FM Transmitter Project

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Overall Design

The audio signal is input into the modulator/oscillator, where the input signal modulates the carrier signal. The modulated signal is then input into a common emitter amplifier and where it is amplified and is then input into the antenna. The antenna transmits the signal to a receiver, where the signal is demodulated and turned into audible sound.

$$\textit{Input Audio Signal} \rightarrow \textit{Modulator} \rightarrow \textit{Carrier Wave} \rightarrow \textit{Amplifier} \rightarrow \textit{Antenna}$$

$$\downarrow$$

$$\textit{Antenna} \rightarrow \textit{Demodulator} \rightarrow \textit{Amplifier} \rightarrow \textit{Speaker}$$

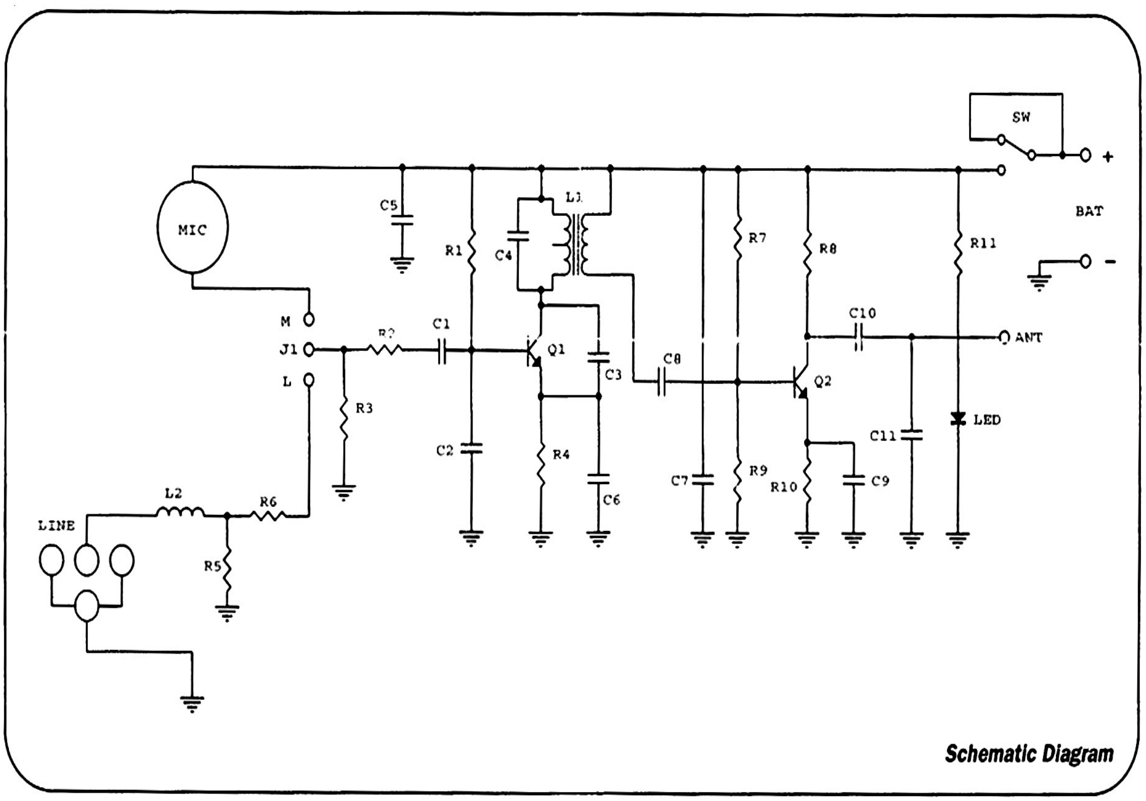

Illustration 1: Design by CanaKit

LC circuit

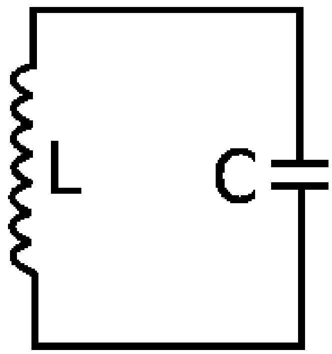

Illustration 2: LC resonance circuit

Courtesy of wikipedia.org

In our FM transmitter, a key element in the operation of the whole circuit is the functioning of the LC circuit. An LC circuit requires an inductor (L), and a capacitor (C), in order to operate. These are usually placed in parallel with each other. When a current is allowed to flow through the circuit, the capacitor will store a certain amount of energy in the electric field between its two plates and will build up a positive charge on one plate and a negative charge on the other. When a capacitor is connected across an inductor, the current is allowed to flow through the inductor and back to the capacitor. This is the basic construction of the circuit.

The current will flow from the positively charged side of the capacitor into the inductor where it will create a magnetic field. The inductor will store the energy transferred from the electric field in the capacitor in its magnetic field which is created by the flow of current in the inductor. The inductor consists of a coil of wires which will cause a magnetic field to be created in the direction opposite of the inward flow of current. Eventually, all of the energy that was originally stored in the capacitors electric field will be transferred to the magnetic field of the inductor, but the current will continue to flow through it and back towards the other plate of the capacitor. With the current continuing to flow it will begin to positively charge the other plate of the capacitor which was originally the negatively charged side. The electric field in the capacitor will again begin to gain energy with the increasing charge being built up on the positive plate. This energy is being transferred back into the electric field from the magnetic field of the inductor which is losing energy as the capacitor is gaining it. Once all of the energy has been transferred back into the capacitor's electric field the plates charges have switched from what they were originally and the current will begin to flow back through the inductor in the opposite direction. This process happens extremely fast and continues to oscillate in this fashion. The frequency of the oscillation is:

$$F_{resonance} = \frac{1}{2\pi\sqrt{LC}}$$

The inductance of the variable inductor when the circuit is tuned to 106.5 MHz is:

$$106.5\text{x}10^{6}\,Hz \approx \frac{1}{2\pi\sqrt{(6\text{x}10^{-12}\,F * L)}}$$

$$L \approx \frac{\left(\frac{1}{106.5\text{x}10^{6}\,Hz * 2\pi}\right)^{2}}{6\text{x}10^{-12}\,F} \approx 3.7\text{x}10^{-7}\,H$$

The oscillation will continue until the circuit is unhooked from an external power supply or until the internal resistance makes the transfer stop. In our transmitter design, the Q1 transistor described below, connected across this LC circuit acts as a voltage controlled oscillator. When the audio signal comes into the transistor, the transistor is turned on and off very quickly. The difference in the input waves changes the capacitance of the LC circuit, and in turn changes the circuit's oscillation rate. This is how the frequency is modulated in accordance with the input signal.

Transistor

The second major component of the radio design is a transistor. Transistors basically function as an electrical switch. This design uses NPN transistors, which are bipolar. The NPN consists of three terminals, the B (base), E (emitter), and C (collector).

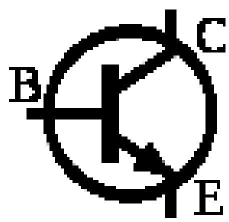

Illustration 3: NPN Transistor Digram

Courtesy of wikipedia.org

The transistor is turned "on" when the base receives a current relatively high compared to the emitter. When the transistor is turned on, the collector and the emitter are electrically connected. The small base current controls a much larger collector current. This type of transistor can be used as an amplifier, and in fact the design of this project uses transistor Q2 in this fashion.

Transistor Q1 receives a signal either from the microphone or from the line in. The mic is grounded by C5. The line in is grounded by R5 and the inductor coil L2 is used to make sure the circuit is not overdriven by the signal coming in from the line. The audio input is selected by the jumper circuit and coupled by capacitor C1 to the base of Q1. Only and AC signal can pass from the audio input to Q1. C7 is a feedback capacitor. The audio signal turns the transistor Q1 on and off. Part of the time, the transistor is off, and creates a small amount of capacitance (1.7 pF according to the data sheet) between the collector and the emitter. When the transistor is turned on, this capacitance disappears, altering the overall capacitance of the oscillating circuit. This action modulates the sinusoidal signal produced by the LC circuit. The frequency of the carrier wave generated by the LC oscillator is either increased or decreased by the audio signal without affecting the amplitude of the carrier wave. Hence, this is called frequency modulation, or FM.

Transistor Q2 receives the transmission signal from the LC circuit via C8, which is a coupling capacitor. This capacitor blocks any DC signal from being transferred between the LC circuit and the amplifier circuit. It only allows an AC signal to be transferred. Q2s base is grounded by C7.

Analysis of transistor Q2, used in a common emitter amplifier circuit:

$I_{base}=0, R_{CE}=\infty, \text{transistor is off}$

$I_{base}=small, R_{CE}=small, \text{transistor is partially on}$

$I_{base}=large, R_{CE}=0, \text{transistor is completly on}, (\text{fully staturated})$

$$I_E=I_C+I_B$$

Since I_C is much larger than I_B,

$$I_E=I_C$$

$$V_C=V_{cc}-R8*I_C$$

The current gain is:

$$h_{FE}=\frac{I_C}{I_B}$$

The voltage gain is:

$$A_v = \frac{R_8}{R_{10}} = \frac{470\,\Omega}{4.7\,\Omega} = 100$$

Antenna

The signal from the amplifier is output to a piece of wire that functions as a Marconi antenna. The antenna is a dipole antenna, one element being the wire and the other being the ground. The antenna is optimized to transmit at 90 MHz. This is the calculation of the optimal length of the antenna that is used to transmit at 90 MHz:

$$\lambda = \frac{c}{f} = \frac{3\text{x}10^{10}\,m/s}{90\text{x}10^{6}}\,Hz = 3.33\,m$$

The optimal length of the antenna is ¼ the length of the wave length, the ground provides the other ¼ wavelength required for the antenna to resonate.

$$\frac{3.33\,m}{4} = .83\,m$$

The optimal length of the antenna for transmitting at 106.5 MHz is:

$$\lambda = \frac{c}{f} = \frac{3\text{x}10^{10}\,m/s}{106.5\text{x}10^{6}}\,Hz = 2.8\,m$$

$$\frac{2.8\,m}{4} = .704\,m$$

FM Modulation

The LC circuits provides a carrier signal at 106.5 MHz. The audio signal is then encoded in the carrier wave through frequency modulation. The carriers amplitude is not altered, bu the frequency is. The alteration in the carrier waves frequency is proportional to the input signals amplitude. There are many different ways to demodulated an FM signal, but a common one is Foster-Seeley discriminator. The receiver takes the modulated signal as the input and feeds it to an oscillator circuit tuned to the carrier frequency. The differences between the modulated signal and the carrier signal generate variations in amplitude of the resultant wave. The variations are then detected by a rectifier and a low pass filter, and the original signal can be extracted.

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