EE313 Analog Laboratory Project Final Report

Frequency Modulated Continuous Wave (FMCW) Based Distance Measuring System

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***Abstract*—This report includes all works related to EE313 Analog Electronics Laboratory Term Project namely a Frequency Modulated Continuous Wave Based Distance Measuring System which is designed by authors.**

***Index Terms*— Amplifier, transmitter, receiver, microphone driver, voltage controlled oscillator, mixer, low pass filter**

I. INTRODUCTION

This project aims to detect distance between two objects by using sound waves. This system has two main parts.
'Transmitter' is the first part of our system. In this part, a well-defined signal, which corresponds sound waves in real life, is produced and controlled with Voltage Controlled Oscillator (VCO). Then, this signal is made ready to transmit. This process includes a power amplifier which boosts the signal and makes it powerful enough to be detected. In this stage of transmitter, the signal is sent to receiver by using 8 Ohm Speaker.
The second part of project is receiver. In the receiver part, a microphone detects the sound waves and these waves are converted to electrical signals thanks to microphone driver. After that a balanced modulator multiplies these signals with the output of VCO signals and the results of these operation become meaningful thanks to low pass filter. All these parts will be investigated in detail in the rest of the report. You may examine the general schema of the design in Figure 1.

II. SYSTEM COMPONENTS

- Resistors (with different values)
- Capacitors (with different values)
- Transistors (2N222, BC547, BD137)
- Op-amps (LM358)
- 8 Ohm 15W Speaker
- Electret Microphone
- Two breadboards

III. CIRCUIT DESIGN

A. Voltage Controlled Oscillator (VCO)

Voltage Controlled Oscillator, which is shown in Figure 2, oscillates between 1 kHz and 5 kHz operation range. To obtain this operation range we set resistors and capacitors with suitable values. Note that the input of VCO is triangular wave with 10 Hz frequency. The amplitude and offset values of input are respectively determined in the lab as 3Vpp and 2V.

B. Power Amplifier

The power output of VCO is very low with respect to capacity of our speaker which may be reached up to 15 Watts. Therefore, we empower VCO output signal before we transfer it to speaker. We constructed a basic common collector amplifier which increases the output current so that we obtained almost 8 Watts output power. The result of this operation illustrated in Figure 3.

C. Microphone Driver

Since electret microphones have a transistor in their capsule, we required to bias electret microphone with 12V from its positive pin to activate it. The signal obtained from this pin is very low, that is mV range, thus, we also designed a common emitter circuit as microphone driver as seen from the Figure 4.

D. Balanced Modulator (Mixer):

In this part of the circuit, the signal which is the result of sound signal converted in microphone driver circuit and the signal directly coming from the output of voltage controlled oscillator are mathematically multiplied. As calculated in equation (1), this operation is resulted in sum and difference of the frequencies of signals.

$$\boldsymbol{\mathcal{F}}\{\, \mathrm{x(t)} \,.\, \cos(\omega_c t) \,\} \;=\; \frac{1}{2}\mathrm{X}(\omega_c - \omega) + \frac{1}{2}\mathrm{X}(\omega_c + \omega) \tag{1}$$

When multiplied signal is observed as FFT in oscilloscope, we also see two strong signals consisting of the sum and difference of the frequencies of signals. In Figure 5, the voltage output of balanced modulator shows that the multiplication of the sound signal set as 1.6 kHz and another signal coming from VCO and set as 2.3 kHz. The FFT of this output is also shown in Figure 6. It is seen that the FFT of this output has two peak values for 700 Hz and 3.9 kHz.

E. Low Pass Filter

To eliminate sum and obtain only difference of two frequencies, we designed a low pass filter. We have chosen our low pass filter oscillation frequency according to idle mode condition. In Figure *, frequency vs. time graph of transmitted and received signals are shown. In this graph, it is shown that idle interval equals to time in which audio signal reaches modulator. Idle interval is asked from smaller than one over tenth of the period of input triangular waveform as seen from equation (2).

$$\Delta t_{\text{idle}} = \Delta t < \frac{T}{10} = \frac{0.1s}{10} = 0.01s = \Delta t_{max} \tag{2}$$

It is also seen that maximum frequency can be measured is limited with triangle similarity which is shown in the Figure *. This similarity is mathematically expressed in below equations (3) and (4).

$$\Delta t = \frac{\Delta f \text{ x } (T/2)}{f_2 - f_1} \tag{3}$$

$$0.01s = \frac{\Delta f_{max} \text{ x } 0.05\text{s}}{4kHz} \tag{4}$$

As calculated from equation (4), we found maximum frequency difference as 800 Hz with the condition of idle interval. However, we have chosen oscillation frequency of low pass filter as 880 Hz because of available components used in electronic markets.

IV. CONCLUSION

In this project we basically measure a distance by using frequency modulated continuous waves. When we were dealing with our circuits we used many applications which we learned in Analog Electronics laboratory sessions. However, these applications were not enough to accomplish our task. Therefore, we did some research on FMCW systems, microphone drivers and usage areas of amplifiers. All in all, this project was very instructive and beneficial for us, prospective electrical engineers.

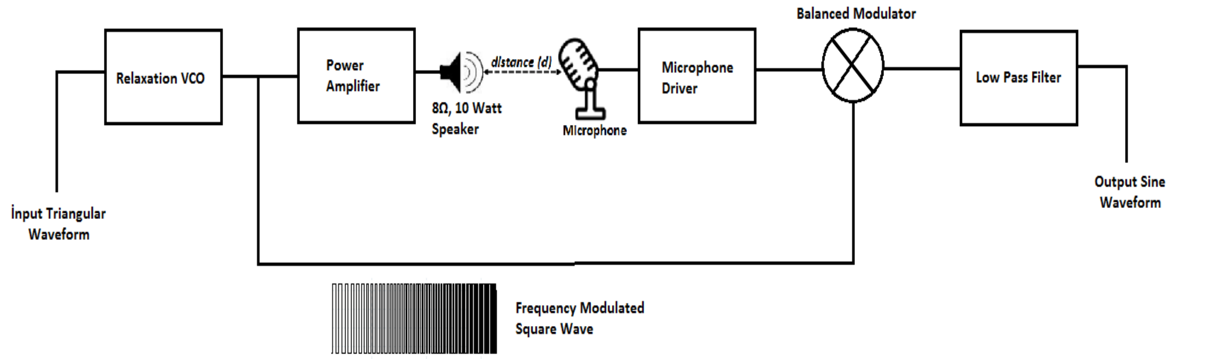

Figure 1: General Schema of the Circuit

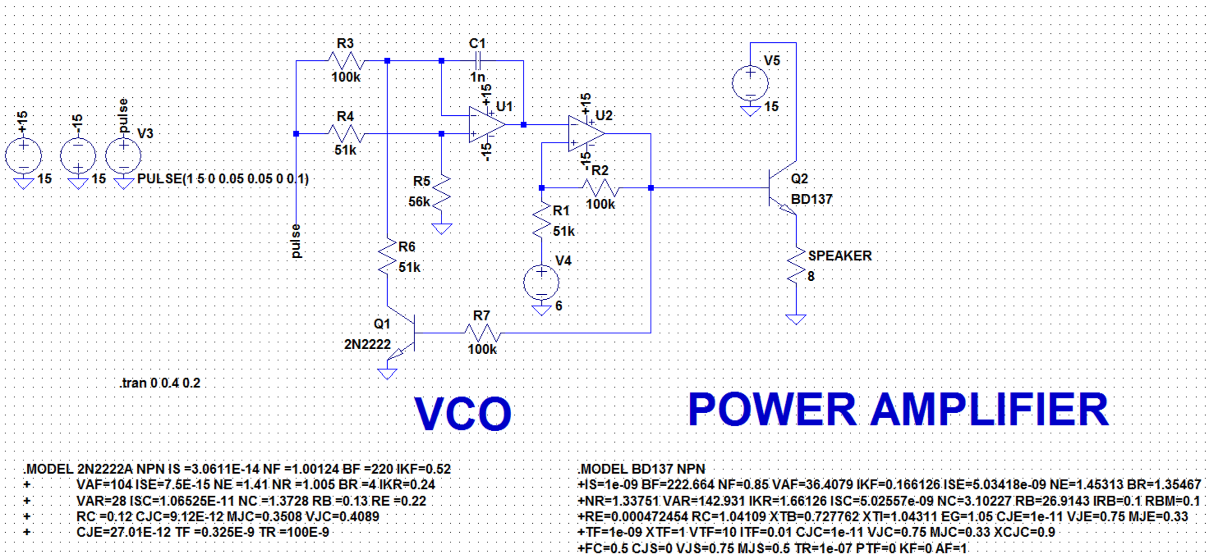

Figure 2. Voltage Controlled Oscillator and Power Amplifier

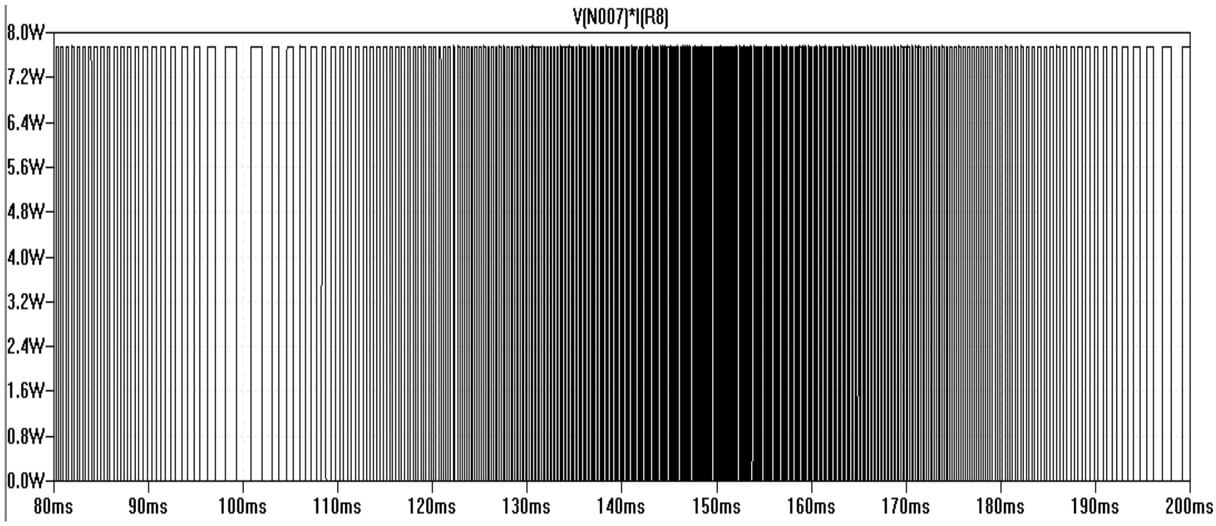

Figure 3. Output Power of Power Amplifier

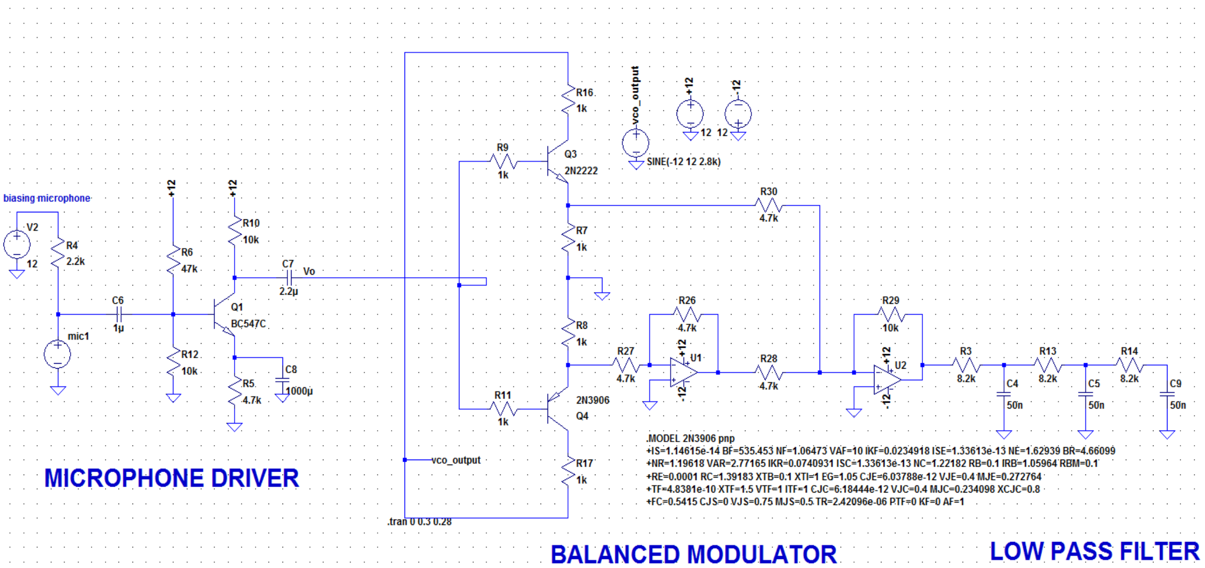

Figure 4. Microphone Driver, Balanced Modulator and Low Pass Filter

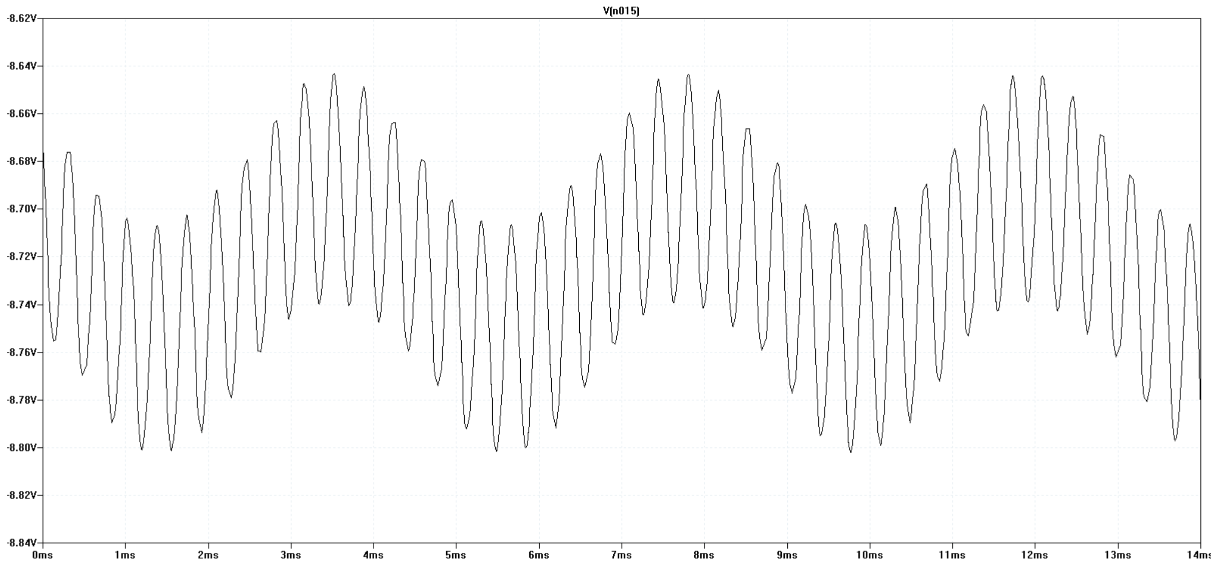

Figure 5. Voltage Output of Mixer

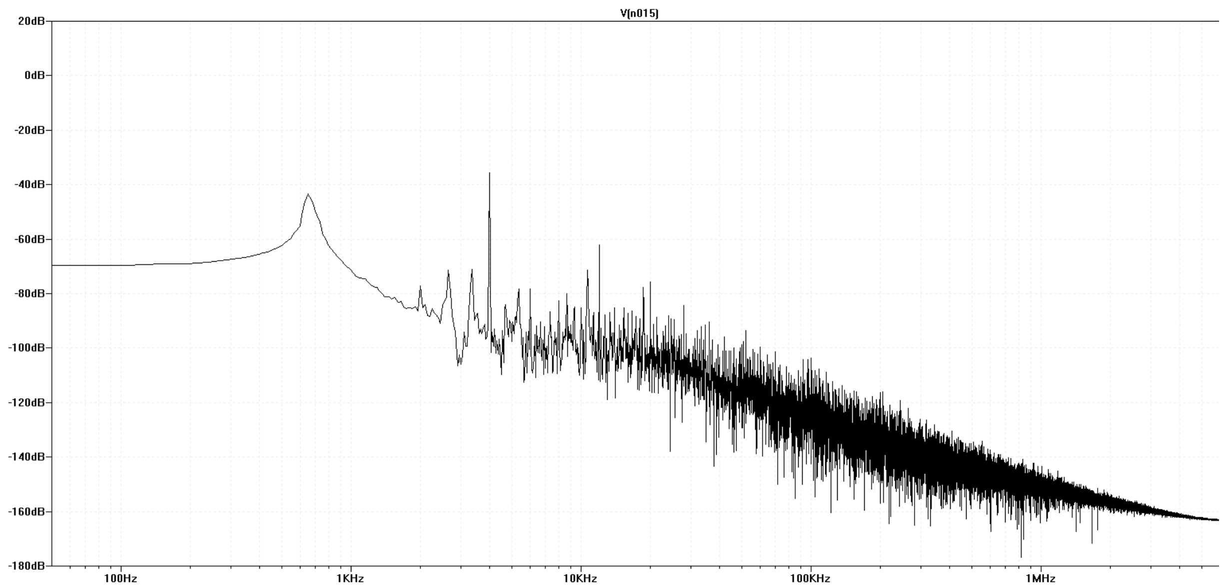

Figure 6. FFT of Mixer Output

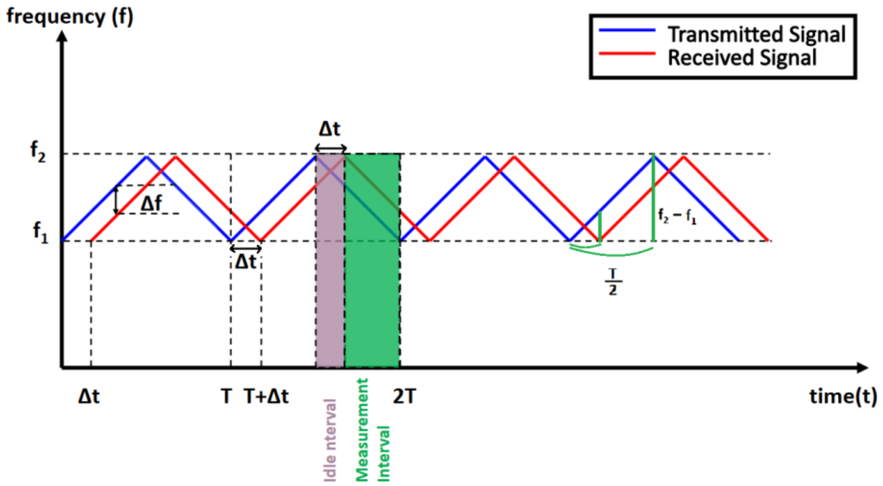

Figure 7. Frequency vs time plot of transmitted and received signals