

Amplitude Modulation Network Design and Simulation for Analog Telecommunications Applications

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Abstract

This paper presents amplitude modulation network design and simulation for analog telecommunications application. The design consists of three sections; a novel Amplitude modulator (Multiplier) which was designed using the logarithmic and anti-logarithmic amplifiers, the audio signal oscillator made up of phase-shift oscillator and the Radio frequency (RF) signal oscillator made up of Hartley oscillator. The complete system was simulated using Multisim software version 14.2 and modulation index calculated at under modulation, 100 percent modulation and over modulation which were compared with other literature where the complete AM modulator was designed using a diode as the multiplier, Wien bridge circuit as the Audio signal Oscillator and Colpitt oscillator as the RF signal Oscillator. Results show that the designed network 1 has output voltages 0.993mV at 100mV, X-Input and 10mV Y-Input to 6.223V at 2.5V at both X and Y input before decreasing to 5.974V at 3V X-Input and 2V Y-Input, greater than the network 2 from literature. Also the modulation index (ϕ_1) with values 0.56, 0.60, 1.00, 1.75, 2.15 as against (ϕ_2) 0.4915, 0.6938, 0.9956, 1.4725 and 1.8042, while depth of modulation of this study (β_1) has higher values of 56%, 60%, 100%, 175%, and 215% than modulation depth values of 49.15%, 69.38%, 99.56%, 147.25% and 180.42%, Except at 700mV message and 1V carrier amplitude where (β_2) is higher than (β_1), when compared with literature was found to be better than that of network 2. Overall, the designed AM modulator (Network 1) was found to be superior in performance in terms of Output Voltages and modulation Index. Also it is in line with standards with little deviation due to component variation. Recommendations were also made for further improvements to functionality.

Keywords: Amplitude Modulation, Analog, Telecommunication, Application, Logarithm

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INTRODUCTION

Amplitude modulation (AM) is a method used in electronic communication, mainly for sending information through a radio wave. AM functions by changing the power of the signal in relation to the message being sent (Sheeanant & Ritwik 2021). For instance, variations in signal strength can represent sounds for a speaker, or determine the brightness of TV pixels. This is different from frequency modulation, which is also used for audio transmissions and involves changing the frequency. An important consideration in amplitude modulation is to describe the depth of modulation i.e. the extent to which the amplitude of carrier wave is changed by the signal. (Haitham & Jihan 2017).

In today's world, information, data, and signals are transmitted between different locations almost instantaneously. This speed is achieved through sophisticated communication systems that use modulation to extend the signal's range. Many of the signals we encounter in everyday life are in the form of sinusoidal waveforms. A sinusoidal wave is a smooth, repetitive oscillating curve that represents these signals. During communication, essential data is transferred as a sinusoidal wave. Modulation, along with its various types, is key to ensuring the quick transfer of signals from the sender to the receiver. Essentially, modulation combines the signal carrying the information with a high-frequency carrier wave to enable faster and more efficient transmission. Modulation is a vital concept within electronics and communication systems, and it involves altering the key characteristics of a signal to facilitate its movement from one point to another. The types of signals utilized in modulation include Modulating, Carrier and Modulated Signals (Rashmi & Sagupha 2020).

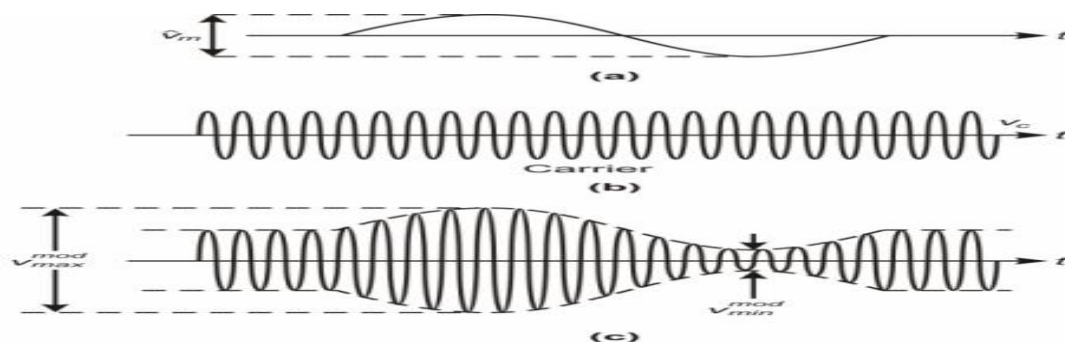


Figure 1: Amplitude modulation a) modulating signal; b) carrier wave; and c) modulated wave

Figure 1 shown, presents three different kinds of signals of message, carrier, and the modulated signal, which is a combination of the message and carrier signals. Modulation typically falls into one of three categories of Frequency Modulation, Phase Modulation and Amplitude Modulation. Additionally a portion of the benefits for Balance are summed up as; Expansion in the Signal Strength; upgrading remote Correspondence Framework; Avoidance of Message Signal From Blending; Among other things, the antenna is smaller. The uses of Modulation include; Inter-conversion of signals from one form to another is one of the most common uses of various types of modulation, Digital signals are transmitted over analog baseband using digital modulation, Simple Tweak is utilized to move the low data transfer capacity transmissions like television or radio transmissions over a higher transmission capacity, Present day regulation procedures are broadly used to complete FDM, that is to say, Recurrence Division Multiplexing amongst others. The Amplitude modulation network is a critical component in AM telecommunications systems, responsible for modulating the baseband signal onto the carrier wave. Traditional modulation techniques often face challenges in achieving high modulation depth and linearity.

There are several studies done on the design of AM circuits like (Robert & Barsanti 2017 : Kareem, Gbotoso & Omogoye 2021), but only little literature is known about the complete design of the AM Modulation circuit but several studies have investigated the design and simulation of AM networks using log amplifiers, phase shift oscillators, and Hartley oscillators. For example, Sedra and Smith (2019) discussed the design of AM networks using log amplifiers and phase shift oscillators. They highlighted the advantages of using log amplifiers, including their high linearity and low distortion. Razavi (2017) presented a comprehensive analysis of AM networks using Hartley oscillators. He discussed the advantages of using Hartley oscillators, including their high frequency stability and low phase noise. Liao (2017) investigated the design of AM networks using log amplifiers and Hartley oscillators. He presented simulation results that demonstrated the effectiveness of using log amplifiers and Hartley oscillators in AM networks. Adekanmbi (2016) presented a design and characterization of a Hartley oscillator for use in AM networks. He highlighted the advantages of using Hartley oscillators, including their high frequency stability and low phase noise. Furthermore, few literatures like Jing and Binbin (2022) presents the design of AM circuit using a diode but only the study by Haitham and Jihan (2017) presented the complete Am Modulation circuit, but designed using diode in the multiplier, wien bridge as the audio signal and colpitts oscillator as the RF oscillator circuit.

In this paper, we propose a novel approach that utilizes log and anti-log multipliers, Phase shift Oscillators as the Audio Oscillator circuit and Hartley Oscillator as the RF signal Oscillator circuit here in known as Network 1 to compare the performance of the modulation network to that of Haitham and Jihan (2017) here in known as Network 2 in order to ascertain whether it is capable of addressing these challenges stated above.

MATERIALS AND METHODS

Device Model of am blocks

To construct the AM modulator, we must construct three crucial components, which are represented by: the AM modulator (Multiplier), the RF signal oscillator, and the audio signal oscillator, as depicted in figure 2.

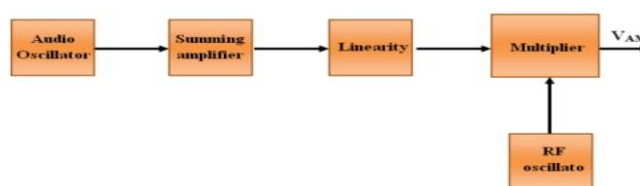


Figure 2: Regular AM Block Diagram (Haitham & Jihan, 2017).

Analog Multiplier Design

The fundamental logarithmic relationship, which states that the product of two terms equals the sum of the logarithms of each term, serves as the foundation for multipliers. This relationship is given as:

$$\ln(N \times M) = \ln N + \ln M \tag{1}$$

This equation explains that adding the logarithms of the two signal voltages effectively multiplies them. There are three steps in the process of multiplication viz

To get the logarithm of a sign voltage utilize a Log speaker

$$Y_1^* = \ln(Y_1) \quad \text{and} \quad Y_2^* = \ln(Y_2) \tag{2}$$

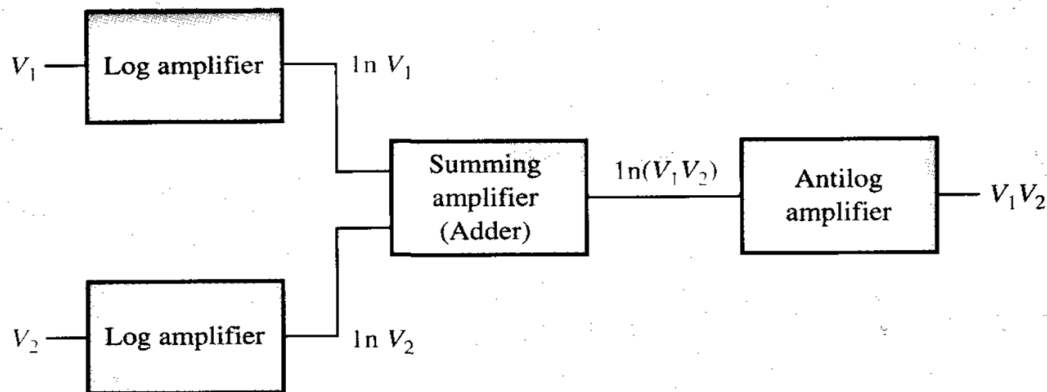
1. Adding the results of two log intensifiers, you get the logarithm of the result of the two unique information voltages.

$$Y_o^* = Y_1^* + Y_2^* = \ln(Y_1) + \ln(Y_2) = \ln(Y_1 \cdot Y_2) \quad (3)$$

2. You can determine the product of the two input voltages by introducing antilogarithm as shown in eqn. 4 :

$$Y_o = \text{antilog}(Y_o^*) = \text{antilog}[\ln(Y_1 \cdot Y_2)] = Y_1 \cdot Y_2 \quad (4)$$

The whole process of adding two inputs is depicted in figure 3.



1. Figure 3. Block Diagram of Analog Multiplier (www.electronics.dit.ie retrieved 2024)

A multiplier is a gadget having two information parts and a result port where two input signals are combined to produce a signal at the output. The transfer characteristics give the product of the two input voltages divided by a multiplier coefficient β , if both the input and output signals are voltages.

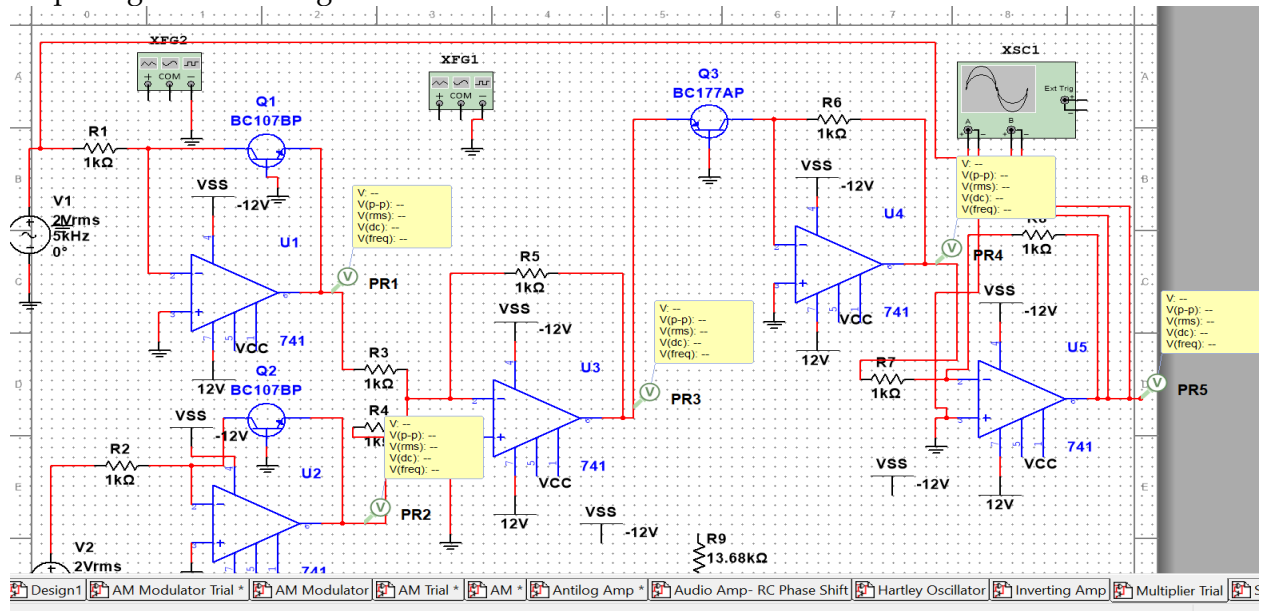


Figure 4. Analog Multiplier Circuit (www.electronics.dit.ie retrieved 2024)

The following is a list of the log amplifiers' outputs:

- $Y_o(\log_1) = -\beta_1 \cdot \ln\left(\frac{Y_{in1}}{\beta_2}\right) \quad (5)$

- $Y_o(\log_2) = -\beta_1 \cdot \ln\left(\frac{Y_{in2}}{\beta_2}\right) \quad (6)$

Where $\beta_1 = 0.02Y$, $\beta_2 = r \cdot I_{ebo}$ and $r=r_1=r_2=r_6$

The unity-gain summing amplifier adds and inverts the two output voltages from the log amplifiers, resulting in the following: summing amplifier to produce the following result:

$$Y_{o(sum)} = \beta_1 \cdot \ln \left[\ln \left(\frac{Y_{in1}}{\beta_2} \right) + \ln \left(\frac{Y_{in2}}{\beta_2} \right) \right] = \beta_1 \cdot \ln \left(\frac{Y_{in1} \cdot Y_{in2}}{\beta_2} \right) \quad (7)$$

The antilog amplifier is then subjected to eqn. 7, and the result for the multiplier yield voltage is given in eqn. 8.

$$Y_{o(exp)} = -\beta_2 \cdot \exp \left(\frac{Y_{o(sum)}}{\beta_1} \right) = -\beta_2 \cdot \exp \left[\frac{1}{\beta_1} \beta_1 \cdot \ln \left(\frac{Y_{in1} \cdot Y_{in2}}{\beta_2} \right) \right] = -\beta_2 \left(\frac{Y_{in1} \cdot Y_{in2}}{\beta_2} \right) = - \left(\frac{Y_{in1} \cdot Y_{in2}}{\beta_2} \right) \quad (8)$$

The result of the antilog (exp) intensifier is a steady (1/β2) times the result of the information voltages. Therefore, the inverting amplifier with a voltage gain of -β2 produces the final output.

$$Y_o = -\beta_2 - \left(-\frac{Y_{in1} \cdot Y_{in2}}{\beta_2} \right) = Y_{in1} \cdot Y_{in2} \quad (9)$$

(i). Device Model of Multiplier

The stages of modeling the multiplier presented in Figure 3 follows

- **Basic Logarithmic Amplifier using Transistor**

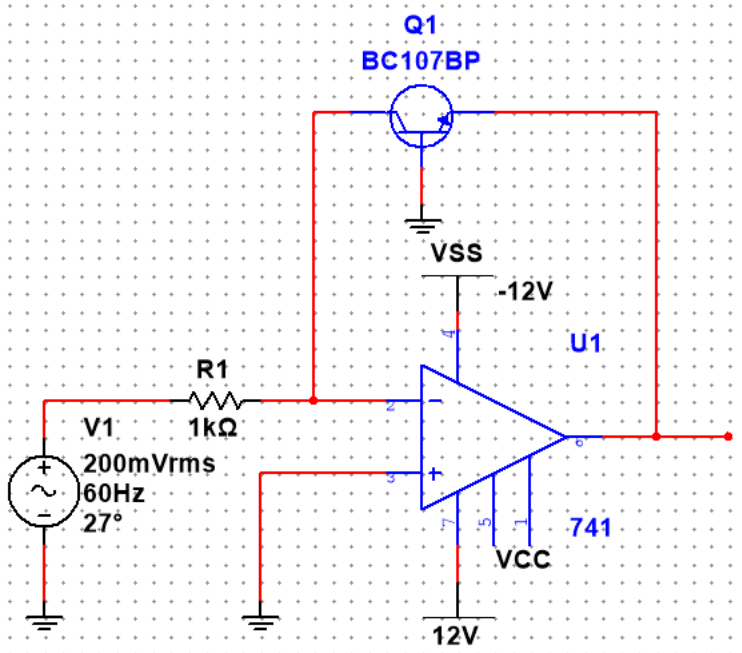


Figure 5. Logarithmic Amplifier using Transistor(www.electronics.dit.ie retrieved 2024)

$$Y_B = 0 \quad (10)$$

$$Y_0 = Y_{BE} \ln \left(\frac{I_C}{I_S} \right) \quad I = I_C = \frac{Y_{in}}{r} \quad (11)$$

$$Y_{BE} = -Y_T \ln \left(\frac{Y_{in1}}{r_s I_s} \right) \quad I = I_C = \frac{Y_{in}}{r} \quad (12)$$

$$Y_{ref} = r I_s = 1m\Omega \times 1\mu A = IV \quad (13)$$

Let r= 1kΩ, Is=1μA, Y_T = 26mV for

$$Y_{01} = -Y_T \ln \left[\frac{Y_{in}}{1} \right] = -Y_T \ln(Y_{in1}) \quad (14)$$

1. Block Two: Basic Logarithmic Amplifier using Transistor (www.electronics.dit.ie retrieved 2024)

$$Y_0 = -Y_T \ln \left[\frac{Y_{In2}}{Y_{ref}} \right] \quad \text{Let } r_2 = 1k\Omega, I_S = 1\mu A, Y_T = 26mV \text{ for } 27^\circ C \quad (15)$$

$$Y_0 = -Y_T \ln \left[\frac{Y_{In2}}{1m\Omega \times 1\mu A} \right] \quad Y_{ref} = 1k\Omega \times 1\mu A = IV$$

$$Y_{02} = -Y_T \ln[Y_{In2}] \quad (16)$$

Summing Amplifier

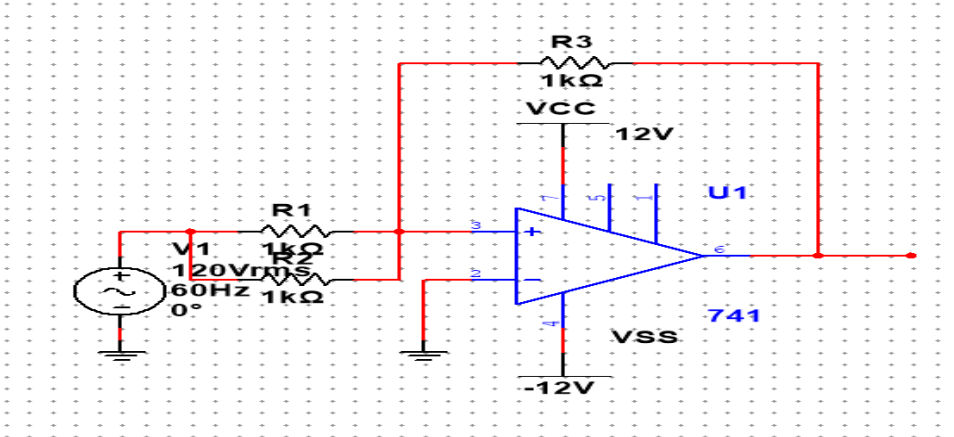


Figure 6. Summing Amplifier Circuit (Haitham & Jihan 2017).

The output voltage (Y_o) is given by the following equations:

$$Y_o = Y_T \frac{R_5}{R_3} \times Y_{01} - \frac{r_5}{r_3} \times Y_{02} \quad (17)$$

Let $r_5, r_3, r_4 = 1k\Omega$

$$\text{So the output will be } Y_{out} = -(Y_{01} \times Y_{02}) \quad (18)$$

Substituting the equation of Y_{01} and Y_{02} in equation 19 gives

$$Y_o = -\{-Y_T \ln(Y_{In1}) - Y_T \ln[Y_{In2}]\} \quad (19)$$

$$Y_o = Y_T \ln [Y_{In1} + Y_{In2}] \quad (20)$$

Antilog Amplifier

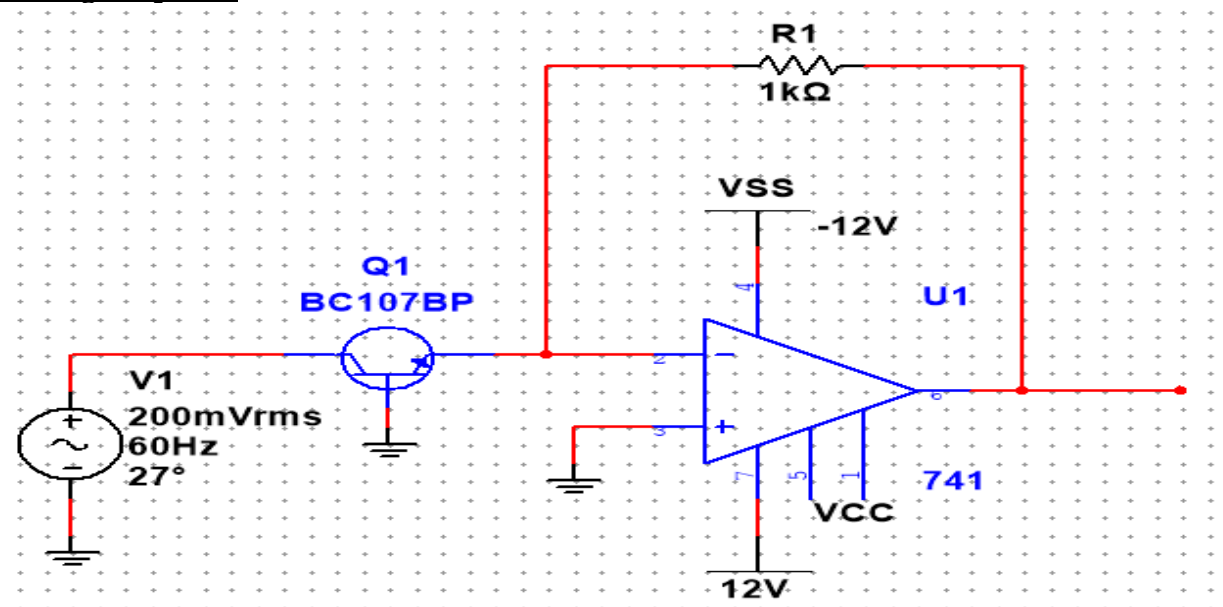


Figure 7. Antilogarithm Amplifier Circuit (Haitham & Jihan 2017)

$$Y_{BE} = I_s e^{Y_0 + Y_t} \quad \text{Let } r_s = 1k\Omega \text{ and } I_s = 1mA, \quad (21)$$

Substituting Y in equation 4, we have:

$Y_{out} = r_f I_c$ (characteristics equation of pn junction)

$$I_c = I_{EBO} e^{Y_{BE}/Y_T} \quad Y_0 = -[Y_{01} + Y_{02}]$$

Substituting into equation for Y_o .

$$Y_o = r_f I_{EBO} e^{Y_{BE}/Y_T}$$

Assume $I_{EBO} = 40nA$, $Y_{in} = 175.1mv$ and $Y_{In} = 175.1mv$ and $r_f = 68k$

As you can see $Y_{In} = Y_{BE}$

The exponential can be expressed as an antilogarithm as follows

$$Y_o = -r_f I_{EBO} \text{ antilog} \left(\frac{Y_{In}}{Y_T} \right) \quad (22)$$

Inverting Amplifiers

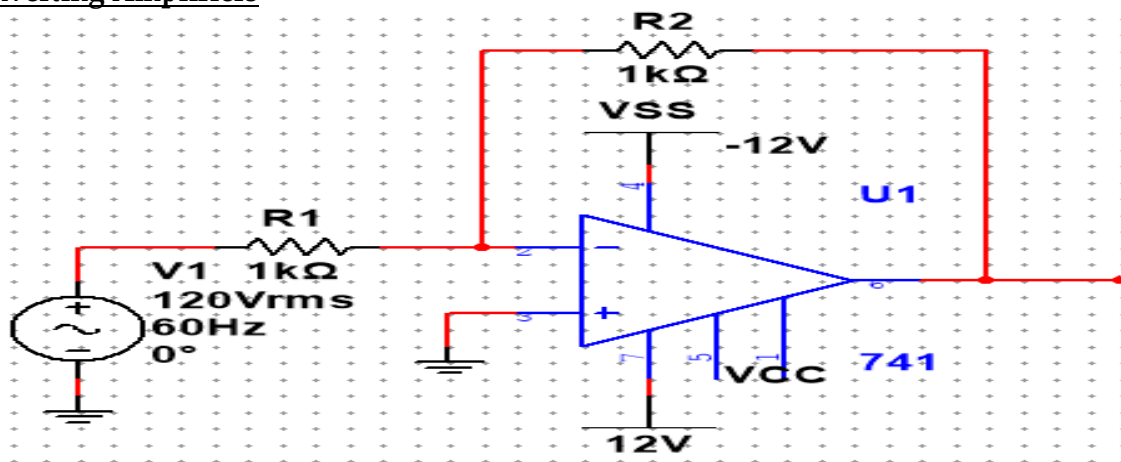


Figure 8. Inverting Amplifier Circuit (Haitham & Jihan 2017)

$$Y_f = -\frac{r_{11}}{r_{10}} - (Y_c)$$

Let $r_{11} = r_{10} = r_{10} = 1K\Omega$

$Y_f = Y_c$

Substituting the equation of Y_c in equation 14, the output is

$$Y_f = -[-(Y_x + Y_y)]$$

$Y_f = Y_x + Y_y$ (Suvajit, Tapas, & Radha 2017)

iii. Design of RF Oscillator Using an OP AMP. (Hartley Oscillator)

Ralph Hartley came up with the idea of the harmonic oscillator known as the Basic Logarithmic Amplifier Using Transistor Hartley Oscillator in 1915. These create the waves in the area of radio frequency using the adjusted cycle of Oscillators which are then utilized and consequently are likewise alluded to as RF Oscillators. The tank circuit, which usually consists of a capacitor connected in parallel with the two serially connected inductors, determines its frequency of oscillation.

Hartley oscillators are accessible in a wide range of setups including series-or shunt supplied, common-base structured or common-emitter, and BJT (Bipolar junction Transistor) or FET (Field Effect Transistor) enhancer based.

Note that the semiconductor based intensifier part of Figure 1 could actually be supplanted by a speaker of some other kind like that of a modifying enhancer shaped by an Operation Amp as shown in Figure 2. This kind of oscillator works in a similar way to the one shown earlier, however, since the gain of the inverting amplifier is given as $-r_f / r_1$, the feedback resistor r_f can be used to individually adjust the

oscillator's gain in this case. So it may be very well noted that, in this situation, the increase of the circuit is less subject to the circuit components of the tank cycle hence frequency stability of the oscillator is improved as a result.

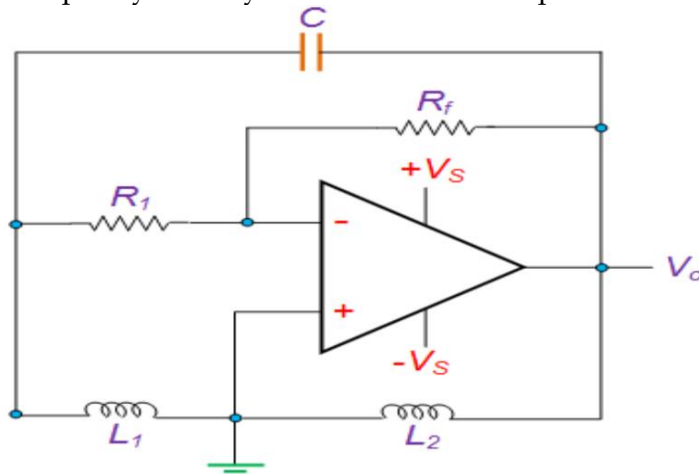


Figure 9. Hartley Oscillator Using Op amp

One of the advantages of the Hartley oscillators is that, they are simple-to-tune circuits that only require a capacitor and two inductors or a tapped coil. This outcomes in a steady state yield all through its wide functional frequency range which ordinarily goes from 20 KHz to 30 MHz. This kind of oscillator, on the other hand, is not suitable for low frequencies because it would require a large inductor, which would make the circuit bulky. Additionally, the high harmonic content of the Hartley Oscillator's output makes it unsuitable for applications requiring a pure sine wave. Such an oscillator has its frequency as;

$$F = \frac{1}{2 \times \pi \sqrt{L_{eff} C}}$$

L_{eff} is the effective series inductance which is expressed as $L_{eff} = L_1 + L_2$; if the coils are wound on different cores and $L_{eff} = L_1 + L_2 + 2M$; if the coils are wound on the same core.

$$\beta = \frac{L_1}{L_2}; \text{ if the coils are wound on different cores}$$

$$\beta = \frac{L_1 + M}{L_2 + M}; \text{ (if the coils are wound on the same core with M indicating the mutual inductance) (Adekanmbi \& Abumere 2017)}$$

For the Hartley oscillator, the frequency of the oscillation is given by;

$$f_o = \frac{1}{2\pi\sqrt{(L_{eq}C)}} \text{ Where } L_{eq} = L_1 + L_2$$

Let $L_1 = 1.0 \times 10^{-6}$ and $L_2 = 0.1 \times 10^{-6}$

Therefore $L_{eq} = 1.0 \times 10^{-6} + 0.1 \times 10^{-6} = 1.1 \times 10^{-6}$

Let the capacitor value be 1nF i.e $C = 1 \times 10^{-9}$

$$\text{Therefore, } f_o = \frac{1}{[2 \times 3.142(1.1 \times 10^{-6} \times 1 \times 10^{-9})]} \quad f_o = 4.799 \text{ MHz}$$

The minimum gain required is 10, therefore the gain is $A = \frac{r_2}{r}$

$10 = 100 \times 10^3 / r$, therefore the maximum value of $r = 100 \times 10^3 / 10 = 10 \text{ k}\Omega$

iv. Device Model of Audio circuit.

The rC phase-shift oscillator, a sinusoidal feedback oscillator, is here presented in Figure 10. The three feedback loops of rC stages can each produce a maximum phase

shift close to 90 degrees. Swaying happens at the frequency where the absolute stage shift through the three rC circuits is 180°. In order to satisfy the requirement for oscillation of a 360° (or 0°) phase shift around the feedback loop, the inversion of the op-amp itself provides an additional 180°.

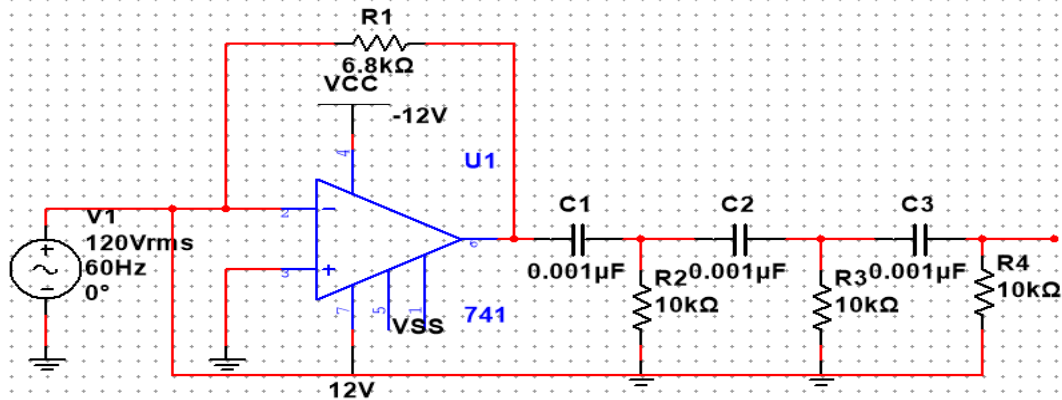


Figure 10. rC Phase-Shift Oscillator

The three-stage rC feedback loop is weakened by a factor Y where $29Y = 1$ where $Y = r_3/r_f$. The deduction of this surprising outcome is yielded "Determinations of Chosen Conditions" at www.pearsonhighered.com/floyd. The op-amp's closed-loop voltage gain (set by r_f and r_3) must be greater than 29 to satisfy the greater-than-unity loop gain requirement. The following equation also states the frequency of oscillation (f_r) (Floyd 1999, p.816)

$$C_1 = C_2 = C_3 = C. \text{ and } r_1 = r_2 = r_3 = r \quad f_r = 1 / 2\pi\sqrt{6RC}$$

$$\text{Gain} = 29 \text{ and } Y = \frac{1-r_3}{29 r_f} ; \text{ therefore } \frac{r_f}{r_3} = 29 ; r_f = 29r_3 = 29(10k) = 290k$$

Since $r_1=r_2=r_3=r$ and $C_1=C_2=C_3=C$, therefore

$$f_r = \frac{1}{2\pi\sqrt{6rC}} = \frac{1}{2\pi\sqrt{6 \times (10k\Omega)(0.001\mu F)}} = 6.5\text{kHz}$$

The complete electronic circuit of the multiplier is presented in Figure 11 which went through two tests to verify workability of the multiplier. These are DC and AC tests.

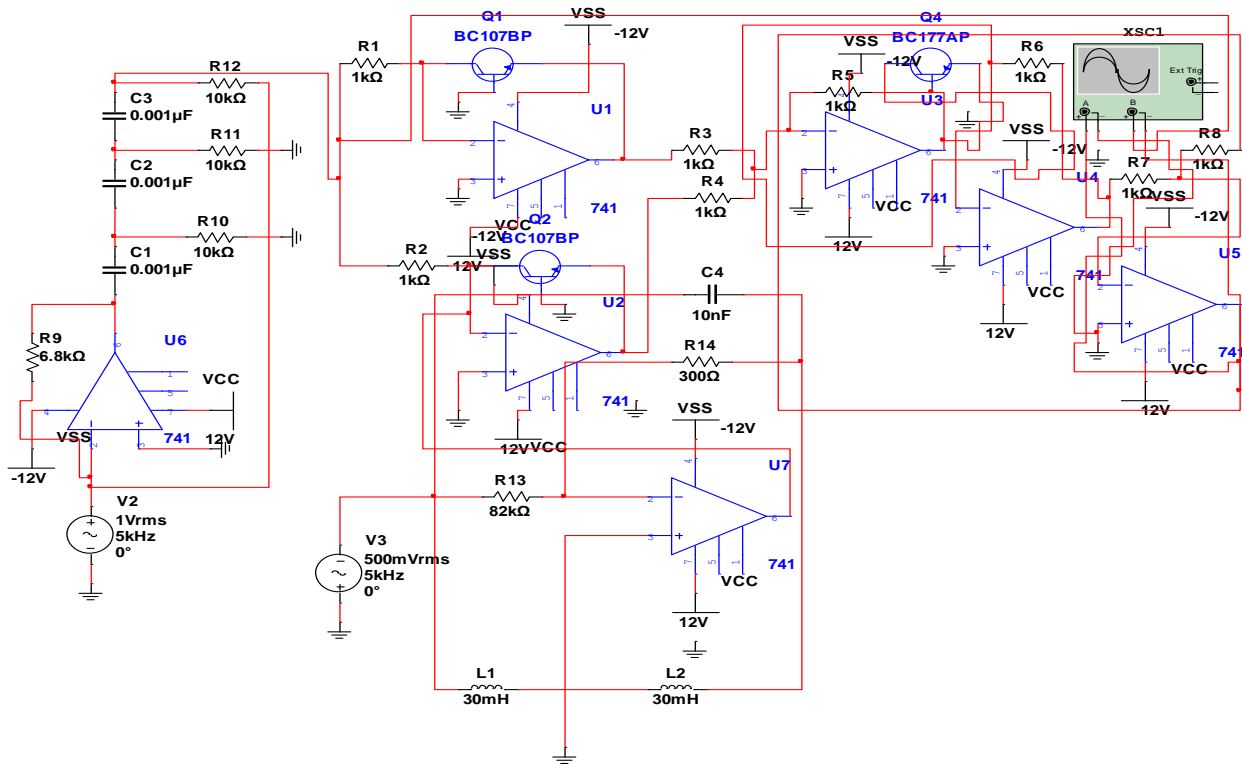


Figure 11. Complete electronic circuit of the Multiplier

RESULTS AND DISCUSSION

The DC input was added while the output results were monitored when the performance of the multiplier was carried out and the result was compared with that of Haitham and Jihan (2017, pp. 7026-7033) presented in table 1.

Table 1. DC Test of Multiplier

Input(X)	Input(Y)	Output(this Study)	Output(Haitham and Jihan, 2017)
100mV	10mV	12.30V	0.993mV
100mV	100mV	9.95V	9.983mV
100mV	250mV	9.95V	24.963mV
100mV	500mV	9.93V	49.919mV
100mV	2V	9.92V	199.404mV
1V	1V	9.66V	0.998V
1V	2V	9.64V	1.998V
2V	2V	9.69V	3.987V
2.5V	2.5V	9.66V	6.223V
3V	2V	9.66V	5.974V

Another Test was carried out at sinusoidal inputs with variable frequencies and results presented in Figure 12.

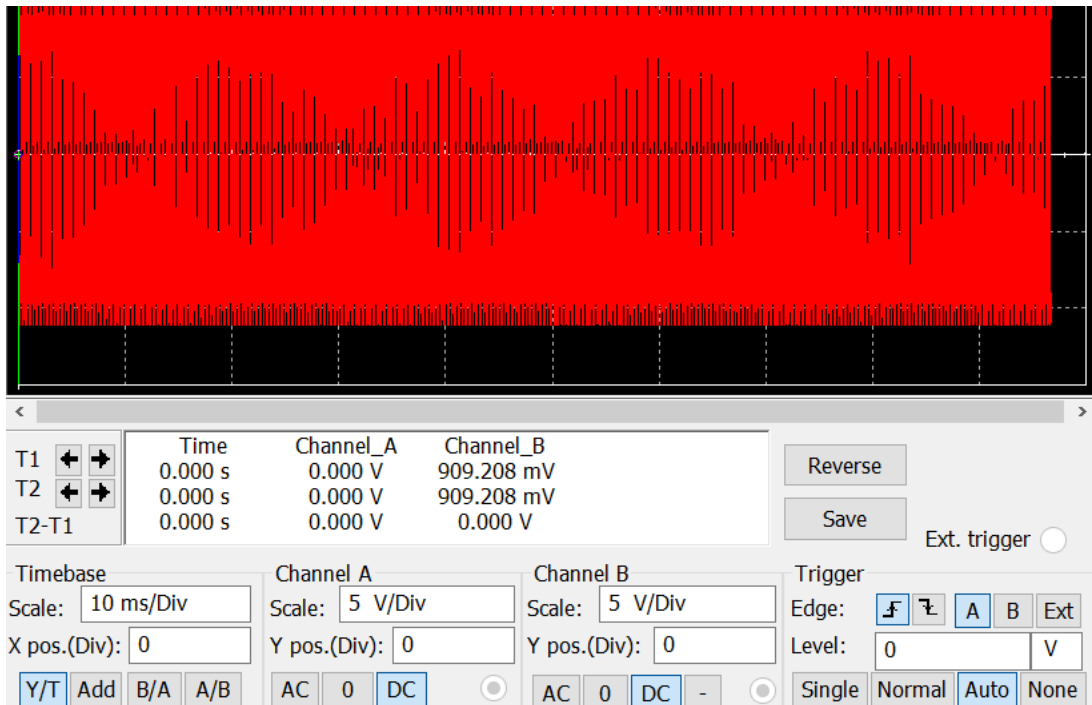


Figure 12. AC Test of Multiplier Circuit

The design circuit of rF Oscillator utilizing the rC Phase Shift Oscillator circuit was tested and the waveform presented in Figure 13.

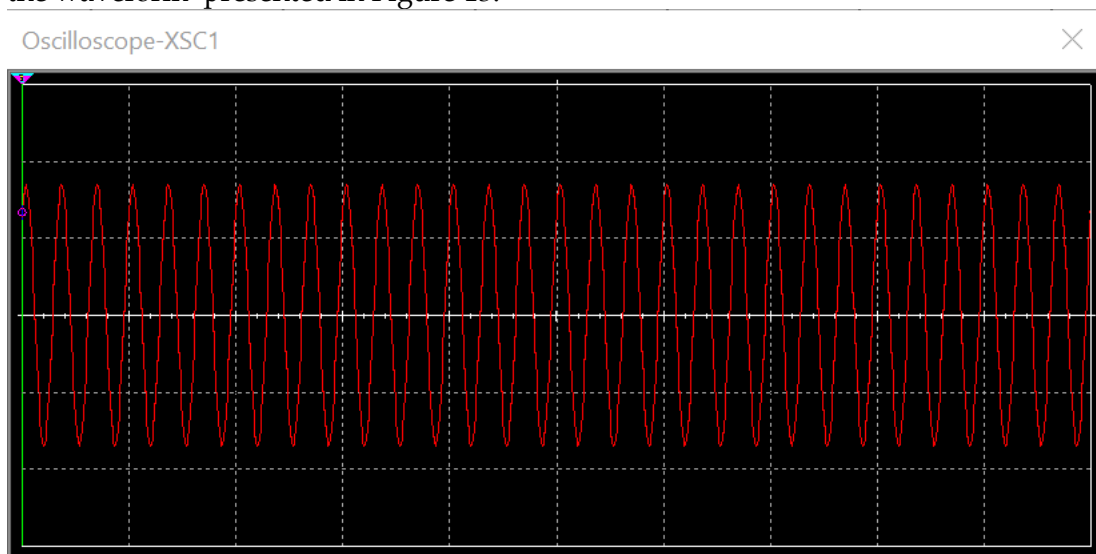


Figure 13. rC-Phase Shift Oscillator Output Waveform(Audio)

After that, the design of the Hartley Oscillator, testing was performed and the result of the waveform presented in Figure 14.

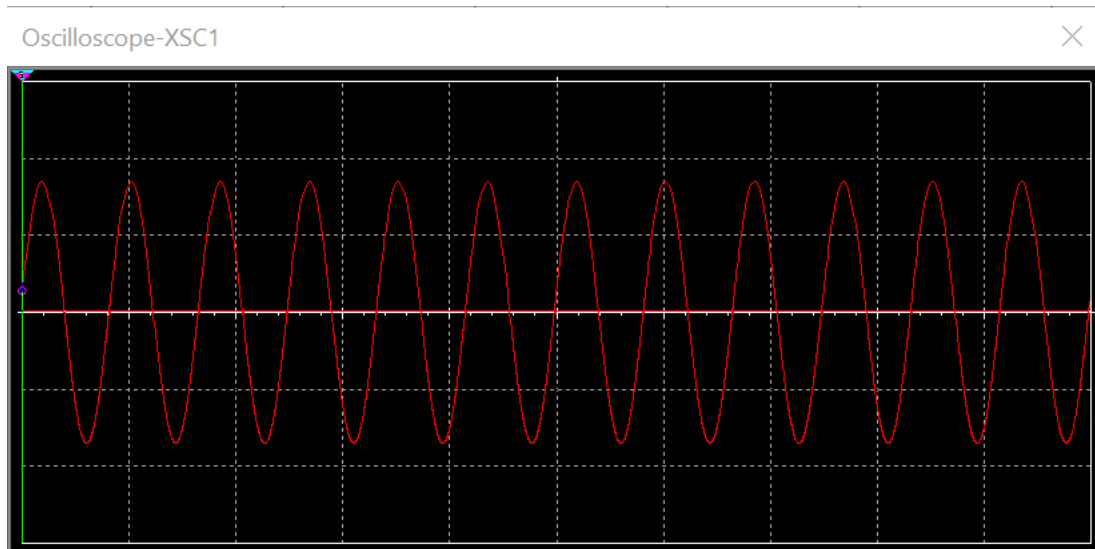


Figure 14. Hartley Oscillator Output Waveform

The whole circuit was then put together for the Amplitude Modulation and simulation carried out using the complete circuit presented in Figure 15.

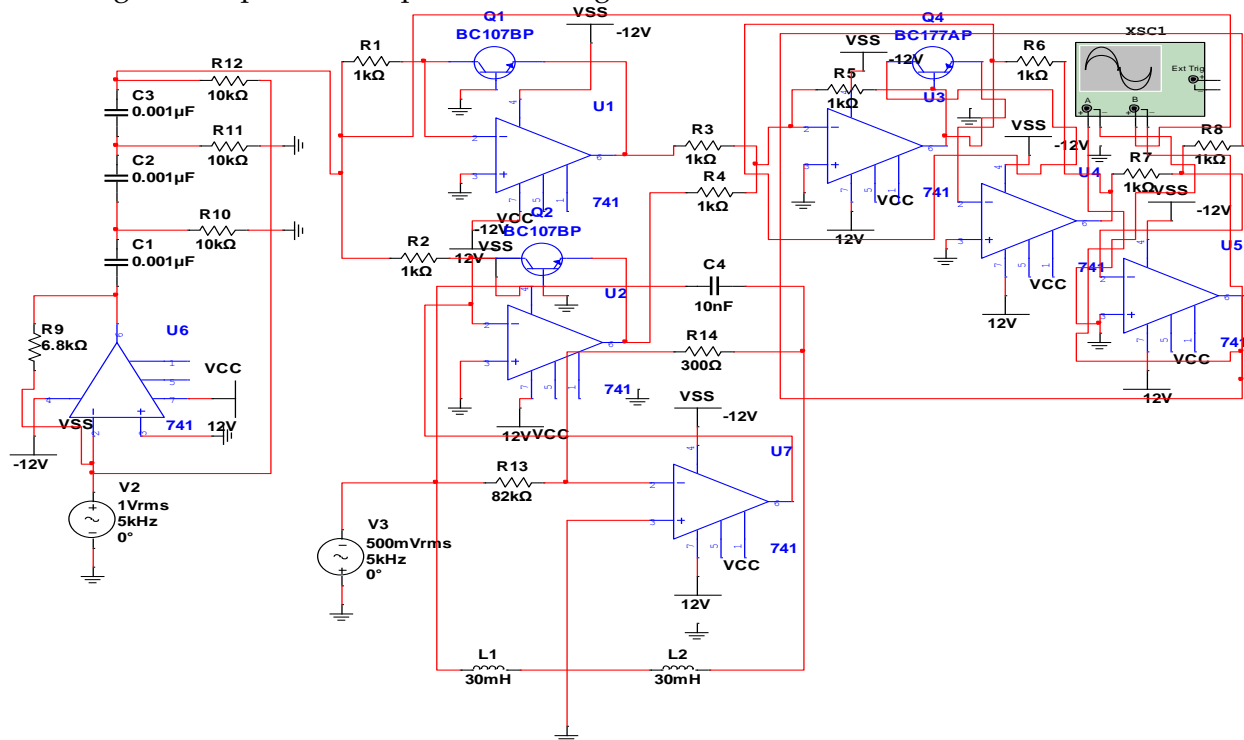


Figure 15. Complete Design of Amplitude Modulation System Block

The circuit presented in Figure 15 was tested to determine the modulation index using variable estimates of Amplitude.

MODULATION INDEX

The AM index quantifies the amplitude variations of an unmodulated carrier. Similar to other modulation indices, in amplitude modulation (AM), this quantity—often referred to as modulation depth—reflects the extent of modulation around its baseline level. In AM, it specifically pertains to changes in carrier amplitude and is defined as follows:

$$\text{Modulation index } (\phi) = \frac{Y_{Max} - Y_{Min}}{Y_{Max} + Y_{Min}}$$

$$\phi = \frac{H_m}{H_c}$$

where: Hm is message amplitude and Hc is carrier amplitude

Modulation Depth (β %) = *modulation index* * 100% .

The calculated and simulated tests of device models are shown in tables (2) and (3).

Table 2. Calculated Result of the AM Design

S/N	Message Amplitude(Hm)	Carrier Amplitude (Hc)	Modulation Index(ϕ)	Modulation Depth (β %)	Type of Modulation Index
1	500mV	1V	0.50	50	Under Modulation
2	700mV	1V	0.70	70	Under Modulation
3	1V	1V	1.00	100	100% Modulation
4	1.5V	900mV	1.67	167%	Over Modulation
5	1V	500mV	2.00	200%	Over Modulation

Table 3. Simulated Result of the AM Design

S/N	Message Amplitude(Hm)	Carrier Amplitude (Hc)	Modulation Index(ϕ)		Modulation Depth (β %)		Type of Modulation Index
			ϕ_1	ϕ_2	(β_1)	(β_2)	
1	500mV	1V	0.56	0.4915	56.00	49.15	Under Modulation
2	700mV	1V	0.60	0.6938	60.00	69.38	Under Modulation
3	1V	1V	1.00	0.9956	100.00	99.56	100% Modulation
4	1.5V	900mV	1.75	1.4725	175.00	147.25	Over Modulation
5	1V	500mV	2.15	1.8042	215.00	180.25	Over Modulation

Figures 16, 17 and 18 presents output waveforms with respect to the modulation index

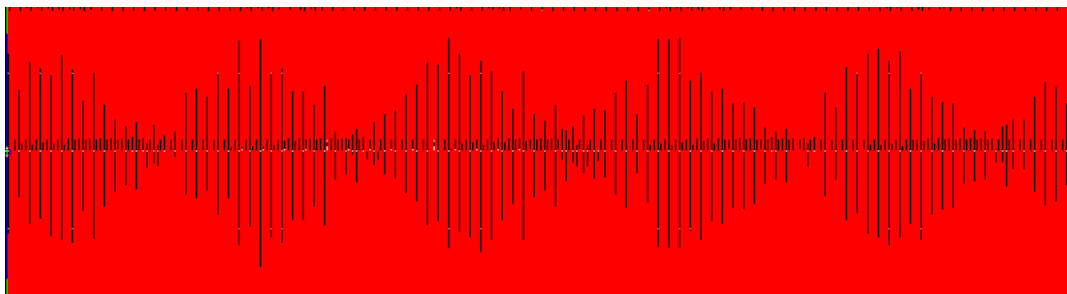


Figure 16. Undermodulation(Table 3, S/N. 1)

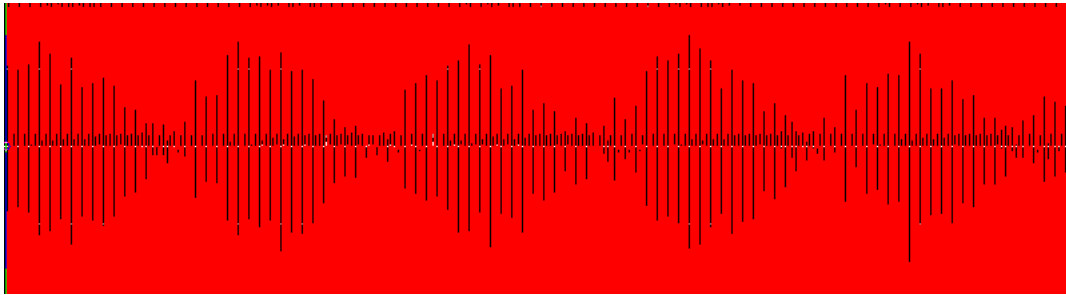


Figure 17. 100% Modulation(Table 3, S/N. 3)

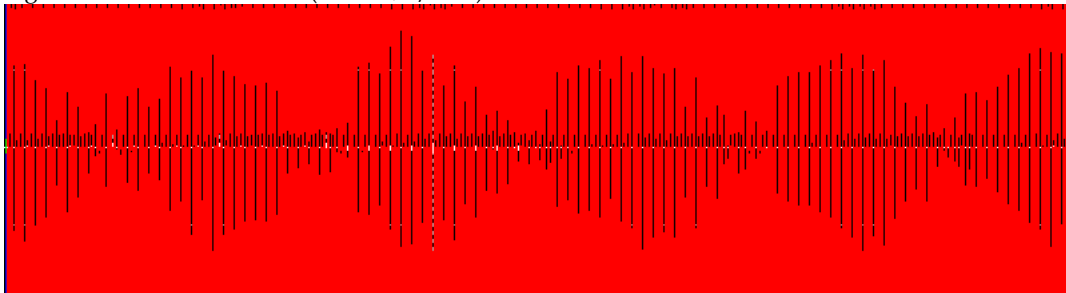


Figure 18. Overmodulation(Table 3, S/N. 5)

DISCUSSION

Table 1 summarizes the key voltages from the simulated multiplier was tested with two DC inputs, where the Voltages decreased from 12.30V to 9.92V at inputs of 100mV X-input and 2V Y-input. It then increases to 9.66V at 1V both X and Y inputs before stabilizing at 3V and 2V, X and Y inputs. The Multiplier was also tested with AC using different input frequencies and result presented in figure 12. Again the RF oscillator and audio network were simulated and results presented in figures 13 and 14. These show strict adherence with working principles. The whole Amplitude Modulation complete circuit was put together as presented in figure 15 and tested and results obtained were presented in tables 2 and 3. Plots of modulation index along with other variables in Figures 16, 17 and 18 show undermodulated , perfect modulation and over modulated waves respectively. These parameters are crucial for the efficient operation of the modulation network and ensuring high-quality modulation of the input signal onto the carrier wave.

The simulated result in Table 1 was compared with an already existent literature (Haitham & Jihan, 2017), in terms of output voltage produced, modulation indices and depth of modulation. It was found that the output voltages increased from 0.993mV at 100mV, X-Input and 10mV Y-Input to 6.223V at 2.5V at both X and Y input before decreasing to 5.974V at 3V X-Input and 2V Y-Input. From the results presented we can see that the designed Am modulator produces higher output voltages than that of other literature (Haitham & Jihan, 2017). Also, Comparison was made using Table 3 in terms of the modulation index (ϕ_1) and the depth of modulation (β_1) of this study against that of already existent literature (ϕ_2) and (β_2) of (Haitham & Jihan, 2017) . Result showed that the modulation indices of this study (ϕ_1) were higher than that of (ϕ_2) with values 0.56, 0.60, 1.00, 1.75, 2.15 as against 0.4915, 0.6938, 0.9956, 1.4725 and 1.8042, while the depth of modulation of this study (β_1) had higher values of 56%, 60%, 100%, 175%, and 215% indicating better modulation performance than that of (Haitham & Jihan, 2017) study with depth of modulation values of 49.15%, 69.38%, 99.56%, 147.25% and 180.42%, Except at 700mV message and 1V carrier amplitude where (β_2) is higher than (β_1). All the simulations when compared with the theoretical results have been found to be consistent with theory to a greater extent.

Overall, Network 1, which uses a log amplifier, phase shift oscillator, and Hartley oscillator, appears to have better performance parameters compared to Network 2, which uses a diode multiplier, Wien bridge circuit, and Colpitts oscillator.

CONCLUSION

The most important components of AM are the modulator unit, the RF unit, and the audio unit. In this study, logarithmic amplifiers were used to construct the modulator unit, the Hartley oscillator was used to construct the RF unit, and the phase shift oscillator was used to construct the audio unit. The essential designed parts were examined to determine the output waveform for each part to ensure that the design is compatible with the required conditions. These three parts were designed using an operational amplifier and simulated by the program (Multisim version 14.2). The AM system was tested by entering signals that represent carrier signal and message signal with different amplitudes and at frequencies taken from the design of audio circuit and RF circuit. We noticed that the output waveform was identical to the standards, and the modulating index was calculated as a multiple case after the three parts were built into one system. This system represents the final design of the AM system which we refer to as Network 1 and was compared with a design by Haitham and Jihan (2017) who designed and studied the complete AM modulator circuit but using diode, wien bridge and colpitts oscillator which we refer to as network 2.

Therefore, the proposed design of the transistor modulation network utilizing log and anti-log multipliers offers significant improvements in modulation depth, linearity, and signal fidelity. Through simulation studies and analysis, the performance of the modulation network has been thoroughly evaluated, demonstrating its efficacy in enhancing the efficiency of AM telecommunications systems. The reasons for not designing an AM modulation network using a diode multiplier, Wien bridge circuit, and Colpitts oscillator, but instead designing one using a log amplifier, phase shift oscillator, and Hartley oscillator are:

1. Higher Linearity: Log amplifiers have higher linearity compared to diode multipliers, resulting in less distortion and better modulation performance.
2. Improved Frequency Stability: Phase shift oscillators have better frequency stability compared to Wien bridge circuits, ensuring a more stable audio signal.
3. Higher Frequency Range: Hartley oscillators can operate at higher frequency ranges compared to Colpitts oscillators, making them more suitable for RF signal generation.
4. Better Noise Immunity: Log amplifiers have better noise immunity compared to diode multipliers, reducing the impact of noise on the modulation process.
5. Simplified Circuit Design: The use of a log amplifier, phase shift oscillator, and Hartley oscillator can simplify the circuit design, reducing the number of components and making it easier to implement.
6. Improved Modulation Index: The combination of a log amplifier, phase shift oscillator, and Hartley oscillator can provide a higher modulation index, resulting in better modulation performance.
7. Reduced Harmonic Distortion: The use of a log amplifier and phase shift oscillator can reduce harmonic distortion, resulting in a cleaner and more stable output signal.
8. Increased Dynamic Range: The combination of a log amplifier, phase shift oscillator, and Hartley oscillator can provide a wider dynamic range, allowing for a greater range of input signals.
9. Better Temperature Stability: The use of a log amplifier and phase shift oscillator can provide better temperature stability, reducing the impact of temperature changes on the modulation process.

10. Improved Reliability: The combination of a log amplifier, phase shift oscillator, and Hartley oscillator can provide improved reliability, reducing the likelihood of component failure and ensuring a more stable output signal.

These reasons highlight the advantages of designing an AM modulation network using a log amplifier, phase shift oscillator, and Hartley oscillator, rather than a diode multiplier, Wien bridge circuit, and Colpitts oscillator.

Future research may explore further optimizations and integration of advanced signal processing techniques to further enhance the performance of the modulation network.

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