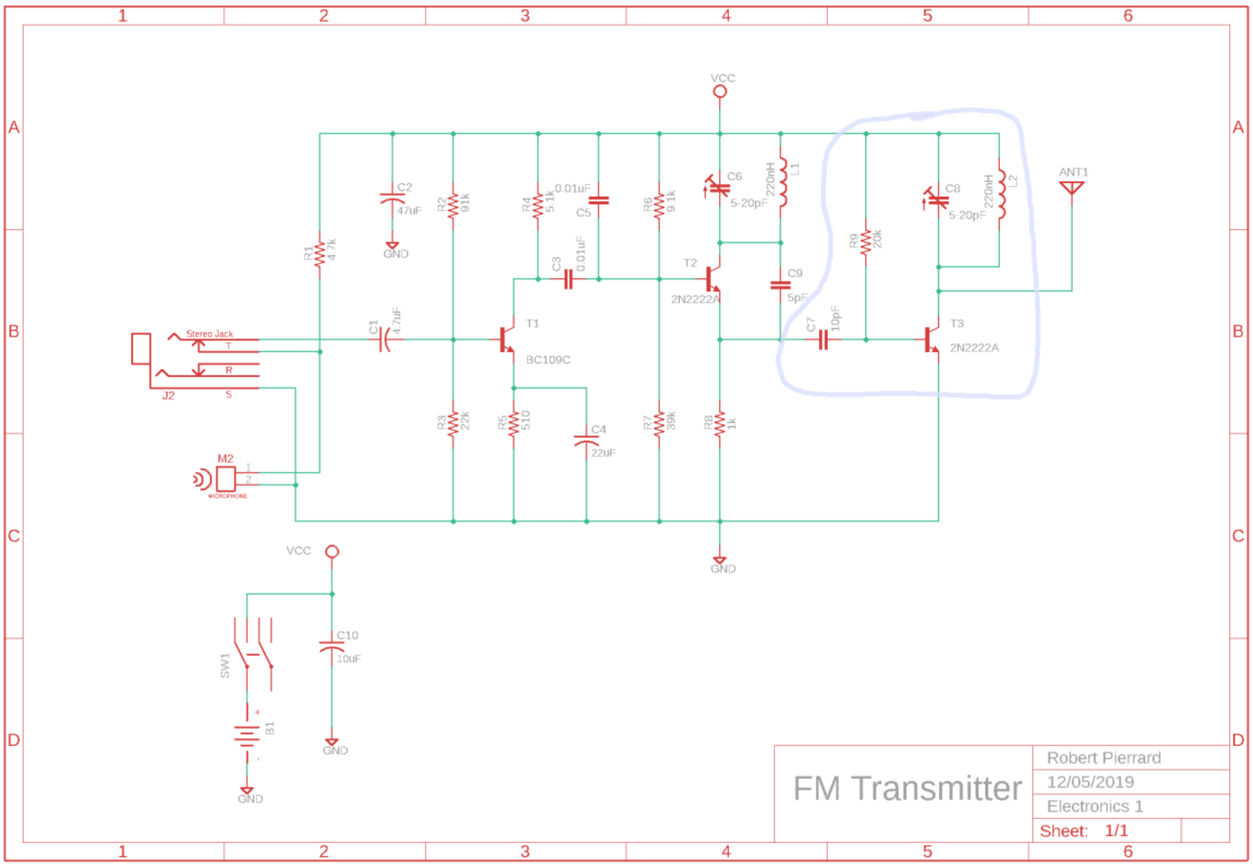
Resistors 6, 7, and 8 were set with the same techniques used for the power amplifier circuit. Using those techniques, we arrive at the values of 9k, 40k, and 1k for resistor 6, 7, and 8 respectively.



Final Power Amplifier:

While the original audio input signal has already been amplified, the combined audio and carrier signal still must be amplified further. Using another LC tank circuit at the emitter of T3, we can create a low power output. The values for capacitor 8 and inductor 2 should be the same as capacitors 6 and inductor 1.

In order to set the DC operating point of T3, an additional coupling capacitor is used. Further, the value of resistor 9 is 20k. This was again derived using the same techniques as the initial power amplifier.



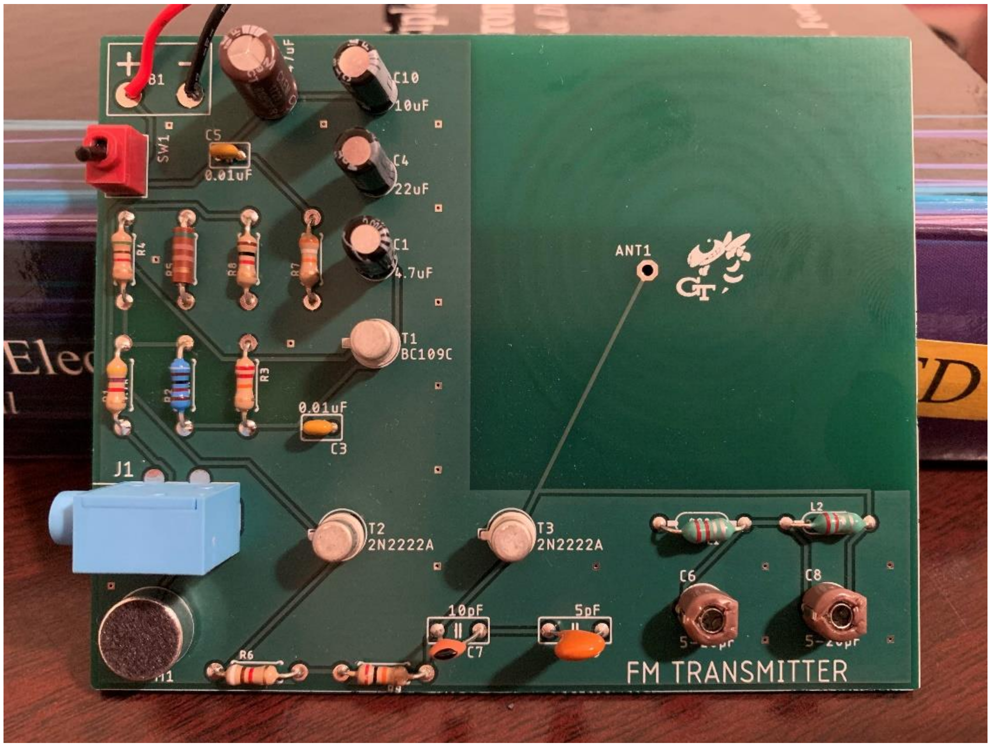
Antenna:

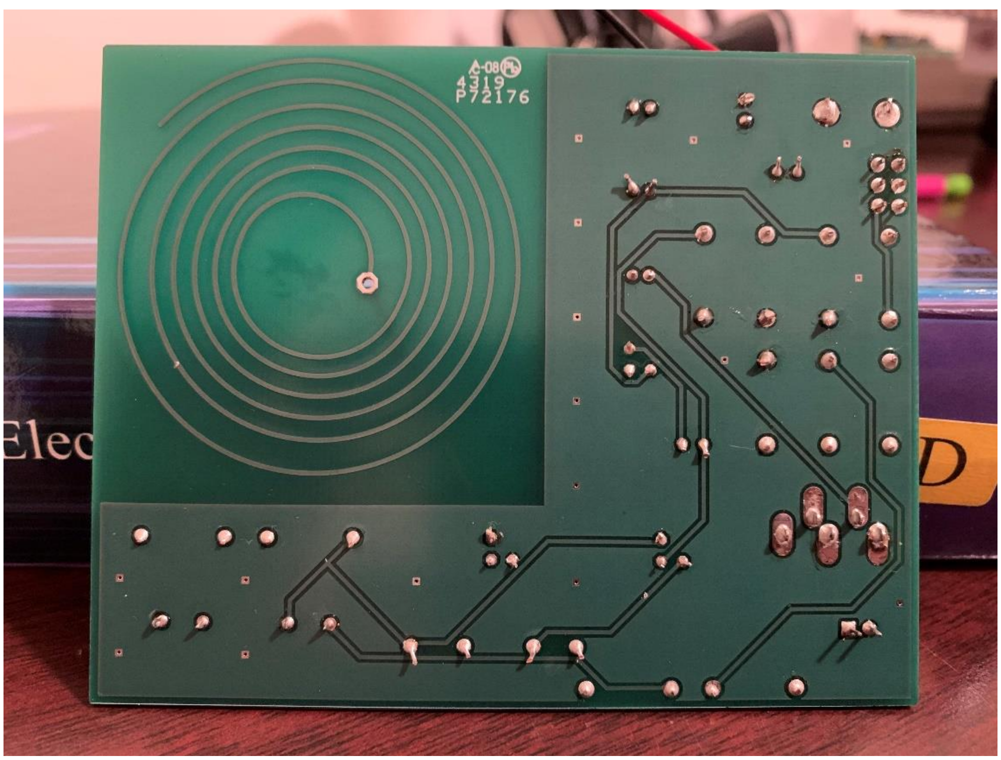
The antenna for this circuit is etched directly onto the PCB. Its total length is approximately 30 inches. This length was chosen so that it is a clean fraction of the total wavelength of the operating frequency, which is approximately 120 inches. Therefore, the antenna is 1/4th the length of the transmitting wavelength.

Power Supply:

The Power Switch simply serves to connect and disconnect the 9V battery power supply from the circuit. Although the power supply is solely DC, Various capacitors such as capacitors 2 and 10 serve to eliminate any AC signals in the power line generated by the oscillators.

Images of the Finished PCB:





Instructions for Operation:

Due to this circuit having no digital display for the frequency of the carrier frequency, it is difficult to operate without an oscilloscope connected to the antenna. It is very difficult to find the appropriate frequency, or adjust that frequency, without any reference. Additionally, for a clean output waveform to be produced, capacitors 6 and 8 must be trimmed to the same value. Since they can be turned independently, it is difficult to know when they are the same value without directly looking at the shape of the output signal on the oscilloscope.

Assuming access to an oscilloscope, operation of this circuit is somewhat straightforward. First, connect a 9V battery to the power terminals and flip the switch upwards (towards the power terminals, away from the audio jack). Next, play any type of audio signal through the audio jack. This signal can be music from your phone, laptop, or any other audio device.

Now it is time to tune the output frequency. Connect the oscilloscope to the antenna and observe the shape of the waveform. If it is not clearly sinusoidal, adjust only one of the variable capacitors until it is. Once the signal is sinusoidal, observe the frequency. This is the current broadcast signal of the FM transmitter. If you tune a radio to this frequency, in megahertz, then you should be able to hear the audio signal playing through your radio speakers. However, there is a good chance that this frequency is already being occupied by a local radio station. Therefore, you must be able to tune the output frequency of the FM transmitter.

Within a small range, you can adjust the broadcast signal by changing only one of the variable capacitors. However, if you tune a capacitor too far in one direction, then you will quickly see the waveform become distorted on the oscilloscope, and thus rendered useless. Nevertheless, you can adjust only one capacitor for fine tuning. For greater variation in output frequency, both capacitors must be adjusted by the same amount. This will change the output frequency according to the formula previously discussed:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Once the transmitted frequency is close to the radio frequency, you should be able to hear the audio signal coming through. From there, the signal can be made clearer by adjusting the receiver frequency by simply changing the radio station, or by adjusting the transmitter frequency as explained above. Be wary, by adjusting the capacitors it is very easy to scan right past the target radio station. If going too fast, you may only hear a slight pop instead of your favorite music.