German Jordanian University

Department of Communication Engineering

Digital Communication Systems Lab

CME 313-Lab

Experiment 1

Sampling Theorem

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Experiment 1

Sampling Theorem

Objectives:

By the end of this experiment, the student should be able to:

1. Distinguish between different sampling types.
2. Verify the sampling theorem; sampling and reconstruction.
3. Implement a simple system of PWM and PPM.

Introduction

So far, the experiments in the analog communication have concentrated on communications systems that transmit analog signals. However, digital transmission is fast replacing analog in commercial communications applications. There are several reasons for this including the ability of digital signals and systems to resist interference caused by electrical noise.

Sampling

Sampling is the first step of the transformation of an analog signalto the digital format and usage of computers to process and store data.The basic idea of sampling is to take a **continuous-time signal**, and convert it to a **discrete-time signal.**

Consider the following system shown in Figure 1. This system is called a sampler system

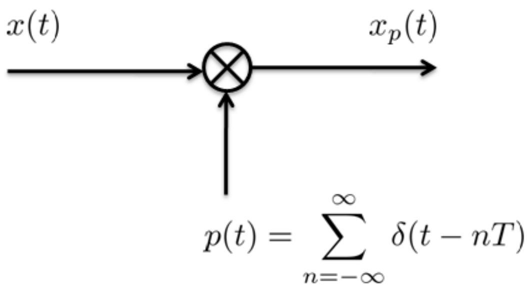


Figure.1 Sampler System

Mathematically, if the continuous-time signal is X(t), we can collect a set of samples by multiplying X(t) with an impulse train P(t):

$$\boldsymbol{P(t) = \sum_{n=-\infty}^{\infty} \delta(t - nT)}$$

where T is the period of the impulse train.

Multiplying x(t) with p(t) yields

$$X_p(t) = X(t) \cdot P(t) \quad \text{.......(1)}$$

$$X_p(t) = \sum_{n=-\infty}^{\infty} X(nT)\,\delta(t - nT) \quad \text{.......(2)}$$

Pictorially, $x_p(t)$ is a set of impulses bounded by the envelop x(t) as shown in Figure 2.

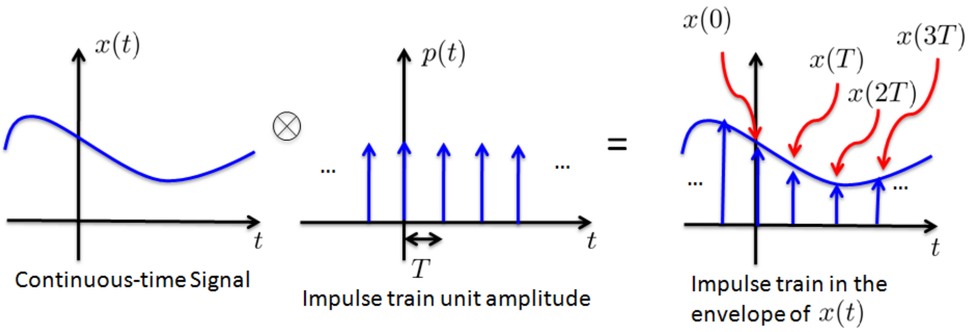


Figure.2 The output signal $X_p(t)$ represents a set of samples of the signal X(t)

<u>Sampler Implementation :</u>

The arrangement to take samples of a message signal is shown in Figure3.In practical P(t) can be generated by using very narrow pulse width. When P (t) has the value **'1'** the switch is on, and when' **0** ' the switch is off. Thus, the output of the switch is sampled signal.

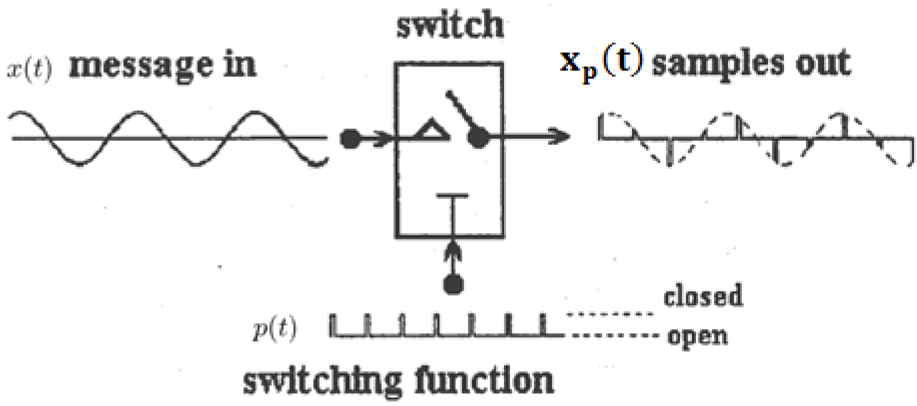


Figure.3 Sampler Implementation

<u>Sampling Types:</u>

Sampling can be made by two types of procedures:

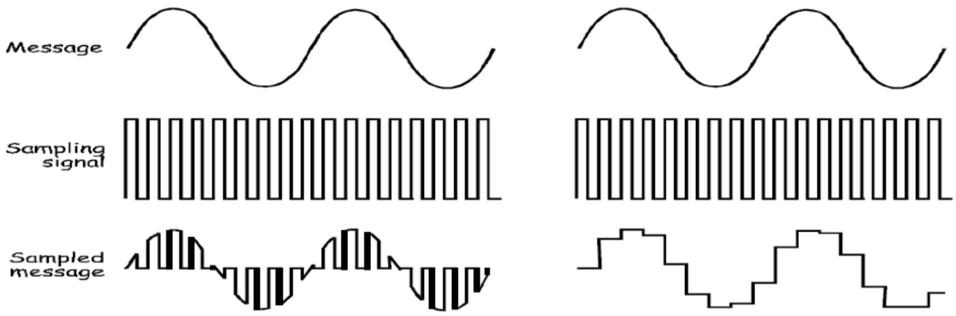
1. **Natural Sampling**

In natural sampling a slice of the waveform is taken and thus, the shape of the top of each sample is the same as that of the message.

2. **Sample and Hold(Flat top)**

   In sample and hold sampling a slice of the waveform is taken but the top of the slice does not preserve the shape of the waveform.

These two sampling types are shown in the Figure 4.



a. Natural Sampling **b.** Sampling and Hold

Figure.4 Comparison between sampling types

Sampling Theorem(Nyquist Criteria)

A more quantitative criterion is provided by the sampling theorem which states that foraccurate representation of a signal X(t) by its time samples X(nT), two conditions mustbe met:

1. The signal X(t) must be band limited, that is, its frequency spectrum must be limited to contain frequencies up to some maximum frequency.

2. The sampling rate f_s must be chosen to be at least twice the maximum frequency f_{max}, that is, $f_s \geq 2f_{max}$ or, in terms of the sampling time interval: $T_s \leq \frac{1}{2f_{max}}$.

Reconstruction

Low pass filter can be used to extract the message signal from samples the reconstruction circuitry is illustrated in figure 5.

Figure.5 Reconstruction Circuit

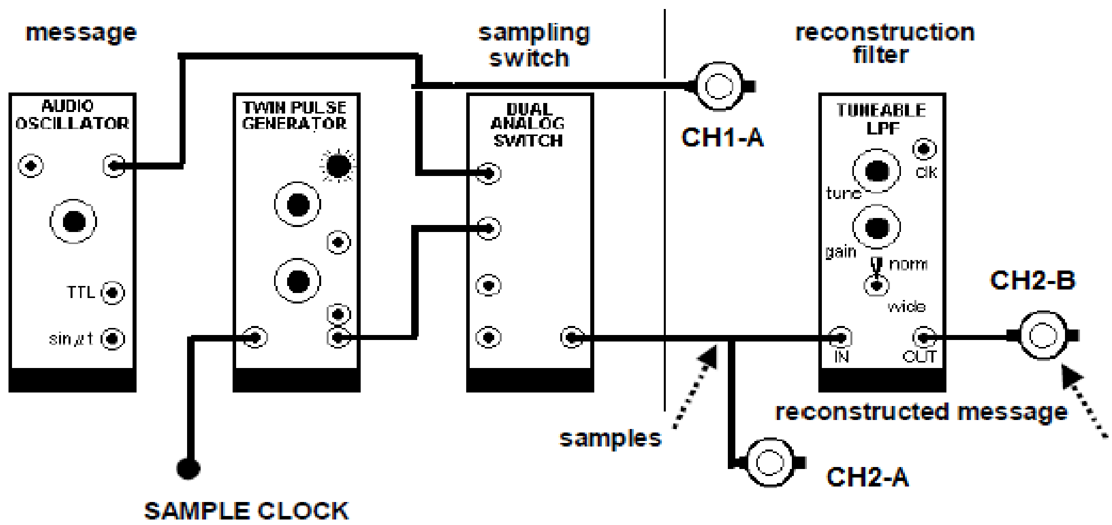
Lab Work

Modules

The following plug in modules are needed for this experiment:
Audio Oscillator, TPG, Dual Analog switch, Tunable LPF, Adder, Utilities.

Procedure:

1. Construct the TIMS model of the sampler and reconstruction filter as shown in below figure



2kHz TTL
8.3kHz

Figure.9 The TIMS model of the sampler and reconstruction filter.

2. Using the frequency counter set the Audio Oscillator frequency about 1.5kHz.
3. Adjust the width of TWP to be fully clockwise.
4. Use 2kHzTTL from the Master signals as fixed sampled rate.
5. **Save the message signal, the pulse train signal and the sampled signal in your lab sheets.**
6. Vary the cutoff frequency to get the best recovered signal.

- **Compare between the original message signal and recovered signal, if there any difference explain the reasons in you lab sheet.**

7. Replace 2kHz TTL with 8.3kHz sample clock and repeat points from 5 to 7.