FR. CONCEICAO RODRIGUES COLLEGE OF ENGINEERING (CRCE)
Department of Computer Engineering (CE)

3. SIGNAL SAMPLING & RECONSTRUCTION

1. Course, Subject & Experiment Details

Academic Year	2018 – 2019	Estimated Time	Experiment No. 3 – 02 Hours
Course & Semester	S.E. (COMP) – Sem. III	Subject Name	Basic Electronics Lab
Chapter No. & Unit	05 – Unit 5.1 Mapped with CO-2	Chapter Title	Concept of Sampling
Experiment Type	Hardware (Trainer Kits)	Subject Code	CSL 302

2. Aim & Objective of Experiment

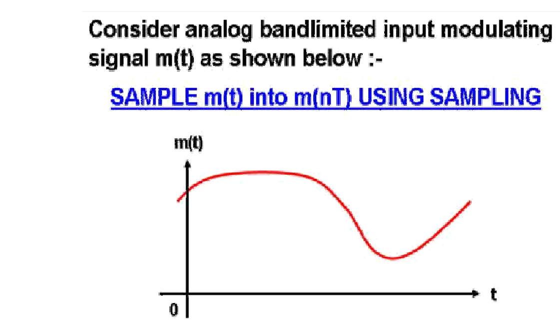
This experiment aims at making students understand one of the fundamental theorems in communication systems engineering viz. Nyquist – Shannon – Hartley Sampling Theorem & its applications to analog pulse & digital pulse modulation technique. The objective lies in verifying the sampling theorem where a signal must be fully represented by its samples & also completely recovered from the same.

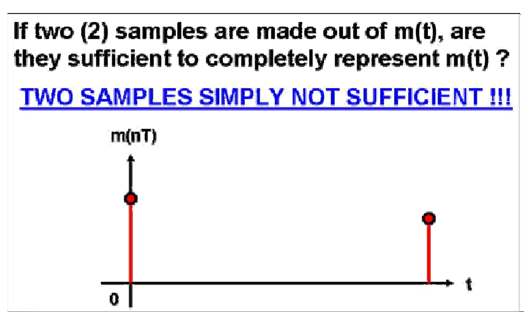
3. Expected Outcome of Experiment

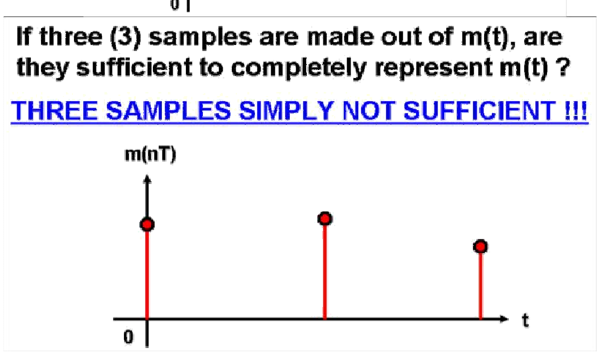
- Verification of the Nyquist – Shannon – Hartley Sampling Theorem for bandlimited signals
- Generation of an output analog sampled signal from it's continuous time-domain version
- Representation of the original analog signal m(t) completely in terms of it's sampled version
- Verifying that original analog signal m(t) can be fully recovered from it's individual samples

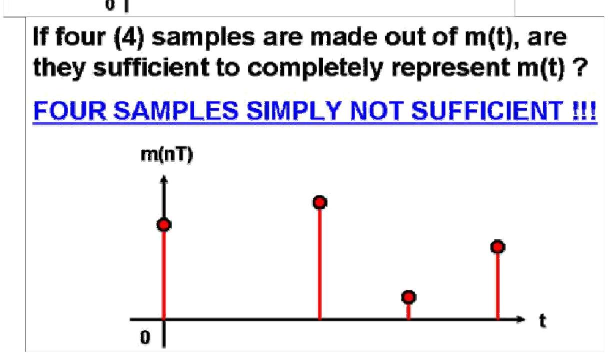
4. Brief Theoretical Description

(a) Introduction to Signal Sampling :-



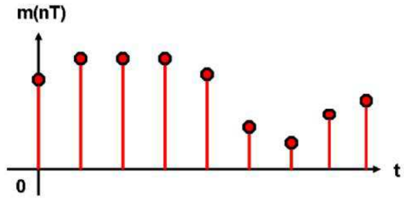






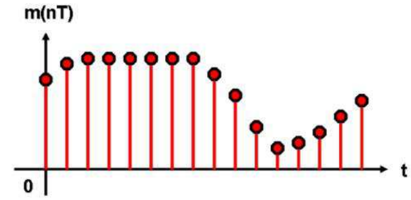
If eight (8) samples are made out of m(t), are they sufficient to completely represent m(t) ?

EIGHT SAMPLES ARE FINE – BUT RECOVERY ?



If sixteen (16) samples are made of m(t), are they sufficient to completely represent m(t) ?

THIS IS THE BEST SAMPLING PROCESS !!!



In the sampling process, a continuous time-domain audio frequency modulating (baseband) signal has been converted into discrete time-domain signal. This conversion can be done a high-speed switching action where the switch position is controlled by the sampling signal (carrier pulses). The sampling signal is a periodic train of pulses of unit amplitude & time period (T_s). This time is known as sampling time & during this time period, the switch is closed so that the sampled signal is equal to the input signal. In the remaining time the switch is open hence no input signal appears at the output, where the intervals are distinguished by 'T_s' seconds apart.

(b) Statement of Sampling Theorem :-

For analog input bandlimited modulating signal m(t) the sampling should be done in such a way that :-

- The sampled version of m(t) should be represented completely in terms of its sampled output
- It should be possible to recover the original signal m(t) from its sampled version at the receiver

Hence the frequency at which sampling should be done is given by the following equation :-

$$\boxed{f_s \geq 2f_m}$$

Nyquist Interval refers to the total time interval between each successive pulse of the carrier & is given by :-

$$\boxed{T_s \leq \frac{1}{2f_m}}$$

Above equations are necessary & sufficient for all the following conditions :-

- Sampled representation of input signal $v_m(t)$
- Recovery of $v_m(t)$ from it's sampled version

Nyquist – Shannon – Hartley sampling theorem states that the maximum sampling frequency (f_s) should be :-

$$\boxed{f_s \geq 2f_m}$$

Nyquist Rate is simply the sampling frequency itself & is described by the sampling theorem equation :-

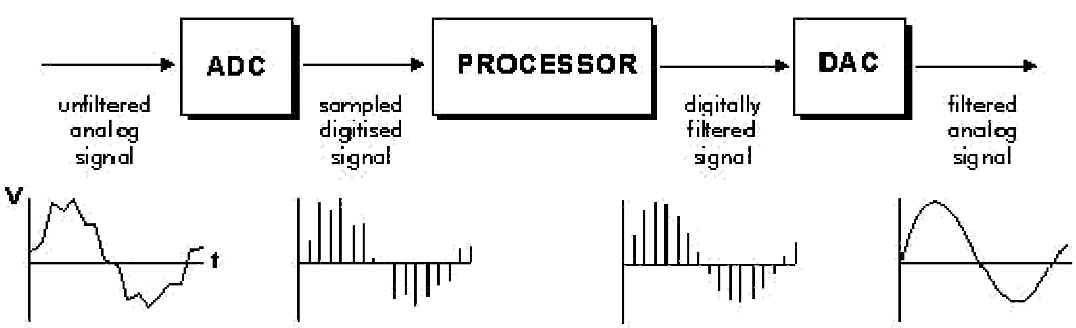
$$\boxed{f_s \geq \frac{2}{T_m}}$$

where T_m is maximum time period of input modulating signal

- **Impulse Sampling Process**
- **Natural Sampling Process**
- **Flat – Top Sampling Process**

Each of the above sampling processes or techniques depends on the shape or characteristics of sampled output signal amplitude

Natural Sampling & Flat – Top Sampling process are physically implementable



5. Experimental Procedure

1. Apply input modulating signal frequency of 10 KHz to natural sampler.
2. Set sampling frequency of the input carrier signal to 20 KHz.
3. Observe the sampled signal at the output of the natural sampler.
4. Apply this output to the second order and fourth order low pass filter (LPF).
5. Observe the reconstructed signal & record the waveforms.
6. Change sampling frequency with the help of push button & repeat above procedure
7. Then change the sampler to Sample & Hold (S & H) to repeat the above procedure.
8. Record all output waveforms, including the sampled output & reconstructed signal.

6. Apparatus Required

- Signal Sampling & Reconstruction Trainer Kit
- Cathode Ray Oscilloscope (CRO)
- Patch Cords & CRO Probes

7. Conclusions & Inferences

Students should explain in brief the concluded outcome from the experiment & its inference, as obtained from the nature of the graph which explains the system behavior as per the conditions

8. Practical & Real Life Applications

Signal sampling & reconstruction is widely used in analog & digital signal processing, which themselves find innumerable applications in various engineering domains. Analog & digital pulse modulation techniques uses the sampling theorem where individual samples completely represent the original analog signal, which can also be recovered from its sampled version, where only provided that $f_s \geq 2f_m$

9. Post Lab Questions

1. Explain the concept of impulse sampling with neat block diagram & appropriate waveforms, along with its advantages & disadvantages.

2. Explain natural sampling process with neat block / circuit diagram & appropriate waveforms, stating its advantages & disadvantages.

3. What is meant by Nyquist rate in Sampling? State the sampling theorem. what happens if the sampling is done at less than $2f_{max}$.

4. Describe the concept of sample & hold (S & H) circuit with neat diagram & waveforms. Explain how it differs from the flat-top sampling process.

5. Systematically perform comparison of all three types of sampling processes – viz. impulse sampling, natural sampling & flat-top sampling process.

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