

## Single Transistor FM Transmitter Design

In telecommunications, frequency modulation (FM) conveys information over a carrier wave by varying its frequency. FM is commonly used at VHF radio frequencies for high-fidelity broadcasts of music and speech. Throughout the world, the broadcast band falls within the VHF part of the radio spectrum. Usually 87.5 - 108.0 MHz is used to transmit and receive the FM signals. Designing and assembling an FM transmitter is a difficult task. The Note given here explains how a simple FM transmitter is designed and assembled.

### Design Considerations

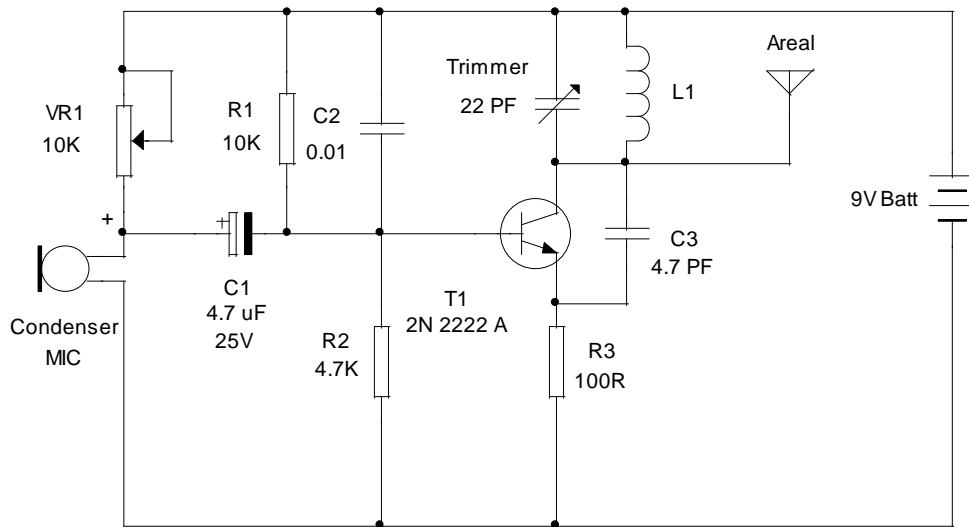
The performance of an FM transmitter depends on two important aspects.

1. Tuning of the FM transmitter to the desired frequency. Even a slight change in the coil specification or slight change in the variable capacitor value can shift the harmonic frequency instead of the 88-108 MHz FM band.
2. Length of the Antenna used to transmit the frequency.

The important parameters for the optimum performance of an FM transmitter are :

1. Transmitter frequency, output power and range of transmission.
2. Antenna length.
3. Coil diameter, length, number of turns and gauge of the wire used for coil winding.

The circuit diagram shown below is that of a Single transistor FM transmitter with a range of 30-50 feet and 100 – 125 milli watt output.



L1 Air Core Coil

Coil Specification - 5 Turn 22 SWG Enameled Copper Wire

Coil Length 0.25 Inch - Diameter 0.265 Inch

The design details of each component are as follows.

### 1. Condenser MIC

The condenser MIC is used to pick up the sound signals. The diaphragm inside the MIC vibrates according to the air pressure changes and generates AC signals. Variable resistor VR1 adjusts the current through the MIC and thus determines the sensitivity of MIC. The condenser MIC should be directly soldered on the PCB to get maximum sensitivity. Sleeving the MIC inside plastic tubing can increase its sensitivity enormously.

### 2. Decoupling Capacitors

C1 is the first decoupling capacitor impedes the different frequencies of speech signals. C1 modulates the current to the base of transistor. The 4.7 uF capacitor isolates the microphone from the base voltage of the transistor and only allows alternating current (AC) signals to pass.

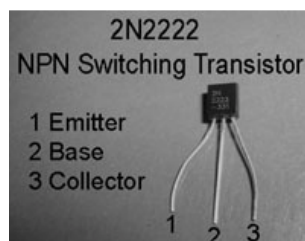
A large value capacitor induces bass (low frequencies) while a low value one gives treble (high frequencies). Capacitor C2 (0.01) act as the decoupling capacitor. Capacitor C3 across the transistor T1 keeps the tank circuit vibrating. As long as the current exists across the inductor coil L1 and the Trimmer capacitor, the tank circuit (Coil-Trimmed) will vibrate at the resonant frequency. When the tank circuit vibrates for long time, the frequency decays due to heating. Presence of the capacitor C3 prevents this decay. A capacitor between 4 and 10 PF is necessary.

### 3. Resistors

Variable resistor VR1 restricts the current through the MIC. The voltage divider R1 and R2 limits the base current of T1 and R3 forms the emitter current limiter. The given values are necessary for the 2N 2222A transistor.

### 4. Transistor

2N 2222A is the common NPN transmitter used in general purpose amplifications. It has maximum power rating of 0.5 Watts. Over powering of 2N 2222A can generate heat and destroy the device. So maximum power output should be around 125 milli watt. Pin assignment of 2N 2222 A is 1 Emitter - 2 Base - 3 Collector (EBC) from the front side (Flat side on which the number is printed).



## 5. Inductor Coil

The inductor used in the circuit is a hand made coil using 22 SWG (Standard Wire Gauge) enameled copper wire. The length, inner diameter, number of turns etc are the important parameters to be considered while making the inductor. Then only the inductor resonates in the 88-108 band FM frequency. For this circuit, the coil radius was selected as 0.26 inches (outer diameter) and 0.13 inner diameter. Coil can be wound around a screw driver (with same diameter) to get a 5 turn coil of 0.2 inch long. Remove the coil from the screw driver and use the 5 turn Air core coil. Remove the enamel from the tips and solder close to the transistor.

The inductance of the coil can be calculated using the formula

$$L = n^2 r^2 / 9r + 10 x$$

Where r is the inner radius of the coil, x is the length of the coil and n, number of turns. The resulting value is in Micro Henry.



## 6. Trimmer capacitor

A small button type variable capacitor with a value of 22 pF can be used to adjust the resonant frequency of the tank circuit. The variable capacitor and the inductor coil form the Tank circuit (LC circuit) that resonates in the 88-108 MHz. In the tank circuit, the capacitor stores electrical energy between its plates while the inductor stores magnetic energy induced by the windings of the coil. The resonant frequency can be calculated using the formula

$$f = 1 / 2 \pi \sqrt{LC} = \text{Hz}$$

Where f is the frequency in hertz, x is the coil length, C is the capacitance of trimmer in Farads, and L is the inductance of coil in Henry.

### Tank Circuit

Every FM transmitter needs an oscillator to generate the radio Frequency (RF) carrier waves. The name 'Tank' circuit comes from the ability of the LC circuit to store energy

for oscillations. The purely reactive elements, the C and the L simply store energy to be returned to the system. In the tank (LC) circuit, the 2N 2222 A transistor and the feedback 4.7 pF capacitor are the oscillating components. The feedback signal makes the base-emitter current of the transistor vary at the resonant frequency. This causes the emitter-collector current to vary at the same frequency. This signal fed to the aerial and radiated as radio waves.



## 7. Antenna

A plastic wire or Telescopic aerial can be used as antenna. The length of the antenna is very important to transmit the signals in the suitable range. As a rule, the length of the antenna should be  $\frac{1}{4}$  of the FM wave length. To determine the length of antenna, use the following equation.

By multiplying the Wave frequency and wave length will give the speed of light.

**Speed of Light = Frequency of Oscillation x Wavelength = in Kms/ Sec**

**Wave length = Speed of light / Frequency = in meters**

**Antenna length = 0.25 x wavelength = in meters**

By using this formula it is easy to select the antennal length. For the circuit mentioned above, a 25-27 inches long antenna is sufficient.



## Assembling and Testing

The circuit can be assembled on a Dot type common PCB or Perf board. The following tips should be considered while assembling the circuit

1. Assemble the components as close as possible, especially the transistor, trimmer and coil to prevent unwanted oscillation.
2. Lead length of capacitors, resistors, transistor should be as small as possible.
3. Solder the MIC directly on the PCB ( use the trimmed leads of the resistors to connect MIC)
4. Observe the polarity of MIC.
5. Check the pins of 2N 2222 A. The pin assignment is E-B-C (Emitter – Base – Collector) from the front side (Flat side on which the number is printed).
6. Coil should stand horizontally above the Emitter of transistor.
7. Coil should be closely wound.

### **How to test**

After assembling the circuit, connect 9 volt battery. A battery operated FM pocket radio is necessary for testing. AC powered FM players will give lesser performance than the battery powered FM receivers due to noise. Tune the FM receiver to a “Dead Air space” (around 108 MHz where there is no station). Place the FM radio 2 feet away from the transmitter. Gently tap on the MIC. If the tank circuit is properly tuned, tapping sound will be heard in the radio. If no sound is heard, slightly pull the coil to separate the windings. Adjust the shaft of the Trimmer slowly with a preset screwdriver. Check again. If the sound is clear, move the FM radio and assess the range. Try again by adjusting the trimmer and position of aerial of both transmitter and FM radio. If the sound clarity is good and there is sufficient range, stick the coil with nail polish or glue to avoid frequency change. The FM transmitter is ready to use.