Department of Electrical Engineering

Communication Systems

AM Modulator and Superheterodyne AM Receiver (999kHz Carrier Frequency and Intermediate Frequency 455kHz)

Project Report

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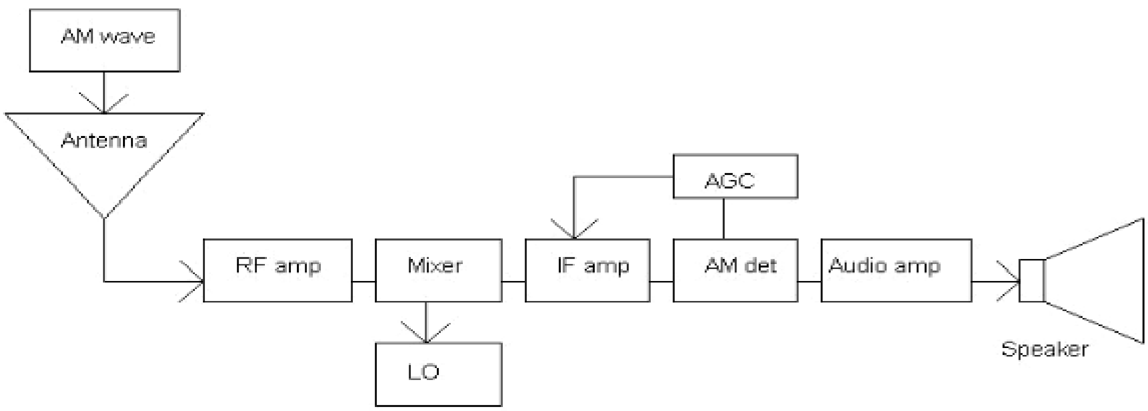
1. Introduction:

The aim of this project is to simulate a complete superheterodyne receiver using Proteus. The specifications set out at the beginning of the project were to take the basic block diagram for the superheterodyne receiver, shown below in figure and then design and simulate it.



Following the block diagram above, the incoming signal is picked up on the antenna and fed to an RF amplifier. The RF amplifier provides some initial gain and selectivity and minimizes radiation of the Local Oscillator (LO) signal through the receiving antenna by isolating the Mixer from the antenna. However, the most important function of the RF amplifier is to eliminate what is known as the image signal.

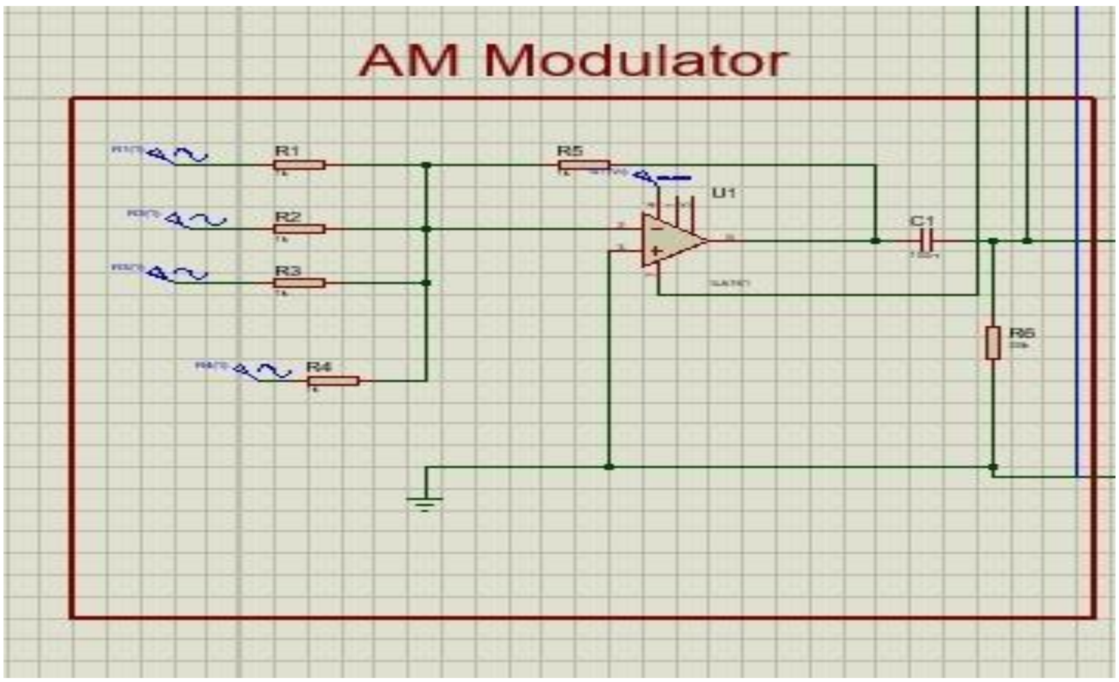
The output of the RF amplifier is then applied to the input of the Mixer. It also has an input from the LO. The Mixer (or Frequency Converter) is a non-linear device, which results in the creation of sum and difference frequencies. The output from the Mixer is a combination of the received signal and the LO signal as well as their sum and difference frequencies. This process is called Heterodyning.

The output of the mixer is amplified by one or more IF amplifier stages. Most of the receiver sensitivity and selectivity is to be found in these stages. All IF stages are fixed and tuned to $\mathbf{F_{if}}$ only (this standard is fixed at 455kHz). Hence, high selectivity can be obtained. The highly amplified IF signal is now applied to the detector or demodulator where the original modulating signal is recovered. The detector output is then amplified to drive a Loudspeaker.

2. Procedure:

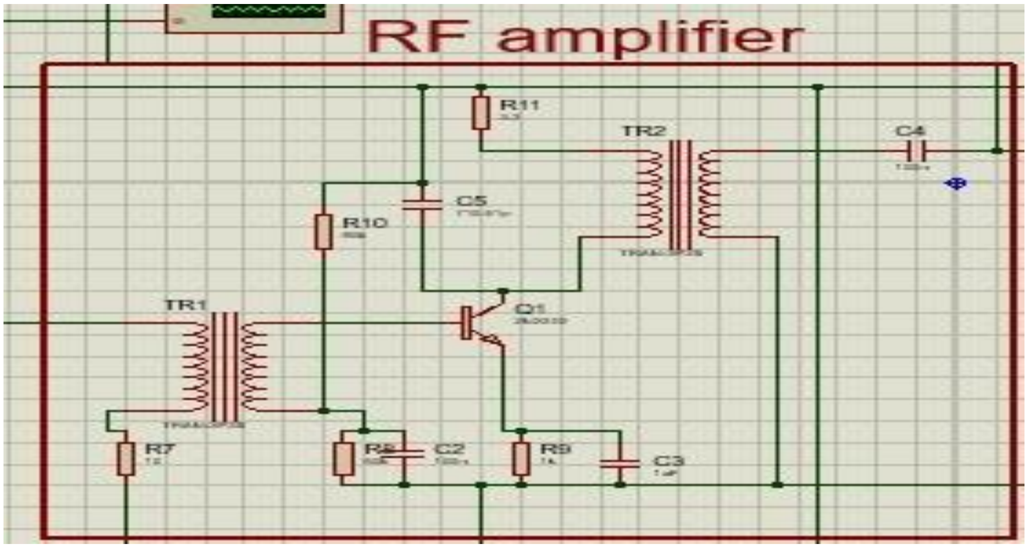
PART 1: GENERATION OF AN AMPLITUDE MODULATED WAVE:

The first stage of the project is to generate an AM signal and to simulate this signal, which is to be picked up by the receiving antenna. In Amplitude Modulation the amplitude of the carrier wave varies in accordance with the amplitude of the modulating signal and the carrier frequency and phase remain unaffected. An increase or decrease in the amplitude of the modulating signal causes a corresponding change in the carrier amplitude. The pattern of amplitude variations is known as the envelope. The information is carried in the envelope and an AM demodulator or envelope detector recovers the information from the envelope.



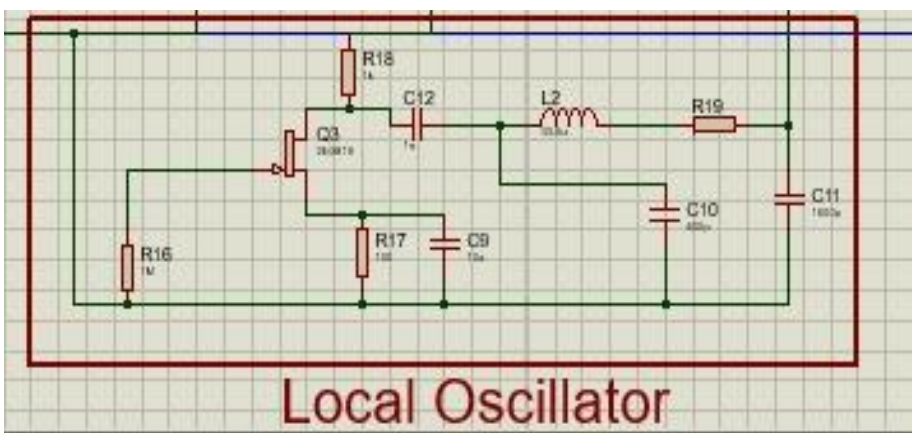
PART 2: DESIGN OF A SINGLE TUNED RF AMPLIFIER:

The function of the RF amplifier is to select and amplify a desired frequency from all those received while rejecting all other frequencies, most notably the image frequency. Since it is a tuned amplifier, it is highly frequency selective and attenuates sufficiently all signals but the one to which it is tuned. The amplified AM signal from the RF amplifier is then fed to the mixer where it is combined with the output from the local oscillator. The AM signal generated previously will be fed into the amplifier in the hierarchy structure.



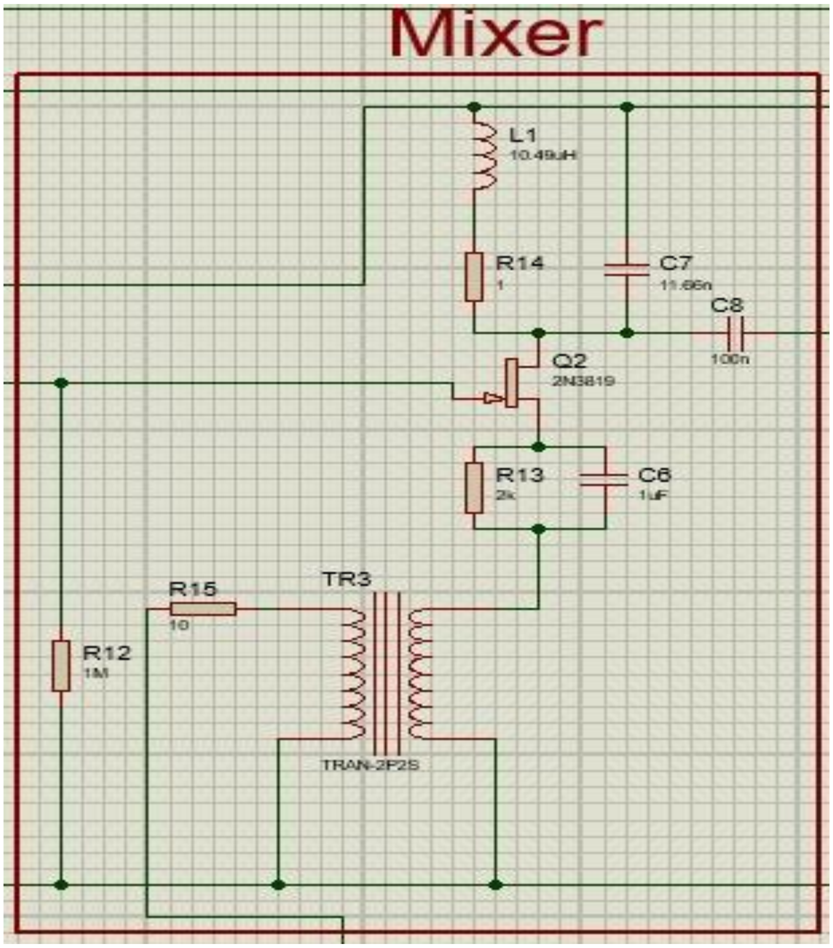
PART 3: LOCAL OSCILLATOR DESIGN:

There are a few important criteria when designing a local oscillator. It is likely that there will be some internal signal loss within the oscillator and therefore to overcome this the oscillator will have to provide some signal gain. The frequency of the oscillator is important, especially in our design for the superheterodyne receiver. The frequency should be variable but, in this design, we are fixing the frequency at the RF frequency plus twice the IF frequency.



PART 4: DESIGN OF MIXER CIRCUIT:

A mixer is a device that converts a signal from one frequency to another. Most high frequency receivers use a mixer to convert the received RF signal to an intermediate frequency (IF) signal. A mixer in RF systems always refers to a circuit 21 with a non-linear component that causes sum and difference frequencies of the input signals to be generated. The mixer is achieved by applying the Local Oscillator (LO) signal to one mixer port and the Radio Frequency (RF) signal to the other port.



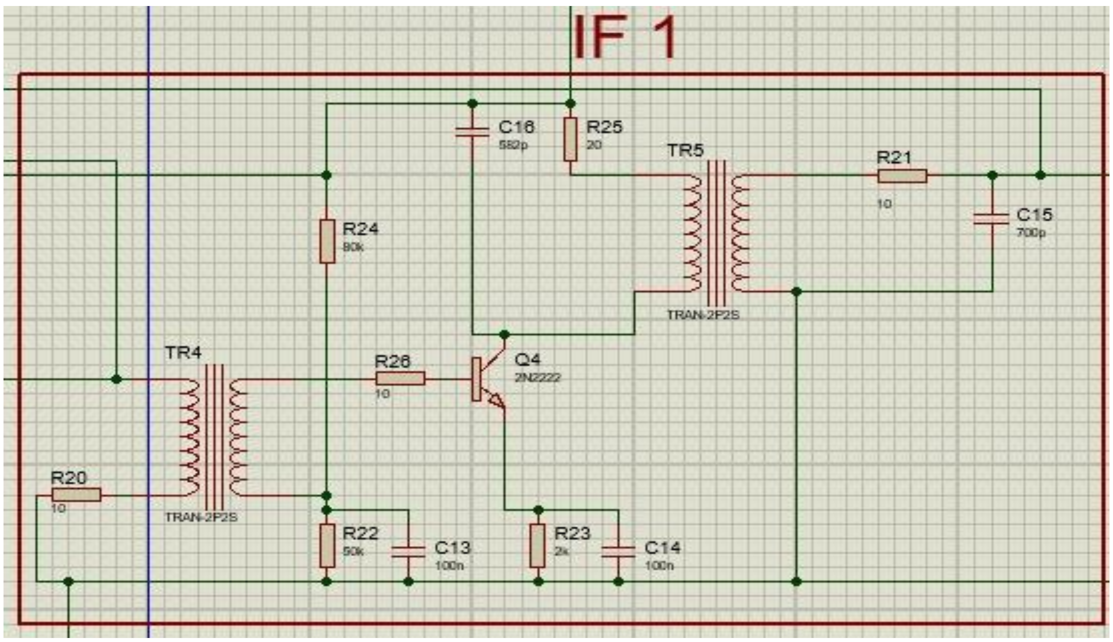
PART 5: DESIGN OF IF STAGE:

The output of the Mixer is amplified by two IF amplifier stages. Most of the receiver sensitivity and selectivity is to be found in the IF stage. The two IF stages are tuned to Fif (= 455kHz). The highly amplified IF signal will then be applied to the Detector where the original modulating signal is recovered.

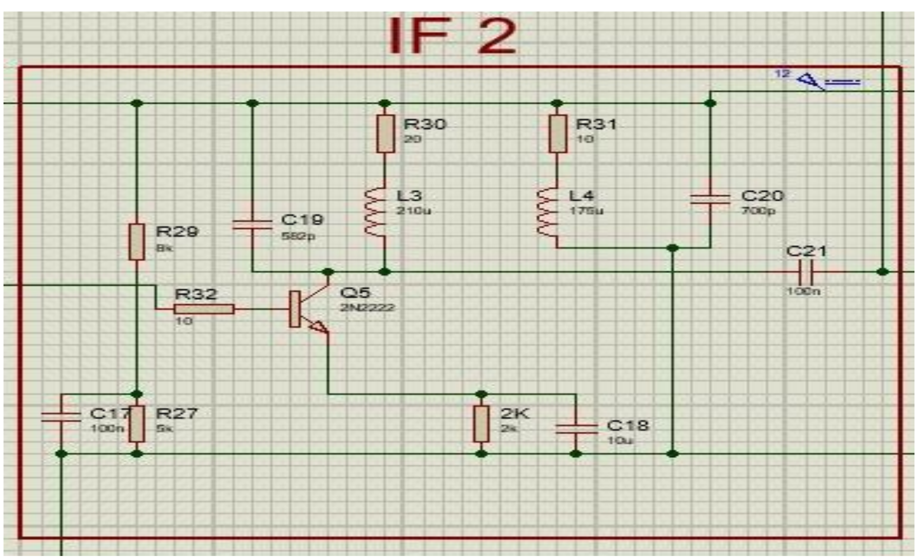
$$f_o \approx \frac{1}{2\pi\sqrt{LC}} = 455kHz$$

Choosing L=175uH then we get C=700pF. The value for the second LC tuned circuit must be calculated. The reason the double tuned circuit is used is to get a flat top response for the amplifier at the resonant frequency. The single-tuned response has a very sharp response, which could lead to the loss of information. However, using double-tuned circuits means a coupling coefficient must be used. The inductance and capacitance values used in the single tuned circuit are referred to as L2 and C2 respectively. Values for L1 and C1 are calculated. As before the L value is chosen (L1=210uH) and the corresponding C value to resonate at 455kHz is C2=582pF.

IF1:

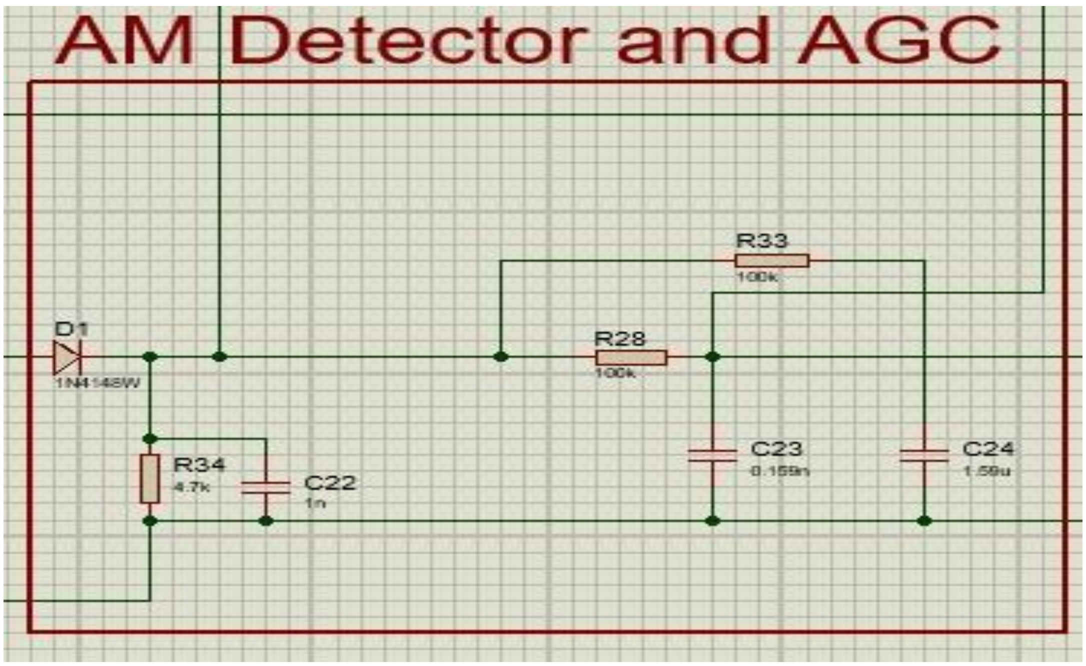


IF2:



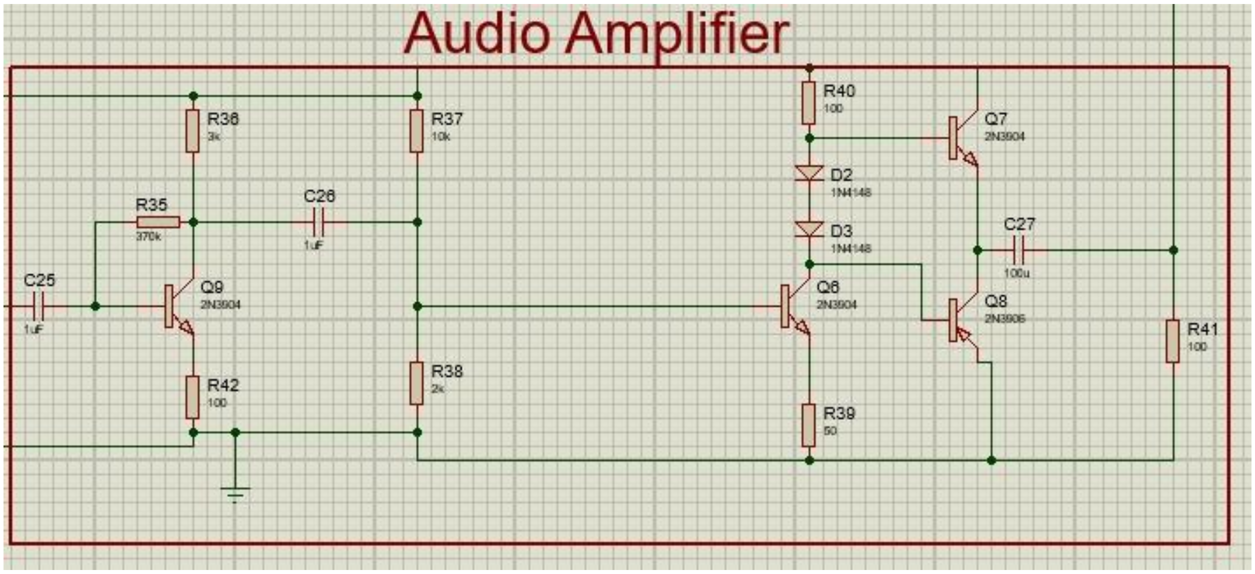
PART 6: AM DETECTION WITH AGC:

For testing the detector circuit, the AM wave generator previously developed is applied to the envelope detector. The main function of the AM detector is to recover the modulated signal. It has another function called automatic gain control (AGC). AGC is required in the superheterodyne receiver to regulate the receiver gain as the input carrier amplitude varies due to a variety of reasons.



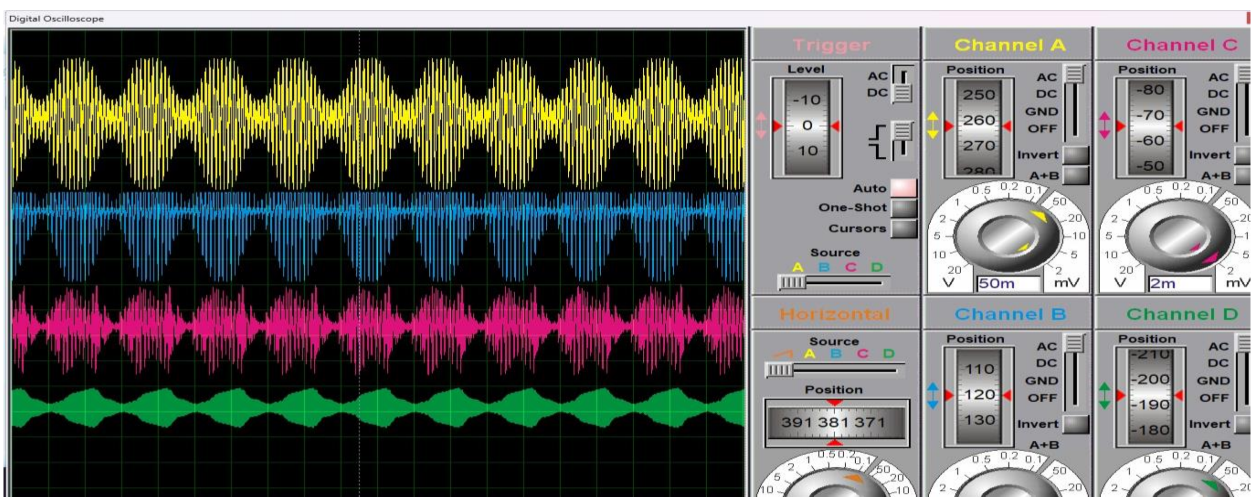
PART 7: DESIGN OF PRE-AMPLIFIER AND POWER AMPLIFIER:

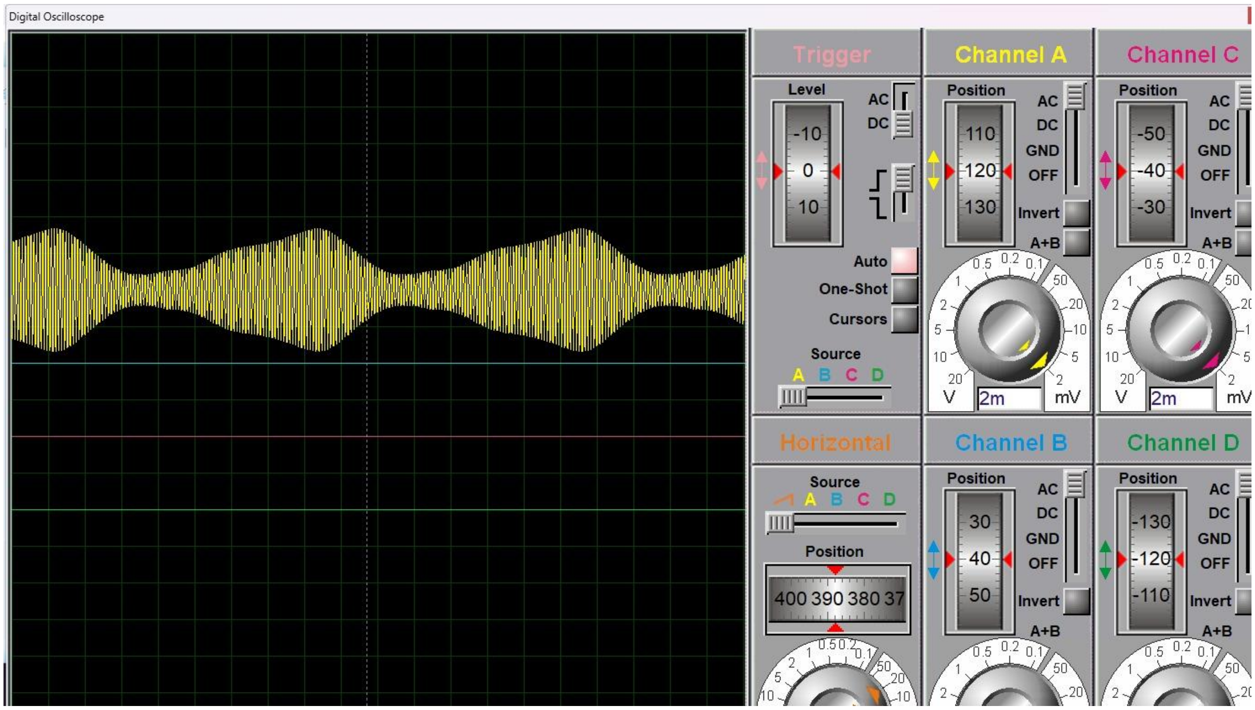
Class A, B, and C amplifiers are used in transmitters. Class A amplifiers are used in low-power stages where device dissipation and efficiency are not critical. Class B and C amplifiers are used where high power and efficiency are required. In the superheterodyne receiver the pre-amplifier stage and power amplifier stage are combined and implemented together as an audio amplifier. Therefore, class C amplifiers cannot be used in audio amplifiers because the output current flows for less than one-half of the input signal cycle. Class B operation is achieved when the active device (in this case the BJT) is biased at cut-off, so that the output current will flow for only one half of the input signal cycle.



3. Final Tests and Result:

With the superheterodyne receiver designed, tested and simulated in its various blocks the results are as follow:





1st wave if the output of AM generated modulated signal.

2nd wave is output of RF amplifier.

3rd wave is output of Mixer.

4th wave is output of IF1.

5th wave is output of IF2.

6th wave should be output of AM detector and Audio Amplifier, but this part of our circuit is not working. This is most likely because of loading effects which is explained below.

Loading effects: the main problem associated with the whole structure is the loading effects between the different blocks of circuit i.e. RF Amplifier and Mixer etc. It is essential to isolate the blocks from each other to avoid one block loading down the entire circuit and effectively stopping the receiver from working. The solution in Proteus is through transformers.

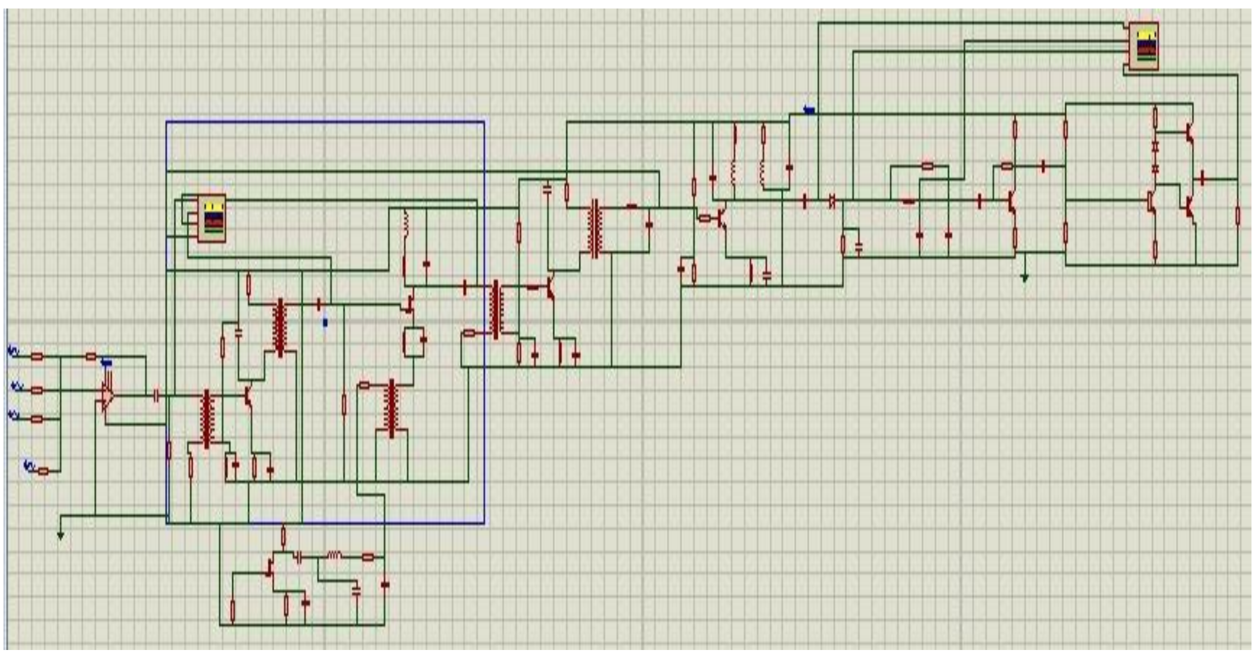
Conclusion:

The main aim of the project was to design and simulate the complete superheterodyne receiver.

The results of the project can be summarized as follows:

An AM wave was generated with a carrier frequency of 999kHz and a modulating frequency of 5kHz (i.e. a 10kHz bandwidth). The AM signal was fed to an RF amplifier. A signal was generated at the local oscillator stage and when “mixed” or heterodyned with the RF signal produced the difference or intermediate frequency. This difference frequency at 455kHz was amplified by two IF stages (most of the sensitivity and selectivity found here). The AM detector now detected this signal. The detector also detected the modulating frequency at 5kHz.

Simulation Design:



Extra Work:

Introduction:

Frequency modulation (FM) is a technique used to encode information in a carrier wave by varying the instantaneous frequency of the wave. It is widely used in radio broadcasting, telecommunications, and signal processing due to its advantages in noise resistance and signal quality.

Basic Principles of Frequency Modulation:

In FM, the frequency of the carrier wave varies in accordance with the amplitude of the input signal (modulating signal). The carrier's amplitude remains constant, while its frequency changes. This can be expressed as:

$$f(t)=f_c+\Delta f\cdot\sin(2\pi f_m t)$$

where:

- $f(t)$ is the instantaneous frequency of the modulated signal.
- fc is the carrier frequency.
- Δf is the frequency deviation, representing the maximum shift from the carrier frequency.
- fm is the frequency of the modulating signal.

FM vs. AM:

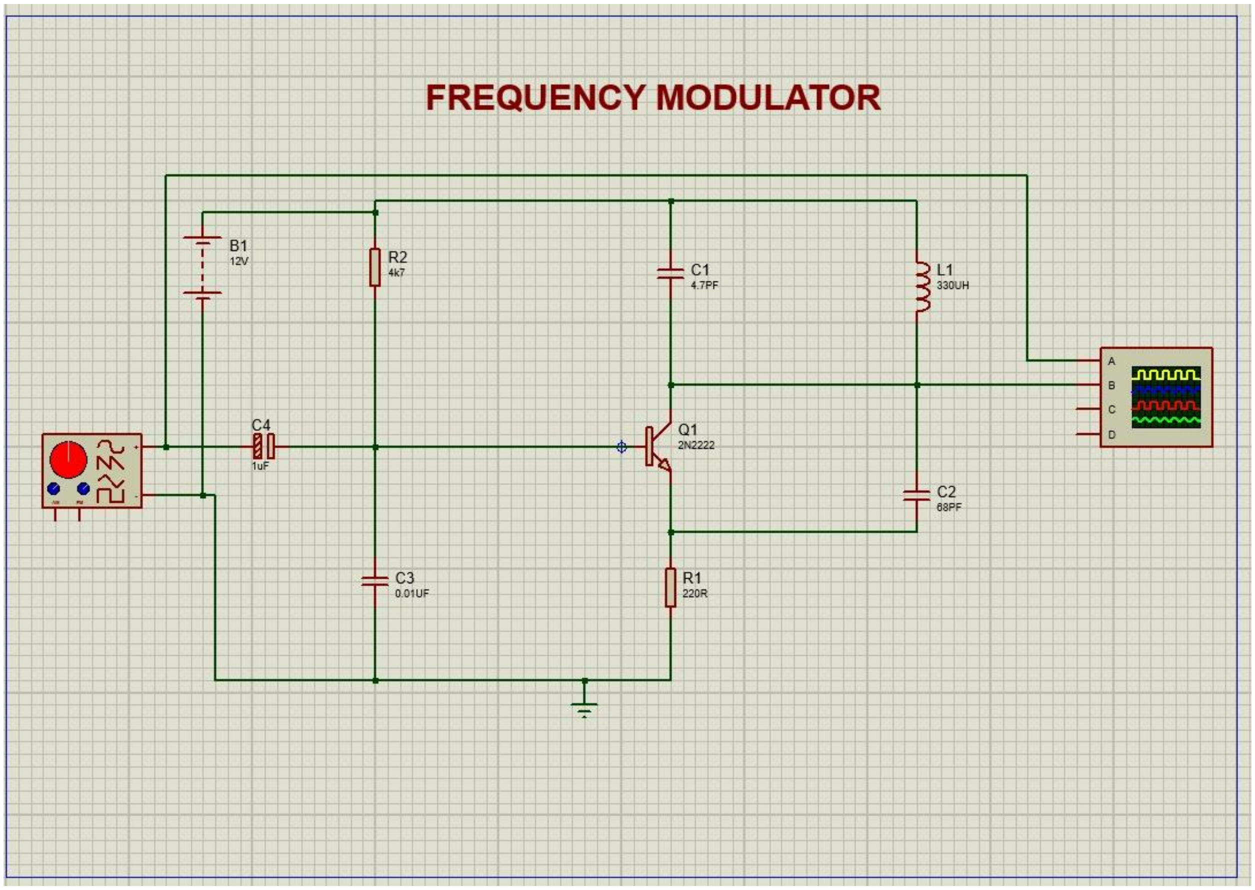
Signal Quality: FM generally provides better signal quality and higher fidelity compared to AM.

Noise Immunity: FM is less affected by noise and interference.

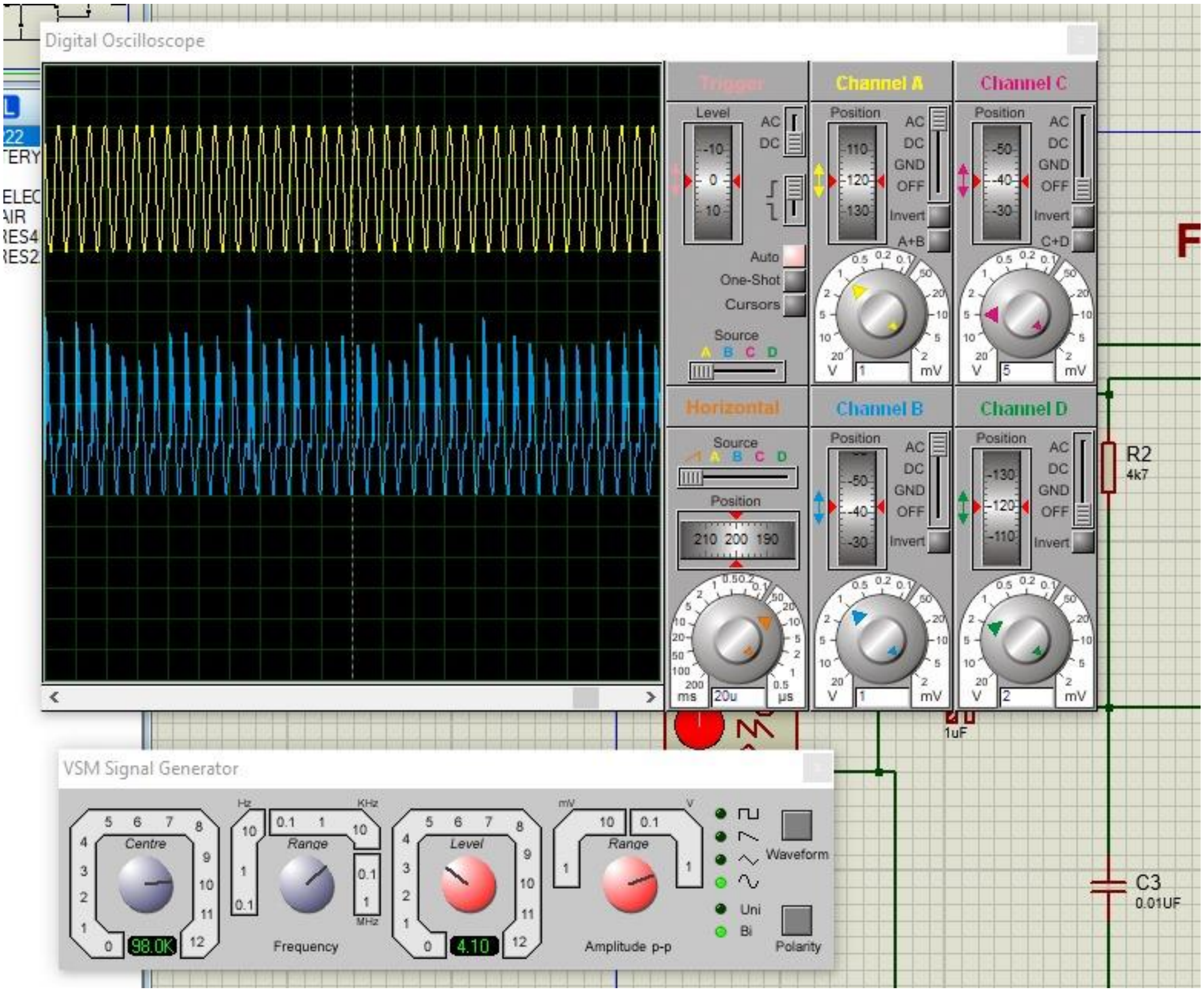
Bandwidth: FM requires more bandwidth than AM.

Transmitter and Receiver Complexity: FM systems are typically more complex and costly than AM systems.

Results:



FREQUENCY MODULATOR
B1
12V
R2
4k7
C1
4.7PF
L1
330UH
C4
1uF
Q1
2N2222
C2
68PF
C3
0.01UF
R1
220R
A
B
C
D



Contribution:

Abdul Hadi and Muhammad Ahmed: AM Modulator and Superheterodyne Receiver.

Muhammad Ammar: FM Modulator.