EE313 ANALOG ELECTRONICS LABORATORY

2017-2018 FALL TERM PROJECT

Introduction:

This document contains the project definition of the EE313 laboratory. Here are the important points about the project:

• Note that this is not a weekend project. Start working on it now. If you would like to test your design, you can use the equipment in the EE313 lab in working hours unless there is a laboratory session proceeding. During weekends, laboratory will be closed.

• The aim of this project work is to make you more familiar with some subjects you were introduced in analog electronics class. However, you may need to do some research and study extra material to accomplish the task. This will be a good first step for 4th year graduation projects.

• The project groups will contain at most 2 students. Although it is not recommended, you may do your project alone. So, determine your project partner as soon as possible. It is not necessary that your lab partner and project partner is the same person.

• You are free and encouraged to use your own ideas. Although your design approach is not limited, the systems are supposed to be economical.

• You are not required to implement your circuit designs on a printed circuit board and you do not have to mount your circuits into a box. Doing so will not increase your grade, but nor will it negatively affect your grade. But your projects should have an aesthetic look (even a circuit on protoboard can have an aesthetic look)

• All assistants are responsible for the project. Primary contact mechanism with the assistants is via email.

• No early demonstration will be allowed (apart from the crucial reasons, such as Erasmus, foreign student, etc.).

Important Dates:

-28th December: Proposal Report

-20-21th January: Project Demonstrations

-22th January 17:00: Final Report Submissions

Report Format

Proposal Report: The aim of the proposal report is for you to start your research early on so that you can have a solid idea about the project. This report will contain preliminary work on your project. A good report should include your proposed way to solve the problem, the equipment required for the solution, some block diagrams of the overall system and any additional info (circuit schematics, mathematical calculations etc.). Maximum page limit for the preliminary report is 3 pages (Times New Roman, 10 point font). Longer reports will be rejected. It is crucial that you determine your project partner, and do some brain storming to come out with solutions well before the preliminary report deadline. You have to upload your proposal report in pdf format to ODTUCLASS until 28th of December, 23:59. Late submissions **will not** be accepted.

Final Report: The final report should be in the IEEE double column paper format (please check the IEEE paper format) and it should not exceed 10 pages in total, any more pages will decrease your grade. The formatting is one of the most important parts of the project. If the final report is not in the IEEE paper format, the project will not be graded and you will get zero from the whole project. Any formatting mistake (such as no figure captions, not referral to the figure in your main text, etc.) will result in grade deduction. You have to upload your proposal report in pdf format to ODTUCLASS until 22th of January, 17:00. Late submissions will not be accepted. Your report should include the following items:

- Theoretical background and literature research
- Design methodology and mathematical analysis of the subsystems
- Simulation results verifying that your subsystems and overall system is working properly.
- Experimental results
- Comparison of the experimental results with the simulation results and mathematical calculations and explanation of any discrepancies.

Grading:

-Proposal Report: 10 pts

-Project Demonstrations: 50 pts

-Final Report: 40 pts

Project Definition:

Design of a Frequency Modulated Continuous Wave (FMCW) Based Distance Measuring System

Aim: In this project, you are going to design a distance measurement system as depicted in Figure 1.

1. The system includes two parts: transmitter and receiver.
2. Your system should work based on FMCW concept. Your VCO should generate signal with variable frequencies and it is needed to be controlled with a triangular wave. As a result, oscillation frequency of VCO will change with time. Details of FMCW is explained in **Appendix**.
3. Output of VCO should be buffered with a power amplifier and it is needed to be transmitted by an 8Ω speaker to the microphone.
4. The signal generated in microphone should be converted into a meaningful electrical signal. Therefore, you need a microphone driver.
5. Since the output of the microphone depends on distance and frequency, you may need an automatic gain controller that controls gain and adjusts the amplitude of microphone signal.
6. To determine the distance, VCO signal and output of the microphone signal should be multiplied. As a result of multiplication, two signals with different frequencies are generated which are summation and difference of VCO and microphone signal frequencies. Frequency difference is proportional with the distance. Therefore, it is needed to extract low frequency signal with a low pass filter.
7. In the measurement interval, signal frequency is proportional with the distance and constant. However, in the idle interval frequency difference changes with time and does not give useful information related to the distance. Idle interval should be a small as possible.

$$idle\ interval_{maximum} < {}^{T}\!/_{10}$$

The system should have following blocks with given specifications.

Voltage Controlled Oscillator (VCO): You should design a voltage controlled oscillator whose operation range is between **1 KHz** and **5 KHz.** Its frequency is needed to be controlled from a control input and a triangular wave with **10 Hz** generates the frequency modulation. For the sake of simplicity, you may generate **square** or **triangular** wave at the output of the oscillator, instead of a **sinusoid**. However, higher order harmonics of the square and triangular waves may affect your distance measurement. Therefore, you may need to find a solution for this problem.

Power Amplifier (Audio Amplifier): Since you are using an 8 Ω speaker, you should buffer the audio signal. The incoming signal should not be clipped. Gain of the previous stages should be arranged so that the input signal of the audio amplifier is not clipped. **Frequency response of the audio amplifier should be flat between 1 KHz and 5 KHz**. Minimum output power should be at least **3 Watts**. You will need to use power transistors and resistors at the output stage. Please note that these components may dissipate too much power and may be hot to touch during operation.

Microphone Driver: There are different types of microphones in the market. Most of the microphones you will use are resistive microphones. Its resistance changes with the intensity of the sound. You need to convert resistance change into voltage. If you are using a different type of microphone, you should use different approaches.

Automatic Gain Controller: Mostly, frequency response of microphones is not sharp and output amplitude of microphones changes with time. To obtain a constant amplitude signal, gain of the amplifier should be automatically controlled. The project may work if you do not get a constant amplitude signal. Therefore, implementation of automatic gain controller is optional.

Mixer (Multiplier, Amplitude Modulator): To determine delay between transmitter and signals, you should extract the instantaneous frequency difference between the transmitter and receiver parts. To achieve this, two signals should be multiplied.

Low-Pass Filter (LPF): Since the output of the mixer includes both difference and summation of instantaneous frequencies. However, we only need the difference information. Therefore, you need to implement a low-pass filter that filters out the signal whose frequency is equal to the summation of the signal frequencies of the transmitter and receiver.

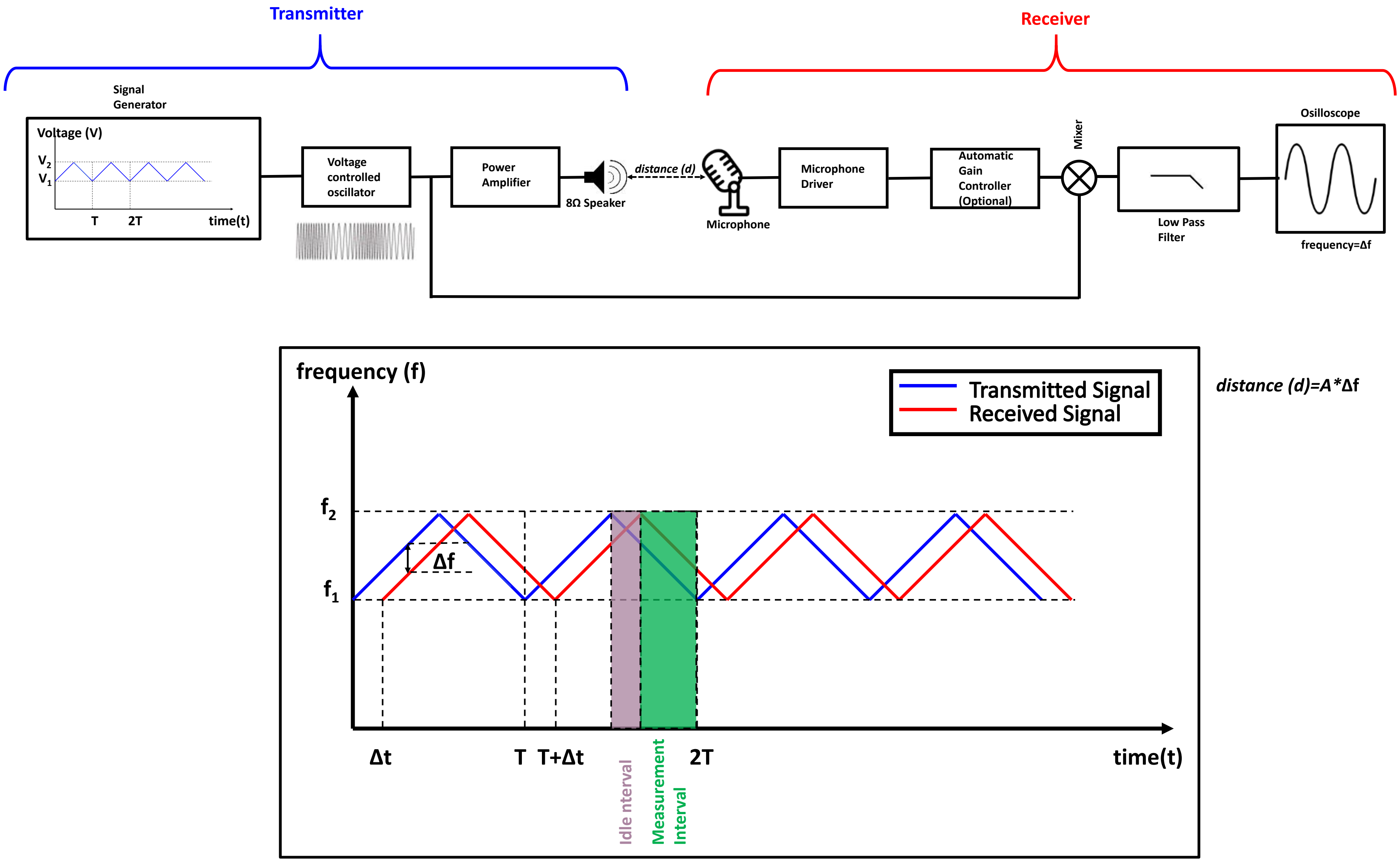

Figure 1: Block diagram of the project

Components Allowed:

-You can use any microphones which do not have integrated drive circuitries.

-You are allowed to use 8 Ω speakers.

-You can use op-amps, any transistors (BJT, MOSFET, JFET etc.), regulators, diodes, resistors, capacitors, inductors available in the market.

-You are not allowed to use audio op-amps.

-The instruments available in the laboratory. (Maximum allowed DC Voltage: ±15 Volts)

APPENDIX

1. Introduction to Radar

The radar was originally an acronym for “radio detection and range”. In general, radars are classified by the type of the waveforms they operate depending on their usage such as detecting velocity and/or distance. They can be Continuous Wave (CW) or Pulsed Radars (PR). As shown in Figure 2, after modulated or unmodulated waveforms are transmitted, propagation takes place. The transmitted wave scatters from a target cross section which is in the search volume of the radar and the reflected wave is received by an antenna. Then, the analysis of the received wave is processed for the range, velocity or some other properties of the target.

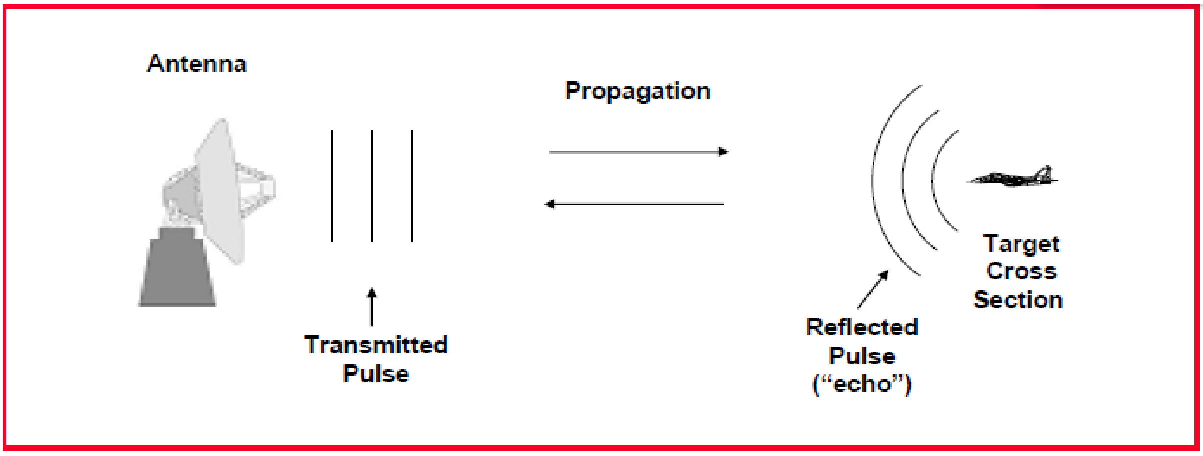

Figure 2: Operation system of radar

Electromagnetic waves propagate at the speed of light ($c=3.10^8$ m/s); hence, the range of the target is:

$$R = \frac{c\,\Delta t}{2}$$

In the project, FMCW signal is transmitted via the speaker, and a sound wave (with speed of 343m/s) is propagating through the microphone which is the receiver. Hence, it is a one-way propagation, not a two-way propagation as in the case of radars. Therefore, the range equation **must** be altered.

2. FMCW Radar

Frequency modulated continuous wave radar is actually a system based on producing beat frequency as a result of the mixer for a transmitted signal and a received signal. Its algorithm is designed for mostly range and velocity detection with high accuracy.

There are mainly four modulation patterns for FMCW such as saw-tooth, triangular, rectangular (square-wave), and stepped (staircase) modulations and all modulation patterns are shown in Figure 3.

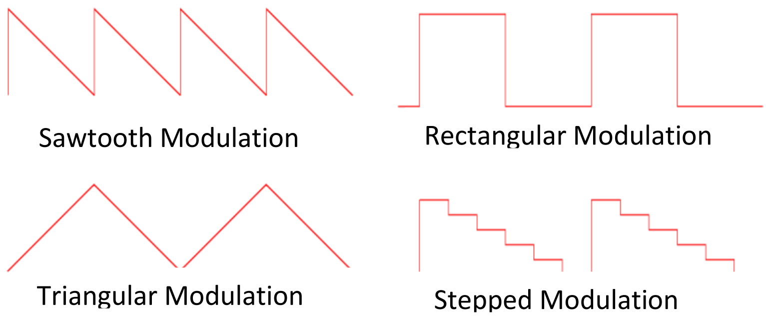

Figure 3: Modulation patterns of FMCW

In general, linear frequency modulated (LFM, triangular modulation) signals are used for this purpose and they are called as chirp waveform. If the frequency is linearly increasing with time, the signal is called up-chirp and if it is decreasing, the signal is called down-chirp. An LFM signal plot is shown in Figure 4.

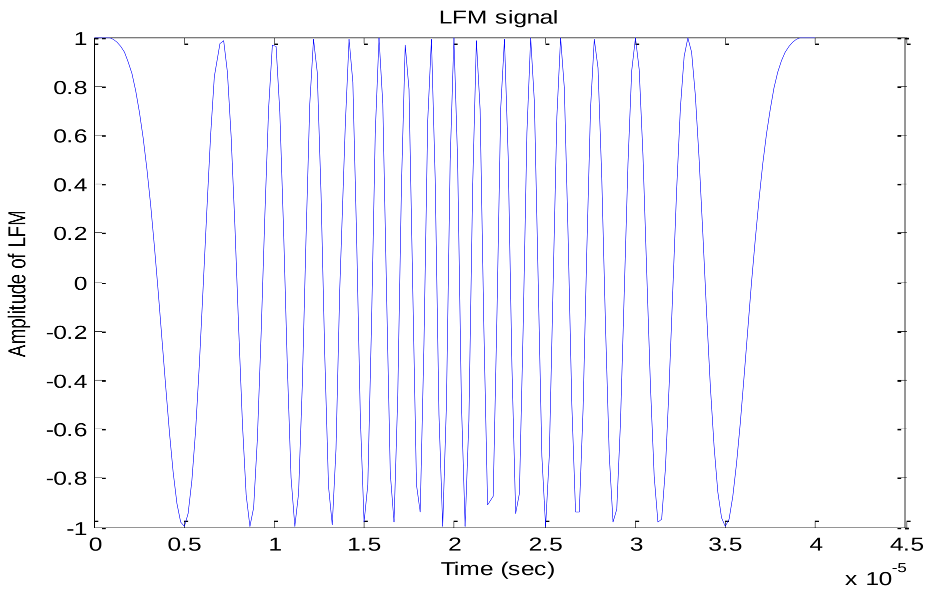

Figure 4: An LFM signal plot