Lab Exercise 1

Introduction To the Lab Assignment and Guidelines

- Lab Safety Guidelines
  - The guidelines related to 'safety' have been uploaded over the Google Classroom (GC). The safety points will also be briefly elaborated by the Lab Engineers during the lab.
- Lab usage Guidelines
  - The general lab guidelines have been uploaded over GC. The guidelines will also be briefly elaborated by the Lab Engineers during the lab.

Lab Assignment: Ultrasonic Doppler Sensor for Motion Detection

Objective

The objective of the lab assignments – over the course of the semester – is to learn how to

(a) Design
(b) Simulate
(c) Fabricate and
(d) Test a narrowband ultrasonic Doppler sensor for motion detection.

Skills Gained

(a) Learn how to read a datasheet and choose appropriate components for a design
(b) Learn how to draw a schematic
(c) Learn how to simulate the behavior of the circuit on LTSpice
(d) Do the PCB layout required for fabrication
(e) Solder components on the PCB
(f) Test the performance of the circuit and compare the performance with simulation results

Software Tools

Tools	Link	Objective
LTSPICE	https://www.analog.com/en/design center/evaluation-hardware-and-software /lt spice-demo-circuits.html	Simulate time domain / frequency domain behavior of the circuit
Eagle CAD	https://www.autodesk.com/products/eagle/free download	Create a schematic of DC power supply design Do a PCB layout and generate a Gerber file

Description

The system level configuration of the ultrasonic narrow band Doppler sensor is shown in Figure.1. The system consists of transmitter and receiver circuits. The transmitter consists of a crystal oscillator that generates a 2MHz sinusoidal signal. The frequency divider divides the 2MHz signal by a factor of 50 to

generate a 40KHz (f_o) output signal. A low pass filter is used to remove any higher order harmonics that may be generated. The filter may be designed as an active filter to provide voltage amplification to the transmitted signal. The signal may be amplified and conveyed to the acoustic transducer where the electrical signal is converted to acoustic signal and transmitted as shown in the equation below.

$$S_{tx}(t)=A_{tx}\cos(2\pi f_o t)$$

The received signal from a moving target consists of a Doppler shifted signal.

$$S_{rx}(t)=A_{rx}\cos(2\pi(f_o+f_D)t)$$

The received signal is much weaker than the transmitted signal ($A_{rx} < A_{tx}$). Hence, the signal is passed through a low noise amplifier for voltage amplification. Then the signal is band pass filtered to remove higher order harmonics and limit external interference. The signal is then captured in the oscilloscope. The frequency domain of the received signal should show a shift in the frequency from 40KHz when a target moves before the sonar. Note that when the hand is moving, the Doppler frequency shift may change with time. Note that the sonar must be configured such that the strong transmitted signal does not directly leak into the receiver. The transducers are typically very directional. So the sonar must be carefully configured such that the transmitter and receiving transducers do not face each other and instead face the target. While performing experiments with a moving target, please ensure that the target is within the field of view of the sonar.

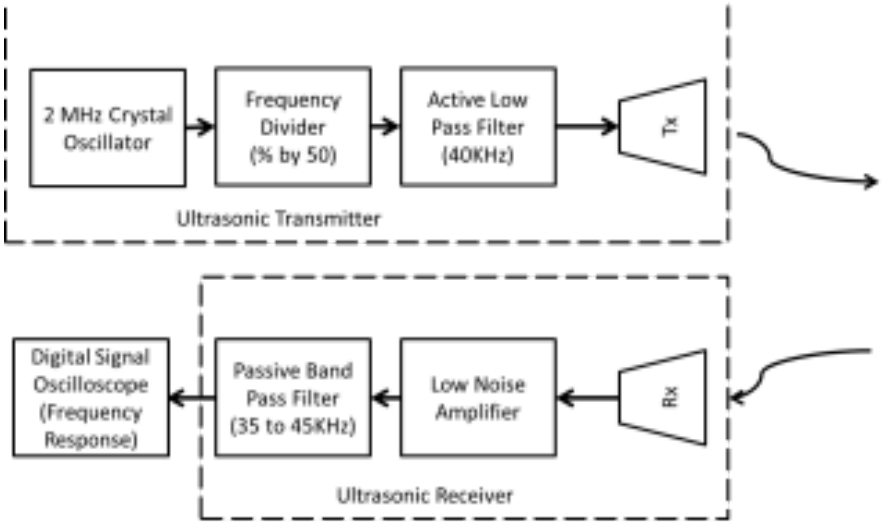

Figure 1. Ultrasonic narrow band Doppler sensor

Suggested Components

Components	Type	Purpose
HC-49U	Crystal Oscillator	Generate 2MHz signal
CD4017BE	Frequency Divider	Convert 2MHz signal to 40KHz signal
CD4049	Buffer Amplifier	Allows for impedance transformation and protects circuits from fluctuations in currents.
MCUSD16A40S12R0	Piezoelectric Transducer	Convert electrical to ultrasonic signal and back (Transmitter and Receiver)
MC33079	Low Noise Amplifier	Amplify received signal without introducing too much noise
	R, L, C	Resistors, inductors, capacitors

Grading Policy

(1) Attendance: Students should show up on time, with their individual lab notebooks and in proper lab attire. They must respect the lab safety policies and demonstrate good lab conduct by respecting the instructions of the lab-in-charge.

(2) Lab results: The lab notebooks/submissions of all the lab teammates will be individually graded by the lab instructors.

(3) Viva: The lab TAs may ask anyone, questions on the lab report/submissions during grading.

- **Become familiar with basics of LTSpice using the LTSPICE user guide**

- The following points shall be discussed in the lab:
  a. choosing components
  b. drawing a circuit
  c. setting up different types of source excitations
  d. carrying out time-domain (transient and steady state) analysis
  e. frequency domain and noise analysis

- Simulate the following circuit and find out the below parameters:
  a. Transient response of the output (output is taken from the output of opamp)
  b. Frequency response of the output signal
  c. Noise contribution in the output signal because of R3