Experiment 5
Signal Sampling

Objective

1. To demonstrate the operation of taking and holding samples of signals.

2. To study the effects of changing the sampling frequency.

Equipment

Sample-and-hold module 296E
Function Generator
Spectrum Analyser
Power supply

Important Notice

Ensure that the 296E module is connected to the power supply as follows:
Red to +15 V
Green to 0 V (ground)
Black to -15V

Introduction

In digital communications, the first step in processing a continuous analogue waveform, is to take its samples. "Samples" are particular values of the signal at regular intervals. From this point on, the "samples" will represent the signal, which could be digitised, or be subjected to various processing techniques.

The samples must be taken frequently enough, so that reconstruction of the original waveform from its discrete samples can be possible.

According to the Sampling Theorem, at least two samples per cycle should be taken so that a faithful reconstruction of the signal can be made. Theoretically, as shown in the waveforms in Figure E5.1, each sample is an instantaneous measurement, but in real life, taking a sample measurement takes time. Furthermore, an instantaneous sample would contain no energy and it would be difficult to transmit or process it. In practice, it is necessary to stretch the sample out in time, or to hold on to it long enough to use it. That is where the name "Sample-and-Hold" comes from. This is also known as flat-top sampling.

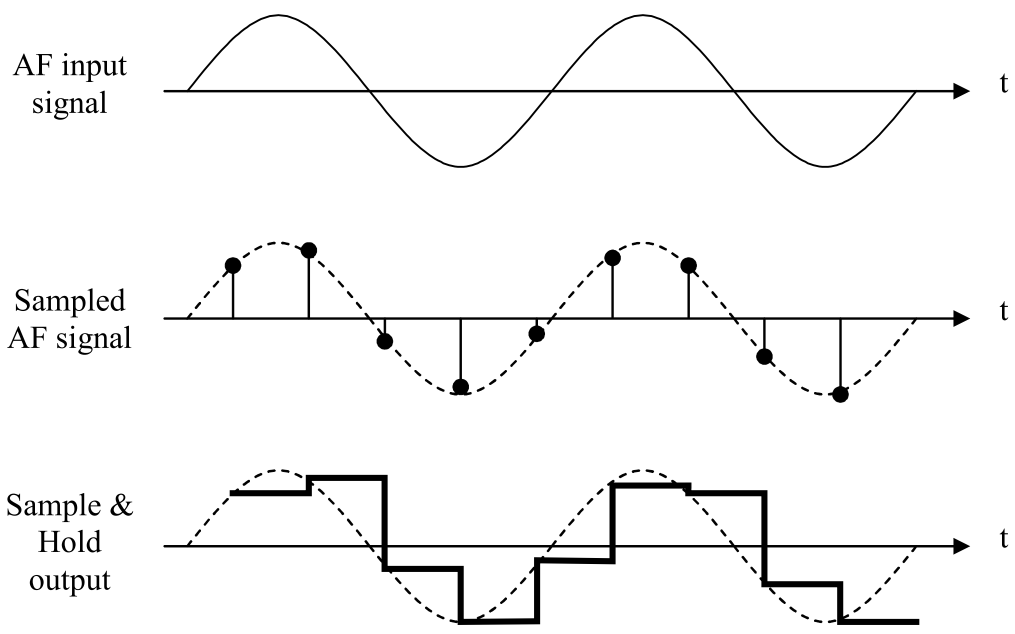


Figure E5.1 Waveform of AF input signal, sampled AF signal, and Sample & Hold output.

Figure E5.2 shows the Sample & Hold module (Module 296E) to be used in this experiment. In Module 296E, there are two sampling circuits. Looking at "Input 1", we can see that it is first buffered and then sampled. The switch at the output of the buffer is usually open, but when the sampling signal (pulse 1) goes "high", the switch is closed and the capacitor is quickly charged (according to the time constant of the circuit). Moments later, when the "pulse 1" goes "low", the switch is opened and the capacitor holds the sample value.

Procedure

Important
Keep the Spectrum Analyser **unconnected** unless you are told otherwise.

A. Sampling and Recovery of Sampled Signal

1. Ensure that the module is correctly connected to the power supply and switch on the latter.

2. Connect the "internal clock output" on the 296E module to "clock input" of the logic control unit.

3. Observe "pulse 1" on oscilloscope. Adjust the period of pulse 1(using clock frequency knob) to 200μs (frequency = 5 kHz) and pulse width (using the sampling pulse knob) to 5μs.

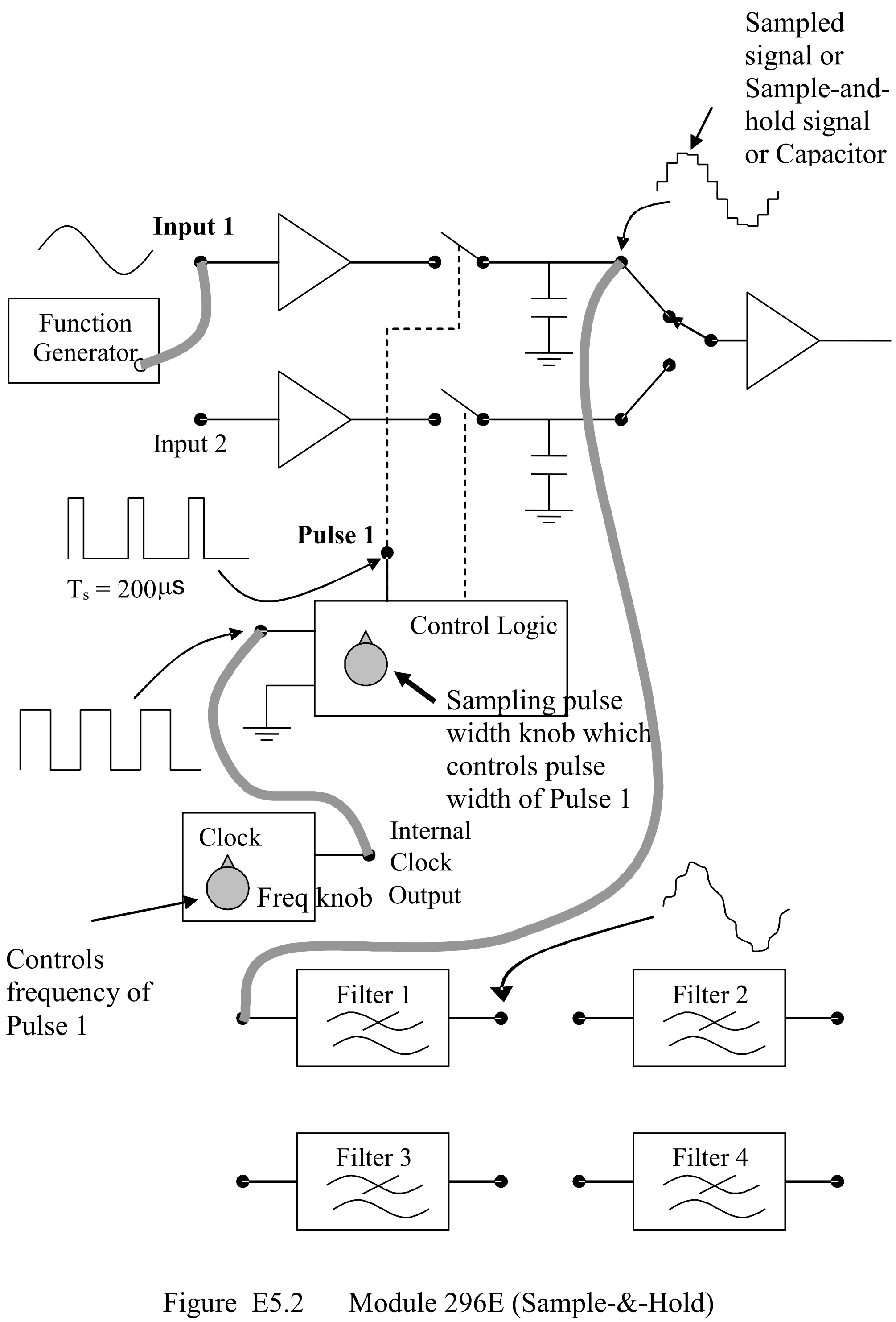


Figure E5.2 Module 296E (Sample-&-Hold)

Question1: what is the sampling frequency ? ________________________

4. Generate and connect a 500 Hz sine wave with 3 V_{pp} amplitude to "input 1" of the 296E module. Observe the "input 1" on CH1 of the oscilloscope. The sampled signal (or sample-and-hold signal) is the voltage across the capacitor. Monitor this voltage on CH2. Sketch both waveforms in the space provided below.

Signal at Input 1

Sampled signal

5. The original signal can be recovered from the sampled signal (or sample-and-hold signal) although it has many harmonics or spurious components. Recovery is done using low-pass filtering which removed or reduced the spurious components. There are four low-pass filters on the 296E module.

6. Connect the sampled signal to the input of filter 1. Observe both input and output of the filter on the oscilloscope; hence verify the effect of low-pass filtering.

7. Now observe the filter output together with the sinusoidal input waveform on the oscilloscope and hence verify their similarity. Filter 1 (a LPF) has recovered the original sinusoidal input although with some distortion (See Figure E5.3).

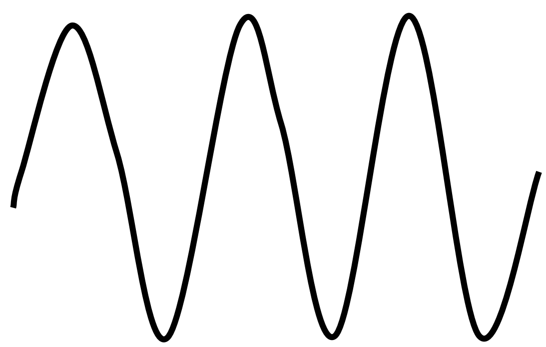


Figure E5.3 Recovered signal at the LPF output

B. Relation Between Sampling And Signal Frequencies

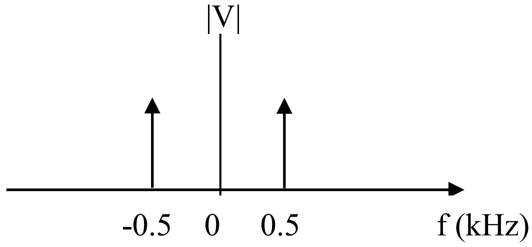
1. With the same sinusoidal input signal connected to "input 1" and the **sampling frequency** remaining at 5 kHz, set the pulse width to maximum.

3. Monitor the spectrum of the sampled signal (or sample-and-hold signal) using the spectrum analyser up to 15 kHz. Sketch the spectrum.

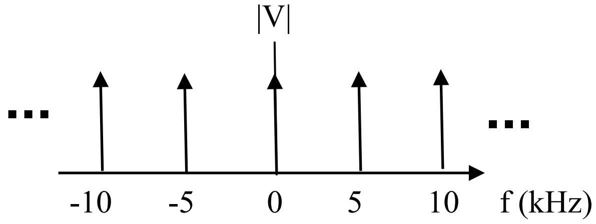
> **Important**
> **Make sure that you have set the input signal voltage level as instructed before connect the signal to the spectrum analyser.**

3. Apply the concepts learnt in the chapter of sampling i.e. verify by deriving the spectrum of the sampled signal theoretically (assume ideal sampling): you need to find the convolution of the sine spectrum and the unit impulse train spectrum. Leave out amplitude values.

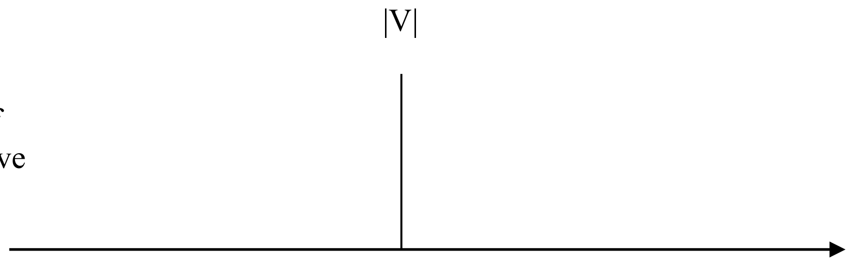
Spectrum of 500 Hz sine wave



Spectrum of unit impulse train of frequency 5 kHz



Spectrum of the sampled signal = Convolution of the 2 spectra above



Question 2: Is the observed spectrum on the spectrum analyser as expected?

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4. Continue to raise the frequency of the function generator, and observe that at a particular frequency, aliasing just occurs in spectrum of the sampled signal i.e. the second copy of the signal spectrum just coincides with the first. Note down the input signal frequency at this point (This is the maximum signal frequency for the sampling frequency of 5 kHz):

$f_{m\,(max)}$: ____________________________

Question 3: How does your observation relate to Sampling Theorem I?

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