Voice Signal Transmission and Reception Using Amplitude Modulation

[Implement DSB signal transmission & Direct Conversion Receiver(DCR) based signal reception.]

1.Shadman Sobhan - 1906109

2.Fahim Ahmed – 1906110

3.Atiqur Rahaman Shoan – 1906111

4.Kazi Abrar Mahmud – 1906112

5.Shadid Yousuf - 1906113

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Department of Electrical and Electronic Engineering

Course No.: EEE 310

Course Title: Communication Laboratory

Group : 3

Project on

Voice Signal Transmission and Reception Using Amplitude Modulation

Submitted to,

1.**Dr. Lutfa Akter**

Professor

Department of Electrical & Electronic Engineering

2. **Barproda Halder**

Lecturer

Department of Electrical & Electronic Engineering

Submitted by,

1.Shadman Sobhan - 1906109

2.Fahim Ahmed – 1906110

3.Atiqur Rahaman Shoan – 1906111

4.Kazi Abrar Mahmud – 1906112

5.Shadid Yousuf - 1906113

Table of Contents

Table of Figures

Abstract:

Amplitude modulation (AM) is a widely used technique for transmitting and receiving voice signals over long distances. In this technique, the amplitude of a high-frequency carrier signal is varied in proportion to the instantaneous amplitude of the voice signal. The modulated signal is then transmitted through the communication channel, and at the receiver, the original voice signal is extracted by demodulating the received signal.

Here we Implemented DSB(Double-sideband) signal transmission & Direct Conversion Receiver(DCR) based signal reception.Before implementing the hardware we simulated our whole system using Eagle Schematics software .This process helped us to predict any overlooked faults in our circuit design and to optimize the process furthermore.

After finalizing the design we developed the actual hardware for the system and compared its output with our simulation results .In order to generalize the process more we designed a variable frequency oscillator instead of a fixed carrier generator .This will help us to further develop and improve our system in the future.

Objectives:

1. Implement DSB signal transmission & Direct Conversion Receiver(DCR) based signal reception.
2. Develop Software base simulation and PCB design.
3. Used the software base model to further improve upon the design.
4. Comparison between simulated result with the result obtained from developed hardware.

Required Components:

1. Si5351 Module
2. MC1496 Gilbert Cell
3. LCD Display
4. Arduino Nano(For the display)
5. LM317T Adjustable voltage regulator
6. Potentiometer(1k , 10k & 50k ohm)
7. Resistances & capacitors.
8. Purfboards
9. Antenna(Telescopic)

Working Principles:

Here we discuss about all the blocks that were used to complete the scheme .Each block was design in a modular way so that in future they can be reconfigured and be used to develop different communication schemes.

Amplitude modulator:

In order to achieve modulation between two electrical signal we used transistors arranged in Gilbert cell like structure. This special array of differential transistor pairs can found in MC1496 IC design and manufactured by Motorola.The basic schematic diagram for analysisng MC1496 is given below

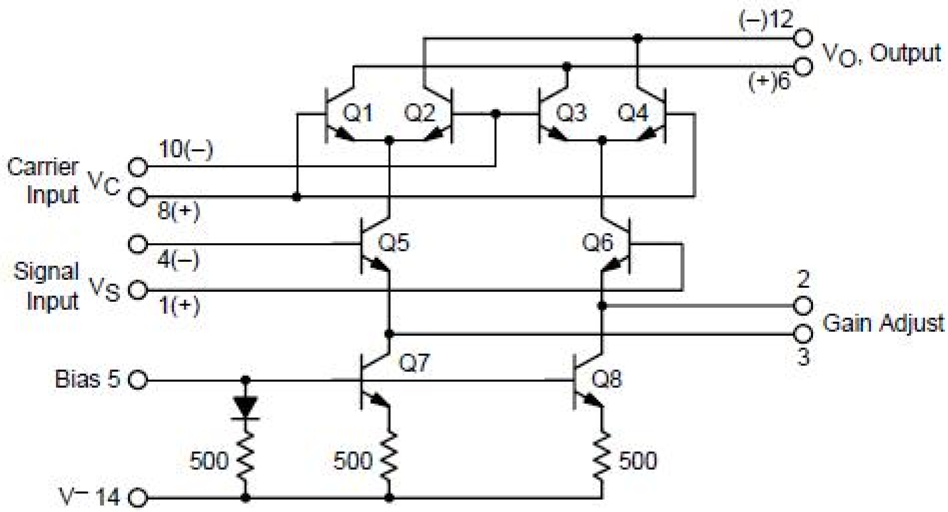


Figure 1: MC1496 Schematic

MC1496 Device operation:

The most common mode of operation of the MC1496 consists of applying a high level input signal to the dual differential amplifiers, Q1, Q2, Q3, and Q4, (carrier input port) and a low level input signal to the lower differential amplifier, Q5 and Q6, (modulating signal input port). This results in saturated switching operation of carrier dual differential amplifiers, and linear operation of the modulating differential amplifier.
The resulting output signal contains only the sum and difference frequency components and amplitude information of the modulating signal. This is the desired condition for the majority of the applications of the MC1496.

Saturated operation of the carrier–input dual differential amplifiers also generates harmonics .Reducing the carrier input amplitude to its linear range greatly reduces these harmonics in the output signal. However, it has the disadvantages of reducing device gain and causing the output signal to contain carrier signal amplitude variations. The carrier input differential amplifiers have no emitter degeneration. Therefore, the carrier input levels for linear and saturated operation are readily calculated .The crossover point is in the vicinity of 15–20 mV rms, with linear operation below this level and saturated operation above it.

DC Bias:

A significant portion of the DC bias circuitry for the MC1496 must be supplied externally. While this has the disadvantage of requiring several external components, it has the advantage of versatility. The MC1496 may be operated with either single or dual power supplies at practically any supply voltage(s) a semiconductor system has available. Further, the external load and emitter resistors provide the designer with complete freedom in setting device gain. The DC bias design procedure consists of setting bias currents and 4 bias voltage levels, which not exceeding absolute maximum voltage, current, and dissipation ratings. The current levels in the MC1496 are set by controlling I5 (subscripts refer to pin numbers). For bias current design the following assumption may be made:

$$I_5 = I_6 = I_{12} = \frac{I_{14}}{3}$$

Since base currents may be neglected, I5 flows through a forward biased diode and a 500 W resistor to pin 14. When pin 14 is grounded, I5 is most conveniently adjusted by driving pin 5 from a current source. When pin 14 is connected to a negative supply, I5 may be set by connecting a resistor from pin 5 to ground (R5). The value of R5 may be computed from the following expression:

$$R_5 = \frac{|V_{14}| - \phi}{I_5} - 500\ \Omega$$

where ø = the diode forward voltage, or about 0.75 Vdc at TA = 25°C. The absolute maximum rating for I5 is 10 mA. For all applications described in the article, bias current I5 has been set at 1 mA. The MC1496 has been characterized at this bias current and it is the recommended current unless there is a conflict with power dissipation requirements. The 4 bias voltage levels that must be set up externally are:

pins 6 and 12 most positive;
pins 8 and 10 next most positive;
pins 1 and 4 next most positive;
pin 14 most negative.

The intermediate voltage levels may be provided by a voltage divider(s) or any other convenient source such as ground in a dual power supply system. It is recommended that the voltage divider be designed for a minimum current of 1 mA. Then I1, I4, I7, and I8 need not be considered in the divider design as they are transistor base currents.

For maintaining at least 2 volts collector-base bias on all transistors while not exceeding the voltages given in the absolute maximum rating table

$$30\ \text{Vdc} \geq [(V_6, V_{12}) - (V_8, V_{10})] \geq 2\ \text{Vdc}$$
$$30\ \text{Vdc} \geq [(V_8, V_{10}) - (V_1, V_4)] \geq 2.7\ \text{Vdc}$$
$$30\ \text{Vdc} \geq [(V_1, V_4) - (V_5)] \geq 2.7\ \text{Vdc}$$

We use this table and external resistors at each pin of MC1496 to a certain per-defined bias voltage at each point.

Special Achievement:

In order to achieve all this requirements we developed a simulation model for MC1496 from scratch

The scripting language that we used for this task is ‘ngspice’ .Code written to mimic the operational behaviour of MC1496 can bundled with Eagle schematic software.Then we used the software to observe the behavior of our designed circuit and modify it accordingly.

The ngspice script for realizing the model in Eagle is given below:

```
*
.TEMP=25.0
*    Mixer Circuit
*
*------------------Subcircuit description-------------------
.subckt MC1496 1 2 3 4 5 6 8 10 12 14
* Tail current Source
Q1 3 5 19 Q2n3904
Q2 2 5 13 Q2n3904
* Input transistors
Q3 7 4 3 Q2n3904
Q4 9 1 2 Q2n3904
*LO quad switching Transistors
Q5 6 8 7 Q2n3904
Q6 6 10 9 Q2n3904
Q7 12 10 7 Q2n3904
Q8 12 8 9 Q2n3904
* Emitter degeneration resistors
RE1 19 14 500
RE2 13 14 500
*
* Current Mirror
Q9 5 5 15 Q2n3904
Rd 15 14 500
.ENDS
*------------------------Ends Subcircuit-------------------
*---------------------------Models---------------------------
.MODEL Q2N3904 NPN
+ISS=0 XTF=1 NS=1
+CJS=0 VJS=0.5 PTF=0
+MJS=0 EG=1.1 AF=1
+ITF=0.5 VTF=1 BF=280.92203
+BR=20 IS=2.3673E-15 VAF=130.20848
+VAR=11.074004 IKF=0.23419 ISE=3.0707E-16
+NE=1.19409 IKR=7.80101 ISC=3.5223E-12
+NC=1.33867 IRB=1.8864E-4 NF=0.97302
+NR=0.97623 RBM=1E-2 RB=69.94226
```

```
+RC=3E-02 RE=0.2569 MJE=0.36064
+MJC=0.29228 VJE=0.81795 VJC=0.45460
+TF=5E-10 TR=6.2636E-09 CJE=6.7441E-12
+CJC=3.4247E-12 FC=0.95 XCJC=0.95425

.MODEL D1N914 D(Is=168.1E-21 N=1 Rs=.1 Ikf=0 Xti=3 Eg=1.11
+ Cjo=4p M=.3333 Vj=.75 Fc=.5 Isr=100p Nr=2 Bv=100
+ Ibv=100u Tt=11.54n)
*-------------------------End Models---------------------------

.END
```

The designed Component following this script :

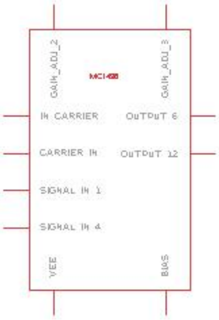


Figure 2: Designed Component(MC1496)

Figure 3 shows the MC1496 in a balanced modulator circuit operating with +12 and –8 volt supplies. Excellent gain and carrier suppression can be obtained with this circuit by operating the upper (carrier) differential amplifiers at a saturated level and the lower differential amplifier in a linear mode.The recommended input signal levels are 60 mV rms for the carrier and 300 mV rms for the maximum modulating signal levels.

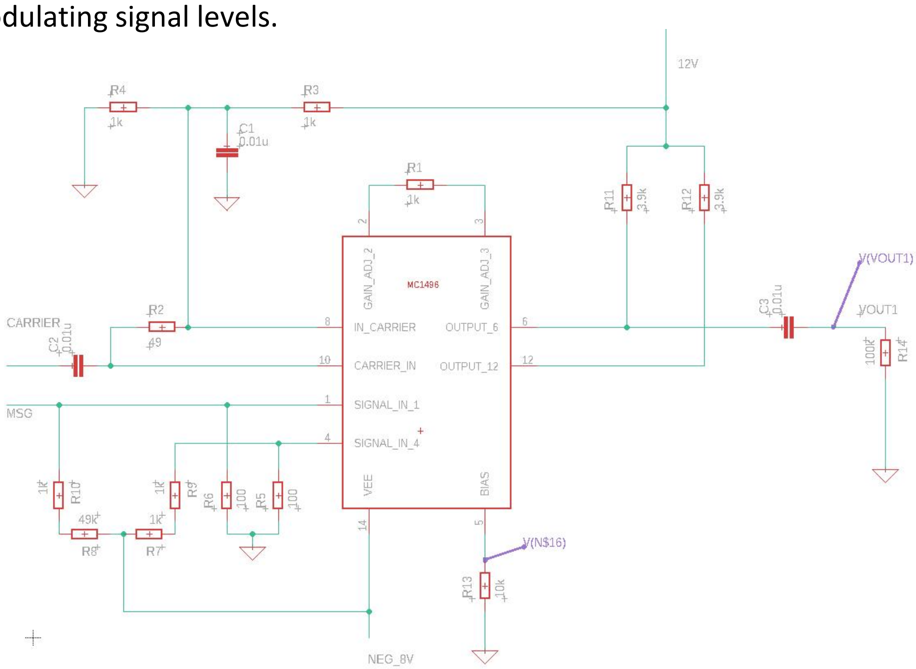


Figure 3: Amplitude Modulator Circuit

The modulating signal must be kept at a level to insure linear operation of lower differential amplifier Q5–Q6. If the signal input level is too high, harmonics of the modulating signal are generated and appear in the output as spurious sidebands of the suppressed carrier. For a maximum modulating signal input of 300 mV rms, the suppression of these spurious sidebands is typically 55 dB at a carrier frequency of 500 kHz

Operating with a high level carrier input has the advantages of maximizing device gain and insuring that any amplitude variations present on the carrier do not appear on the output sidebands. It has the disadvantage of increasing some of the spurious signals. Fourier analysis for a 50% duty cycle switching waveform at the carrier differential amplifiers predicts no even harmonics of the carrier.

Product Detector(Demodulation):

The product detector, also known as a synchronous detector or a ring modulator, multiplies the DSB signal by a locally generated carrier signal that is synchronized in phase and frequency with the original carrier signal. The resulting product signal contains both the sum and difference frequencies of the two input signals. If the original carrier frequency is much higher than the highest frequency in the baseband signal, the product signal will mainly contain the difference frequency component, which is the baseband signal.

The steps for DSB demodulation using a product detector are as follows:

1. Generate a local carrier signal with the same frequency and phase as the original carrier signal.
2. Multiply the DSB signal with the local carrier signal using a product detector.
3. Filter the product signal to remove the unwanted sum frequency component and any high-frequency noise.
4. Amplify and further process the baseband signal to obtain the desired output.

The simplified block diagram for our DCR is given below

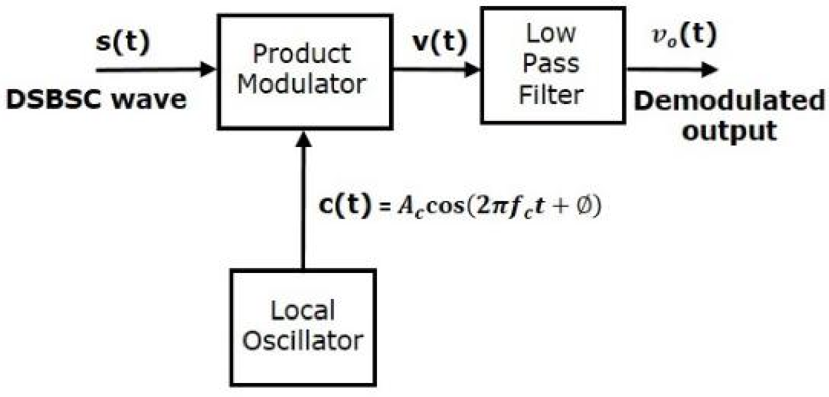


Figure 4: DCR Block diagram

The advantage of using a product detector for DSB demodulation is that it does not require the original carrier signal to be present. This makes it suitable for recovering signals from a variety of sources, including radio broadcasts and audio recordings. However, the demodulated output may contain some distortion due to the presence of unwanted frequency components in the product signal. Careful design and adjustment of the product detector and filter can help minimize this distortion.

The scheme that we used for demodulating the signal is DCR(Direct conversion receiver) which is realized by the product detector.

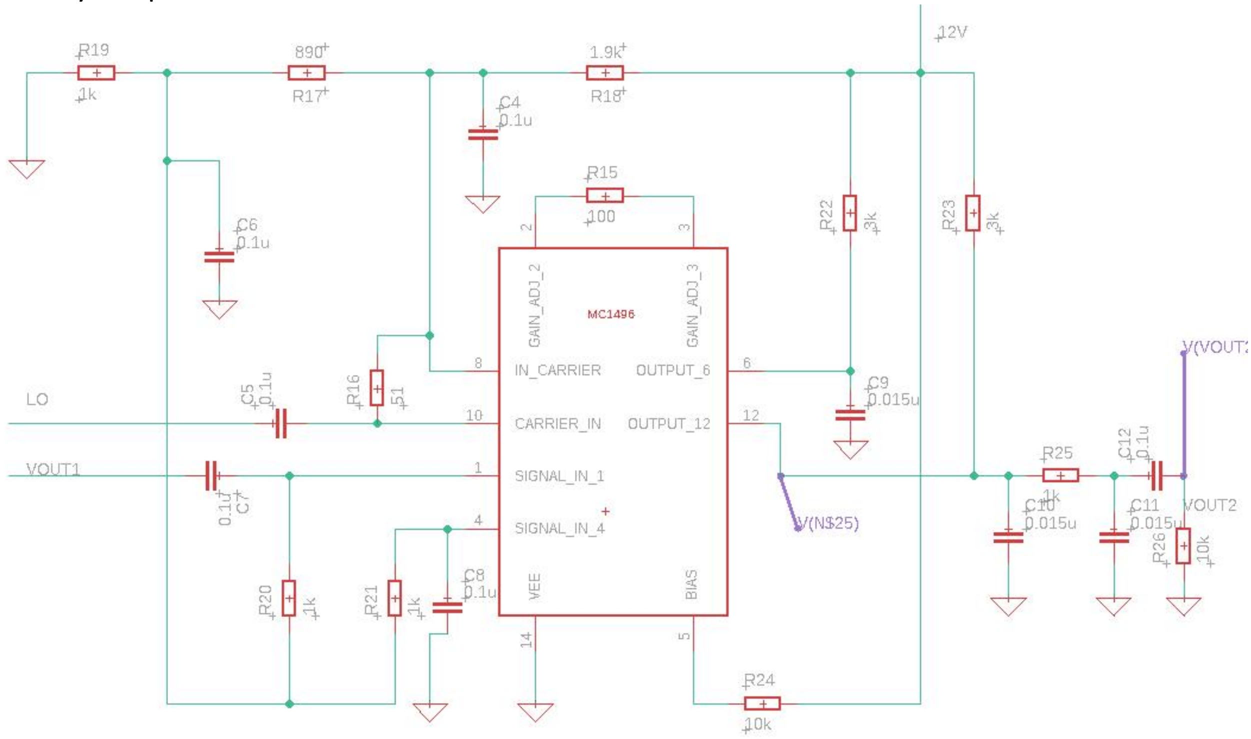


Figure 5:Product Detector

Another advantage of the MC1496 product detector is its high sensitivity. The sensitivity of the product detector shown in Figure 8 for a 9 MHz SSB signal input and a 10 dB signal plus noise to noise [(S + N)/N] ratio at the output is 3 microvolts. For a 20 dB (S + N)/N ratio audio output signal it is 9 microvolts.

Variable Frequency Oscillator(VFO)

A variable frequency oscillator (VFO) is an electronic oscillator that can generate a continuously adjustable frequency signal within a certain range. The purpose of a VFO is to provide a stable, tunable signal for use in various applications, such as in radio frequency (RF) communication systems.
In RF communication systems, a VFO is often used as the local oscillator in a superheterodyne receiver or a transmitter. The local oscillator generates a frequency that is mixed with the incoming or outgoing signal to produce an intermediate frequency (IF) signal that is easier to process or transmit. By using a VFO as the local oscillator, the receiver or transmitter can be tuned to different frequencies, allowing it to receive or transmit signals on different channels.

THe schematic that we used for VFO is given below

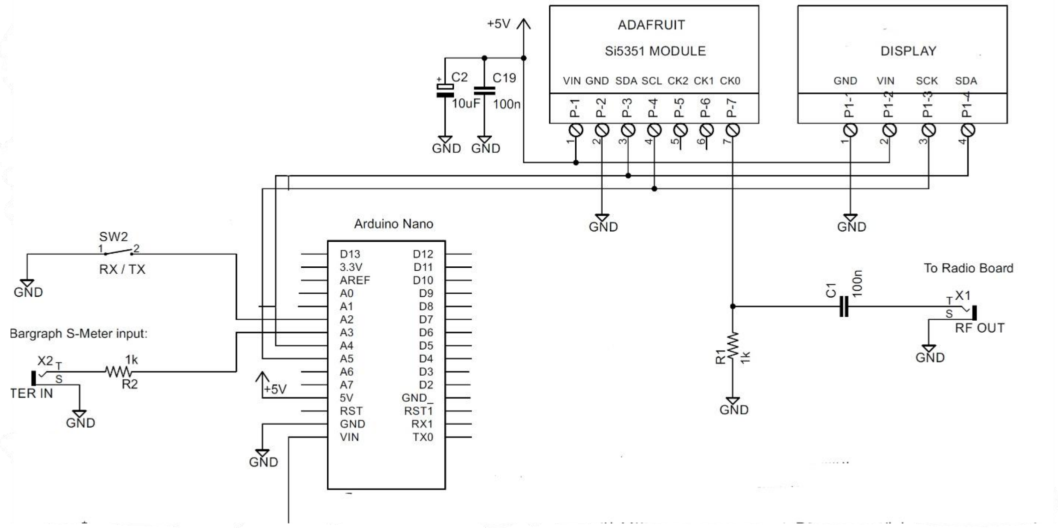


Figure 6: VFO schematic

The VFO block contains a Si5351 module as an oscillator. This oscillator produces square wave of different frequencies. The frequency of the oscillator is controlled by an Arduino Nano, which allows for the frequency to be set and observed on an LCD display. The optimum frequency of the VFO was found to be 40MHz. square wave that goes to the modulation block.

Voltage Regulator Block

It was necessary for us to implement this block because the default power supply introduces distortions in the output of the modulators.

To regulate our voltage to a level of 9V we used LM317T 3-Pin IC The LM317T is an adjustable 3-terminal positive voltage regulator capable of supplying different DC voltage outputs other than the fixed voltage power supply of +5 or +12 volts, or as a variable output voltage from a few volts up to some maximum value all with currents of about 1.5 amperes.

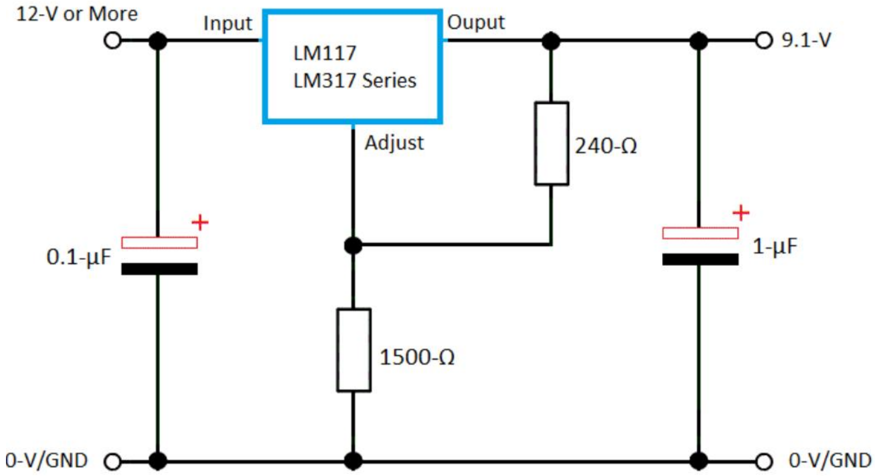


Figure 7:Designed LM317T regulator.

The output voltage of the LM317T is determined by ratio of the two feedback resistors R1 and R2 which form a potential divider network across the output terminal

The voltage across the feedback resistor R1 is a constant 1.25V reference voltage, Vref produced between the “output” and “adjustment” terminal. The adjustment terminal current is a constant current of 100uA. Since the reference voltage across resistor R1 is constant, a constant current i will flow through the other resistor R2, resulting in an output voltage of

$$
\begin{aligned}
V_{out} &= 1.25\left(1+\frac{R_2}{R_1}\right) \\
&= 1.25\left(1+\frac{1500}{240}\right) \\
&\approx 9V
\end{aligned}
$$

The LM317T variable voltage regulator also has built in current limiting and thermal shut down capabilities which makes it short-circuit proof .

Designed Hardware:

Now we will demonstrate process of realizing the circuits that we have discussed earlier .Here we will show both PCB designs and actual circuits & compare the output of real hardwares with that of simulated ones.

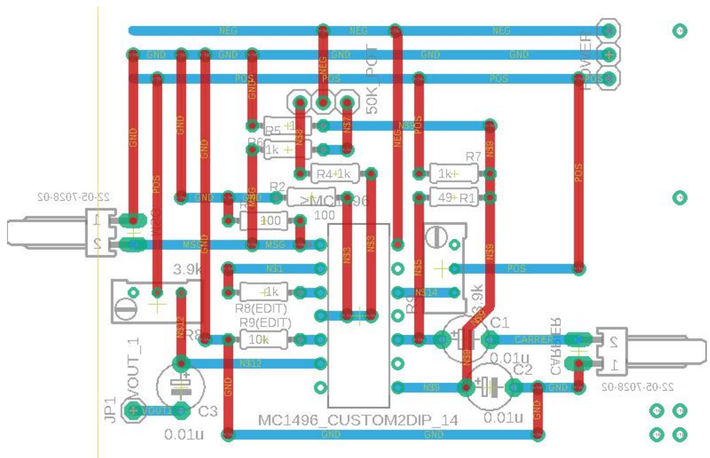
Software suits that we have used

1. Eagle Schematics(Spice - simulation)
2. Eagle PCB design(For designing PCB layouts)

Tools required for Realizing these hardware:

1. Vero-board
2. Multimeter for continuity test
3. Soldering Iron & lead
4. Electrical circuit components (mentioned above)

Amplitude modulator:



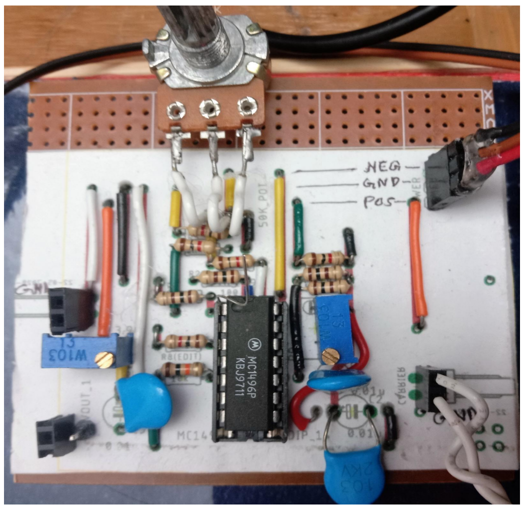


Figure 8:PCB(Left)   Developed circuit(Right)

Simulated output (AM)

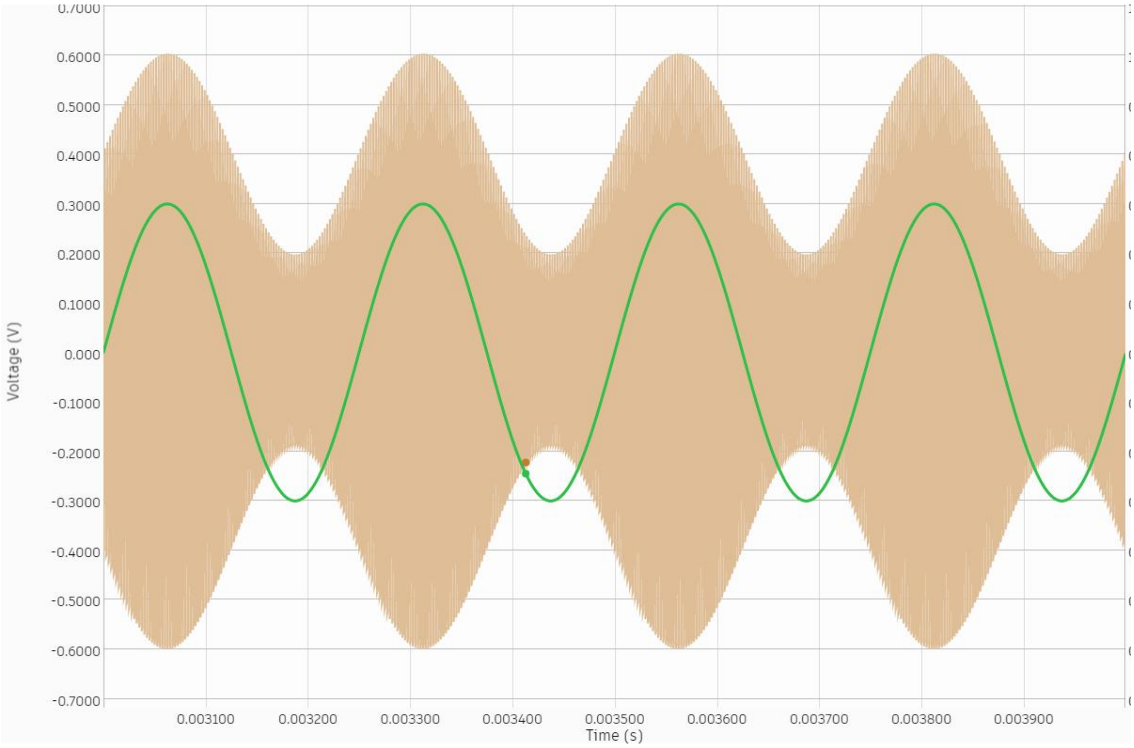


Figure 9: simulation output (DSB+C)

Now let us observe the output of the real hardware using a 20MHz DSO(Digital Storage Oscilloscope)

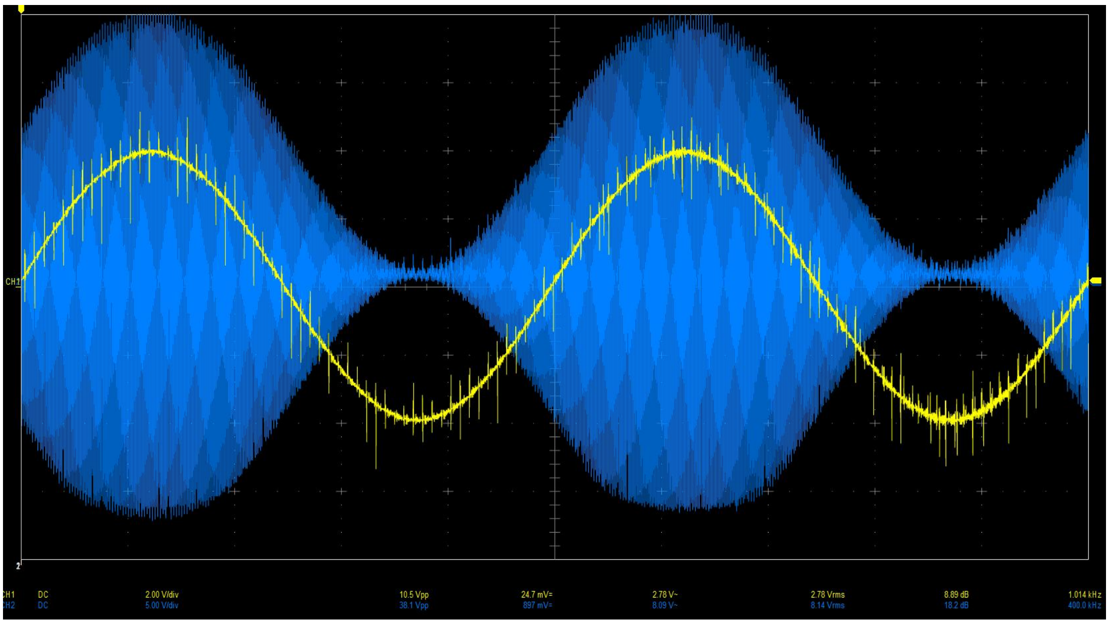


Figure 10: Actual hardware output(DSB+C)

An Interesting aspect of our design is that if rotate the 50k potentiometer CCW it will generate DSB_Suppressed Carrier output .now let us observe this same behaviour in the simulation and actual hardware

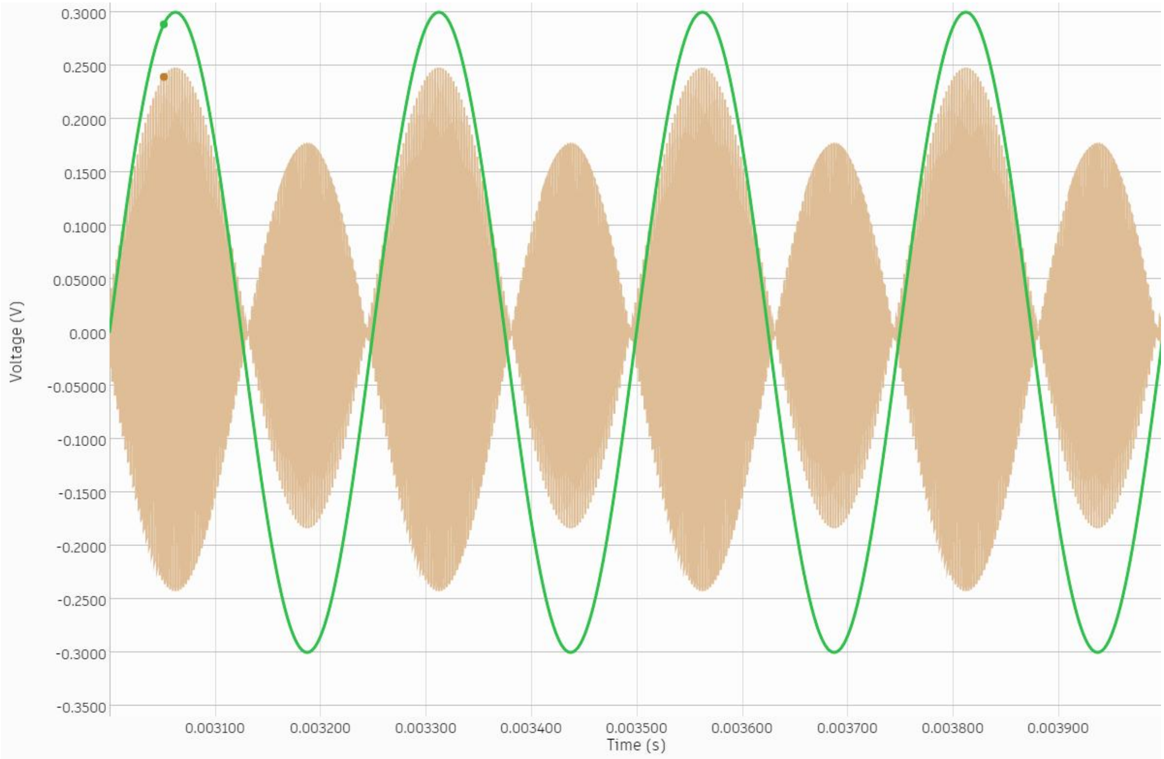


Figure 11: simulated output (DSB-SC)

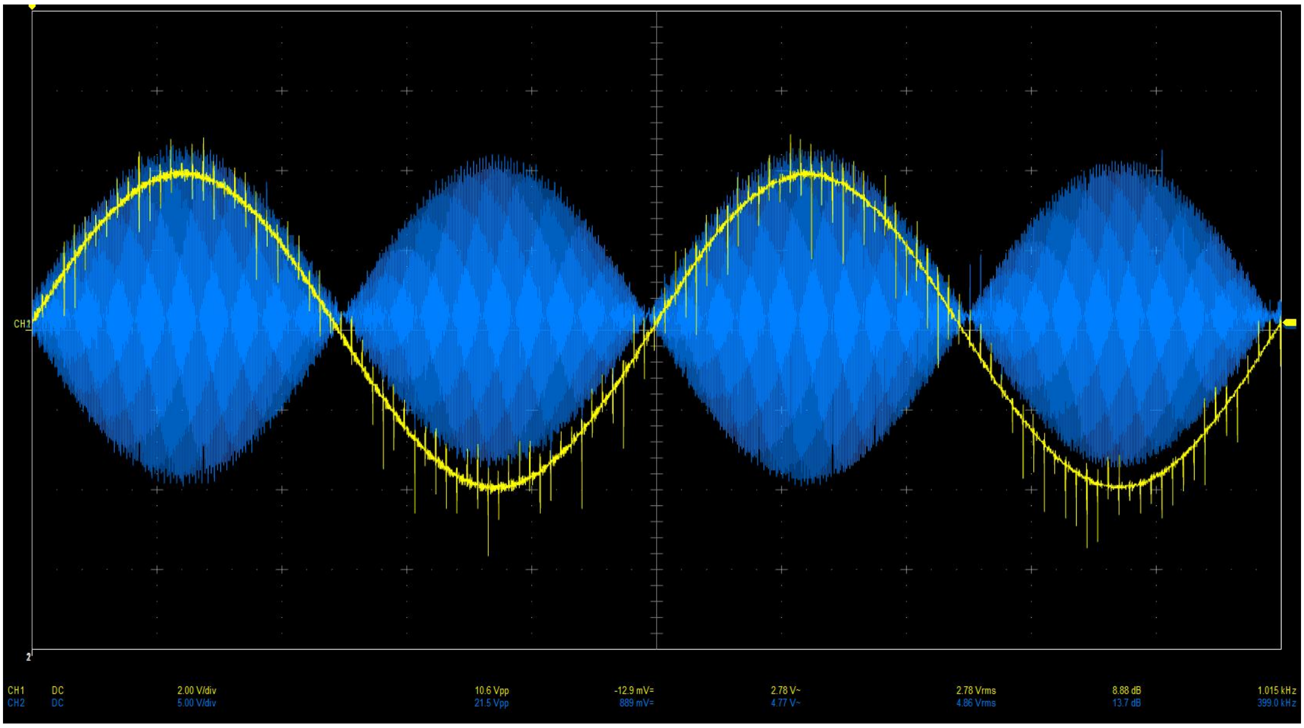
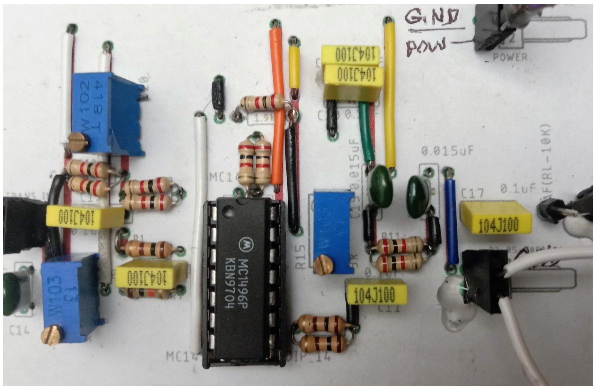
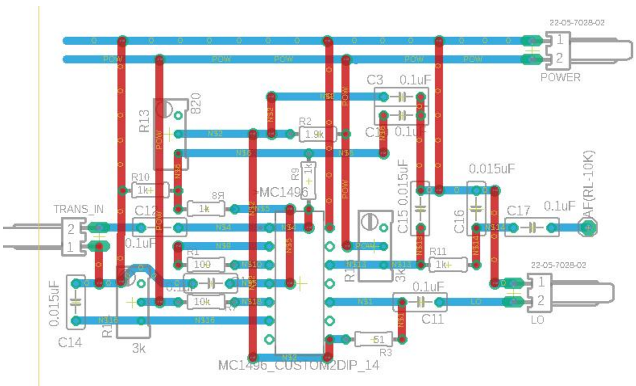


Figure 12: Modulator output(DSB-SC)

Product Detector:





design(Left) & Actual circuit (Right)

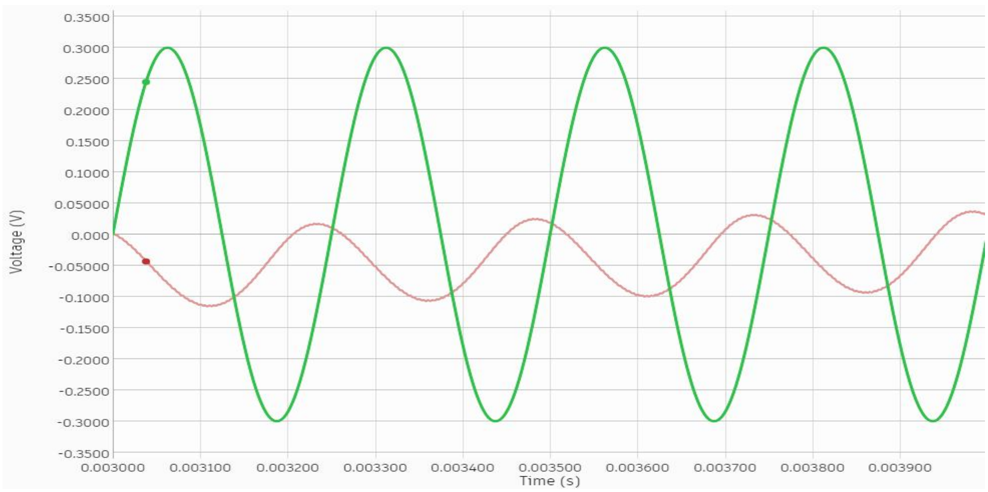


Figure 14: Simulated Output(Product detector)

If we zoom in close enough we will see that there is slight ripple at the reconstructed wave form.But in actual circuit the ripple much more pronounced this because in actual circuit it the transmitted wave is passing through air .hence other noise may superimpose upon it.

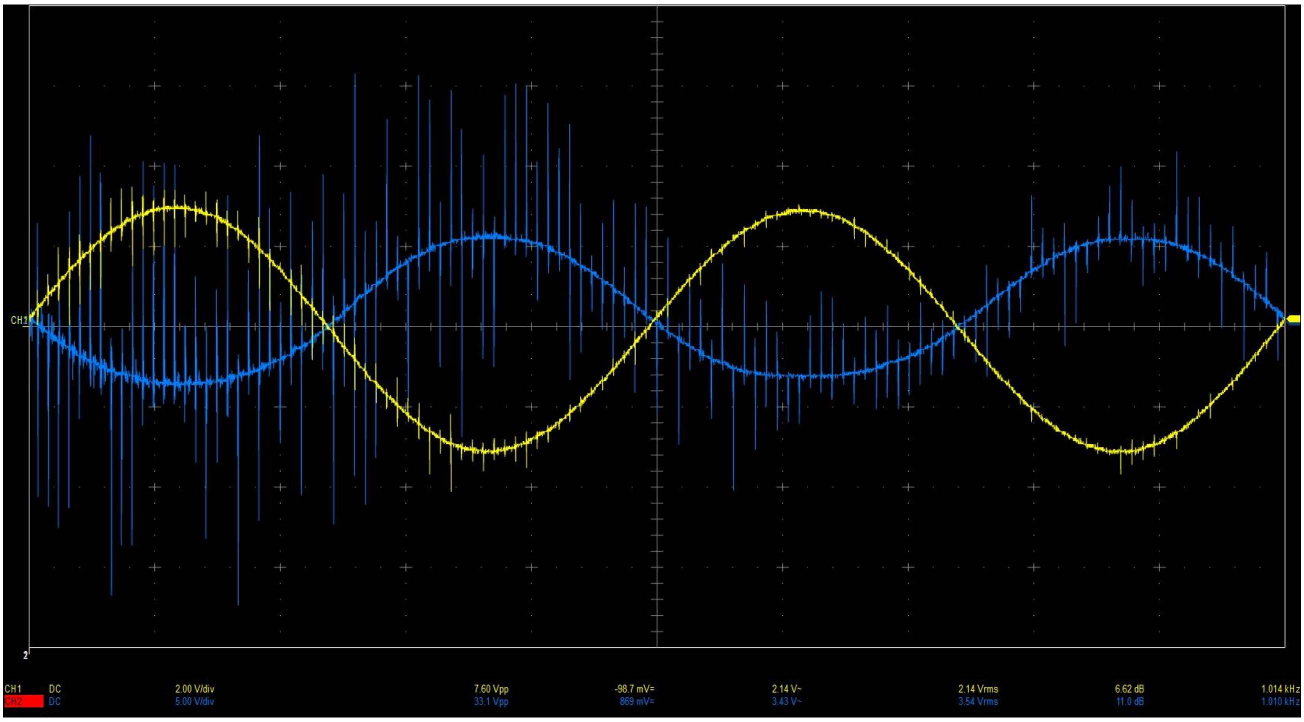


Figure 15: Actual output of product detector

Here **Yellow** colored signal = Input 1kHz monotone
Blue colored signal = reconstructed signal

Complementary Circuit blocks:

Rf amplifier

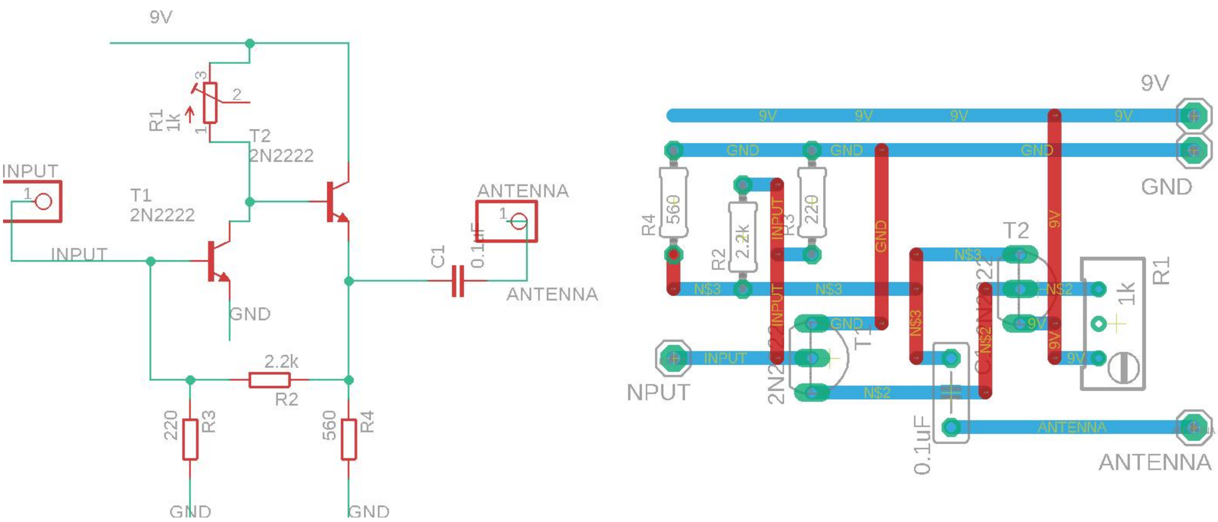


Figure 16: RF Amplifier Schematic(Left) & Designed PCB(Right)

VFO (Variable frequency Oscillator)

Realized circuit of the VFO is given below:

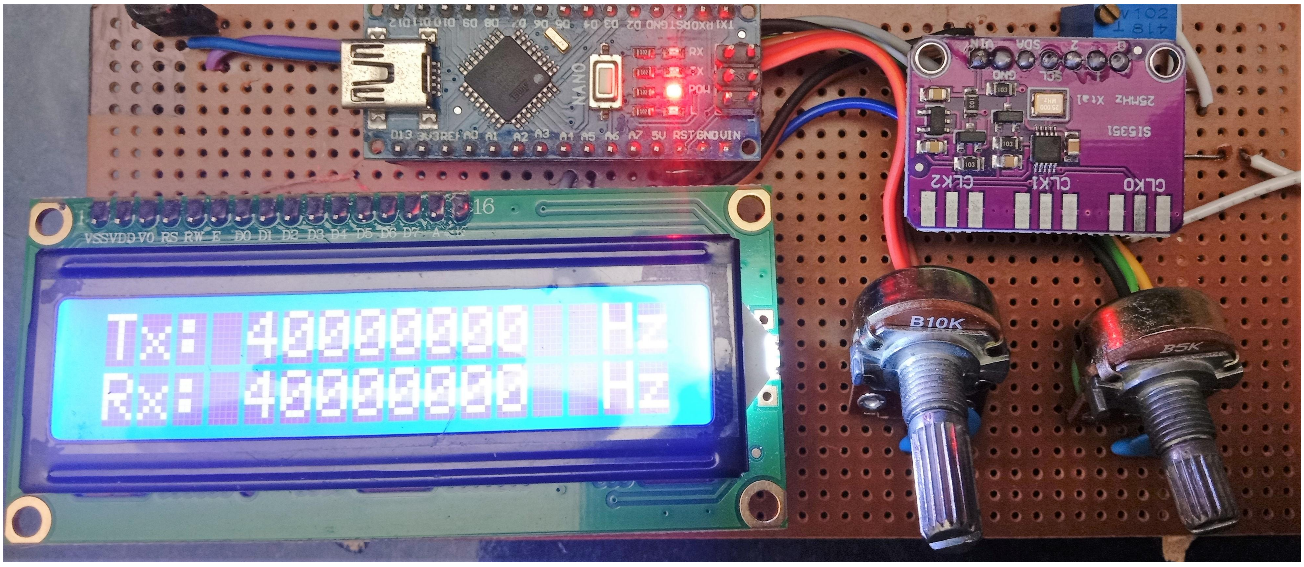


Figure 17: Variable Frequency Oscillator

Regulated Power supply

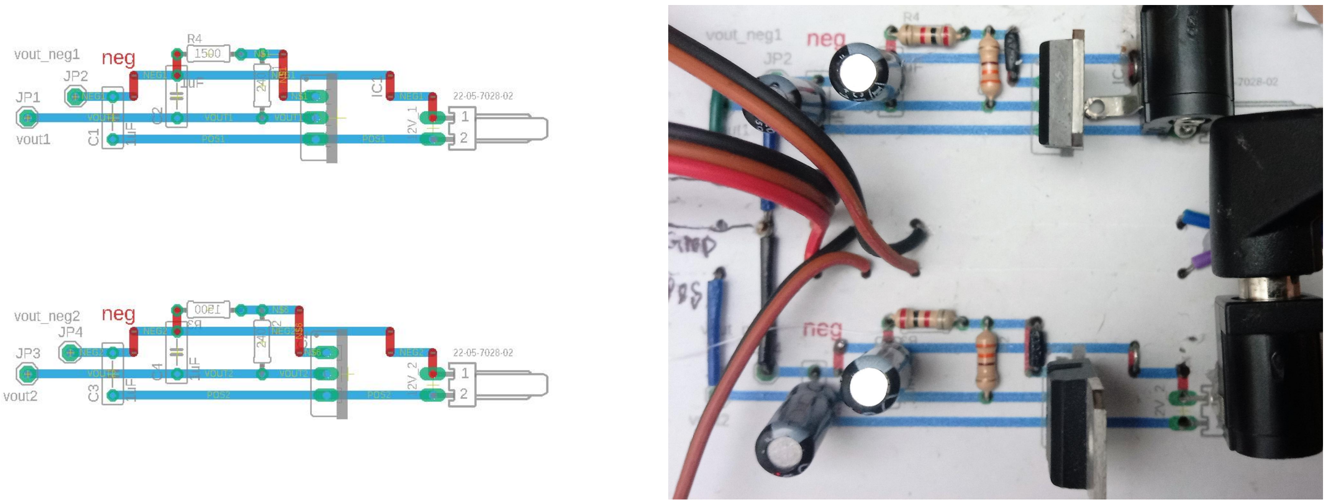


Figure 18: 9V regulated power supply (Left-PCB design & Right-developed hardware)

Note : This power supplied played an important role in smoothing the output of modulator block. Without it we observed a approximate 50Hz ripple at output

The benefit of our AM Scheme:

We can characterize its usage in several points. One of the main for us of choosing this scheme was availability of its components in market.There are several other benefits such as:

1. **Simplicity:** Direct conversion receivers are simpler than superheterodyne receivers since they require fewer stages of frequency conversion. This makes them easier to design, build, and maintain.

2. **Low power consumption:** Direct conversion receivers consume less power than superheterodyne receivers, which is particularly important for battery-powered devices.

3. **Wide bandwidth:** Direct conversion receivers can have a wider bandwidth than superheterodyne receivers, which is important for applications that require a high data rate or wide frequency coverage.

4. **Low phase noise:** Direct conversion receivers can have lower phase noise than superheterodyne receivers, which is important for applications that require high signal fidelity, such as software-defined radios.

5. **Low cost:** Direct conversion receivers can be less expensive than superheterodyne receivers due to their simpler design and fewer components.

However, direct conversion receivers also have some disadvantages. They can be sensitive to DC offsets, which can cause distortion in the received signal, and they can suffer from image rejection issues, which can result in interference from unwanted signals. They may also require more complex signal processing to remove unwanted components from the received signal.

An important point to note that we designed our circuit in such a way that we can improve upon it future iteration especially this modular design can help us to reconfigure the circuit and construct a more advance scheme of communication.

Limitations :

The limitations of the projects include :

- There was no bandpass filter in the modulator ,hence it introduces distortions at the output. As the carrier signal used was a square waveform, it was composed of sinusoidal components of different frequencies. Using a bandpass filter would filter out the unwanted components. However, as the bandpass filter was not used in this project, the output obtained was distorted.

- The signal amplifier that was used in the transmitter is not powerful enough. Due to the low-power amplifier, the signal gets attenuated after being transmitted to a small distance. As a result, the transmission range of this project is limited to few feets.

- A single power supply was used to power up both transmitter & receiver. As this project is merely a prototype, in order to keep the cost low, a single power supply unit was used. This also limits the distance that can be put in between the transmitter and receiver.

- The VFO is limited to some pre-defined frequencies (although it can be changed in the code). Due to this, there was not enough flexibility on setting up the frequency of the oscillator. However, the Arduino Uno can be used to set some predefined frequencies ranging from 8kHz to 160 MHz.

Future Prospects :

The implemented project is simply a prototype communication system which is open to further improvements. The areas where the project offers further modifications and explorations are -

- The hardware is designed in a modular way, that is, each block can be isolated and used separately. Therefore, the VFO block, the Power Supply Unit, The Modulator Block, The Product Detector and the Amplifier Block can be independently utilized in different configuration to develop different communication schemes, such as Heterodyne receiver , in-direct FM modulator etc.

- The variable frequency generator can be used to make a Heterodyne receiver where the local oscillator can be tuned specifically to output IF frequency at the mixer.

- The SNR of the receiver can be improved in future iterations. As previously mentioned, the absence of bandpass filter introduces distortion, the low-power amplifier leads to attenuation and the chosen Low-Pass Filter(LPF) on the receiver side could not eliminate all the noise components. Further research on these components can be carried out for a more successful retrieval of the transmitted signal.

- The MC1496 used in this project is an extremely versatile IC ,and we were also able to create a working simulation model of the component .This in future may help us to develop Frequency doubler , mixer,FM detector and phase detector blocks etc.

Conclusion:

To sum up, the Voice Signal Transmission and Reception using Amplitude Modulation project has implemented several important principles in both the transmission and receiving ends. Although there are some limitations to the project, the modular design of the hardware allows for future improvements and expansion of the communication scheme.

References

1. Gilbert, Barrie, “A DC–500 MHz Amplifier/ Multiplier Principle,” paper delivered at the International Solid State Circuits Conference, February 16, 1968.
2. Gilbert, Barrie, “A Precise Four Quadrant Multiplier with Subnanosecond Response,” IEEE Journal of Solid–State Circuits, Vol. SC–3, No. 4, December 1968.
3. Renschler, E., “Theory and Application of a Linear Four–Quadrant Monolithic Multiplier,” EEE Magazine, Vol. 17, No. 5, May 1969. 5. “Analysis and Basic Operation of the MC1595,” ON Semiconductor, Application Note AN489.