Experiment No. 07 (Sampling and Re-construction of Signals)

Object:-

(a) Experimentally verify the Sampling Theorem and observe the Aliasing effect, using the Scientech **Sampling Trainer Kit model ST-2101**. Trace the "Sampled signal" at any three different sampling frequencies.

(b) Observe the effect of the variation of duty cycle of the sampling pulses and the order of the low-pass filter on the re-construction of the sampled signal. Trace the wave-shapes of the re-constructed signal using 2^{nd} order and 4^{th} order LPF.

Apparatus Used:-

1. Sampling and Reconstruction Trainer kit, model ST-2101 (Scientech Technologies)
2. A 20 MHz, dual channel Oscilloscope.

Brief Theory

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 2 f_m samples per second. This minimum frequency is called as "**Nyquist Rate**". Thus, for the faithful reconstruction of the information signal from its samples, it is necessary that the sampling rate, f_s must be greater than $2f_m$.

Aliasing;-

If the information signal is sampled at a rate lower than that stated by Nyquist criterion, than there is an overlap between the information signal and the side bands of the harmonics. Thus the lower and the higher frequency components get mixed and cause unwanted signals to appear at the demodulator output. This phenomenon is termed as **Aliasing** or Fold-over Distortion. The various reasons for aliasing and the ways for its prevention may be summarized as under:-

A) Aliasing due to under-Sampling:-

If the signal is sampled at a rate lower than 2 f_m, then it causes aliasing, as illustrated in the following figure, where a sinusoidal signal of frequency f_m is being sampled at a rate f_s<2 f_m, and the dots represent the sample points.

The LPF at demodulator effectively joins the sample causing an unwanted frequency component to appear at the output. This unwanted component has a frequency = (fs – fm)

B) Aliasing due to wide band signal:-

The system is designed to take samples at a frequency slightly greater than that stated ny Nyquist rate. If higher frequencies are ever present in the information signal, or it is affected by H. F. noise, then the aliasing will occur. To prevent the aliasing, Anti-aliasing filters are usually installed prior to sampling. In telephone networks, the speech signals are band-limited by filters before sampling to avoid the effect of aliasing.

C) Aliasing due to noise:-

If very small duty cycle is used in sample-and-hold circuit, aliasing may occur if the signal has been affected by the noise. High frequency noise generally mix with the High frequency component of the signal. and hence causes undesirable frequency components to appear at the output. This type of aliasing may, therefore, be prevented by slightly increasing the duty cycle of the sampling pulses.

D) Aliasing due to Filter Roll-off :-

Aliasing may also occur, if appropriate filter response is not chosen and the frequencies above the nominal cut-off frequency of the filter, have significant amplitudes at the filter's output. This is called Aliasing due to Filter Roll-off.

Brief Description of the Kit

The lay-out diagram of the experimental kit is shown on the next page:-
The kit contains the circuits for the following five sections: -

1. Sampling Frequency Selector Section:-

By default, the sampling frequency is set to 32 KHz. But pushing successively the sampling frequency selector switch can change it and the value of the selected frequency is one-tenth of the frequency indicated by the corresponding glowing LED. For example, if the LED corresponding to 20 KHz is glowing, then the selected value of the sampling frequency is 2 KHz.

2. Duty cycle control section:-

Here the duty cycle of the sampling pulses can be varied from 10% to 90%.

3. Sampling Section:-

It provides: Sampled " output at TP-37 and the "sample and hold" output at TP-39. The input sampling pulses are also selected in this section by the INTERNAL / EXTERNAL sampling selector switch.

NB:- The internal pulses are usually selected; because the external pulses need to be synchronized with the information signal (1 KHz internally generated sinusoidal signal available at TP-12 on the sampling frequency selection circuit board) to get the stable trace on the CRO screen.

4. Two Low-pass Filter sections:-

The 2nd order and 4th order LPFs, which provide the reconstructed signal at their outputs, TP-42 and TP-46 respectively.

The 4th order and the 2nd order Low Pass Filters:-

The nth order filter has a rate of fall off of 6n dB/Octave or 20ndB/decade and one capacitor or inductor is required for each pole (order). The following table summarizes the effect of fall-off gradient on a signal such as square wave:-

PROCEDURE:-

1. Set the INTERNAL / EXTERNAL sampling selector switch in INTERNAL position.

2. Put the DUTY CYCLE SELECTOR switch in position 5 (to set 50 % duty cycle).

3. Connect 1 KHz internally generated sinusoidal signal available at tp12 to SIGNAL INPUT on the Sampling Circuit board.

4. Now, turn the ON/OFF switch of the kit to ON.

5. Observe the information signal (1 KHz at tp12) on one channel and the Sample output (at TP-37) on the other channel of the CRO.

6. Connect the Sample Output (TP-37) to the input of 4th order LPF.

7. Trace the Sampled output at TP-37. Note that 32 samples are appearing in one cycle of the information signal, as the default value of the sampling frequency is 32 KHz.

8. Now, keep on reducing the sampling frequency in steps and trace the sampled output at any other two values of the sampling frequencies.

9. Observe the reconstructed signal at the output of the 4th order LPF at tp46 on setting the sampling frequency equal to 2 KHz. Note that it is distorted as fs = 2 fm

(Ref: Nyquist criteria).

10. Now, Connect the Sample Output (TP-37) to the input of 2nd order LPF, and observe the reconstructed signal at the output of the 2nd order LPF (TP-42) at different values of sampling frequencies. Compare the outputs of both the LPFs for the same value of sampling frequency. Which one is better and why? This completes the first part of the experiment.

11. For the second part, keep the sampling rate constant at some appropriate value (say 8 or 16 KHz), and vary the position of DUTY CYCLE SELECTOR switch, and observe the Sampled signal (TP-37) and the reconstructed signal at the output of the 4th order LPF (TP-46) and also at the output of the 2nd order LPF (TP-42) at different values of the duty cycle varying from 40 % (position 4) to 90 % (position 9 of duty cycle selector switch). Record your observations. How does the amplitude of the reconstructed signal vary with the variation of the duty cycle?

12. Now, disconnect the sample output (TP-37) from the input of the LPF and connect "Sample and Hold output (TP-39) to the inputs of the LPFs, and observe the reconstructed signals at their outputs one by one.

13. Vary the duty cycle again and observe that the reconstructed signal has now become independent of duty cycle variation. Measure the amplitude of the reconstructed signal at (TP-46) and at (TP-42) one by one.

14. Comment on the results obtained by using the 4th order LPF and the 2nd order LPF.

OBSERVATIONS:-

For a 1 KHz sine wave (internal information signal at TP-12) and for 50 % duty cycle pulses,
Minimum sampling rate for undistorted reconstructed signal using 4th order LPF =
Minimum sampling rate for undistorted reconstructed signal using 2nd order LPF =
Tabulate your observations for the second part of the experiment:-

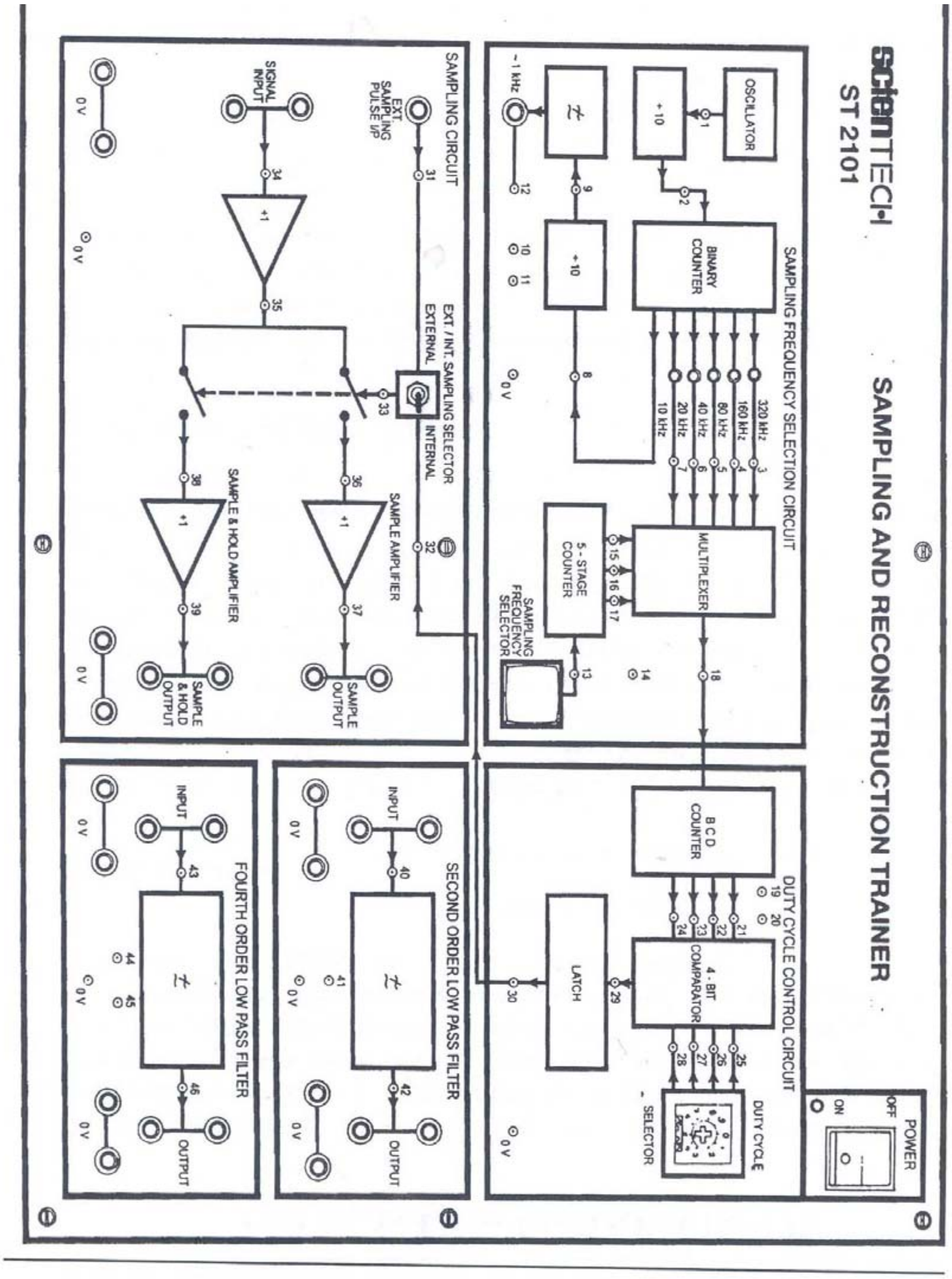
RESULTs & Comments:-

References:-

1) B. P. Lathi : Communication Systems
2) Scientech Technologies Pvt. Ltd. : WORK BOOK of Sampling and Reconstruction Trainer ST-2101 WB
3) Scientech Technologies Pvt.Ltd. : Operating Manual of Sampling and Reconstruction Trainer ST-2101 OM

****

The lay-out diagram of the experimental kit , model ST-2101 is shown on the following page:-


scientech
ST 2101
SAMPLING AND RECONSTRUCTION TRAINER
SAMPLING FREQUENCY SELECTION CIRCUIT
OSCILLATOR
BINARY COUNTER
MULTIPLEXER
5 - STAGE COUNTER
SAMPLING FREQUENCY SELECTOR
320 kHz
160 kHz
80 kHz
40 kHz
20 kHz
10 kHz
~ 1 kHz
DUTY CYCLE CONTROL CIRCUIT
B C D COUNTER
4 - BIT COMPARATOR
LATCH
DUTY CYCLE SELECTOR
POWER
OFF
ON
SAMPLING CIRCUIT
EXT SAMPLING PULSE I/P
SIGNAL INPUT
EXT / INT. SAMPLING SELECTOR
EXTERNAL
INTERNAL
SAMPLE AMPLIFIER
SAMPLE & HOLD AMPLIFIER
SAMPLE OUTPUT
SAMPLE & HOLD OUTPUT
SECOND ORDER LOW PASS FILTER
FOURTH ORDER LOW PASS FILTER
INPUT
OUTPUT
0 V