BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

Course No. : EEE 310

Course Title : Communication Systems I Laboratory

Name of the Project : FM Transmitter

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Date of Submission : 25/02/2023

Objectives

1. To understand the basic principles of FM transmission and the various components used in an FM transmitter.
2. To design and build a functional FM transmitter circuit that can transmit audio signals over a radio frequency band.
3. To test the FM transmitter and ensure that it meets the design specifications for output power, frequency stability, and signal quality.
4. To investigate the factors that affect the performance of an FM transmitter, such as antenna design, circuit layout, and power supply stability.

FM Transmitter

Transmitters are said to be electronic units that accepts the information signal to be transmitted and converts it into Radio Frequency signal capable of being transmitted over long distances. FM transmitter is basically a frequency modulated transmitter.
Here, a technique called frequency modulation was introduced to ensure the transmission of signals over long distance.

Frequency Modulation

FM transmission is a modulation technique in which the frequency of a carrier wave is varied according to the amplitude of a modulating signal. The modulating signal is typically an audio signal, such as music or speech. The basic principle of FM transmission can be explained using the following equations:

$$\mathrm{f_i(t)} = f_c + k_f m(t)$$

$$k_f = frequency\ sensitivity\ factor\left(\frac{Hz}{volt}\right)$$

$$\theta_i(t) = 2\pi \int_0^t f_i(\tau)d\tau = 2\pi f_c t + 2\pi k_f \int_0^t m(\tau)d\tau$$

Frequency-modulated signal:

$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau)d\tau\right]$$

Here, s(t) is FM Signal which’s frequency depends on the message signal’s amplitude.

Equipment:

Necessary equipment used for this project are:

a. Resistors: 3 units of 10kΩ, 1 unit of 1MΩ, 1unit of 100kΩ, 1unit of 100Ω, 1 unit of 1kΩ
b. Capacitors: 0.1µF(2 pieces), 0.01µF, 4.7pF and one 20pF variable capacitor.
c. Inductors: 10 pieces of 1µH
d. BJTs: 2 pieces of 2N222 npn transistor
e. Microphone: 1 unit Condenser Mic
f. Antenna: A piece of spiral shaped copper wire
g. Printed circuit board
h. Jumper wires
i. Oscilloscope
j. Multimeter
k. Soldering iron

Circuit Diagram:

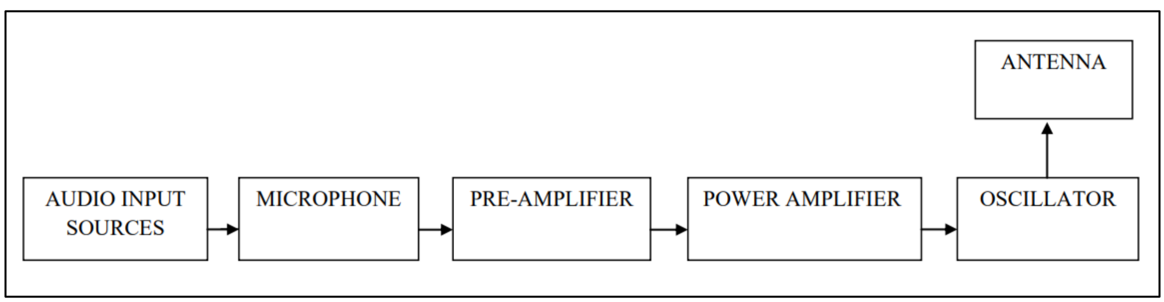


Figure: Block Diagram of FM Transmitter

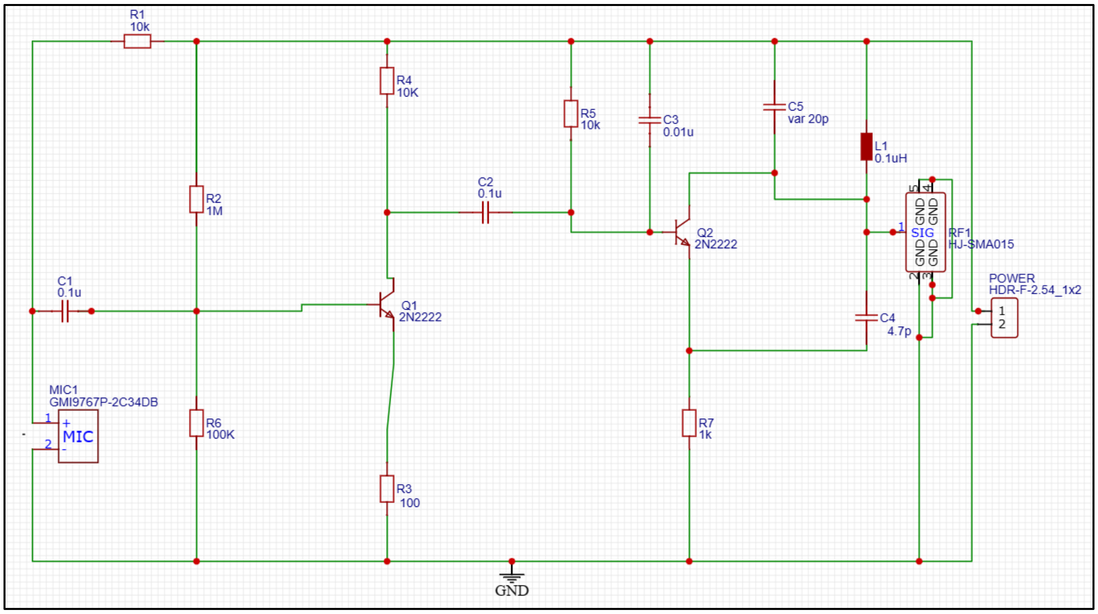


Figure: Designed PCB of FM Transmitter

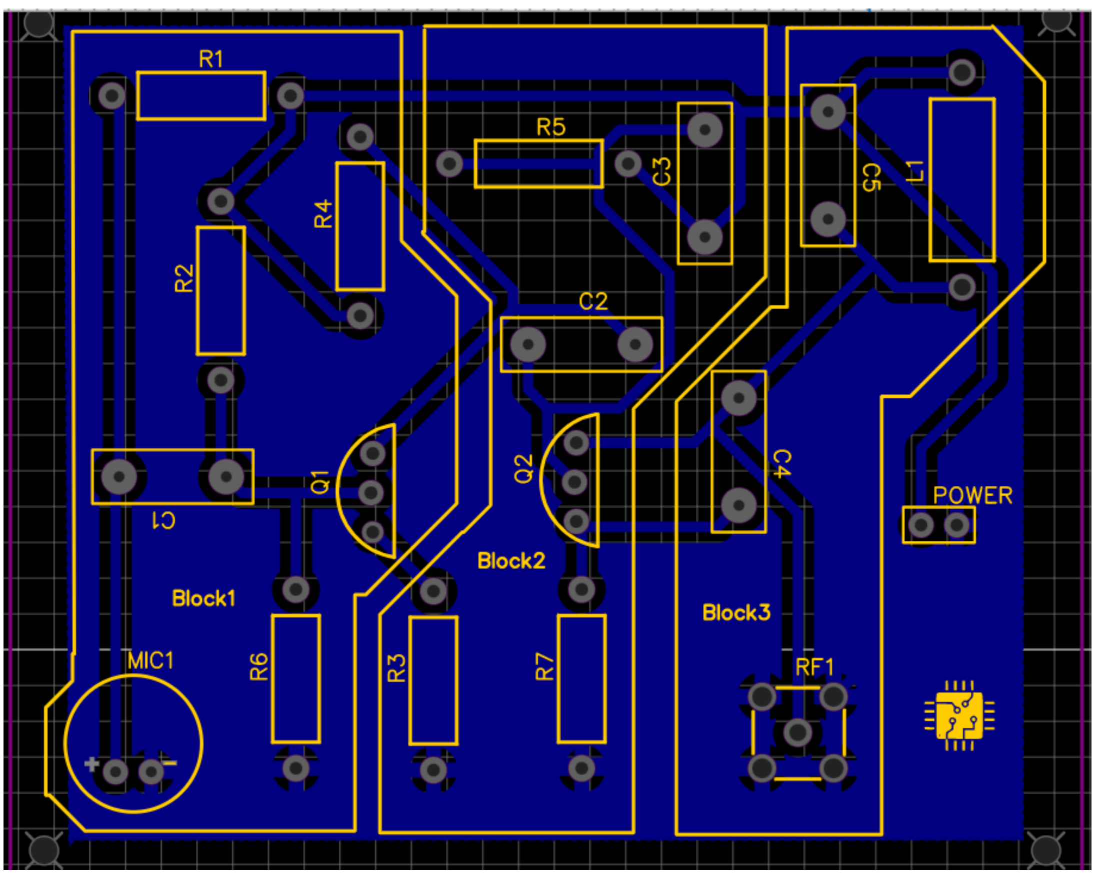


Figure: PCB layout

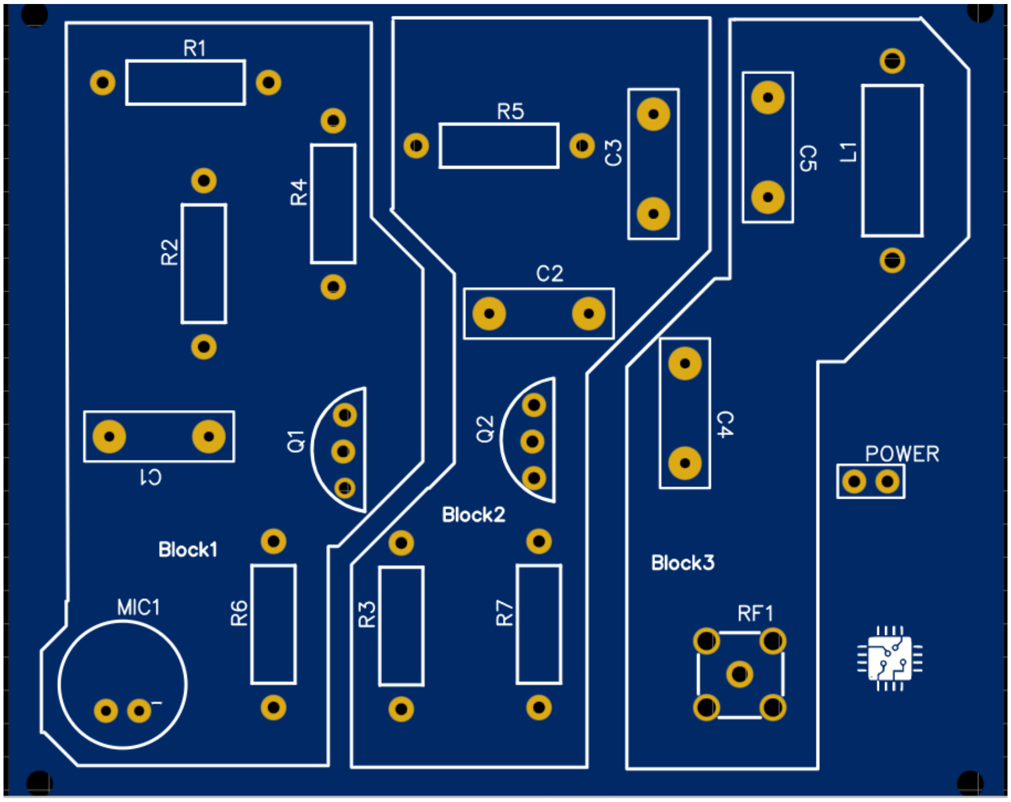


Figure: 2D view of PCB

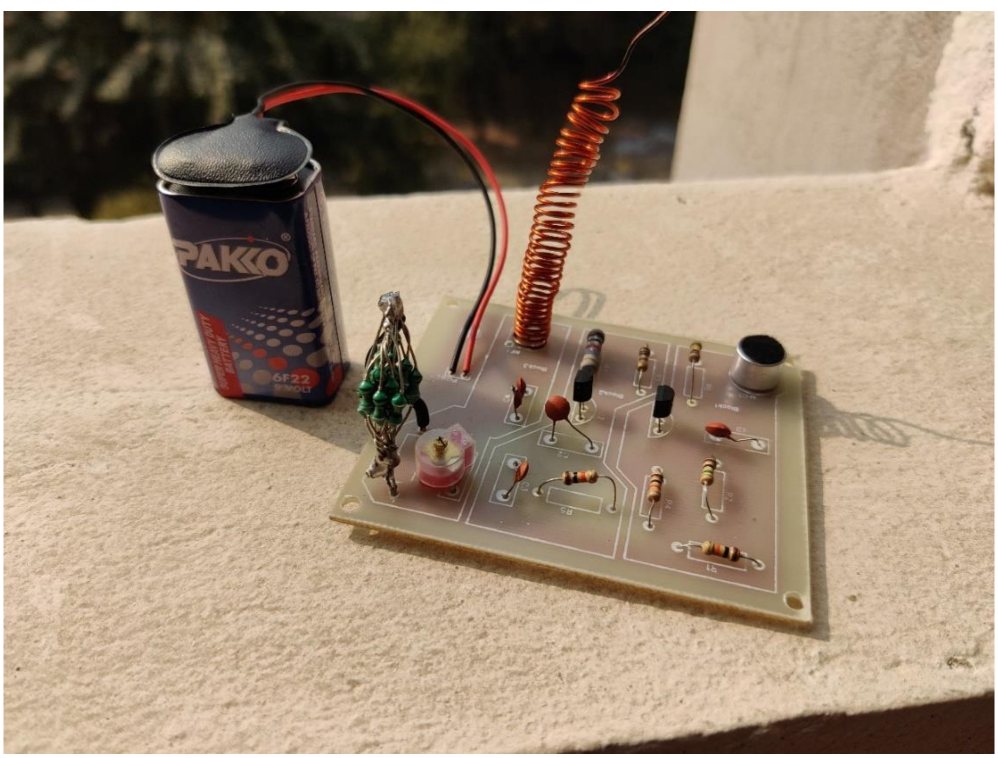


Figure: Circuit on PCB

Working Principle:

The FM transmitter block diagram represents the information signal in audio form which it is transduced into electrical signals and the corresponding processing signal is later undergone before being sent to the transmitter.
To explain the working principle, it is easier to separate the circuit into three major blocks-

a. Audio input Source Block
b. Pre-amplification Block
c. Power Amplification Block

a. Audio input Source Block

The audio input sources block represents the audio signals coming into microphones MICROPHONE ->PRE-AMPLIFIER ->OSCILLATOR ->ANTENNA ->AUDIO INPUT SOURCES ->POWER AMPLIFIER 5 from the radio players, cassette players and any audio signal source that one would like to transmit at any point in time. To make audio mechanical wave to electric signal we need a condenser mic which is basically a transducer.

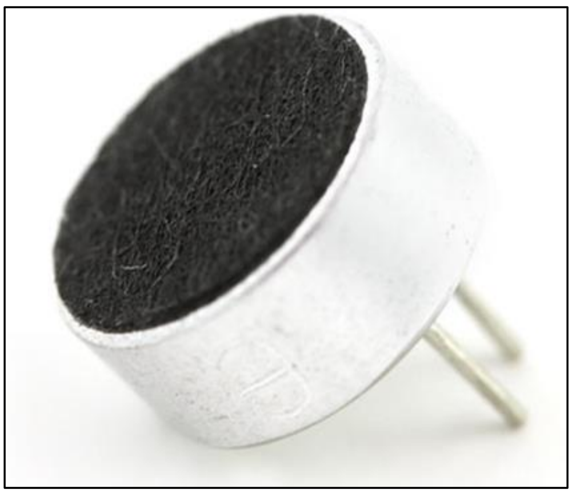


Figure: Condenser Microphone

A transducer is a device that converts energy from one form to another form. Transducers in terms of electro acoustic converts sound wave energy to electrical signal energy and vice versa. Transducer that converts changes in air pressure into corresponding changes in electrical signals is called microphone. Several varieties of microphones exist which may be classified according to the basic principle of operation. These include its resistance, moving coil induction, and capacitance and piezoelectric effect property.

b. Pre-amplification Block

The next stage is the pre-amplification stage. This pre-amplifier amplifies the input signals and does pre-emphasis by also integrating a high-pass filter to satisfy lower frequencies of the audio signals. For a satisfactory reproduction of music and speech for entertainment, the frequency ranges of 102MHz to 105 MHz are recommended. This block basically consists of a npn transistor and some resistance for biasing purpose.

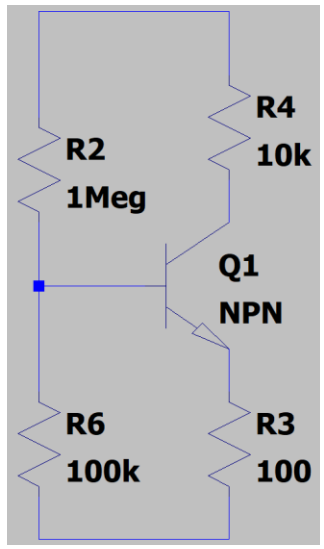


Figure: CE amplifier

c. Power Amplification Block

After pre-amplification, the power amplifier boosts signals efficiency and its rate of transmission then signal is connected to the oscillator to modulate it. The oscillator is to generate the carrier frequency within the range of 102MHz to 105MHz and this will be modulated. The carrier is coupled to the antenna.

LC circuit:

In project we used an oscillation circuit, but in practical it has resistance. Hence it generates high frequency damped oscillation.

$$Ri + L\frac{di}{dt} = -\frac{1}{C}\int idt$$

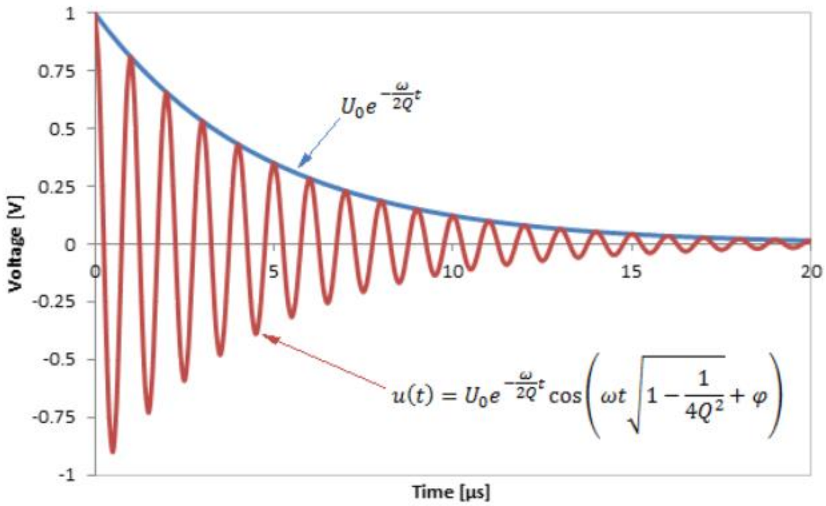
$$L\frac{di^2}{dt^2} + R\frac{di}{dt} + \frac{1}{C}i = 0$$

Here Solution is : $-\alpha - \sqrt{\alpha^2 - \omega_0^2}\,,\ -\alpha + \sqrt{\alpha^2 - \omega_0^2}$

$$\alpha = \frac{R}{2L}\ is\ called\ damping\ coefficient$$

$$\omega_o = \sqrt{\frac{1}{LC}} \textit{ is the resonant frequency of the circuit}$$

When $\alpha^2 < \omega_0^2$ *then the oscillation is underdamped.*



To get rid of this damped oscillatory carrier, we have to form a circuit to feedback it continuous voltage. An amplifier of block 3 (power amplifier) did this perfectly.

To power up the oscillator LC circuit, a class-A power amplifier has been used. This class-A power amplifier is least efficient but has the highest sound fidelity.

Simulation:

Simulation for the circuit has been performed in pspice.

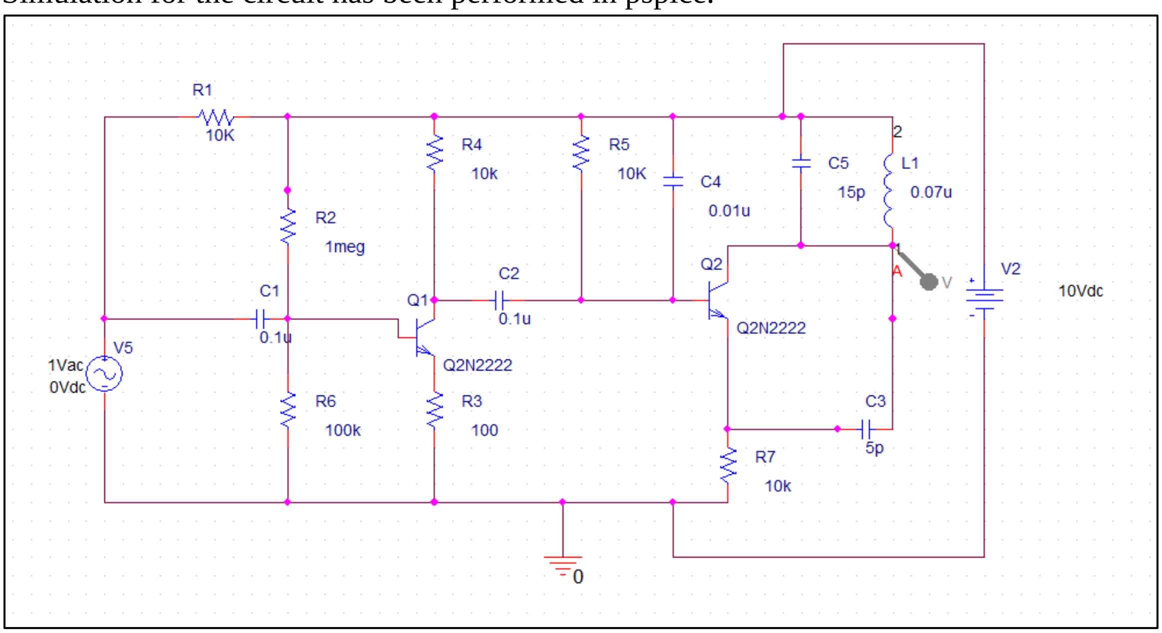


Figure: Schematic Diagram

Figure: 22pF variable Capacitor

For the LC oscillator circuit:

We know that, Resonant frequency, $f = \frac{1}{2\pi\sqrt{LC}}$

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times3.1416\times\sqrt{0.07\times10^{-6}\times20\times10^{-12}}} Hz = 134.5MHz$$; when C = 20pF

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times3.1416\times\sqrt{0.07\times10^{-6}\times15\times10^{-12}}} Hz = 155.3MHz$$; when C = 15pF

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times3.1416\times\sqrt{0.07\times10^{-6}\times22\times10^{-12}}} Hz = 128.2MHz$$; when C = 22pF

From the above calculation, it has been observed that the variable capacitor allows us to make the FM frequency changed. We finally set the value of C 22pF.

From Simulation of the above circuit:

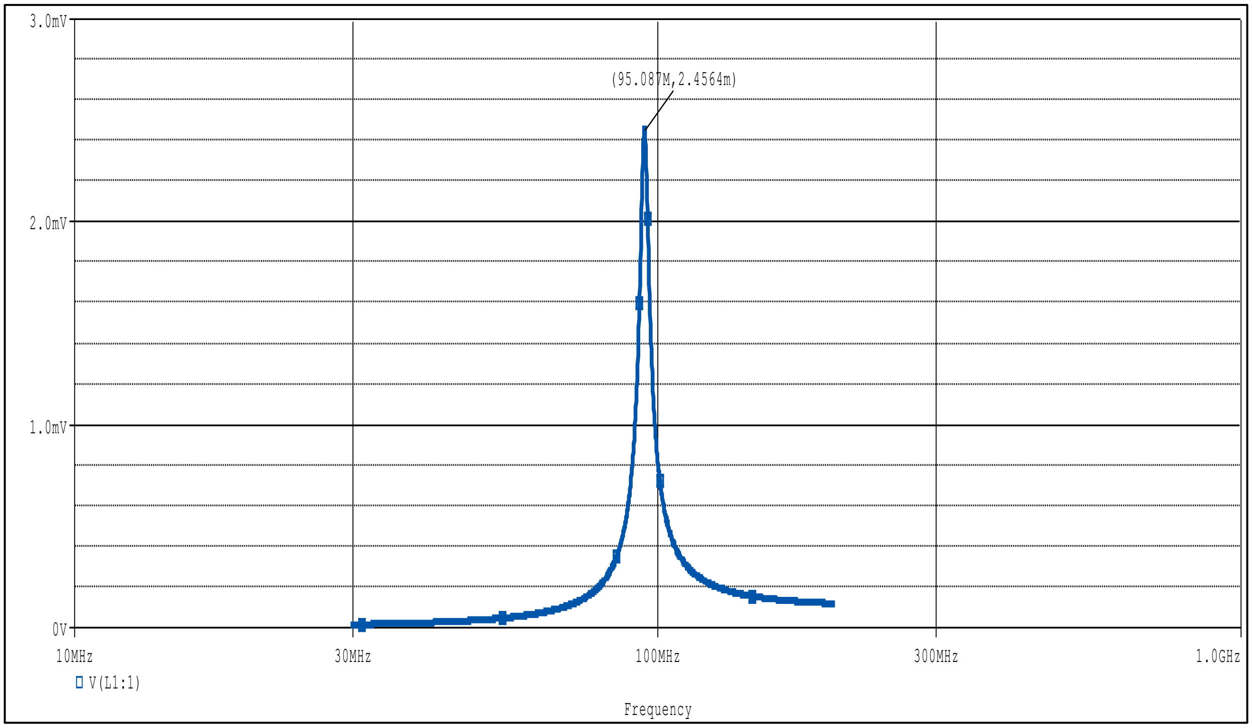


Figure: Pspice frequency spectrum of output for C = 20pF

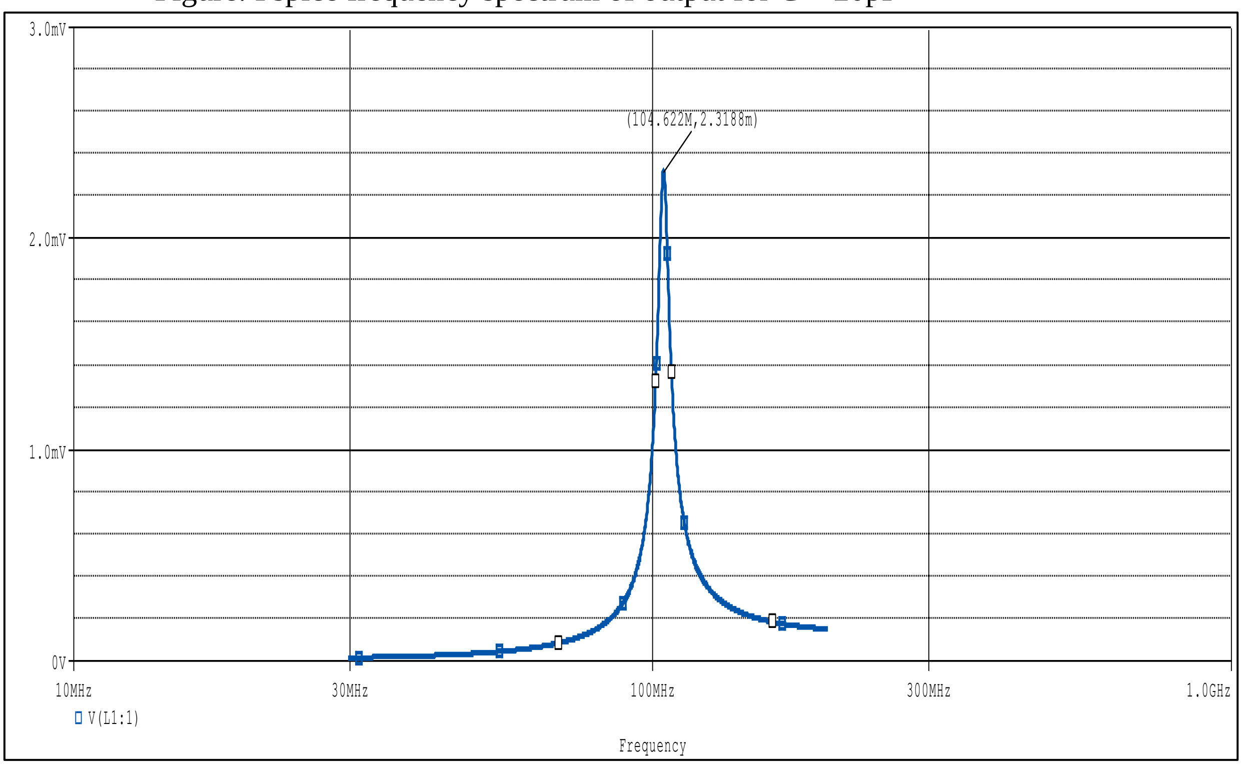


Figure: Pspice frequency spectrum of output for C =15p

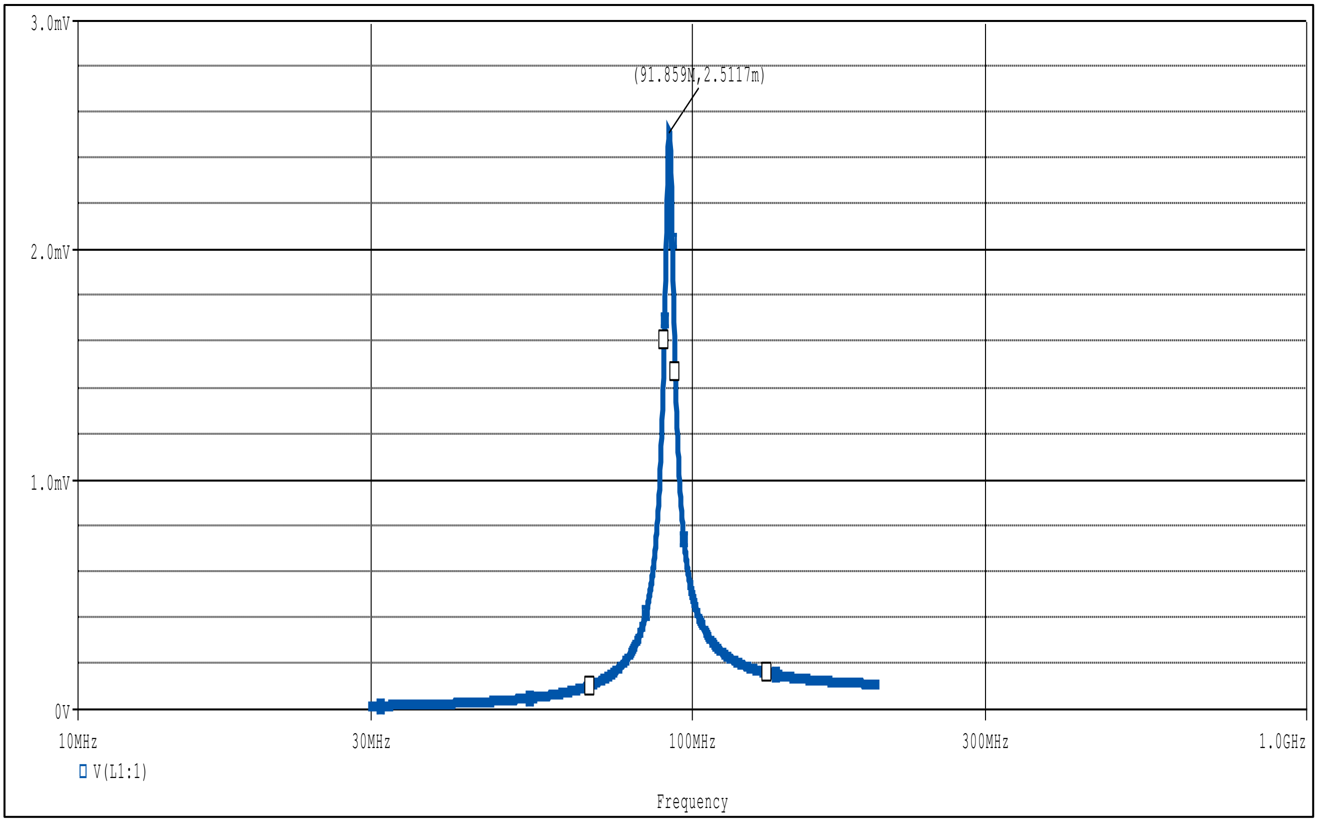


Figure: Pspice frequency spectrum of output for C =22p

Oscilloscope Output:

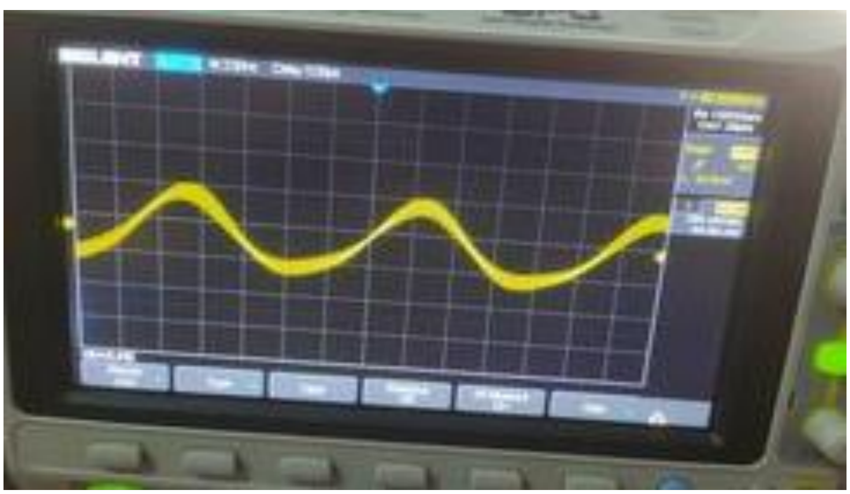


Figure: When no message is given as input, only carrier shows its high frequency component of about 90MHz.

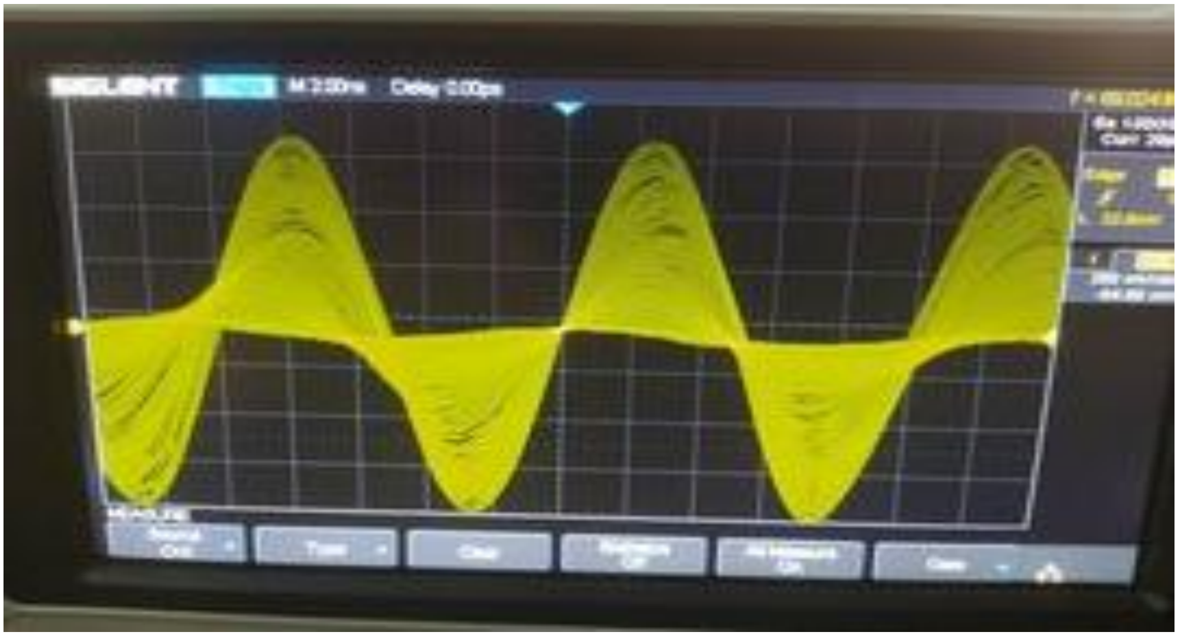


Figure: When the mic introduced some random input signal, the output response is varied according to the input.

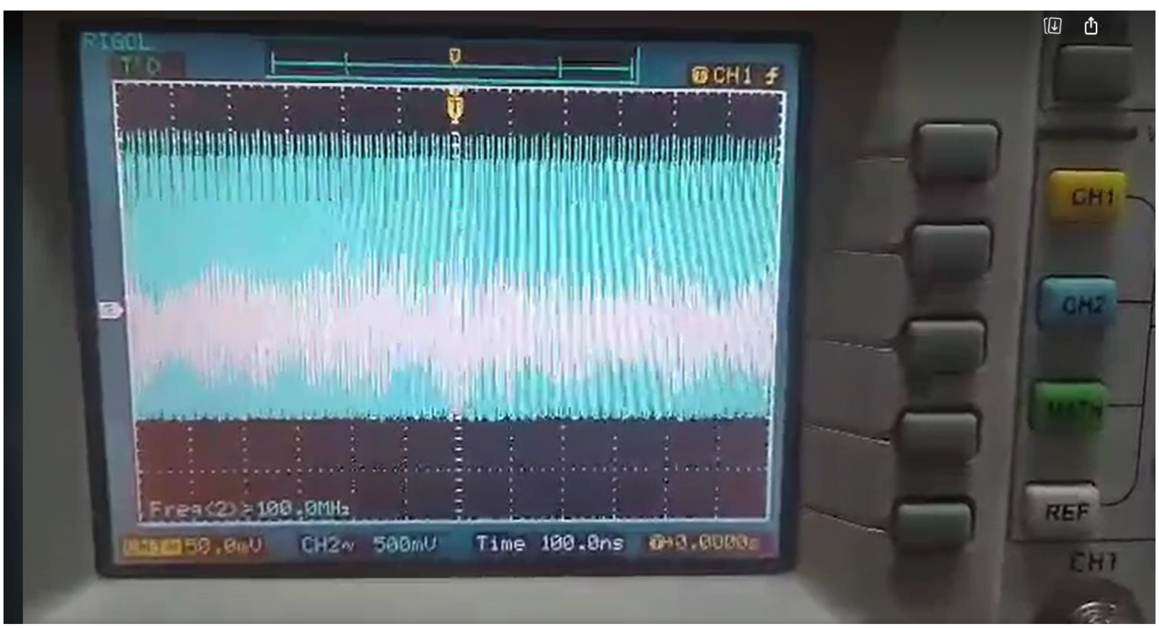


Fig: When function generator was used as input electrical signal instead of any audio signal, frequency of output signal varies significantly along with the sinusoidal message signal’s amplitude.

Ensuring the quality of an FM transmitter involves several factors that should be considered during the design, construction, and testing phases. Here are some key factors to consider to ensure the quality of an FM transmitter:

1. Component selection: Choosing high-quality components is essential for building a high-quality FM transmitter. Using components that are well-matched and of good quality will help ensure that the transmitter performs well and is reliable.

2. Circuit design: Designing the circuit to be stable and efficient is critical for ensuring the quality of the FM transmitter. The circuit should be designed to provide a stable and accurate output signal with minimal distortion. Additionally, the circuit should be designed to be easily tunable, and the frequency should be easily adjustable to meet regulatory requirements.

3. Proper grounding: Proper grounding is essential for minimizing interference and noise in the FM transmitter. The circuit should be grounded properly, and the ground connections should be kept as short as possible to reduce the possibility of noise.

4. Adequate shielding: Adequate shielding is important for minimizing interference from external sources. The transmitter should be shielded with metal or other suitable materials to prevent electromagnetic interference.

5. Testing and tuning: Testing and tuning the FM transmitter are important steps to ensure that it is functioning properly. The transmitter should be tested thoroughly to ensure that the output signal is stable and that it meets regulatory requirements.

6. Power supply: The power supply used for the FM transmitter should be stable and provide the correct voltage and current. A stable power supply will help ensure that the transmitter performs reliably and that there is no unwanted noise or interference.

Difficulties faced during project:

Antenna Mounting: For Antenna, at first, we opted for a RF antenna 75Ohm. But it needs 3.5mm adapter which was not available then. So, we designed a spiral shaped copper wire as antenna. But this antenna is not mountable on our pcb.

Soldering: As there was no green masking on our designed pcb, it was very difficult to soldering over the copper.

Unavailability of component: Few components like 0.1μH is not available in different shops of electronics. So, we have to fabricate this one by connecting 10, 1μH inductors in parallel.

Discussion

Making a simple FM transmitter can be a great introduction to electronics and signal processing, but it also comes with certain limitations. Some of the limitations that can be faced when making a simple FM transmitter are:

1. Limited range: A simple FM transmitter typically has a limited range due to the low power output. The range of the transmitter is dependent on several factors such as the power output, frequency used, antenna design, and terrain.

2. Poor signal quality: The signal quality of a simple FM transmitter may not be as good as that of a commercial transmitter due to the lack of sophisticated signal processing circuits. The signal may be prone to noise and interference, resulting in a distorted signal.

3. Limited frequency range: A simple FM transmitter typically operates on a limited frequency range, typically within the FM band. The frequency range is dependent on the components used in the circuit and the design of the oscillator circuit.

4. Regulatory restrictions: In some countries, the use of FM transmitters is regulated, and there are restrictions on the frequency range and power output that can be used. A simple FM transmitter may not be able to comply with these regulations.
5. Power supply limitations: A simple FM transmitter may require a specific type of power supply, which may not be readily available or easily accessible. The power supply used may also impact the performance of the transmitter.

6. Interference: A simple FM transmitter may be susceptible to interference from other electronic devices in the vicinity. This can cause the signal to become distorted or lost