Completely Modeled & Simulated wireless Usb-FM Transmission in Very-fine-pitch Quad Flat Pack

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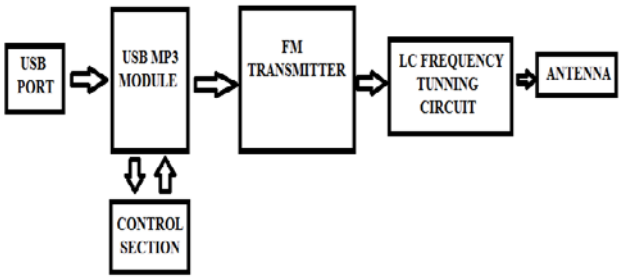
***Abstract*—** The project has actually been done in two parts, modeling & analysis. The modeling has been explained with the help of schematics & circuit diagrams. The analysis has been done on the whole design & its partial hardware. Different Graphs has been taken with the help of oscilloscope before modulation & after modulation. The graphs obtained give the clear idea that the Fm Transmitter is fully capable to transmit any audio data coming from any source like Usb or microphone. Although Strong calculations has been done for inductance matching & antenna height calculation but still more work can be done on the antenna to improve its reception.FM transmission rules & Regulations has been read & given extra consideration before making the actual hardware & during its troubleshooting & analysis. this project is actually based upon the designing of a Short range wireless USB-*FM Transmitter* which can transmit data contained in the USB flash drive over short distance using ROHM® BU9458kv Semiconductor chip. The chip is designed in a new packaging called VQFP-64(Very-fine-pitch Quad Flat Pack).The first section is FM Transmission and the second is USB-mp3 module. The FM Transmitter is designed by using two BC-547 transistors. The Usb mp3- Module is designed by using ROHM® BU9458kv Semiconductor chip. The mp3 songs can be played directly from the usb flash drive by using MODE-1(default mode) of the semiconductor chip without programming it. Successful Transmission of audio signal through the designed FM Transmitter is a proof of the correctness of the design. The experimental results on FM transmitter ensure that design is capable to transmit usb data if it is implemented completely on commercial basis.

***Keywords*—** Wireless Usb-Fm Transmitter using BU9458kv, VQFP-64 Packaging chip, fabrication of complex integrated audio devices.

I. INTRODUCTION

THIS project is utilizing Frequency modulation technique to design *Short range wireless USB-FM Transmitter using ROHM® BU9458kv Semiconductor chip*. The chip is fabricated in VQFP-64 Packaging (Very-fine-pitch Quad Flat Pack). This is the key point of the research paper. Because, designing a Short range wireless USB-FM Transmitter on such a small integrated scale can lead to decrement in size of many audio-visual devices. Additionally the current chip has been used in many complex VLSI products[1].Also safety measures for wireless communication have been studied from various resources and followed with VQFP-64 in this paper[2]
The designed circuit cannot be implemented on breadboard due to its ultra-small size. Therefore the PCB design is directly made after testing it on software Proteus® version 6.9 to observe the accurateness of the design. The testing has successfully done in the laboratory to assemble the semiconductor chip on PCB.



USB FM TRANSMITTER SCHEMATIC

Figure 1 (USB Fm Transmitter Schematic)

1 is the schematic of the design made in this project. It can be seen, that the design is divided in to six parts. Every part has its own theoretical background, which has to be understood before putting hands on the hardware side. Following are the names & a brief functionality of each part included in the schematic.

- **USB PORT**
  A Simple USB type– A connector is used for interfacing Usb pen drive with the device.
- **USB-MP3 Module (ROHM ® BU9458Kv - VQFP-64 Packaging)**
  An Usb-mp3 module is utilized in between the FM Transmitter & Usb pen drive to browse and play the mp3 files from the connected Usb pen drive. A standard USB version 2.0 ports is used for this purpose. A Rohm Semiconductor chip (BU9458) is

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Author has done his Masters in Electronics & Telecommunication. He is further excelling his career as a *Research Assistant & Doctorate student* in Izmir Advanced Institute of Technology, Turkey on Turkish Government fully funded research grant. After finishing his postgraduate he had started his teaching career in one of the top engineering schools of Pakistan. He served in department of Electronic Engineering as a *lecturer and undergraduate research supervisor* in UIT-Hamdard University in Pakistan before accepting Turkish Government Research grant. (phone: +905070368248; email:ahmed.areeb@gmail.com, areebahmed@iyte.edu.tr).

utilized in a designed circuit to perform this duty. The circuit designed for this purpose is very complex & has four parts to give the final audio output to the designed Fm Transmitter.

- **FM TRANSMITTER**
  A FM transmitter is design to perform the frequency modulation on the complex incoming data coming from the usb pen drive in mp3-format.
- **LC Frequency Tuning Circuit**
  A LC tuning circuit is utilized to transmit the modulated data to the desired frequency. This circuit is the most important part because the transmitting frequency depends on this part.
- **Antenna**
  A final antenna is placed after the FM transmitter to transmit the data in a form of electromagnetic waves. This antenna is also made after calculating its length from theoretical calculations.
- **Control Section**
  A control section is also made to control the flow of incoming data from the Usb pen drive. Additionally it can play and stop the working of the device internally rather than powering on & off the main supply. An indication section is also included with the control section to inform the status of the design.

II. ARCHITECTURE

There is a lot of work done in the area of FM Transmission and USB related devices. Especially in the field of FM Transmission, different designs has been made and successfully implemented. All FM Transmitter designs are a trade-off between range, quality & complexity. Firstly, a good FM Transmitter design has to be made in order to further extend to use it with the Rohm® Semiconductor chip. There are some designs available for this purpose but they are not very reliable & also complex to make, resulting in an expensive & less reliable device. Firstly, proper understanding of FM Transmitter types is necessary to utilize it on such a small scale of VQFP-64 packaging. However there are many devices available with a name of USB-FM Transmitter. But they are not actually transmitting data from USB Flash drive instead of only taking power from the USB port. Therefore a background theory is discussed in this section of the paper.

A. Types of FM Transmitter

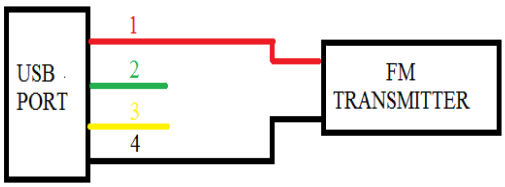
Basically there are two types of FM Transmitter

- Mono FM Transmitters
- Stereo FM Transmitters

Mono Audio Channel can play one sound from two speakers at the same time. While, a stereo channel utilizes two individual channels to play sound from two different speakers (3). So, there are two types of FM transmitters available depending upon the type of sound coming from it. However, a Mono FM Transmitter is utilized in the circuit.

B. USB POWERED FM TRANSMITTER

There are many designs available with the names of USB FM Transmitter. But that is not actually an FM transmitter capable of transmitting data contained in the USB flash drive. Indeed they are actually USB powered FM Transmitter. They are simple FM Transmitter circuits taking power supply from USB port of the computer or laptop instead of a battery. These types of FM Transmitters are easy to build. However, any FM Transmitter can also be transformed to a circuit which can take power from an usb port and transmit audio signal coming from microphone using frequency modulation technique. The figure 2 given below will elucidate this technique.



1 = Power Supply from USB Port FM Transmitter
2 = Data + pin
3 = Data - pin
4 = Ground from USB port to FM Transmitter

Figure 2 (Usb Power Pins)

As it can be seen that only the power supply & ground pins from the Usb port are utilized in this method. The data + & data – pins are not used in these types of circuit. It means that the usb port is used only to get power from computer or laptop. It is not providing data contained in the usb flash drive. The above diagram is place just to clarify the basic concept used in USB Powered FM Transmitter.

C. Usb port Architectural Overview

The architectural overview of the usb port is very important part in this project as the whole design depends upon data coming from the flash drive. The male ports for both type-A & type-B are shown in figure 3(4).

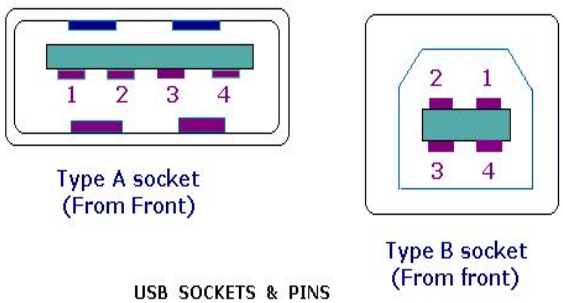


Figure 3 (Usb Sockets & Pins)

The project is utilizing type-A female port contained in the design. It is connected to type-A male port which is inside the usb flash drive.

III. MODELING

This chapter of the report is based on all the designing steps taken to design the final schematic of the wireless USB- FM Transmission via Rohm® BU9458kv semiconductor chip. The designing has been done in three parts. Basically they are three steps mentioned below.

- FM Transmitter Designing
- Usb Mp3 Module Designing
- Control & Indication section Designing

A. FM Transmitter Designing

The frequency modulation is used in this project to make a Short range transmitter. So a brief description about this technique is elucidated below(5).

Considering an information signal $V_m(t)$
& a carrier signal
$V_c(t) = V_{co}\sin(2\pi f_c t + \square)$
The modulated fm signal will be

$$V_{fm} = V_{co}\sin(2\pi[f_c + \frac{\Delta f}{V_{mo}}V_m(t)]t + \square)$$

The possible frequency spectrum of the FM modulated wave form is given below also in figure 4 (6).

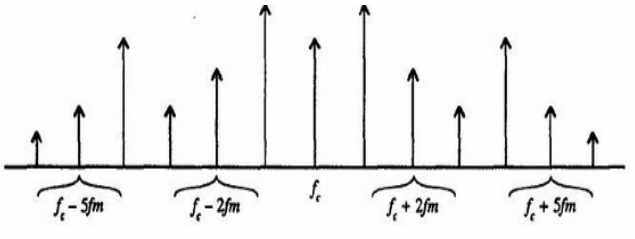


Figure 4 (Possible Frequency Spectrum)

Firstly the FM Transmitter has to be designed which can take analog data as input and module it with frequency modulation scheme and produce wireless modulated signal. The signal will be transmitted through the designed antenna according to the chosen transmitting frequency. The schematic designed for this purpose is given below in figure 5.

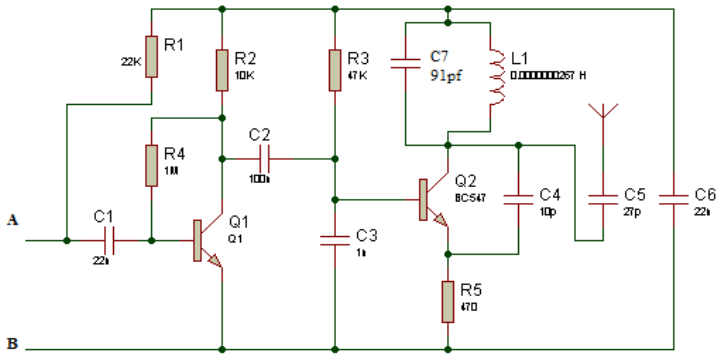


Figure 5 (FM Transmitter Circuit)

This design can transmit the modulated wireless signal to a distance of 100-200 meters. The components involve in the designing process are given below with names and values.
Resistor1 (R1) = 22 kilo Ohms
Resistor2 (R2) = 10 kilo Ohms
Resistor3 (R3) = 47 kilo Ohms
Resistor4 (R4) = 1 Mega Ohm
Resistor5 (R5) = 470 Ohms
Capacitor1 (C1) = 22 Niño Farad
Capacitor2 (C2) = 100 Niño Farad
Capacitor3 (C3) = 1 Niño Farad
Capacitor4 (C4) = 10 Pico Farad
Capacitor5 (C5) = 27 Pico Farad
Capacitor6 (C6) = 22 Niño Farad
Capacitor7 (C7) = 91 Pico Farad
Q1 & Q2 = BC-547 Transistors
Aerial = Copper wire of calculated length
Coil = 5 turns coil (length of coil = 7 millimeters, diameter of coil = 3 millimeters,
Number of turns =5)

The points A & B shown in FM Transmitter schematic given above are left for the input voice signal generation. The connections points can also be attached to the output coming from the Usb-Mp3 module. Since, it is already in an analog form so other form of converter is not needed here to change the form of audio input signal.
The first transistor is performing the audio amplifier stage. The amplifier stage is made across the first BC-547 transistor. BC-547 is normally called audio low power transistor (7). Isolation of the input signals, coming from the connections point A&B, from the transistor base voltage is carried out by capacitor (C1). The capacitor only allows the Ac signals to pass from that point. The amplified output is given out by the collector of the Q1. It is then forwarded to the base of the second transistor Q2. The modulation of the resonant frequency of the tuning circuit is carried out here by altering the junction capacitance of Q2. Basically, junction capacitance is associated with the charge variation in the depletion layer (8).
An LC- tuning circuit is used with the second transistor Q2. Basically, a LC circuit is used to generate signals at a particular frequency. They are also used to achieve and sustain oscillation (9). It is also acts as a resonator. The resonator

contains inductor and capacitor as energy storage elements (9). The capacitor in the circuit stores electrical energy between its plates. That energy storage depends upon the voltage applied across it. However the inductor stores energy in the magnetic field across it. That energy storage depends upon the current flowing across it. A Colpitts oscillator is used in the design. In this type of oscillator, the feedback is obtained from the coupling capacitor (10). This is the whole working methodology of the FM Transmitter design

B. Usb-Mp3 Module Designing

After designing the FM Transmitter, the Usb-Mp3 module is designed to transfer the data contained in the Usb flash drive to the FM Transmitter. So, the usb mp3 module is designed in such a way that it can browse the files automatically from the usb flash drive and transfer it to the FM Transmitter input points A & B in analog form. But there are certain units needed to design this module. The Units need to understand before designing the module is given below.

- USB host controller
- FAT file system
- Mp3 decoder
- Sampling Rate Converter
- Digital to Analog converter
- System controller

Usb device cannot be included in any design unless an Usb controller is not included in the design. Many hardware designs include usb devices in the design. But the hardware must include a controller chip that manages Usb communications (11). Therefore an usb host controller had to be included in the design to control Usb. A standard USB 2.0 is used in the designed circuit.

Several file formats are used for audio and video files. They are classified on the basis of the compression level done on the data files. In this project the mp3 data files are used for transmission. Mp3 is basically related to layer 3 of MPEG-1 codec (12). The MPEG-1 codec has three parts named as layers.

A Digital to analog (DAC) converter has to be used after the sampling rate converter. DAC converter converts the digital data input to analog output (voltage or current) which is proportional to the applied digital input (13). An overall system controller is also needed to control the whole module. A system controller is added to monitor the progress of all the units discussed above.

The functionality of each unit is described above to understand the functionally of Usb-mp3 module. A single chip from ROHM® technology has been used to carry out all of these step by step functions described above. The chip name is BU9458Kv semiconductor IC. The chip is designed especially to be utilized for small audio related devices. The chip is available on VQFP-64 (Very Thin Quad Flat Package).

There are two modes to operate chip. They are named below

- Standalone mode (Mode-1)
- Slave mode (Mode-2)

In standalone mode, the chip behaves according to the built in controller inside it. The built controller controls & monitors all functions in progress. While in slave mode, the chip can be connected to an external controller. The mode-1 functionality described above is enough to carry out the functions needed for the design used in this project. Therefore external controller is not needed. Above that it helps to reduce the complexity of the design.

There are total 64 pins in BU9458Kv semiconductor chip. But not all the pins are used for designing the USB Fm Transmitter. The utilized pins out of 64 available pins of Bu9458Kv are listed below in Table-1 with proper description to clarify the design.

Table 1 (Pin Description & Utilization)

Pin Number	Pin Name	Description (Purpose to use in the design)
1	Reset system	It should be high at the time when the chip restarts
2	SEL_SLAVE	It is kept high to indicate the controller that the chip is in standalone mode
3	SEL_MP3	It is kept low to indicate and make sure that the chip process all mp1, mp2 & mp3 data. Otherwise, only mp3 will be played
4	SEL_DOUT	It is kept high to disable the digital audio output as analog output is required to feed to the Fm Transmitter.
5	SEL_VOL	It is kept high to enable the volume controller
6	SEL_APLAY	It is kept high to disable the auto play function of the chip since it will be controlled by the control section.
7	SEL_UTPKT	It is kept high for the normal operation rather than test packet transmission first.
10	KEY_ROW1	Key Matrix terminal for Key for Row 1 out of 4
11	KEY_ROW2	Key Matrix terminal for Key for Row 2 out of 4
12	KEY_ROW3	Key Matrix terminal for Key for Row 3 out of 4
13	KEY_ROW4	Key Matrix terminal for Key for Row 4 out of 4
14	KEY_COL1	Key Matrix terminal for Key for column 1 out of 3
15	KEY_COL2	Key Matrix terminal for Key for column 2 out of 3
16	KEY_COL3	Key Matrix terminal for Key for column 3 out of 3
33	USB_DM	Negative data terminal for USB flash drive
34	USB_DP	Positive data terminal for USB flash drive
36	REXT1	Connected to the ground

		terminal of the USB flash drive
38	VDD_PLL	Power Supply for internal PLL system
40	XIN_PLL	PLL input terminal
41	XOUT_PLL	PLL output terminal
42	VSS_PLL	PLL ground terminal
43	DAVSS	Audio output DAC ground terminal
46	LDACO	LEFT audio DAC output. Only left output is utilised to fed the Fm transmitter input point A
47	DAVDD	DAC power supply terminal
49	LED_ERRO R	Lightening output to report Error
50	LED_PLAY	Lightening output to report successful playback of files
52	LED_PUSB	Lightening output to report successful memory access from USB
53	LED_ACCE SS	Lightening output to report Error
55	LED_REPE AT	Lightening output to report repeat playback for any file

C. Control & Indication section Designing

The Control & indication section is also included in the design by using chip functionalities of key matrix controller & LED controller. The default key matrix controller can have 12 switches & 7 Led (light Emitting Diode). However, 11 control switches and 5 Led are used according to the need of the design. The diagram for both control switching system and LED indication system are shown below in figure 6.

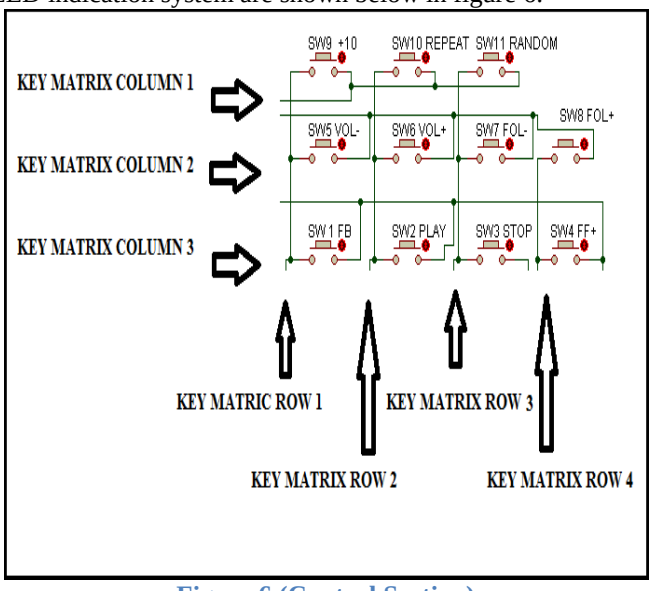


Figure 6 (Control Section)

The working of each switch is given in Table-2 below.

Table 2 (Control Section Description)

Switch Number	Switch Name	Description
SW1	FB	This switch informs the controller to search the previous file in the folder of the current file If the switch is hold for 2 seconds, then the controller fast backward the current playing file
SW2	PLAY	It will play the file and it can pause the current file temporarily
SW3	STOP	It will pause the current file permanently
SW4	FF	This switch informs the controller to search the next file in the folder of the current file If the switch is hold for 2 seconds, then the controller fast forward the current playing file
SW5	VOL-	Sound volume can be decreased from 0dB (maximum Volume to -∞ (minimum volume)
SW6	VOL+	Sound volume can be increased from -∞ (minimum volume) to 0dB (maximum Volume)
SW7	FOL-	It will start playing the files in the previous folder of the USB flash drive
SW8	FOL+	It will start playing the files in the next folder of the USB flash drive
SW9	+10	It will play the files 10 files next to the current file
SW10	REPEAT	It will simply repeat the files being played from the current folder
SW11	RANDOM	It will simply select files on random basis and play it.

D. Complete Schematic

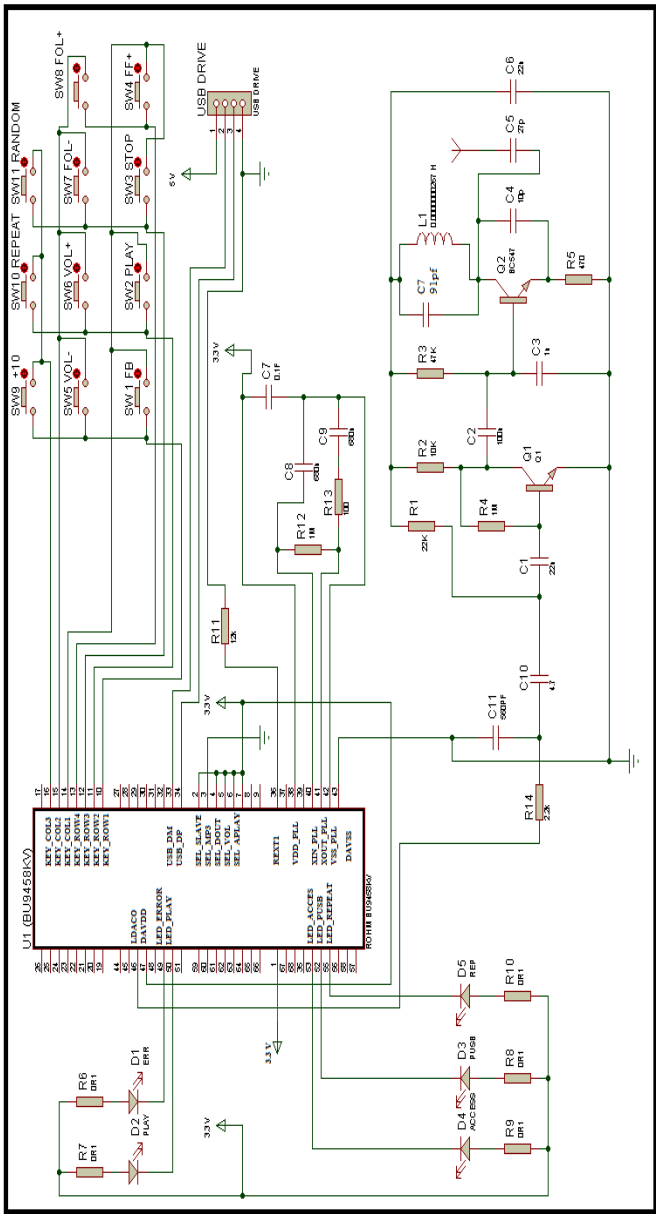


Figure 7 (Complete Circuit Diagram)

E. Specification & Features

The capabilities of the whole design have to be analyzed after complete designing of the USB-FM transmitter. These capabilities are referred as specification & features. These specification & features of the whole design are given below.

- UBS 2.0 full speed host Interface
- Mp3 decoding function contained (MPEG layer 1,2 & 3, Supports sampling rate 8k to 48k, Bit rate 8 to 320 kbps)
- Sampling rate converter (converts all files to 44.1 Kilo-Hertz)
- Contained system controller (control all system operations)
- Contained FAT analysis system (FAT-16 & FAT-32)
- File Browsing function
- Ability to Fast forward & backward
- Audio Digital to Analogy conversion
- Sound effects function
- Key Matrix control system (controls 11 keys)
- Led Indication system (controls 5 LED's)

E. PCB Architecture

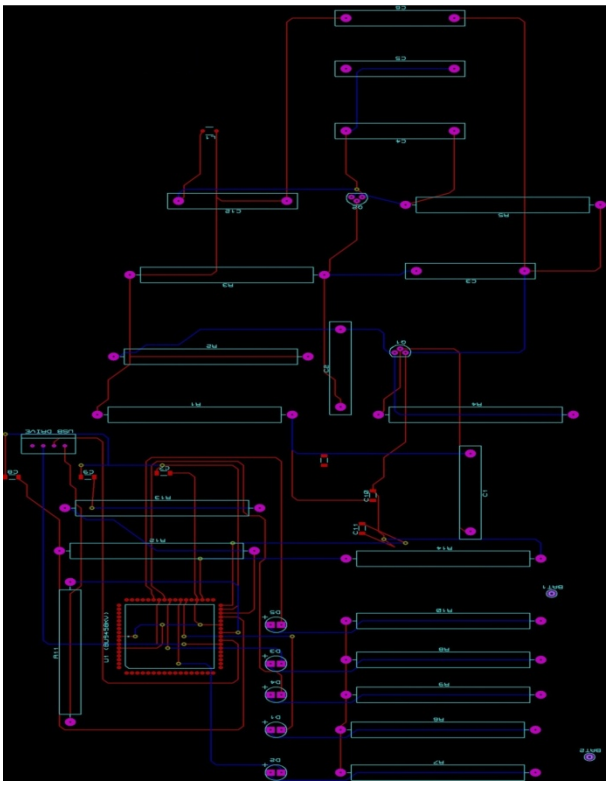


Figure 8 (Complete PCB Schematic)

IV. MATH

There are certain calculations need to be done to design the USB FM transmitter. In LC-tuning circuit, First the inductance of the coil has to be found first to further calculate the transmission frequency. A solenoid inductor is utilised in the LC-tuning circuit. There are not enough gaps between the windings of the coil. Therefore, the inductance of the solenoid coil is calculated with formula given in (1).

$$L = \frac{d^2 n^2}{length + 0.45d} \qquad (1) \qquad (14)$$

Where L = inductance of the coil in Micro Henry
n = number of turns
d = Diameter of the each winding in meters
Length = Length of solenoid meters
The value used in designing the coil the LC-tuning circuit are given below.
n = number of turns = 5
d = Diameter of the each winding = 0.0030 meters
Length = Length of solenoid = 0.0058 meters
The inductance of the solenoid used in the design comes out to 0.0311 μH after putting values in (1)
The formula to calculate the transmitting frequency in LC-tuning circuit is given in (2).

$$f_{osc} = \frac{1}{2\pi\sqrt{LC}} \quad (2) \qquad (15)$$

Where L => inductance = 0.0311 μH

C => Capacitor used = 91 Pico-Farad

The f_{osc} value after putting the values of 'C' & 'L' in equation (2) comes out to be 94.50 Mega-Hertz. The value of capacitor used makes the transmitting frequency to fall in the FM Band. Wavelength can be calculated by utilizing the transmitting frequency in the formula given below.

$$\text{Wavelength} = \frac{Speed\ Of\ light}{Frequency} \quad (5) \quad (16)$$

Where, Speed of light = $3 \times 10^8\ m/_S$

Frequency value should be in hertz, which is 94.50 $\times 10^6$ Hertz from equation (2)

The value of wavelength after putting the frequency value in equation (5) comes out to be

Wavelength = 3.174 meters

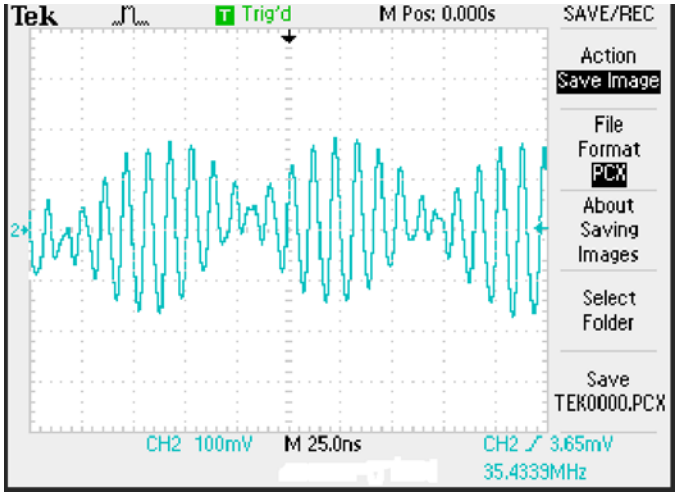
As quarter wavelength antenna is utilized in the design for transmission. So equation (4) is used for antenna height calculation. The antenna height comes out to be

$$\text{Antenna Height} = \frac{3.174}{4} = 79.35 \text{ cm}$$

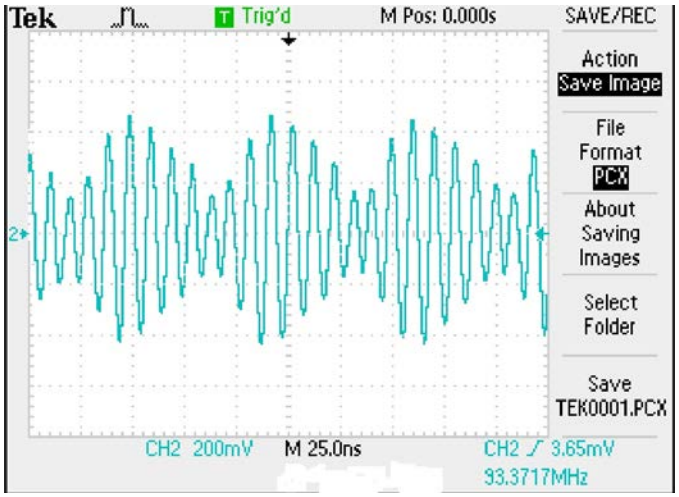
Additionally the antenna can be made more appropriate and advanced by using various performance enhancement techniques [17].

v. Analysis

The results obtained are recorded and saved with the help of oscilloscope. This section will show the results in a form of graphs taken from oscilloscope. It will also briefly explain the graphs to further understand the design and the objectives achieved from the designed Fm Transmitter module. Firstly the input has been given in a form of songs played in a microphone attached to points A & B of the Fm Transmitter. The initial converted input audio signal from the microphone is of 424 Milli-Volts. The original frequency of this signal is 49.974 Hertz. This frequency is not enough to transmit it wirelessly to a distance required. Therefore the designed Fm Transmitter will module it and gives a modulated signal through the antenna. It is said earlier that the Fm Transmitter was first implemented on the breadboard to troubleshoot the design properly so the transmitter was implemented with the trim capacitor of 50-95 Pico-Farad. Two graphs are also taken with the two different capacitances they are shown below.

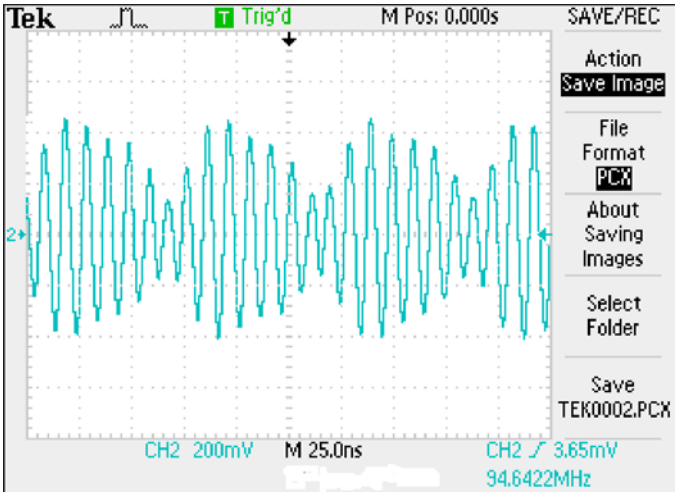


Graph 1 (Modulated Signal outside FM Band)



Graph 2 (Modulated Signal Inside the Frequency Band)

It can be seen that the Fm Transmitter is transmitting at two different frequencies by changing the trim capacitances. The frequency in first graph is outside the Fm Band therefore the use of incorrect capacitor in LC circuit can badly affect transmitting frequency. The frequency in second graph is inside the Fm Band. The second graph is taken at maximum trim capacitance of the Fm Transmitter which is 91 Pico-farad. Therefore in actual design 91 Pico Farad is used to get the desire frequency inside the Fm Band. After using the desire capacitor of 91 Pico-farad in the final design of Fm transmitter, this modulated waveform is achieved.



Graph 3 (Final Modulated Signal)

This waveform is exactly close to the calculated value of 94.50 Mega-hertz in equation (2) in section 5 of chapter 4 as shown in the above graph. The results obtained and shown are enough to proof the efficiency of the Fm Transmitter Design. The Modulated frequency in the above graph is 94.64 Mega-Hertz. The difference between the theoretical calculated value and the practical value is 0.14 Mega-Hertz. This difference is not a big difference and it usually arises due to the some to due slide changes in components ideal and real values. For Example the inductance calculated is not exact. It is just the theoretical way to calculate it. But still it is giving values very close to the ideal values. The inductor Q- factor with 94.50 Mega-hertz comes out to be 176. These results prove the credibility of the design and the closeness to the ideal theoretical values

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