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INFORMATION TECHNOLOGY
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Department
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Circuit Theory and Devices

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Lab_5: LPF and BPF design in LTSpice

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Objective:

The objective of this lab assignment is to learn how to
1. To develop a prototype of a SONAR receiver on a breadboard and test its desired outcome.
2. With SONAR Tx and Rx, observe the Doppler shift in the received signal from a moving metal target.

Theoretical Calculations:

Transmitted signal from Sonar Tx is approximated using the following equations,

→ $S_{tx}(t) = A_t \cos(2\pi f_o t)$

→ $S_{rx}(t) = A_r \times \cos(2\pi(f_o \pm f_d)t)$

$$V_o = \left[\frac{v_{in}^2(\omega^4 C_1^2 C_3^2 R_3^2) + A}{B}\right]^{1/2}$$

we have following equations,

$$\frac{V_L - V_x}{1/s \cdot 1\mu} = \frac{V_x - V_o}{10k} \quad \text{— (1)}$$

$$\frac{12 - V_y}{68k} = \frac{V_y}{68k} + \frac{V_y}{1/s \cdot 10M} \quad \text{— (2)}$$

$$V_x = V_y \quad \text{— (3)}$$

output freq, $f_{out} = f_i + f_o$

Observations:

1**. Transmitted Signal:** The transmitted signal from the SONAR Tx is a pure sinusoidal wave with a frequency of "fo." This signal is generated and sent to the target as an ultrasonic pulse.

2. **Received Signal:** When this ultrasonic pulse encounters a moving metal target, it reflects off the target and returns to the receiver as a Doppler-shifted signal. The received signal has a frequency of "fo + fD".

3. **Low Noise Amplification:** The received signal is typically much weaker than the transmitted signal. Therefore, it is passed through a low-noise amplifier (e.g., TL072) to amplify the signal while minimising noise.

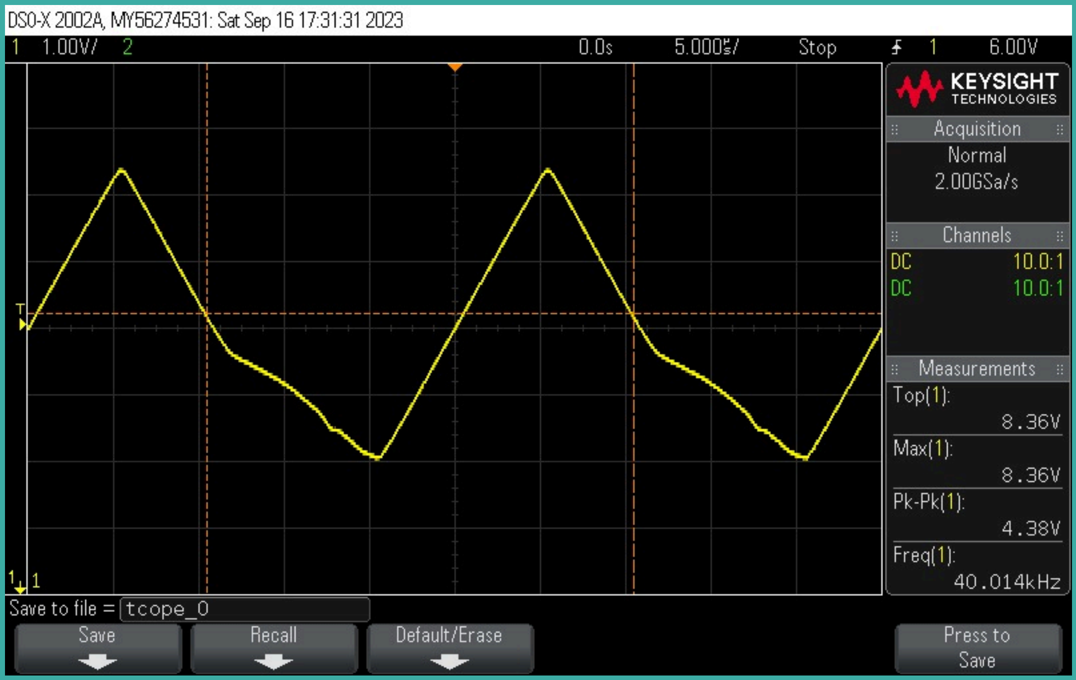
4. **Band Pass Filtering: After amplification, the signal is passed through a bandpass filter**. The purpose of this filter is to remove higher-order harmonics and limit external interference.

5. **Frequency Shift Observation:** By comparing the transmitted and received signals on the oscilloscope, you should observe a frequency shift in the received signal compared to the transmitted signal. The shift will be equal to "fD," which corresponds to the Doppler frequency shift caused by the motion of the metal target.

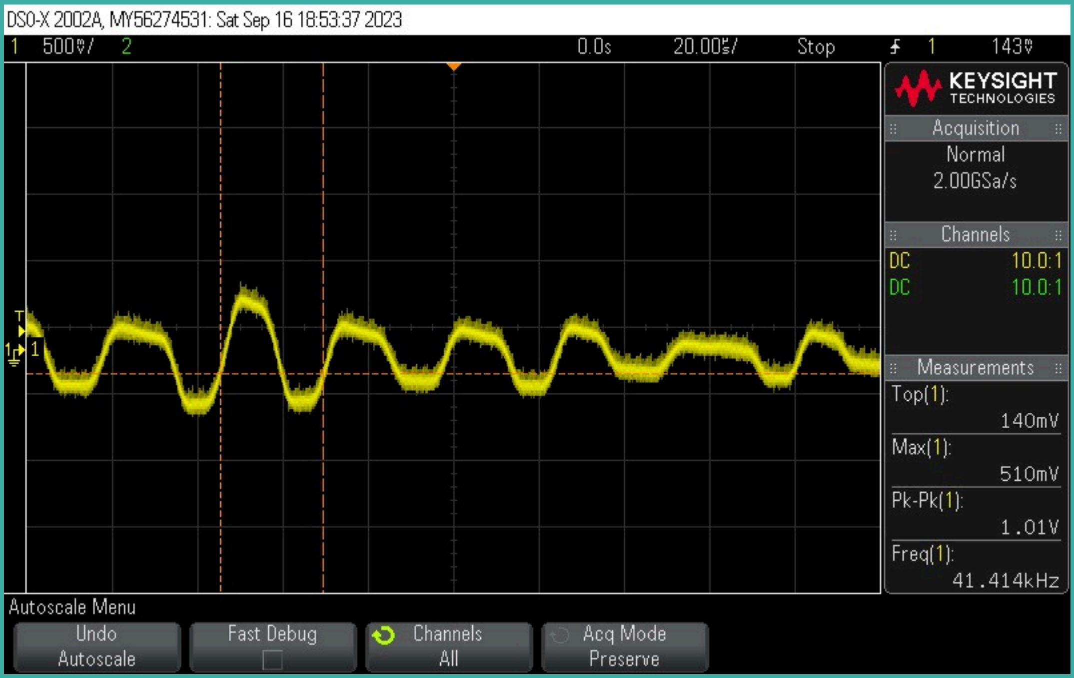
6. **Oscilloscope Observation:** The filtered signal is then captured and observed using an oscilloscope. The oscilloscope will display the received signal waveform in the time domain.

7. **Change in Doppler Frequency:** If the target is in motion, the Doppler frequency shift "fD" may change with time. This change in frequency can be observed as variations in the received signal's frequency on the oscilloscope as the target moves relative to the SONAR sensor.

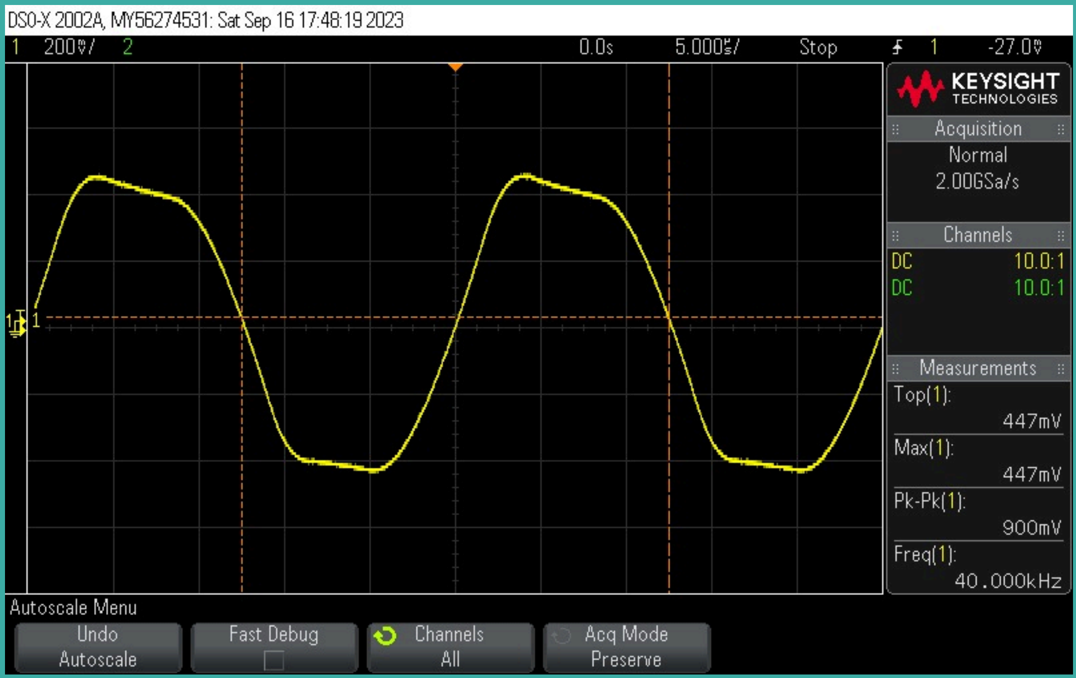
Plots:



DSO-X 2002A, MY56274531: Sat Sep 16 17:31:31 2023
1 1.00V/ 2
0.0s
5.000us/
Stop
1 6.00V
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
2.00GSa/s
Channels
DC 10.0:1
DC 10.0:1
Measurements
Top(1): 8.36V
Max(1): 8.36V
Pk-Pk(1): 4.38V
Freq(1): 40.014kHz
Save to file = tcope_0
Save
Recall
Default/Erase
Press to Save



DSO-X 2002A, MY56274531: Sat Sep 16 18:53:37 2023
1 500mV/ 2
0.0s
20.00us/
Stop
1 143mV
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
2.00GSa/s
Channels
DC 10.0:1
DC 10.0:1
Measurements
Top(1): 140mV
Max(1): 510mV
Pk-Pk(1): 1.01V
Freq(1): 41.414kHz
Autoscale Menu
Undo Autoscale
Fast Debug
Channels All
Acq Mode Preserve



Conclusions:

In this experiment, we designed and implemented a SONAR system's receiving (Rx) part to detect and analyse Doppler-shifted signals from moving metal targets. We achieved the following key findings:

Signal Amplification: We successfully amplified the weak received signal using a low noise amplifier (TL072). This amplification step improved our ability to detect and analyse the Doppler-shifted signal.

Frequency Shift Observation: Through the use of bandpass filtering and oscilloscope observation, we clearly observed a frequency shift in the received signal compared to the transmitted signal. This frequency shift was due to the Doppler effect caused by the motion of the metal target.

Doppler Effect Detection: The experiment demonstrated the fundamental principle of Doppler SONAR, where changes in the received signal's frequency provided valuable information about the velocity and direction of the moving target relative to the SONAR sensor.

- **Dynamic Doppler Shift:** We observed that the Doppler frequency shift could change over time as the target moved. This dynamic shift allowed us to study the target's motion characteristics.

Our SONAR Rx system effectively detected and analysed Doppler-shifted signals from moving metal targets. These observations are fundamental for various applications, including object detection, tracking, and environmental monitoring using SONAR technology.