Washington State University

School of Electrical Engineering and Computer Science

EE 352 Electrical Engineering Laboratory

Project Interim Report

AM Radio

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Abstract

The purpose of the project is the design and construct an AM radio capable of modulating, transmitting, and demodulating a single tone signal s(t) for all single tone's frequencies between 300Hz and 3000Hz. In the AM Radio, an oscillator is needed to send a clock frequency, a mixer is needed to combine two non-linear circuits to create a new frequency from both signals applied to it. A band pass filter will be used to filter out frequencies outside the bandwidth of the bandpass filter, and the power amplifier is used to amplify the signals amplitude. Both the simulated and constructed circuits met the requirements of applying a clock frequency from the oscillator, then combining both the sin input and oscillator frequency through the mixer generating a modulating signal. The band pass filter then filters out frequencies outside the range of frequencies. The power amplifier met the desired requirement of amplifying the signal amplitude.

Introduction:

A transmitter in an AM radio has five different components in order to generate a successful AM signal. The first being an oscillator circuit. The oscillator used is the Wien Bridge Oscillator which has low distortion and low resonance frequency that can be easily adjusted. The frequency is adjusted through the changes in resistor and capacitor values. The second component used is the signal generator/microphone which is simply a signal applied through the AM radio at a given AC amplitude at a specific frequency. The third component is the mixer which takes the signal generators AC signal and combines into the clock frequency that carries the signal by modulating the AM signal. The fourth component is a band pass filter which is a circuit that has both a low pass and high pass filter to create a bandwidth of frequencies to be sent. The bandwidth filters out frequencies outside the bandwidth range which helps reduce noise in the AM radio. The fifth component of the transmitter is the power amplifier which has a gain more than one in which the power amplifier can absorb a great amount of power. The power amplifier is used to amplify the AM signals amplitude.

AM Modulation is used for radio transmission and two-way radio communication applications. Amplitude modulation needs a carrier amplitude to be modulated. The signal is carried in the graph shown in Fig.1

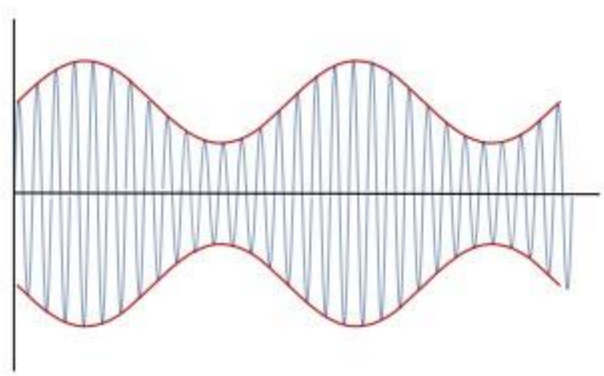

Fig.1 – AM Modulation Signal

For a radio signal to carry information, the signal must be modulated or changed. To achieve this, the amplitude in variation with sound is changed where the change in amplitude is a result of enveloping shown in Fig.2

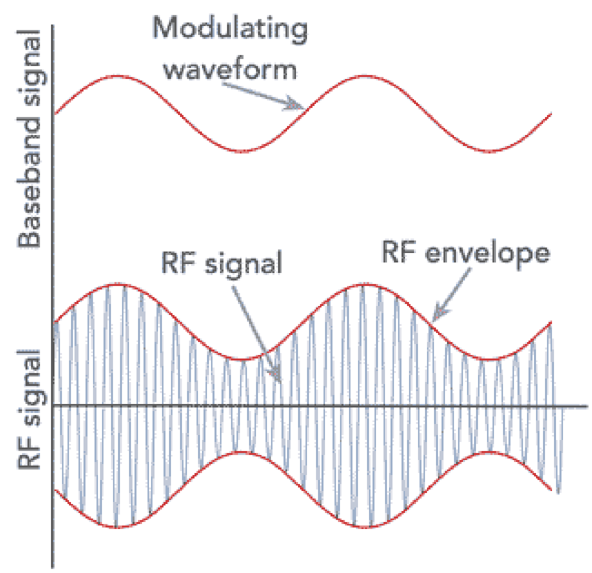

Fig.2 – Enveloping, Modulating waveform, RF signal

In Fig.2 the signal is the wave carried within the waveform where the enveloping is each amplitudes peak. This results in the broadcasting signal to be carried within the RF signal at the oscillators clock frequency. The mathematical expressions for time-domains of the waves are

$$m\,(t) = A_m \cos(2\pi f_m t)$$

$$c\,(t) = A_c \cos(2\pi f_c t)$$

Where m(t) is the modulating signal and c(t) is the carrier signal. The constant A for each signal is the amplitudes of both the modulation signal and carrier signal and *f* is the frequency of both signals. The AM modulation equation with both the modulating signal and carrier signal is given by

$$s(t) = [A_c + A_m \cos(2\pi f_m t)] \cos(2\pi f_c t)$$

The time domain of the AM signal is the time vs. carrier amplitude shown in Fig.3

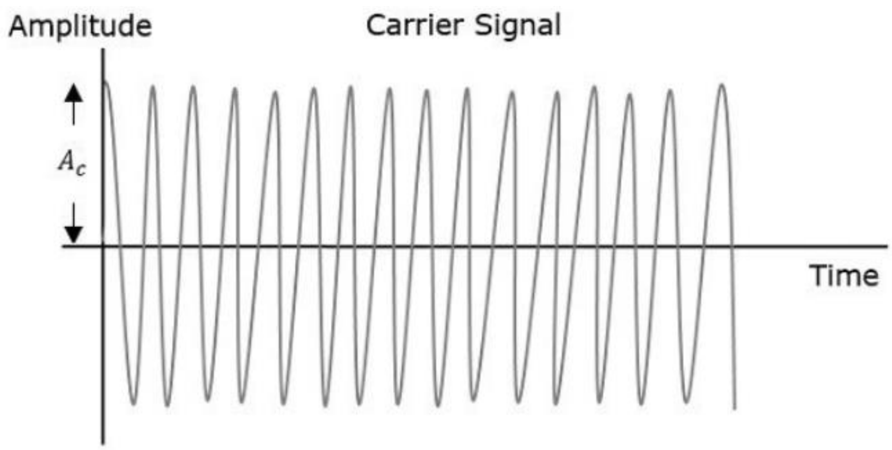

Fig.3 – Time domain of AM signal

The carrier signal contains no information but is a high frequency signal. The modulating wave in Fig.1 contains the message signal, and when combined the carrier signal and modulating wave result in an AM modulated wave. The frequency domain of an AM radio produces more information about the audio signal due to each signal amplitude at each specific frequency rather than an averaged RMS amplitude value such as the time domain. The carrier signal is within the frequency domain like Fig.4

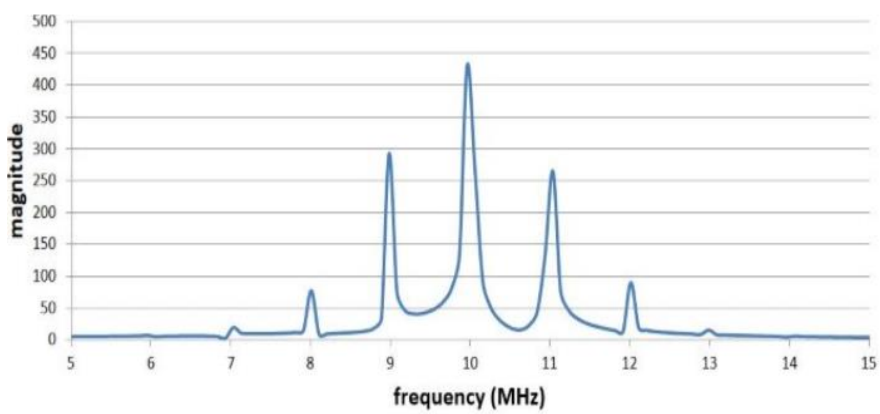

Fig.4 – Frequency Domain

The Wein Bridge Oscillator will create a clock frequency where a steady signal like Fig.5

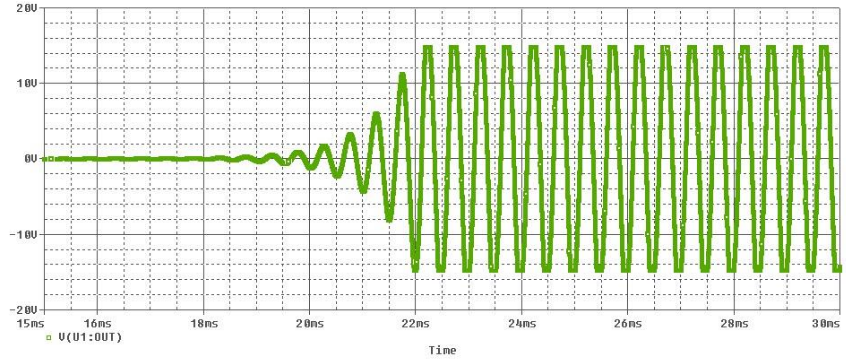

Fig.5 – Oscillator signal

In Fig.5 as time increases the signal will be generated as a base that will carry the information signal when going through the mixer. The signal will provide a base that the mixer will take and combine the input signal in order to transfer it to the receiver to output the signal. The mixer will take two signals, one being the clock frequency of the Wien bridge oscillator and the second being the input signal with a specified amplitude and frequency. The mixer will combine both signals into one creating an AM modulation signal where the information is carried through the modulating waveform and moved with the carrier signal which causes enveloping at each peak amplitude. A band pass filter is used to filter out signals not in the bandwidth of frequencies. The signals outside the bandwidth is noise which causes a random disturbance within the signal itself. The bandpass filter will help eliminate the noise minimizing the random disturbances to get clean signals within the AM radio. Transmitters amplitude can be relatively low due to a specific design. To help amplify the radio frequency a power amplifier is used to amplify the signals amplitude increasing the power signal.

The specifications for the transmitter include the oscillators gain to be greater than 2 and less than 5. When designing the circuits, the capacitor values must be kept simple following analog parts kit capacitor values to avoid mass use of capacitors. Also, resistor values must be kept to at least 1 or 2 resistors to combine into one resistor by itself or 2 in parallel or in series to minimize noise from circuit. The input signal will be a signal generator of an amplitude of 1VAC at a range of 300Hz to 3000Hz. The output will be a single tone sin wave where the output is a clear signal from 300Hz to 3000Hz. The carrier frequency must be within the range of 50000Hz to 60000Hz where the design is expected to work for only one carrier frequency. The carrier frequency is found through the Wien bridge oscillator by adjusting capacitor and resistor values in order to have a gain greater than 2 and within the range of 50000-60000Hz. The transmitter bandpass filters frequency response must have a lower stop band less than 3000Hz, an upper stop band of double the carrier frequency, and a pass band of a bandwidth of 6000Hz from the carrier frequency obtained within the design.

Theory

There are two main components to building an AM radio. One being a transmitter and the other being a receiver. Within each component lies several subcomponents within both the transmitter and receiver. The internal components that make up the AM radios transmitter is shown in Fig.6

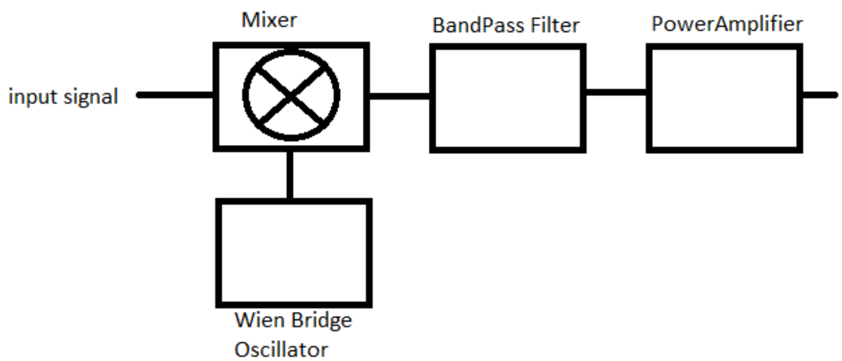

Fig.6 – AM Radio Transmitter block diagram

The transmitter has 5 components to transmit a signal where one of the components is simply an input signal of a specific amplitude and frequency. The Wien Bridge Oscillator shown in Fig.6 is the component that generates the base signal that will carry the input signal. The values of the Wien bridge oscillator determine the cutoff frequency. The Wien Bridge oscillator in the AM radio is shown in Fig.7

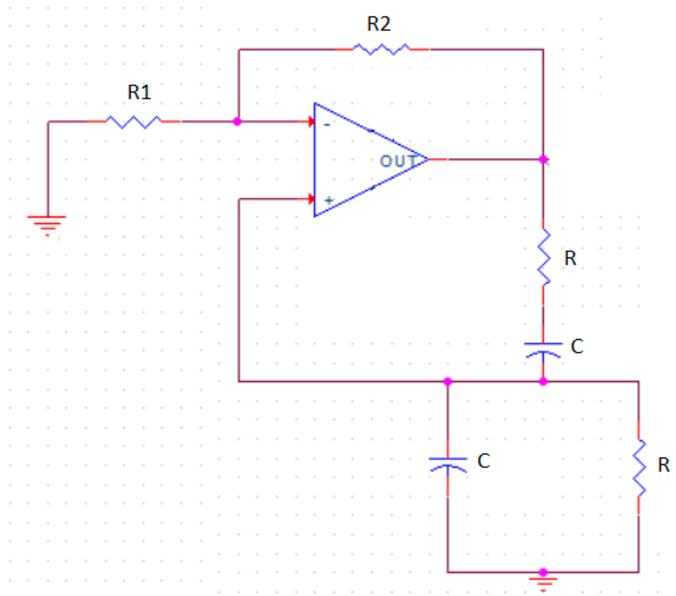

Fig.7 – Wien Bridge Oscillator

Within this design, there will be 4 total resistor values used where the resistor value R will be used to help determine the carrier frequency. The other two resistor values R_1 and R_2 will be used as a simple inverting amplifier to design a specific gain based on the AM radio specifications. Two capacitors are used which help contribute to determining the carrier frequency. The carrier frequency can be determined by the following equation

$$w_o = \frac{1}{RC}$$

The gain of the oscillator is given by the following

$$\text{Gain} = 1 + R_2/R_1$$

All the values used will determine the center frequency, but the resistor R_1 and R_2 will be a set value where the gain will be between 2 and 5. By choosing a capacitor value the resistor R will be the only value changed until a steady clock frequency is generated.

The mixer shown in Fig.8 is the circuit that combines both the carrier signal and waveform signal to create an AM modulating signal.

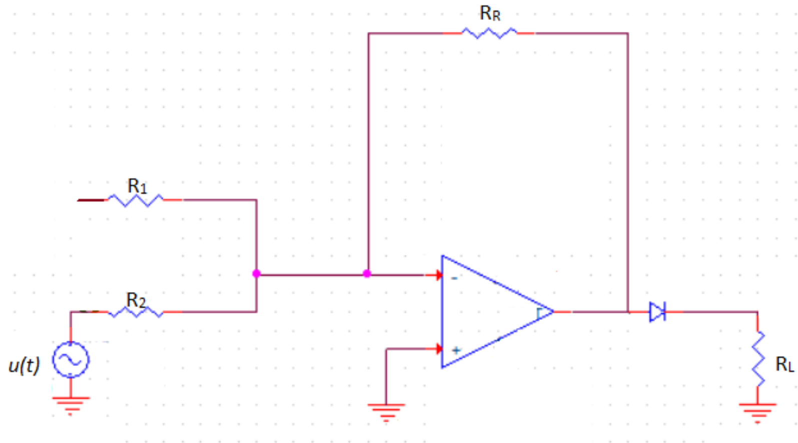

Fig.8 – Mixer

The mixer will take two separate signals and combine into 1 signal called an Amplitude Modulated Signal shown in Fig.9

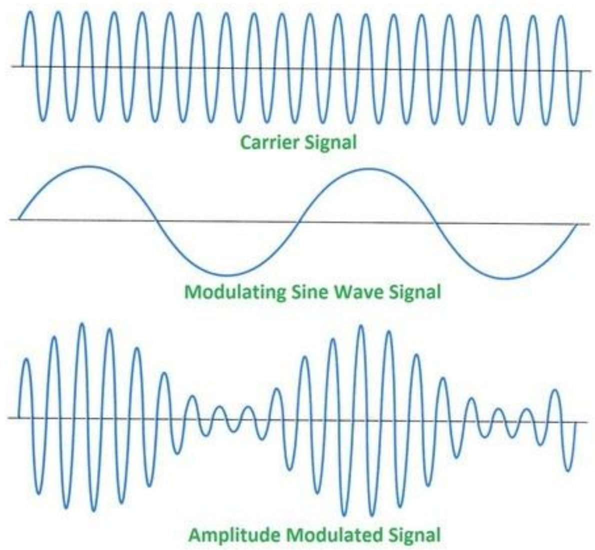

Fig.9 – Amplitude Modulating Signal

From Fig.9 the oscillator creates the carrier signal or a clock frequency of a steady signal, while the input signal is a sin wave signal. The diode in the mixer will remove the lower half of the signal as the positive signal is what will carry this information. The Band Pass Filter shown in Fig.10 is a circuit that passes frequencies within a certain range and rejects frequencies outside the bandwidth. This help eliminate noise within the information signal minimizing the distortion. The band pass filter used 3 resistor values and 2 capacitors. The capacitor values will both remain the same while the resistor values will change.

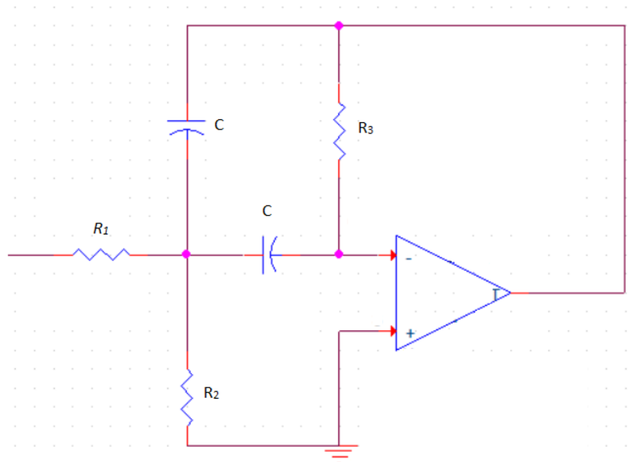

Fig.10 – Band Pass Filter

A band pass filter is a second order circuit where a rand of frequencies are defined within a bandwidth of frequencies shown in Fig.11

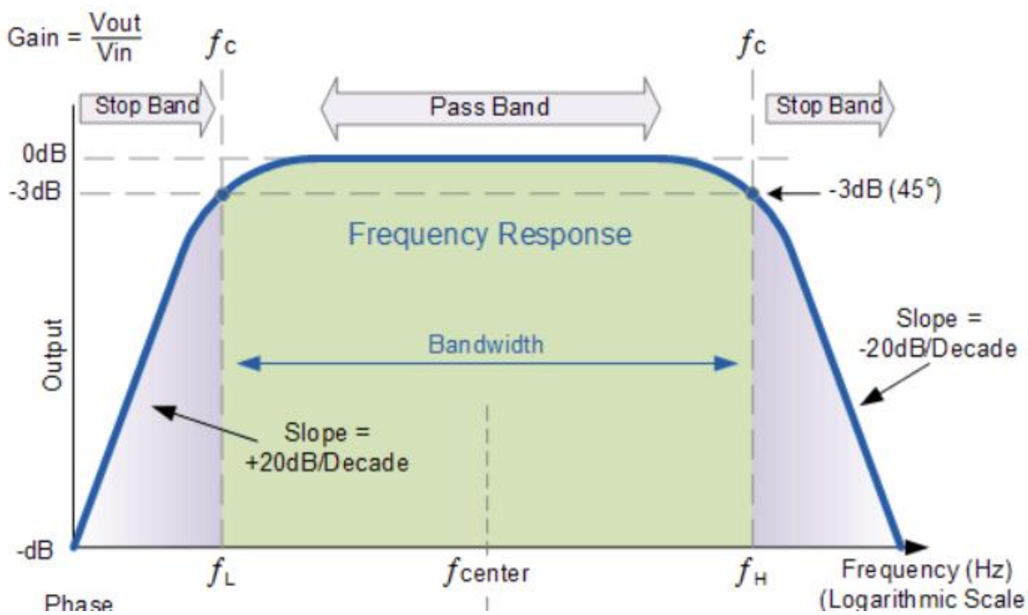

Fig.11 – Band Pass Filter

The bandpass filter will eliminate noise based on values obtained through the center frequency found from the oscillator and by choosing a capacitor value within the band pass filter. The transfer function of the bandpass filter is by the following

$$H(s) = \frac{-KBs}{s^2+Bs+w^2}$$

The value of K will remain constant of 1 while the value of B is the bandwidth from the center frequency is rad/s. with the value of K, B, center frequency, and capacitor value, the three resistor values can be found by the following 3 equations

$$R_1 = Q/K$$

$$R_2 = Q/(2Q^2 - K)$$

$$R_3 = 2Q$$

Results and Analysis:

The simulation in PSPICE for the oscillator was designed by choosing a specific gain of 3.13V/V. These resistor values where R_1 = 22k, and R_2 = 47k. The chosen capacitor value is 470nF which was used to find the value of R to get a center frequency of 55k. The desired result ended in a R value of 470Ω. The PSPICE circuit for the oscillator is shown in Fig.12

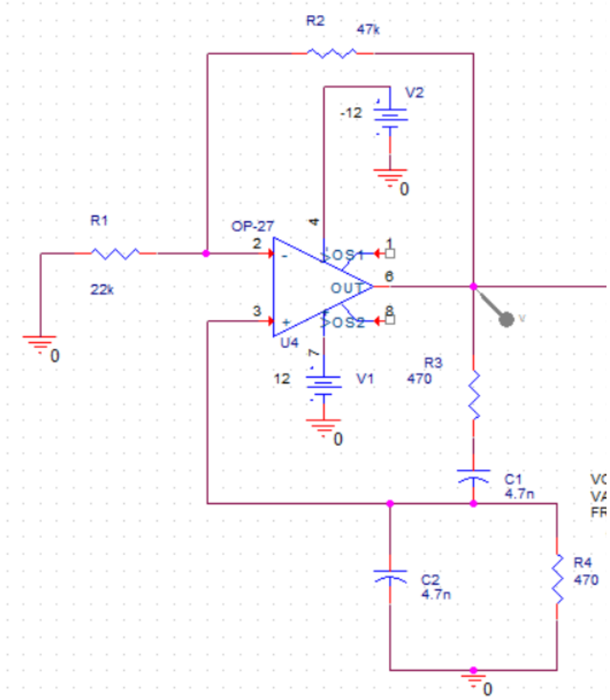

Fig.12 – PSPICE oscillator circuit

The output voltage is measured after the feedback resistor just before entering the mixer. There is no AC or DC signal sourcing the circuit as the oscillator will create a clock frequency based on the circuit itself. When simulated, the output signal is shown inFig.13

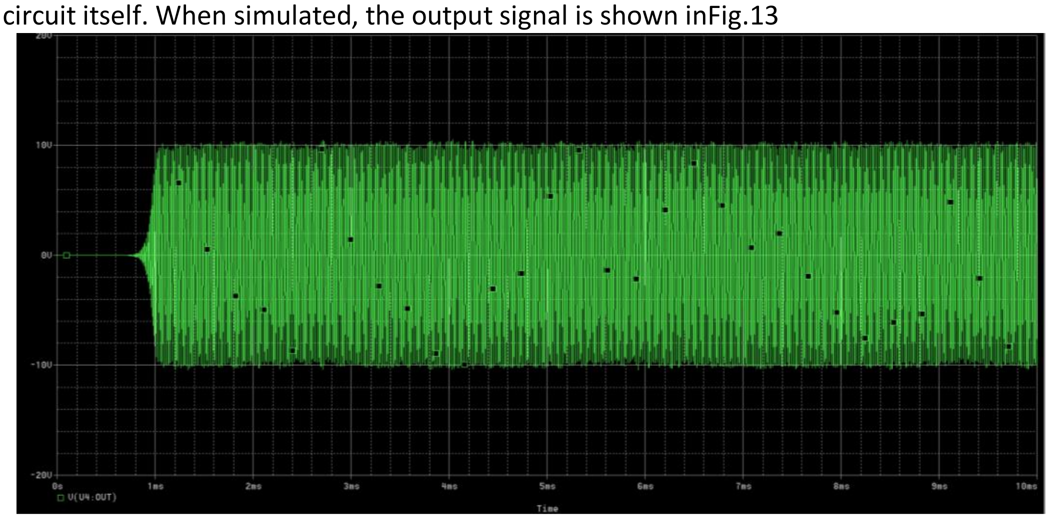

Fig.13 – Oscillator output signal

The simulated oscillator matches how the oscillator is supposed to work by generating a steady signal. The oscillator worked on the first values tried within the oscillator. The center frequency from this signal is shown in Fig.14

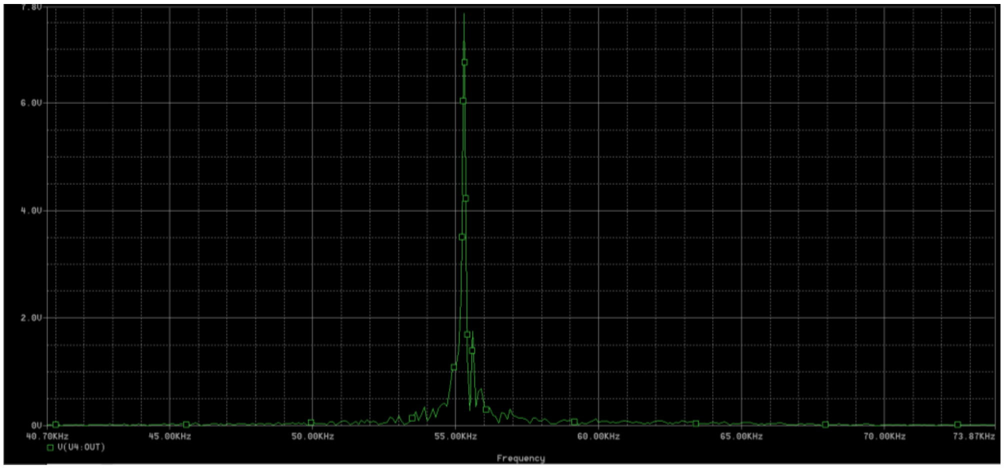

Fig.14 – Center frequency

The center frequency is seen at around 55.2kHz which is in the range of 50k-60kHz. The values of the capacitor and resistors meet the design specification for the Wien bridge oscillator as the gain is between 2 and 5, and the center frequency is at about 55k.

The mixer is designed with R_1 = 20k, R_R = 10k, R_L =1000 and R_2 = 4700. The simulated circuit is shown in Fig.15

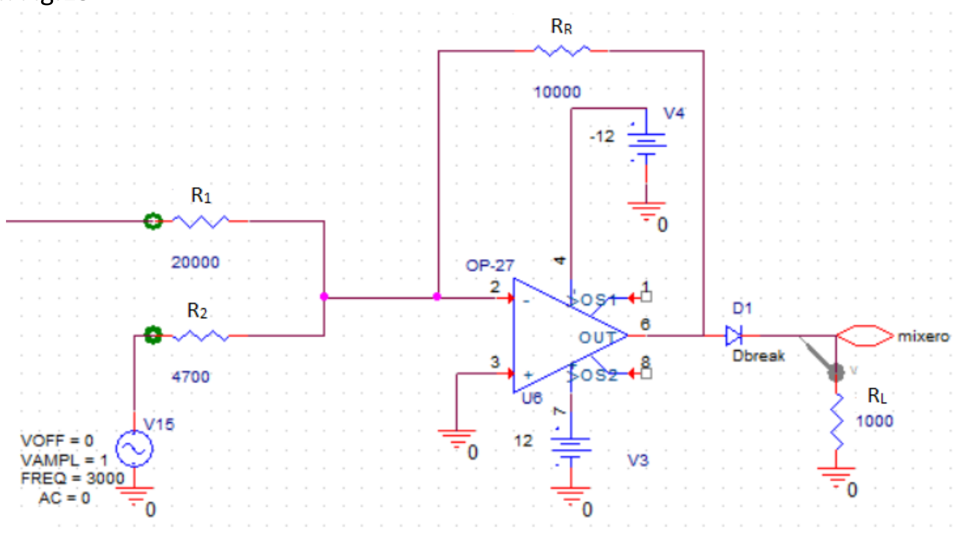

Fig.15 – PSPICE mixer circuit

From Fig.15 the op amp must be powered with +12V and -12V. The circuit is implemented where the input signal is at an amplitude of 1V and a frequency of both 300Hz and 3000Hz. The output signal for both frequencies is shown in Fig.16ab and Fig.17

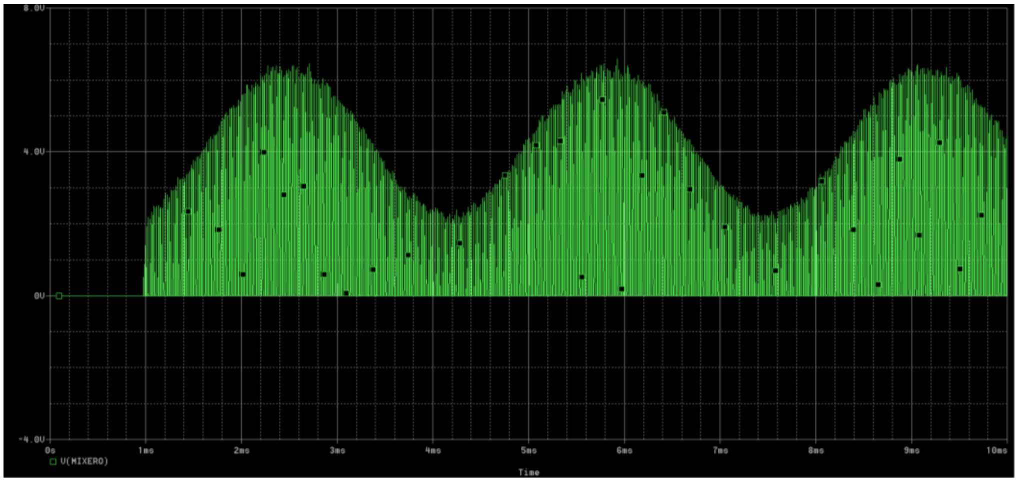

Fig.16a – Mixer output with 300Hz input frequency

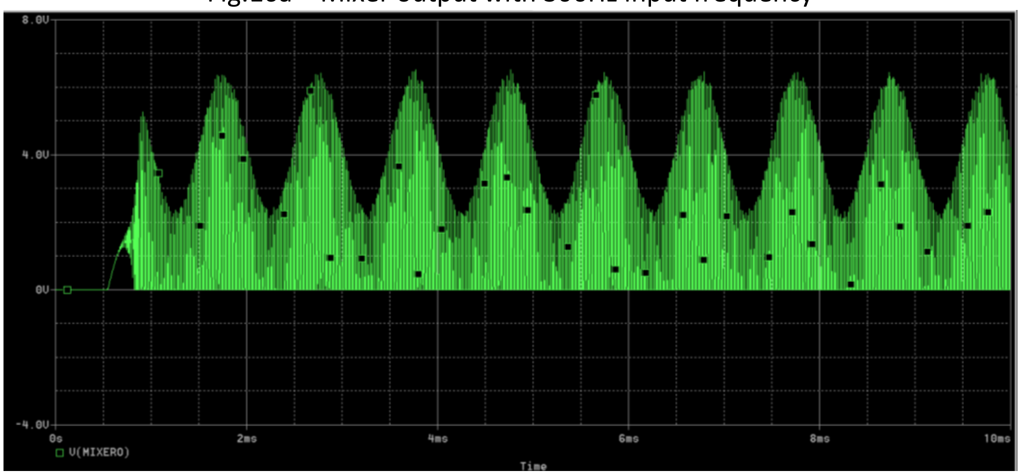

Fig.16b – Mixer output with 1000Hz input frequency

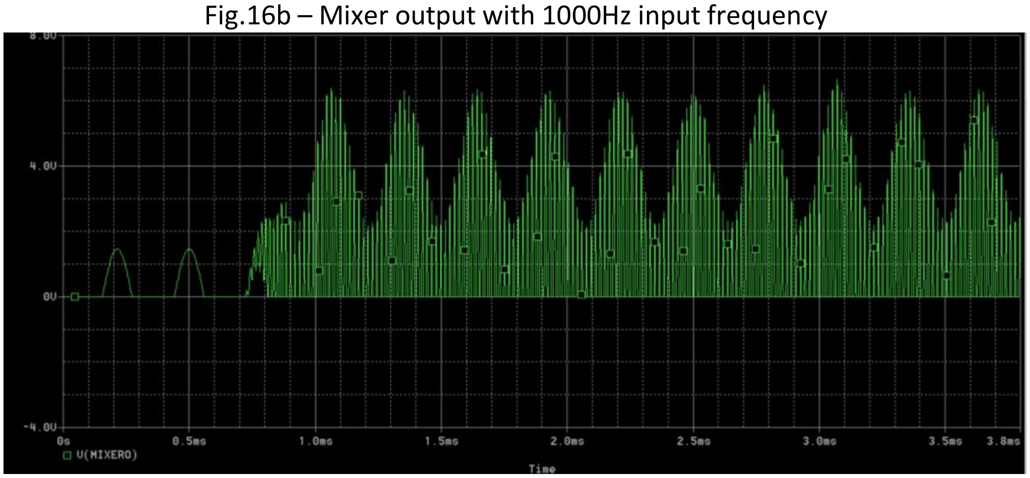

Fig. 17 – Mixer output with 3500Hz input frequency

From both figures of the output signal, the diode removes the lower half of the signal leaving the positive signal only. The mixer does meet the design requirements as at the minimum and maximum frequencies, the signal is an AM modulation signal. The enveloping can be seen at each peak's amplitude bounded by the modulating signal which also matches the functionality of the mixer.

The band pass filter is designed within MATLAB where the values are calculated for R_1, R_2, and R_3 with a set center frequency, bandwidth, K value, and chosen capacitor value. The capacitor value selected is a 1nF capacitor, a bandwidth of 18849rad/s, a cutoff frequency of 345575rad/s, and a K value of 1. From MATLAB the transfer function obtain is

$$\frac{-3.77e04}{s^2 + 3.77e04\ s + 1.194e11}$$

The Resistor values obtained are R_1 = 27k, R_2 = 51k, and R_3 = 158. The simulated band pass filter is shown in Fig.18

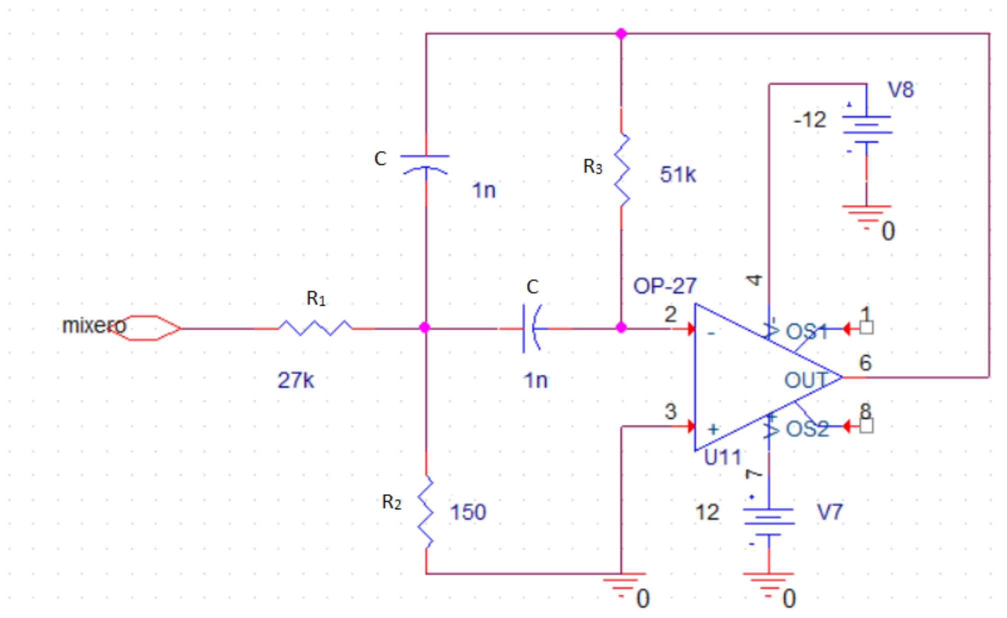

Fig.18 – PSPICE band pass filter circuit

The resulting output for the band pass filter is simulated and shown in Fig.19abc

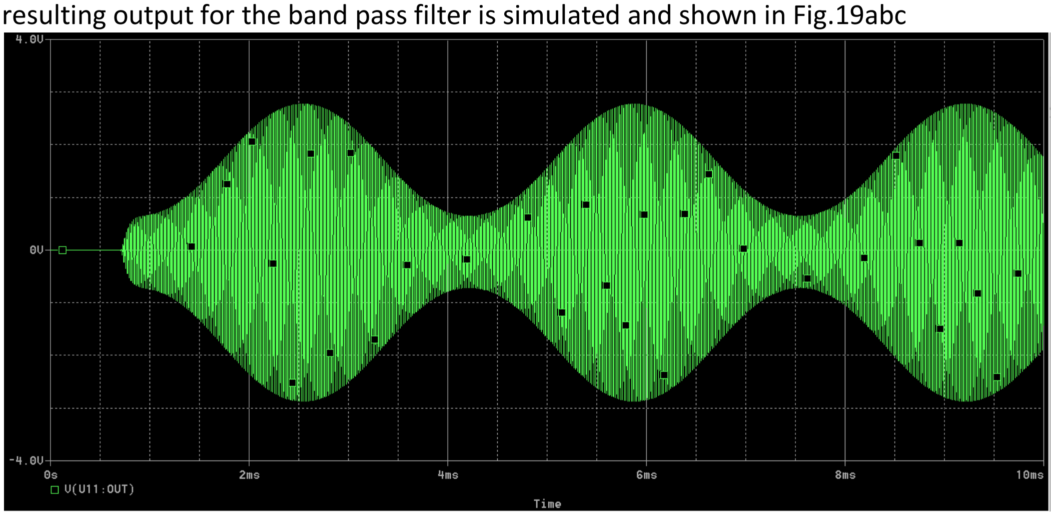

Fig.19a – Simulated Band pass filter output at 300Hz

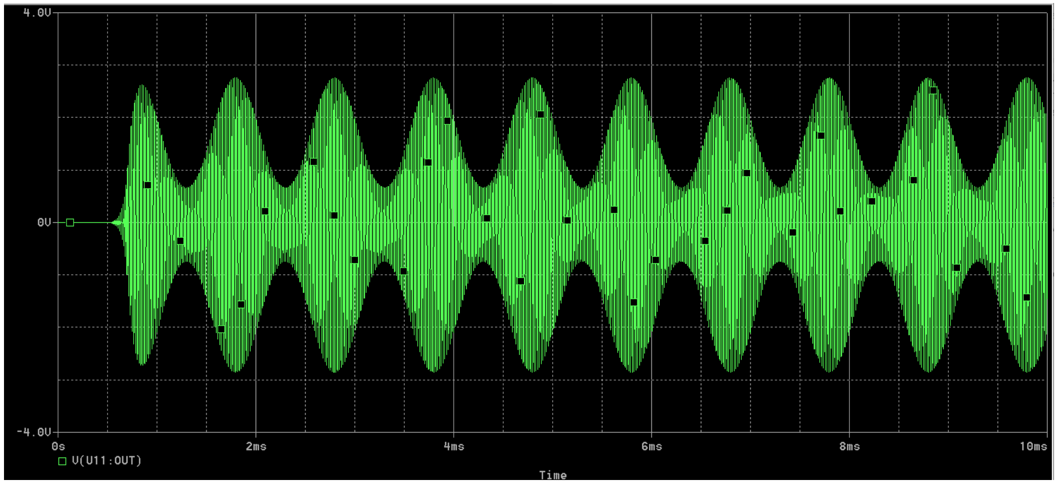

Fig.19b – Simulated Band pass filter output at 1000Hz

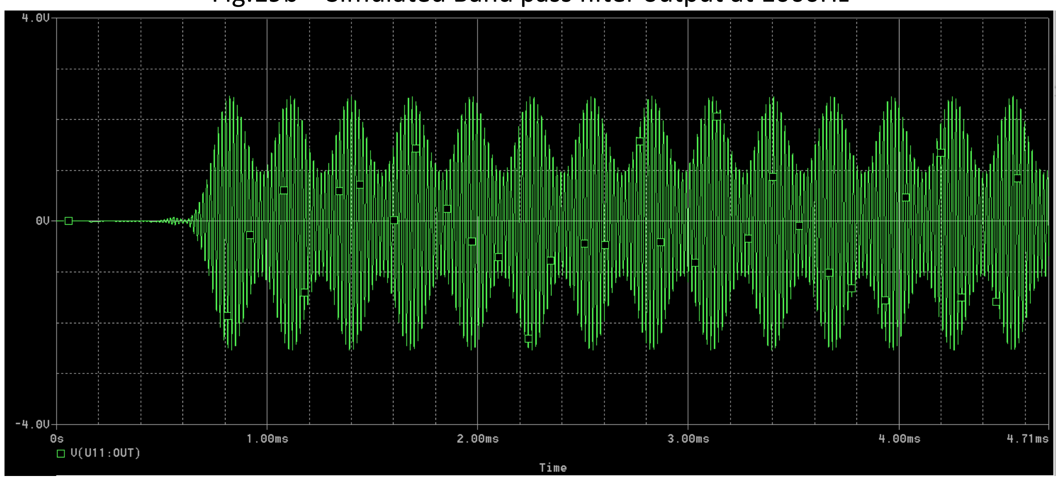

Fig.19c – Simulated Band pass filter output at 3500Hz

Fig.19 shows that the AM modulation signal looks much clearer than the output of the mixer. The band pass filter meets the requirements of filtering out signals outside of the bandwidth as the simulation shows a smooth modulating signal at both the negative and positive peaks. The signals amplitude is at a relatively low amplitude shown in Fig.19 with a 3.7 zero to peak amplitude. The design requirements must be within a range of 5 – 8V zero to peak. A power amplifier is used to achieve this where the gain of the power amplifier is relative to the amplitude needed for the circuit.

Methodology:

1- Design Wien Bridge oscillator
2- Adjust oscillator until center frequency is between 50k-60kHz
3- Design the mixer to combine the clock signal and the modulation signal
4- Design the band pass filter to filter out frequencies outside the bandwidth

Conclusions

The AM radios transmitter was simulated successfully and each of the components met the requirements. The Wien bridge oscillator generates a clock frequency while the mixer takes the input signal and clock frequency and combines them in one AM modulating signal. The bandpass filter filters the frequencies outside of the bandwidth of frequencies while the power amplifier amplifies the signals amplitude.

References

1- https://www.analog.com/media/en/training-seminars/design-handbooks/Basic-Linear-Design/Chapter8.pdf

2- https://www.electronics-tutorials.ws/filter/filter_4.html

3- https://www.electronics-notes.com/articles/analogue_circuits/operational-amplifier-op-amp/wien-bridge-sine-wave-oscillator-generator.php

4- https://www.allaboutcircuits.com/textbook/radio-frequency-analysis-design/radio-frequency-modulation/phase-modulation-theory-time-domain-frequency-domain/

AM Project Check List PSPICE Simulation for Interim Report

Name: Nicholas Keister

Partners :

Partner :

1- ______ Oscillator Circuit
2- ______ AM Modulator (Mixer)
3- ______ Bandpass Filter
4- ______ Power Amplifier

Each group needs to show progress demo by checking each module.

Items 1-4 are need to be checked by October 11, 2019. This will give you a jump start to finish the project on time and without affecting your study time in other courses.

AM Project Check List for implementing each circuit.

Name:____________________________
Partners 1:________________________
Partner 2:_________________________

1- AG Oscillator Circuit
2- AG AM Modulator (Mixer)
3- AG Bandpass Filter
4- AG Power Amplifier
5- __________ Envelop Detector (Peak Detector)
6- __________ Baseband bandpass filter
7- __________ Audio amplifier (comparator & Buffer Amplifier)
8- __________ Speaker Sound (Buzzer)

Each group needs to show progress demo by checking each module.

Items 1-4 are need to be checked by November 1 2019. This will give you a jump start to finish the project on time and without affecting your study time in other courses.