<u>EXPERIMENT 2:</u> SAMPLING AND RECONSTRUCTION OF SIGNAL

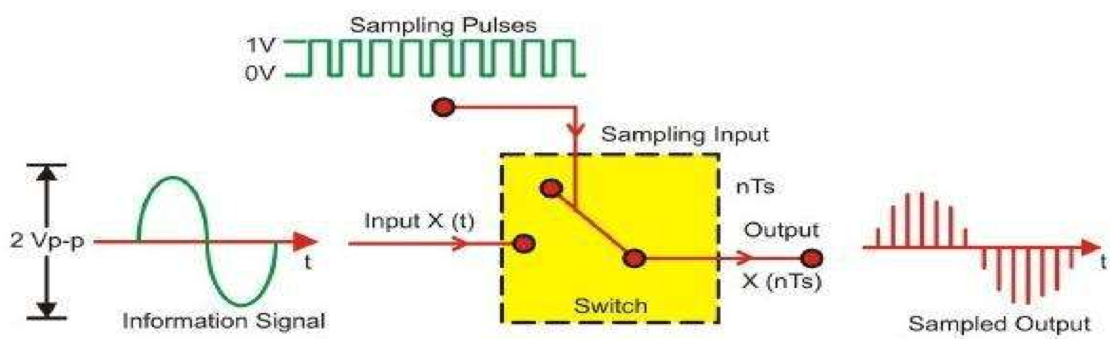
Date: 27/01/2020

<u>Aim:</u> Study of Sampling and Reconstruction of signal. Verify Nyquist criteria. Model ST21O1 W kit, connecting wires, CRO/DSO

<u>Apparatus:</u> Model ST 2151 W kit, connection wires, CRO/DSO

<u>Sampling Theory:</u>

The signals we use in the real world, such as our voice, are called "analog" signals. To process these signals for digital communication, we need to convert analog signals to "digital" form. While an analog signal is continuous in both time and amplitude, a digital signal is discrete in both time and amplitude. To convert continuous time signal to discrete time signal, a process is used called as sampling. The value of the signal is measured at certain intervals in time. Each measurement is referred to as a sample.



In electronics, a sample and hold circuit is used to interface real world, changing analogue signals to a subsequent system such as an analog-to-digital converter. The purpose of this circuit is to hold the analogue value steady for a short time while the converter or other following system performs some operation that takes a little time. In most circuits, a capacitor is used to store the analogue voltage and an electronic switch or gate is used to alternately connect and disconnect the capacitor from the analogue input. The rate at which this switch is operated is the sampling rate of the system.

NYQUIST CRITERION (SAMPLING THEOREM):

The Nyquist Criterion states that a continuous signal band limited to f_m Hz can be completely represented by and reconstructed from the samples taken at a rate greater than or equal to 2fm samples/second. The minimum sampling frequency is calls as NYQUIST RATE i.e. for faithful reproduction.

SAMPLE AND HOLD:

One way to maintain reasonable pulse energy is to hold the sample value until the next sample is taken. This technique is formed as Sample and Hold technique. A buffered Sample and Hold circuit consists of unity gain buffers preceding and succeeding the charging capacitor. The high input impedance of the proceeding buffer prevents the loading of the message source and also ensures that the capacitor charges by a constant rate irrespective of the source impedance.

<u>Procedure:</u>

A. Set up for Sampling and reconstruction of signal.

Initial set up of trainer:
Duty cycle selector switch position : Position 5
Sampling selector switch : Internal position

1. Connect the power cord to the trainer. Keep the power switch in 'Off' position.
2. Connect 1 KHz Sine wave to signal Input as shown in Fig.1.1.
3. Switch 'On' the trainer's power supply & Oscilloscope.
4. Connect BNC connector to the CRO and to the trainer's output port.

You can observe the process of step-by-step generating sine wave signal from Square wave of 1 KHz at TP3, TP4, TP5 and TP6 respectively.

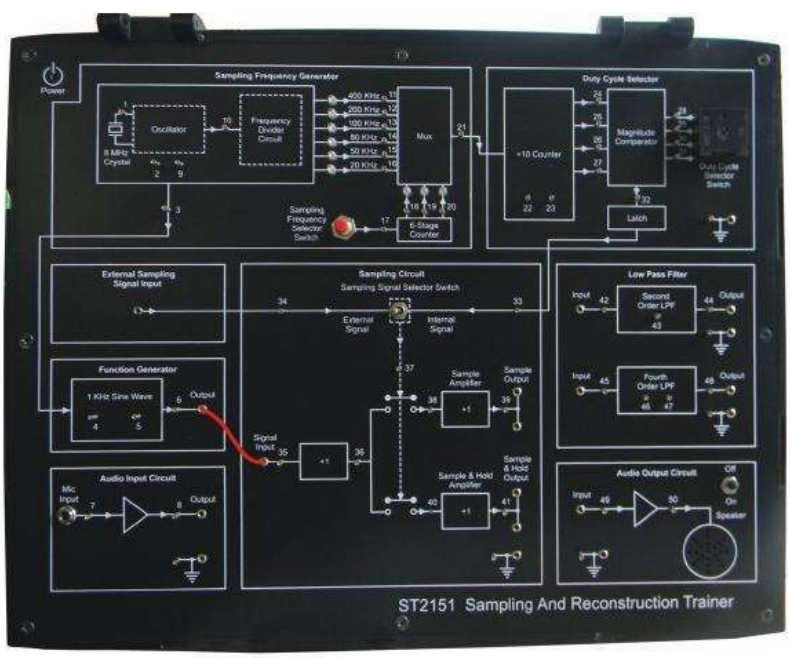


Fig. 1.1. Connection diagram for sampling a signal

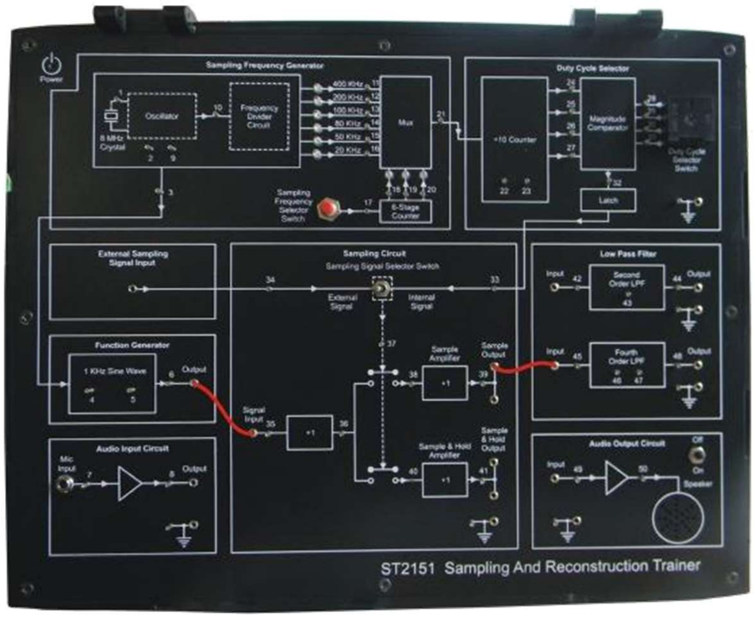


Fig. 1.2. Connection diagram for reconstruction of a sampled signal

B. Set up for effect of Sample Amplifier and Sample and Hold Amplifier on reconstructed signal.

Set up for effect of II order and IV order Low Pass Filter on reconstructed signal.

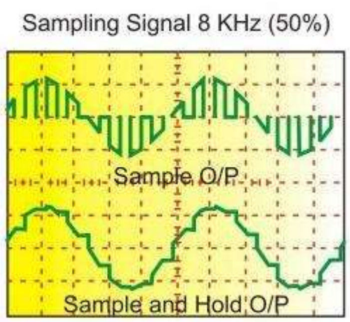
Initial set up of trainer:
Duty cycle selector switch position : Position 5
Sampling selector switch: Internal position
1. Connect the power cord to the trainer. Keep the power switch in ‘Off’ position.
2. Connect 1 KHz Sine wave to signal Input.
3. Switch ‘On’ the trainer's power supply & Oscilloscope.
4. Connect BNC connector to the CRO and to the trainer’s output port.
5. Select sampling frequency of 8 KHz by Sampling Frequency Selector Switch pressed till
6. KHz signal LED glows.
7. Observe 1 KHz sine wave and Sample Output (TP39) on oscilloscope. The display shows
8.KHz sine wave being sampled at 8 KHz, so there are 8 samples for every cycle of the sine wave.

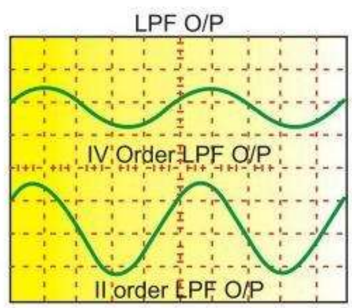
9. Connect Sample Output to Fourth Order low pass filter Input as shown in figure 1.2. Observe the filtered output (TP48) on the oscilloscope. The display shows the reconstructed 1 KHz sine wave.

10. Similarly observe the sampled 1 KHz sine wave at and Sample and Hold Output (TP41) on oscilloscope. The display shows 1 KHz sine wave being sampled and hold signal at 8 KHz. Connect Sample and Hold Output to Second Order low pass filter Input and observe the filtered output (TP44) on oscilloscope. The display shows the reconstructed1 KHz sine wave.

11. By pressing Sampling Frequency Selector Switch, change the sampling frequency from 2 KHz, 5 KHz, 10 KHz, 20 KHz up to 40 KHz (Sampling frequency is 1/10th of the frequency indicated by the illuminated LED). Observe how Sample output (TP39) and Sample and Hold Output (TP41) changes in each case.

Sample Observations:





Observation Table:

Input Frequency (In KHz)	Sampling Frequency (In KHz)	Duty Cycle (In %)	Order of Low Pass Filter	Output Frequency
1.000	2	50	2	1.000
1.000	2	50	4	1.000
1.000	5	50	2	0.998
1.000	5	50	4	1.000
1.000	20	50	2	0.996
1.000	20	50	4	1.003
1.000	10	10	4	0.999
1.000	10	30	4	1.000
1.000	10	60	4	1.000
1.000	10	90	4	1.001

Output Waveforms:

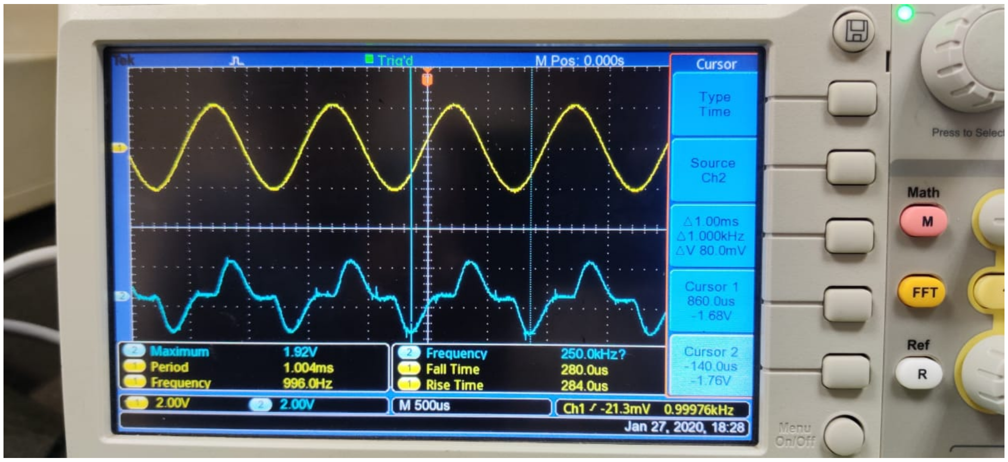


Figure 1: Sampling Frequency : 2KHz, 50% Duty Cycle, 2nd Order Low Pass Filter Output

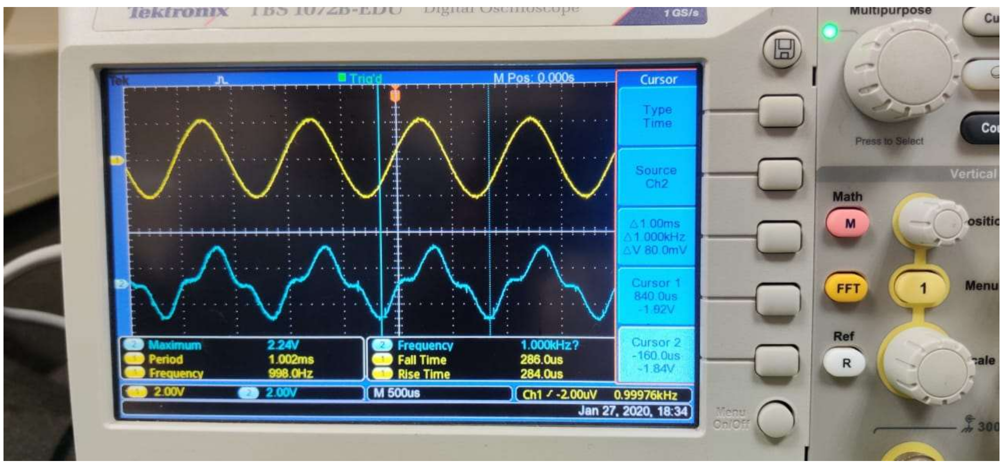


Figure 2: Sampling Frequency : 2KHz, 50% Duty Cycle, 4th Order Low Pass Filter Output

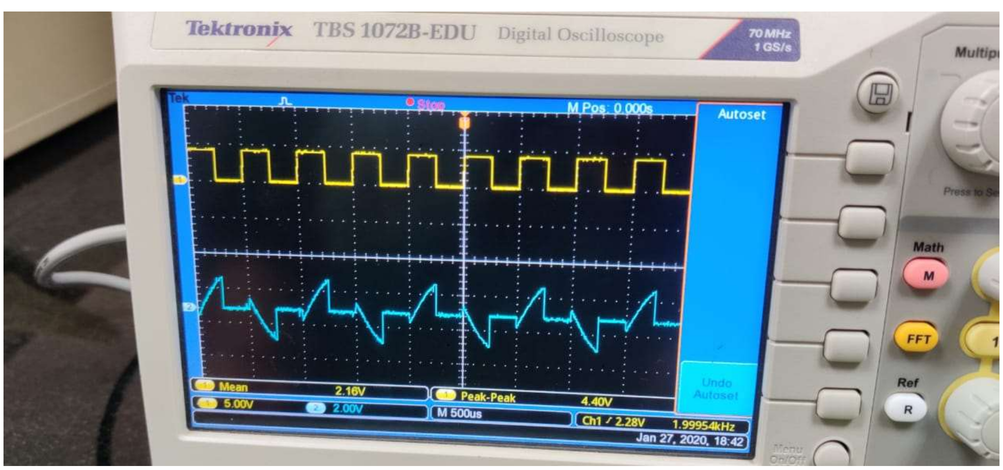


Figure 3: Sampling Frequency : 2KHz, 50% Duty Cycle, Sample Amplifier Output

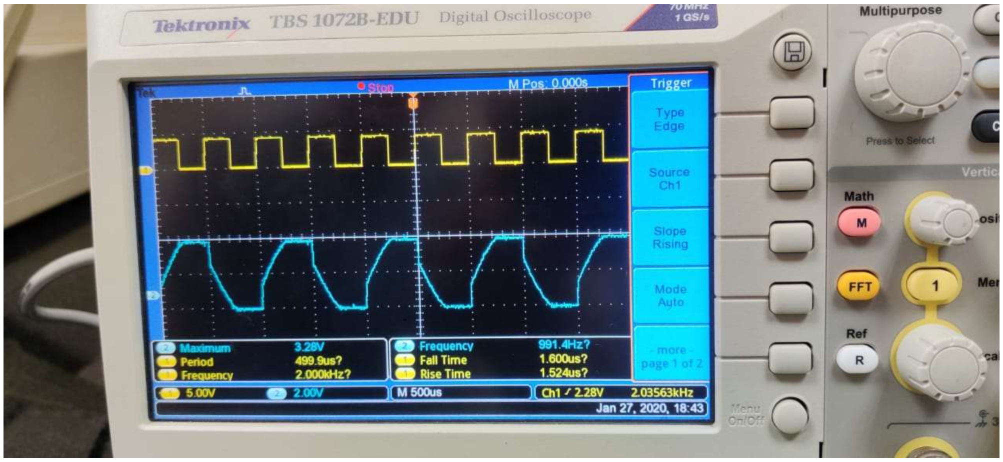


Figure 4: Sampling Frequency : 2KHz, 50% Duty Cycle, Sample and Hold Circuit Output

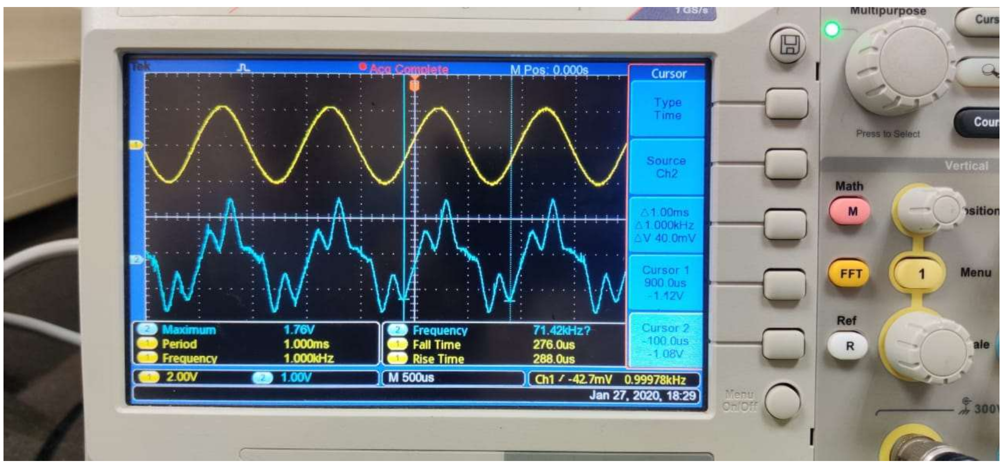


Figure 5: Sampling Frequency : 5KHz, 50% Duty Cycle, 2nd Order Low Pass Filter Output

Figure 6: Sampling Frequency : 5KHz, 50% Duty Cycle, 4th Order Low Pass Filter Output

Figure 7: Sampling Frequency : 5KHz, 50% Duty Cycle, Sample Amplifier Output

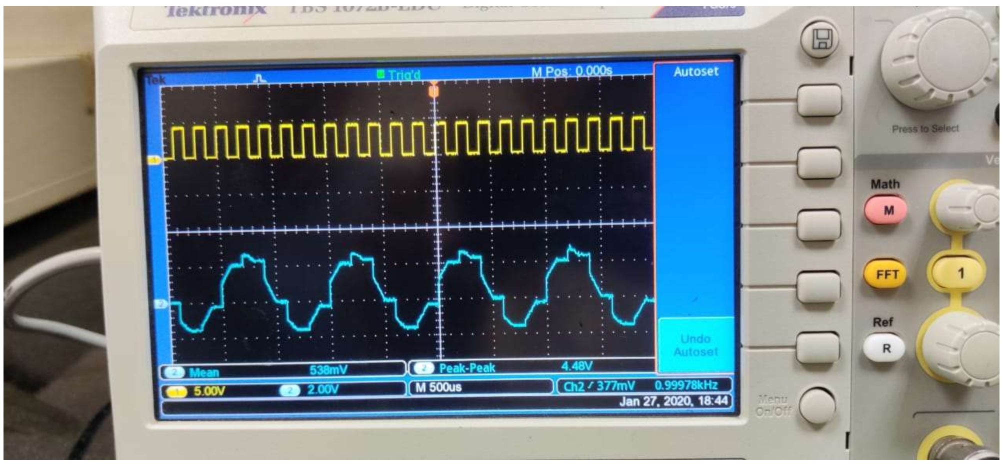


Figure 8: Sampling Frequency : 5KHz, 50% Duty Cycle, Sample and Hold Circuit Output

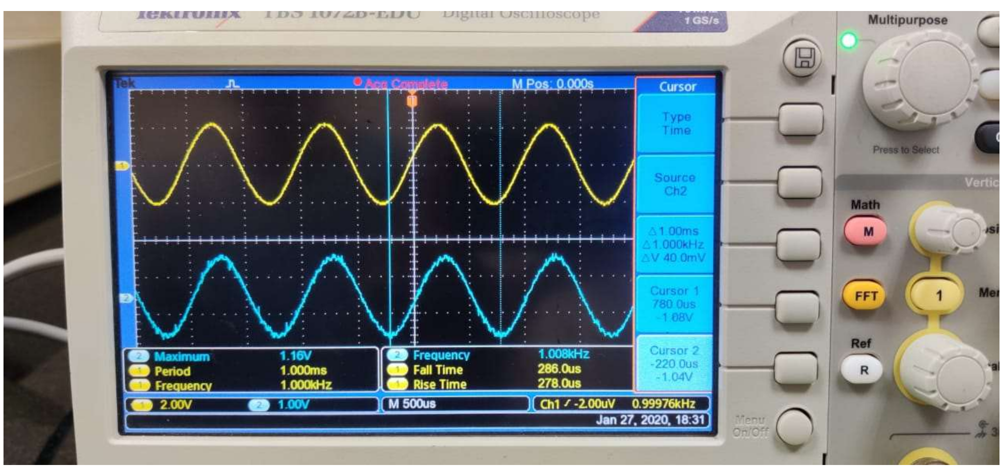


Figure 9: Sampling Frequency : 20KHz, 50% Duty Cycle, 2nd Order Low Pass Filter Output

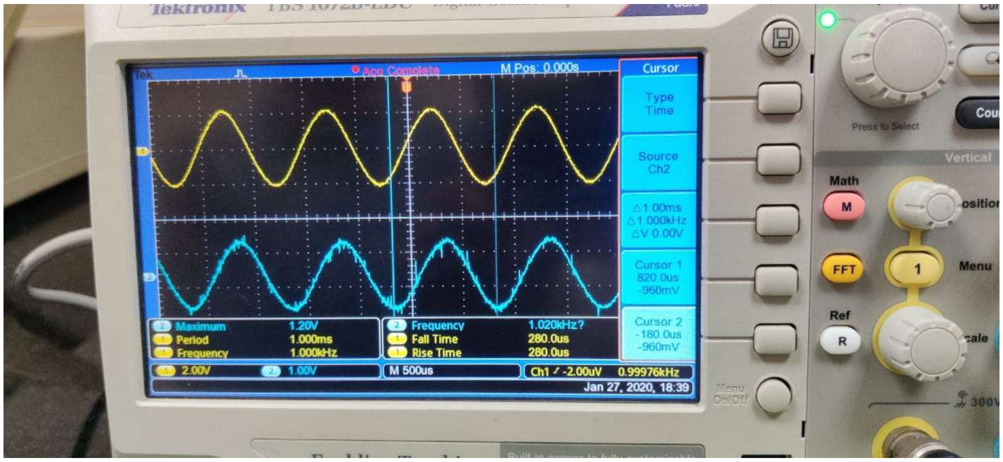


Figure 10: Sampling Frequency : 20KHz, 50% Duty Cycle, 4th Order Low Pass Filter Output

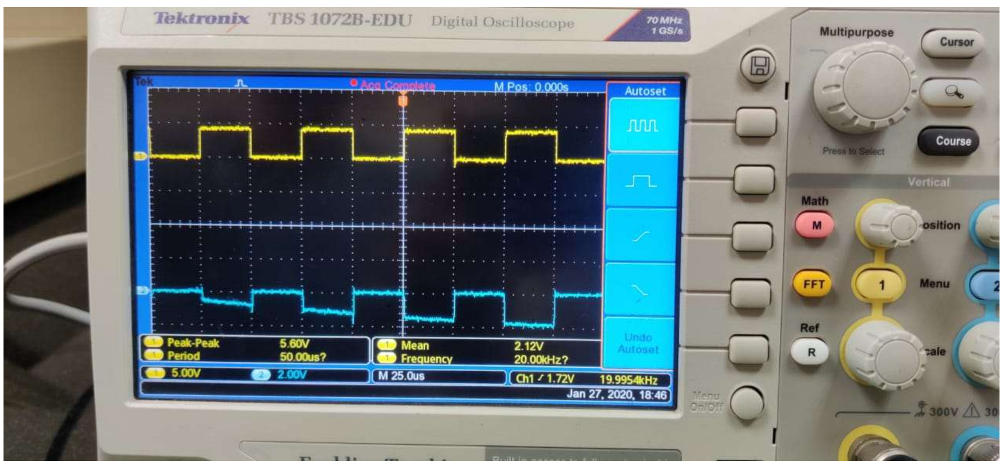


Figure 11: Sampling Frequency : 20KHz, 50% Duty Cycle, Sample Amplifier Output

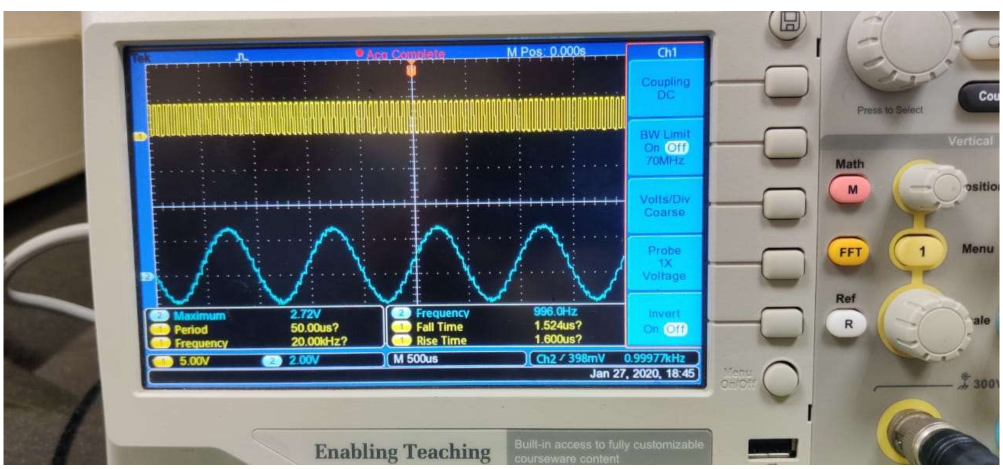


Figure 12: Sampling Frequency : 20KHz, 50% Duty Cycle, Sample and Hold Circuit Output

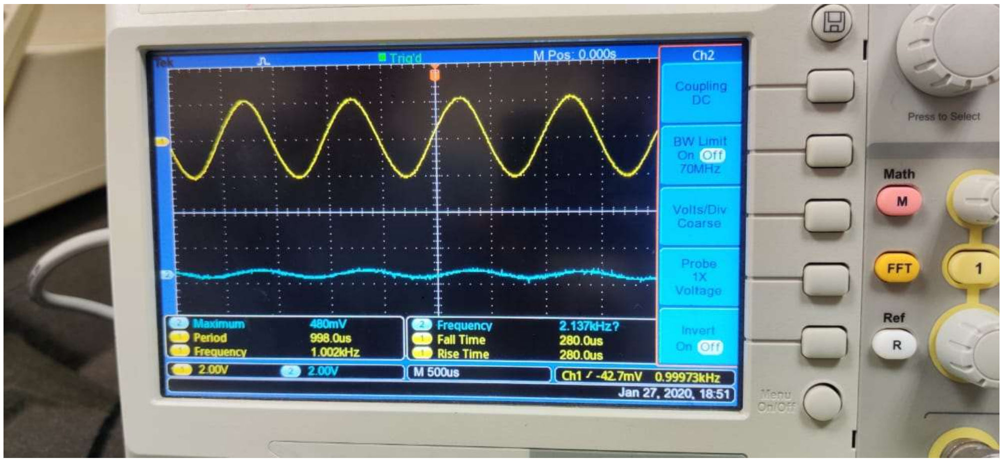


Figure 13: Sampling Frequency : 10KHz, 10% Duty Cycle, 4th Order Low Pass Filter Output

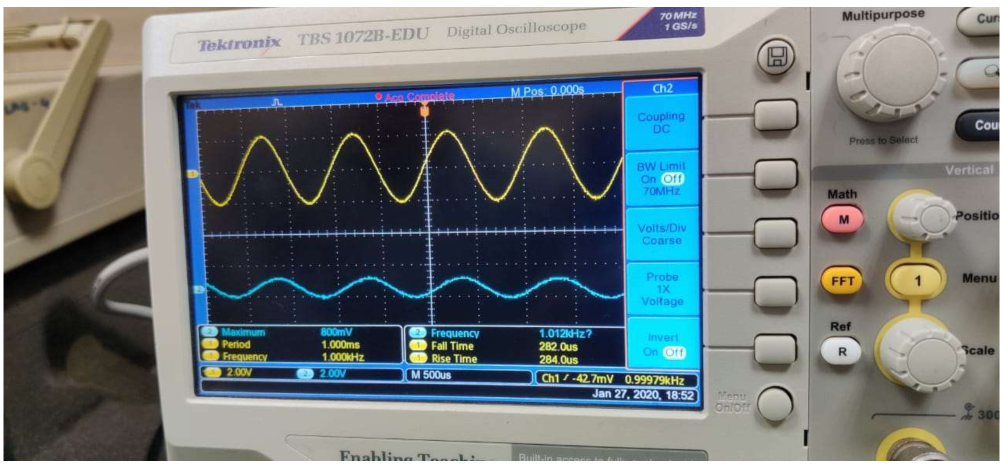


Figure 14: Sampling Frequency : 10KHz, 30% Duty Cycle, 4th Order Low Pass Filter Output

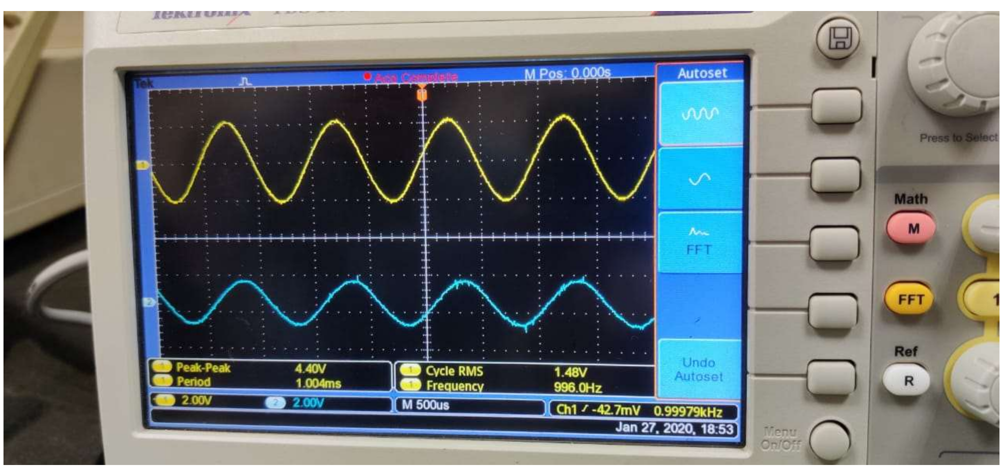


Figure 15: Sampling Frequency : 10KHz, 60% Duty Cycle, 4th Order Low Pass Filter Output

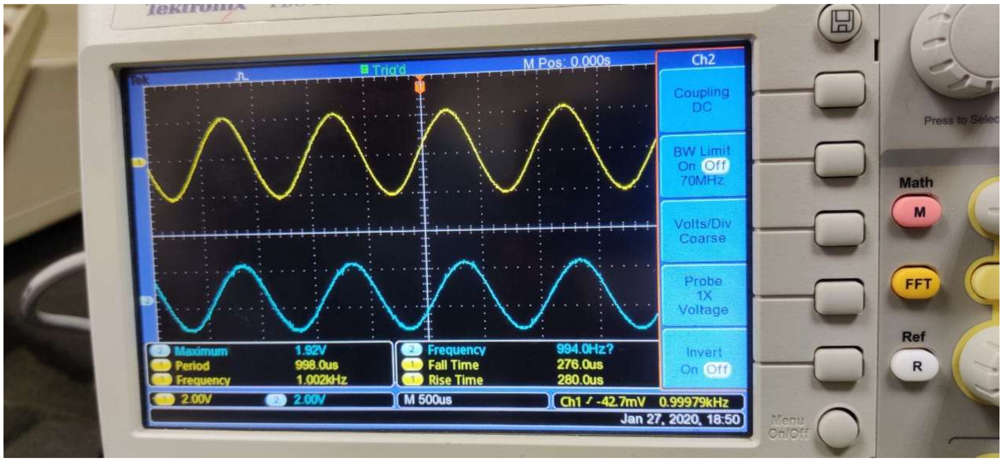


Figure 16: Sampling Frequency : 10KHz, 90% Duty Cycle, 4th Order Low Pass Filter Output

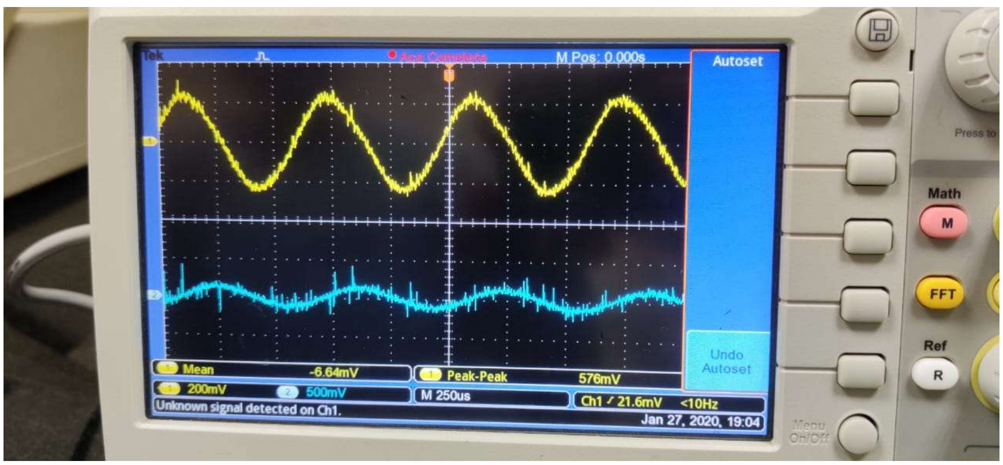


Figure 17: Microphone Voice Output

Conclusion:

Sampling and reconstruction of the signal with frequency 1KHz is thoroughly studied by varying the frequency of Sampling, duty cycle, switching between Sample Amplifier and Sample and Hold Circuit and switching between 2nd Order and 4th Order Low Pass filter.

Ultimately, Nyquist criteria is successfully verified by recording output waveforms as shown above.

Remarks: **Signature**