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Digital FM Transceiver Design and Construction using Microcontroller and I^2C Interfacing Techniques

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Abstract: ***Communication is very much important for every community and radio communication is one of the easiest and simple media to provide information. The project represents the full duplex communication mode of FM transceiver (Radio + Transmitter). This paper describes on how to build a short-range FM transmitter using microcontroller. The paper also describes on how to build a FM radio receiver using micro-controller. Through the FM transmitter we can transmit our voice and any audio signal while through the radio receiver listener can listen any FM broadcasting channel. This project is based on KTMicro IC KT0803K monolithic digital stereo FM transmitter and Phillips TEA5767 radio receiver module. The quality of transmission and radio reception can be improved by Digital Signal Processing and Intelligent Tuning System. The heart of this project is Arduino UNO micro-controller which controls slave devices by Inter-Integrated Circuit (I^2C) communication. The transmitter and the receiver both supports digital tuning and Phase Locked Loop (PLL) concept is used for recovery of the signals. The transmitter of this digital FM transceiver can be used for making announcements in schools, colleges, industries, hospitals, and other places using a condenser mic amplifier circuit and share music with the FM listeners using audio input port of the FM transmitter module. The radio receiver of this transceiver is used for listening any local FM broadcasting channel. It can be also used in specialized application such as local area network. For the construction of the transceiver it requires some small and low cost external equipment's.***

Keywords: ***Arduino UNO, FM transmitter IC KT0803K, TEA5767 FM receiver module, Inter-Integrated Circuit (I^2C), Frequency Modulation (FM), Phase Locked Loop (PLL)***

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I. INTRODUCTION

A transceiver is a combination of transmitter and receiver, a device that both transmits and receives analog or digital signals. Until around 1920 transmitter and receiver were separate units.

In a radio transceiver, the transmitter is silenced while it is receiving or the receiver is silenced while it is transmitting. An electronic switch allows the transmitter and receiver to be connected to the same antenna and prevents transmitting signals while it is receiving or vice-versa. The transceiver we are aimed to make is completely different from earlier transceivers. We use two different Arduino UNO micro-controllers in this project which are the heart of FM transmitter and FM receiver. The transmitter and the receiver will be independent of their operation with two separate transmitting and receiving antennas and finally combined into a single unit providing single power supply at the end. That means both the transmitter and receiver working simultaneously at a time. Transmission and reception can be done either on the same frequency or different frequency. This mode of operation ensures the full duplex communication of the transceiver. Moreover the transceiver also displays the transmitted and received frequency with the help of Liquid Crystal Display (LCD). The transmission and reception frequency can be changed by matrix keypad and B100K potentiometer respectively. Phase Locked Loop (PLL) is used for the recovery of transmitted and received FM signals. Communication among Master and slave devices of the transceiver are achieved through I^2C Communication. Remember that, we can't transmit our voice or music signals into a large area. Because without permission of the government, government agencies or local police station it is illegal in most of the part of the world. Therefore this transceiver can be used in a building, large classrooms, office, hospitals, railway stations, bus stops, ship navigation, in modern cars etc. where the coverage area is relatively small.

II. METHODOLOGY

The prototype is designed using Arduino UNO microcontroller development boards which contains ATmega328P IC. One Arduino UNO controls transmitter section which is interfaced with FM transmitter module, 4×4 Matrix keypad, 16×2 Liquid Crystal Display (LCD). The lcd displays the transmission frequency.

The transmitter module is interfaced with transmitting antenna, audio input jack and condenser microphone. Communication between microcontroller and transmitter module is achieved by I^{2}C methods. Another Arduino UNO controls the receiver section which is interfaced with TEA5767 radio receiver module, LCD display and channel tunning potentiometer.

By changing the potentiometer value, the Arduino UNO contrrols the receiving channel by mapping its value. The output of the TEA5767 radio receiver module is fed to LM386 amplifier in order to drive large speakers. Arduino UNO microcontroller and TEA5767 module communicates through I^{2}C methods. Various sections of the project and their functioning are explained in this paper.

A. Block Diagram of Proposed Design

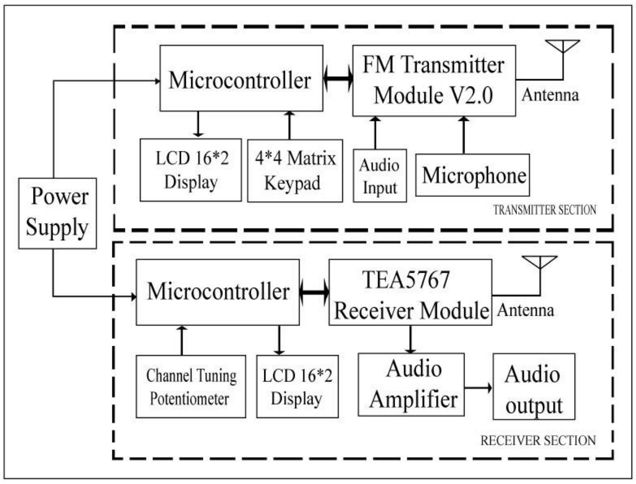

Fig. 1. Block diagram of proposed FM transceiver

B. FM Transmitter Module V2.0

FM transmitter module from elechouse, this board contains monolithic digital stereo FM transmitter IC KT0803K which is responsible to make FM over our Audio input and this IC directly controllable by Arduino board (Micro-controllers) through I^{2}C interface. Stereo input jack given for audio input from external device and also this module has on-board mic to pick up our voice. Audio signal from the mic amplified through 9013 NPN transistor and applied to the TX IC. 32.768 K Crystal provides clock to this module [1].

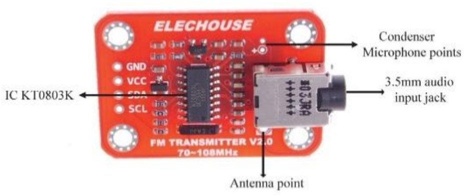

Fig. 2. FM transmitter module

The characteristics of IC KT0803K are given below [2].

- It is conceived audio interface, and used for a microphone or audio wire signal.
- Contains on chip 20-bit audio ADC to convert Left in, Right in audio into digital signal.
- Audio entrance signal regulating of amplitude and microphone regulating of sensitivity.
- Wireless FM audio microphone stereo-transmission FM radio small power.
- FM modulator output is amplified by RF power amplifier and applied to antenna through RF out pin.

Specifications:

- I^{2}C interface 5V TTL compatible
- Arduino plug and play
- Onboard Mic
- VCC Input: 3.0V ~ 5.0V
- Antenna port on the board, any metal line about 75cm can serve as an antenna.
- FM range from 70-108 MHz

IC KT0803K Block diagram

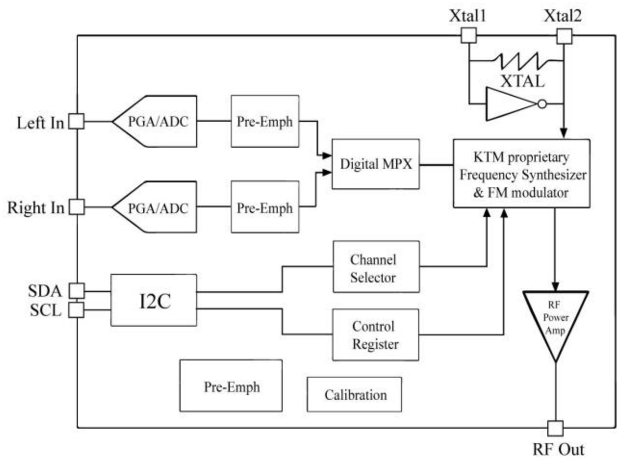

Fig. 3. Block diagram of IC KT0803K [2]

Pin-out diagram of IC KT0803K

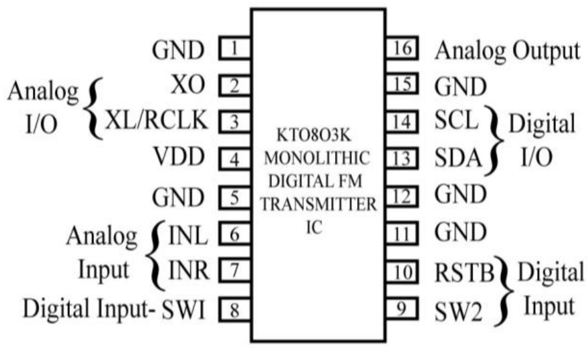

Fig. 4. Pin-out diagram of IC KT0803K

C. TEA5767 FM Stereo Radio Module

The TEA5767 is a simple stereo FM receiver chip. This new generation low voltage FM radio provides a fully integrated intermediate frequency (IF) selectivity and demodulation. This TEA5767 receiver module does not require any coalition (alignment), [3]. The basis of digital tuning is conventional PLL (phase locked loop) concept.

Fig. 5. Pin-out diagram of TEA5767 module

Figure shows the pin diagram of TEA5767 FM Receiver Module with all input and output connections labelling. The characteristics of TEA5767 IC are given below [5].

- High sensitivity due to integrated low-noise Radio
- Frequency input amplifier.
- RF Automatic Gain Control circuit.
- Phase-locked loop (PLL) synthesizer tuning system.
- I^{2}C-bus and 3-wire bus, selectable via pin BUSMODE.
- 7-bit IF counter output via the bus.
- 4-bit level information output via the bus.
- Adjustment-free stereo decoder.
- Autonomous search tuning function.
- Standby mode.
- Two software programmable ports.
- Bus-enable line to switch the bus input and output lines into 3-state mode.

D. Amplifier LM386

The integrated chip LM386 is a low power audio frequency amplifier. It comes in an 8-pin DIP package and used for battery-powered devices such as radios, guitar amplifiers, and hobby electronics projects. It takes an audio input signal and increases its potential anywhere from 20 to 200 times [10]. This amplification is known as voltage gain. As the audio output from TEA5767 module is not enough to drive speakers, LM386 is used here to overcome this problem.

E. Inter-Integrated Circuit (I^{2}C)

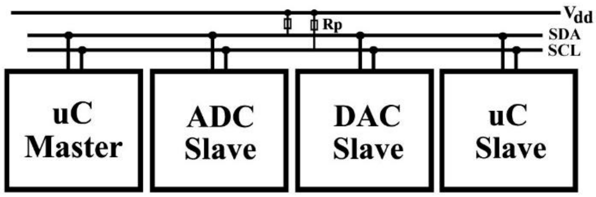

Fig. 6. I^{2}C Bus

I^{2}C (Inter-Integrated Circuit) is pronounced as I squared C, is a multi-master, multi-slave, single ended serial bus for two-wire interface to connect low-speed devices like microcontrollers, EEPROMs, A/D and D/A converters, I/O interfaces and other similar peripherals in embedded systems. It was invented by Philips (now NXP Semiconductors) and now it is used by almost all major IC manufacturers. Each I^{2}C slave device needs an address. I^{2}C only uses two wires to transmit data between devices [6]. I^{2}C which is a bi-directional, two wire and serial communication standard protocol [9], so data is transferred bit by bit along a single wire (the SDA line).

SDA (Serial Data) – The line for the master and slave to send and receive data.
SCL (Serial Clock) – The line that carries the clock signal

F. Phase Locked Loop (PLL)

A phase-locked loop is an electronic system which contains a voltage driven oscillator that constantly adjust to match the frequency of an input signal. In the basic PLL, reference signal and the signal from the voltage controlled oscillator are connected to the two input ports of the phase detector. The output from the phase detector is passed to the loop filter and then filtered signal is applied to the voltage controlled oscillator [7]. They can be used in various devices to demodulate a signal, recover a signal from a noisy communication channel, generate an accurate and stable frequency at multiples of input frequency, or distribute precisely timed clock pulses in digital logic circuits such as microprocessors related devices [4]. Fig. 7 shows a basic PLL system.

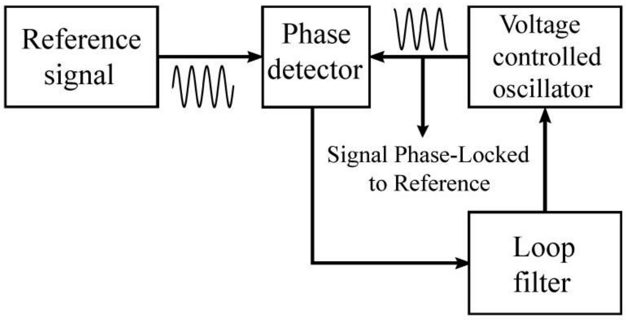

Fig. 7. Basic PLL System

G. Working Procedure

Step – 1: Interfacing FM transmitter slave module with master (Arduino UNO-1) microcontroller.
Step – 2: Setting up microphone input, audio input and transmitting antenna with FM transmitter module.
Step – 3: Interfacing 4×4 matrix keypad with master micro-Controller (Arduino UNO-1).
Step – 4: Interfacing TEA5767 radio receiver slave module with master (Arduino UNO-2) micro-controller.
Step – 5: Setting up receiving antenna and LM386 amplifier with TEA5767 FM radio receiver module.
Step – 6: Interfacing audio speaker with LM386 amplifier.
Step – 7: Interfacing 16×2 Liquid Crystal displays with both transmitter and receiver microcontrollers.
Step – 8: Sketch and upload Arduino IDE transmitter and receiver programs.
Step – 9: Testing and debugging of FM transmitter and receiver programs.
Step – 10: Packaging of the final prototype.

III. REQUIRED SOFTWARE AND LIBRARIES

A. Arduino Software (IDE)

Arduino is an open-source electronics platform based on easy-to-use hardware and software.

Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. We can tell our board what to do by sending a set of instructions to the microcontroller on the board. To do so we use the Arduino programming language (based on Wiring), and the Arduino Software Integrated-Development-Environment (IDE), based on Processing. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide [8].

The Arduino Integrated Development Environment (IDE) software is the platform where programmers do their programming before uploading the programs into Arduino microcontrollers. The environment is written in JAVA and it runs on MAC, Windows, OS and Linux.

B. Required Libraries for Transmitter Programming

Arduino UNO is used the Arduino IDE (Integrated Development Environment) platform for the Embedded programming. From the platform the libraries required for FM transmitter programming are-

- FMTX Library
- Liquid Crystal Library
- Keypad Library
- Wire Library

C. Required Libraries for Receiver Programming

The Libraries required for FM receiver programming are-

- TEA5767Radio Library
- Liquid Crystal Library
- Wire Library

The Liquid Crystal library, Keypad library and Wire library are built in libraries of Arduino IDE. The FMTX library and TEA5767Radio library are the contributed libraries of Arduino IDE. The programs are usually written in the C language with the extended features of Arduino platform. The Arduino UNO than extract the C language into machine language. It must be noted that when we upload any program to the Arduino microcontrollers it requires to select the Arduino board information and COM port i.e. through which communication port the IDE wants to communicate with the microcontroller board. Without selecting the board information and COM port, programmers can't upload any program from the IDE to microcontrollers.

IV. PROGRAMMING FLOWCHART

A. Diagrammatic Representation of Transmitter Programming

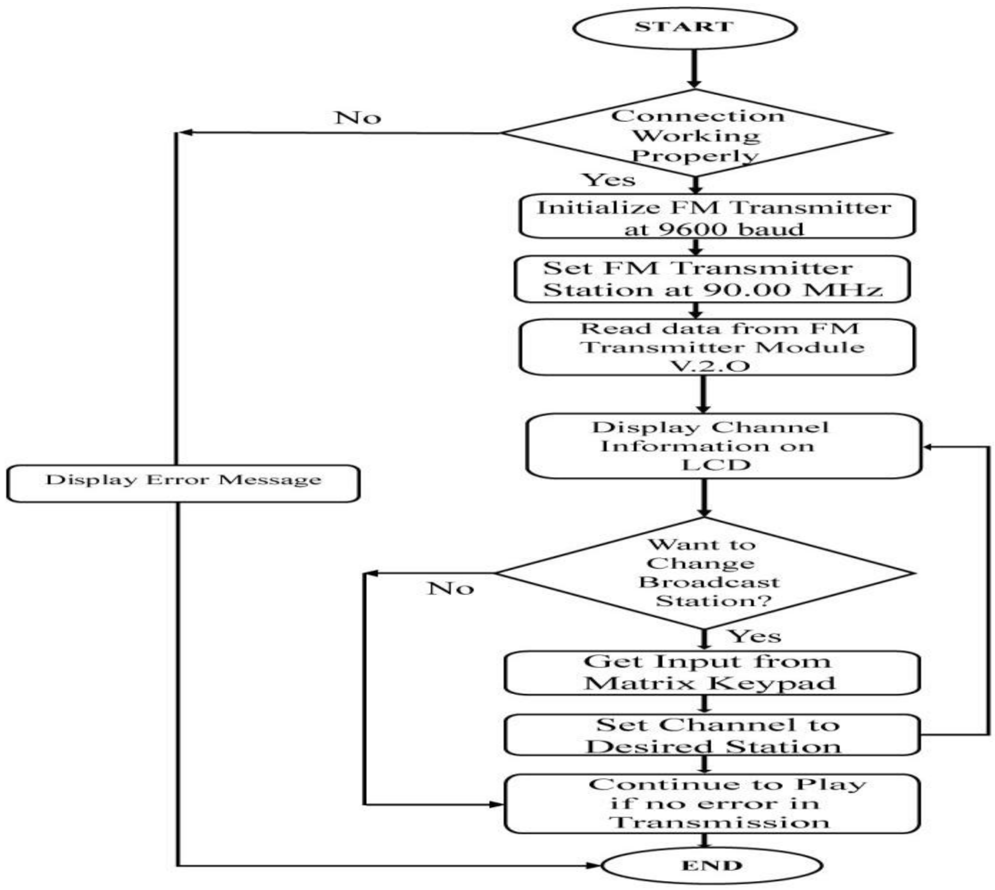

Fig. 8. Process flowchart of Transmitter

B. Diagrammatic Representation of Receiver Programming

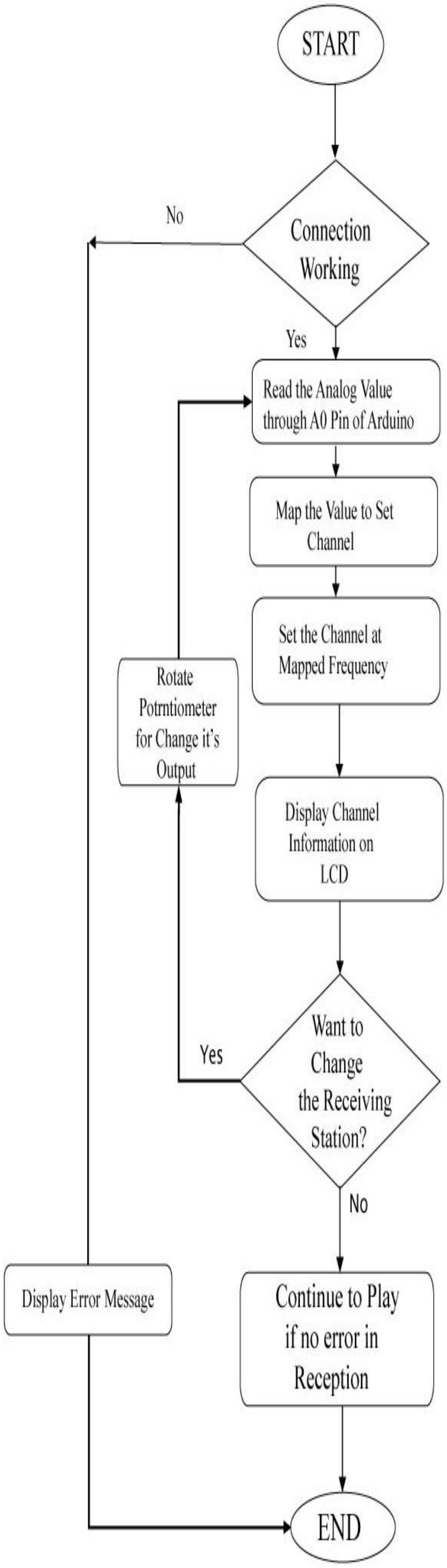

Fig. 9. Process flowchart of Receiver

V. RESULT AND DISCUSSION

Digital FM transceiver is implemented according to the proposed design that describes earlier in the methodology section of this paper. The soldering work and packaging of the final project requires some additional special tools. Transmitting of voice and audio signals through various transmission channel is achieved. The transmission range of the transceiver is 50 meters and any receiver covering that area were picking up the transmission channels. The signal received by the transceiver is resistant to various temperature fluctuations. We were able to implement auto scan feature in the receiver system. Variations in reception are observed when the length of the receiving antenna is changed. The complete project view and different transmission and reception strategies are given in this section.

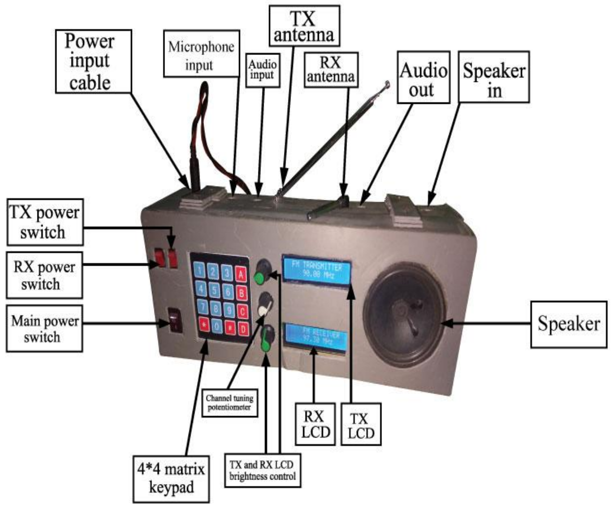

Fig. 10. Outside view of digital FM transceiver

The above figure represents the complete outside view of digital FM transceiver after it has been built according to proposed design. The figure also shows the transmission frequency of the transmitter is set to 90.00 MHz and the receiver receives a broadcasting channel at 97.30 MHz. Channel information are displayed through Liquid Crystal Display.

Fig. 11. Transmission

channel 102.70 MHz

From Fig. 11. We can see that, the transceiver is transmitting at 102.70 MHz and this transmission channel is picked up by an android mobile phone FM radio application. The android mobile phone is located at a distance of 50 meters from the transceiver.

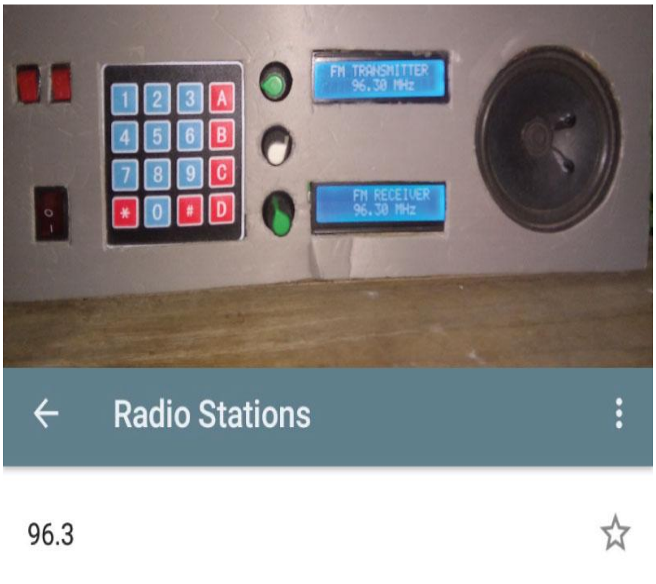

Fig. 12. Transmission and reception channels at 96.3 MHz

Fig. 12 represents that, the transmitter is transmitting at 96.30 MHz and this transmission channel is received by both the TEA5767 radio receiver and an android mobile phone FM radio application.

Fig. 13. Transmission channel at 99.7 MHz and reception channel at 105.3 MHz

Fig. 13 shows that, the transmitter is transmitting at 99.70 MHz and this transmission channel is picked up by both the receiver and an android mobile phone FM radio application. Here the receiver is tuned at 105.3 MHz. Now we can't listen by this receiver what is transmitting at 99.70 MHz, but if we tuned another receiver station to that transmitting channel we can hear whatever is transmitting on that channel. The above strategies from Fig. 11 to Fig. 13 proves the full duplex communication mode of the digital FM transceiver. Moreover, the transmitter and the radio of this transceiver is completely independent to their operation from each other.

VI. PERFORMANCE TESTING

A. Oscilloscope Connection with I2C Bus

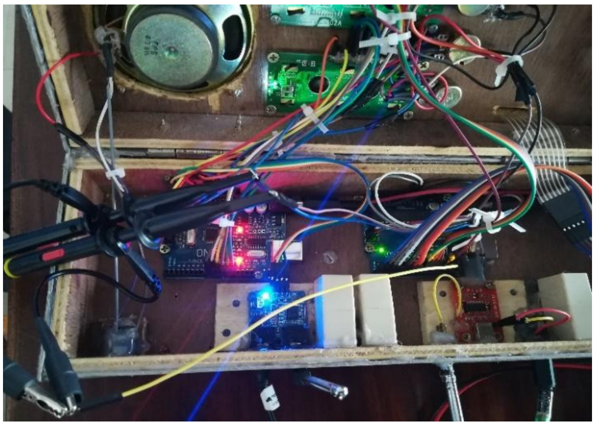

Fig. 14. Inside view of transceiver with probe connection

Fig. 14 shows the inside view of the transceiver. The figure also shows channel 1 connected to SCL pin of microcontroller and channel 2 connected to SDA pin of microcontroller by connecting probes of SIGLENT digital oscilloscope.

B. Representation of SDA and SCL Signals:

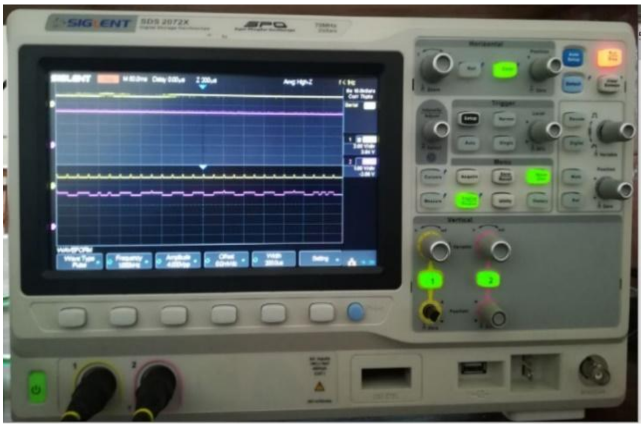

Fig. 15. Serial clock (SCL) and Serial data (SDA) signals

Both the signals in Fig. 15 are observed through channel-1 and channel-2 of the digital oscilloscope at 200 micro-seconds time interval. The Serial clock signal is represented by yellow color and the Serial Data signal is represented by the violet color in the above figure.

C. Representation of Transmitted FM Signals:

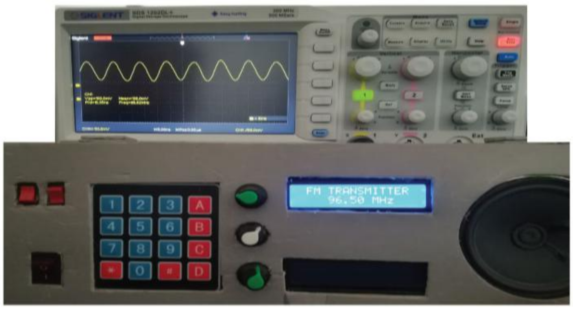

Fig. 16. Transmitted FM Signal at 96.50 MHz

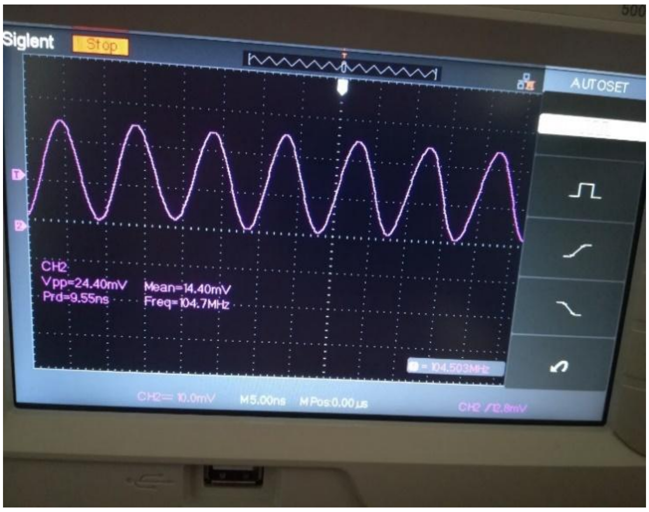

Fig. 17. Transmitted FM Signal at 104.50 MHz

Fig. 16 and Fig. 17 represents the transmitted FM signals when the transmission frequency of the transmitter is set to 96.50 MHz and 104.50 MHz respectively. Both signals are observed at 5.00 ns time interval through SIGLENT (200 MHz) digital oscilloscope.

VII. CONCLUSION

The paper describes the usage of digital systems for FM transmission and reception using Arduino UNO microcontroller.

Communication among master microcontroller and slave devices such as FM transmitter module, TEA5767 radio receiver module, Liquid Crystal display modules are achieved by I^2C method. Transmission and reception frequency details are displayed on LCD display. Tuning of particular transmission and reception frequency can be easily handled using commands by the master microcontrollers. The cost of digital tuning of the transceiver is reduced using combination of microcontroller transmitter module and receiver module. We can transmit our voice and audio signal at any broadcast channel of FM band by the transmitter while we can listen or enjoy FM radio at different channels by the radio receiver. This ensures the full duplex communication mode of the transceiver. Transmission and reception strategies at different channels of the transceiver is proven after completing the project. Further the I^2C bus and transmitted signals at different frequency of the transceiver is tested by digital oscilloscope. It is to be noted that, transmission in FM band which covers a large area in most of the part of the world is illegal without permission. The transmission range of this transceiver is not more than 50 meters. This project requires external 9-12 volt dc power supply for its operation. Further the size of project can be reduced by using ATmega328p IC and some additional components instead of using Arduino development boards. Use of microcontroller in this project provides excellent sensitivity and at the same time better selectivity.

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