

## EXPERIMENT 4: Sampling Theorem

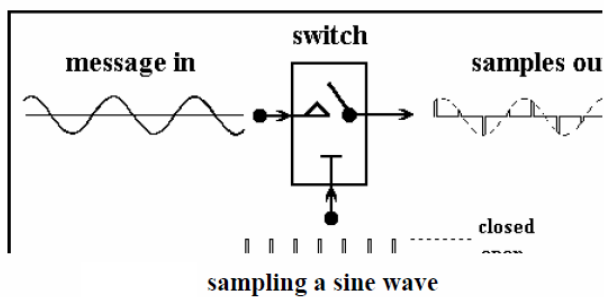
**New Modules:** DUAL ANALOG SWITCH, TWIN PULSE GENERATOR, HEADPHONE AMPLIFIER

### Pre-Lab:

- 1) TIMS-301 Basic Modules User Manual pages: 7, 9, 21, 22.
- 2) Student Text Vol-A1 pages: 121, 122.

Objective: To learn about sampling a message, and recovering the message from the samples.

Illustration of Sampling:



### In-Lab:

- 1) Build the model in Figure 1.

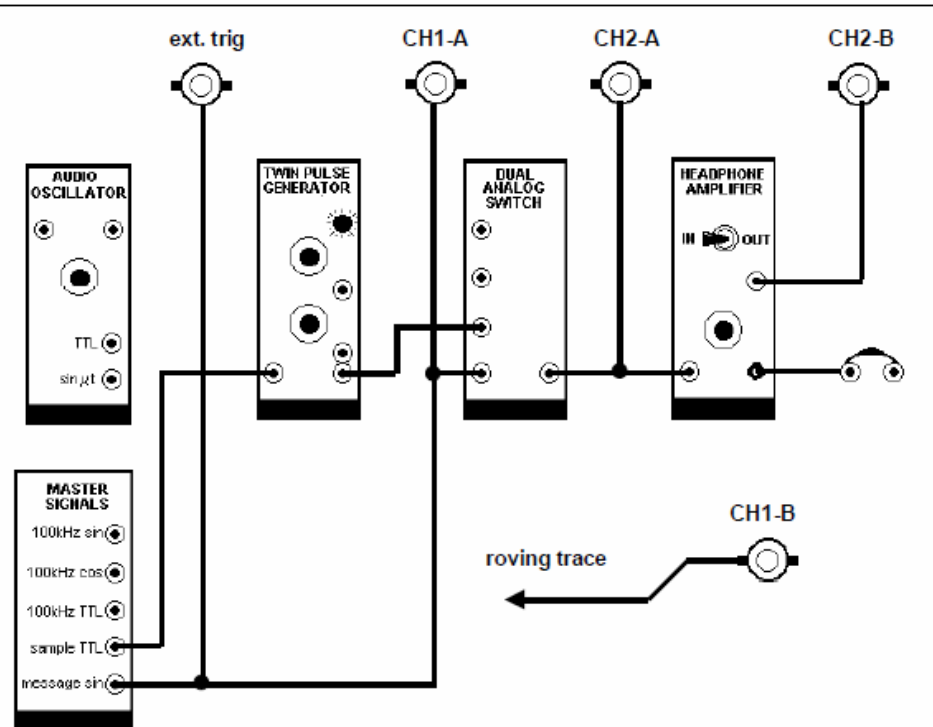


Figure 1

CH1A: 4 V peak to peak 2kHz sinewave for message signal

CH2A: Samples taken from the message signal with a sampling rate of 8.3 kHz

CH2B: Recovered signal from sampled signal

When you look at CH1A and CH2A, you will see the message and the sampled signal as in Figure 2.

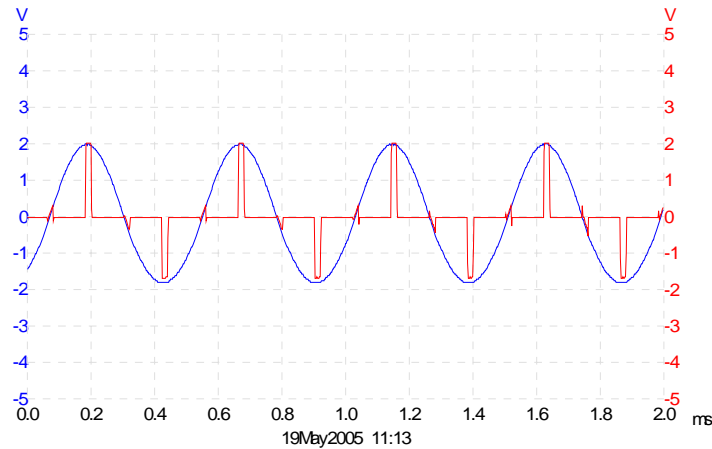


Figure 2

- 2) Change the width of the samples with the front panel WIDTH control on the TWIN PULSE GENERATOR and observe the change in the sample widths.
- 3) Look at CH1B for the reconstructed signal. This comes from HEADPHONE AMPLIFIER that is used as a LPF now (refer to TMS-301 Basic Modules User Manual page: 9).  
(From Fourier series analysis, and consideration of the nature of the sampled signal, you can already conclude that the spectrum of the sampled signal will contain samples at and around harmonics of the switching signal, and the message itself. Therefore, a low pass filter seems the obvious choice to extract the message.)
- 4) The amplitude of the reconstructed signal may be small. You can place the BUFFER AMPLIFIER at the end of the LPF which will amplify the reconstructed signal. Change the width of the samples and observe the reconstructed signal. Discuss the affects of the width of the samples on the amplitude of the reconstructed signal.
- 5) Remove the patch lead from 2.3 kHz SAMPLE CLOCK source on the MASTER SIGNALS, and connect it instead to the VCO TTL OUTPUT socket. Use the FREQUENCY COUNTER to set the VCO to 10 kHz.
- 6) Remove the patch lead from 2 kHz MESSAGE SIGNAL source on the MASTER SIGNALS, and connect it instead to the AUDIO OSCILLATOR  $\sin(\omega t)$  socket. Set the AUDIO OSCILLATOR frequency to 3 kHz. Confirm that the message signal and the reconstructed signal are identical in shape and frequency. (The difference in amplitudes is not important here. But for visual purposes, it is better to place the BUFFER AMPLIFIER at the end of the LPF and adjust it to make the message signal and the reconstructed signal have identical amplitudes.)

- 7) Slowly reduce the sampling rate, which is the VCO frequency. As soon as the reconstructed signal shows signs of aliasing distortion increase the sampling rate until it just disappears. Note down this minimum sampling rate and compare with the theoretical value.

When aliasing distortion occurs, you will get a reconstructed signal like in Figure 3.

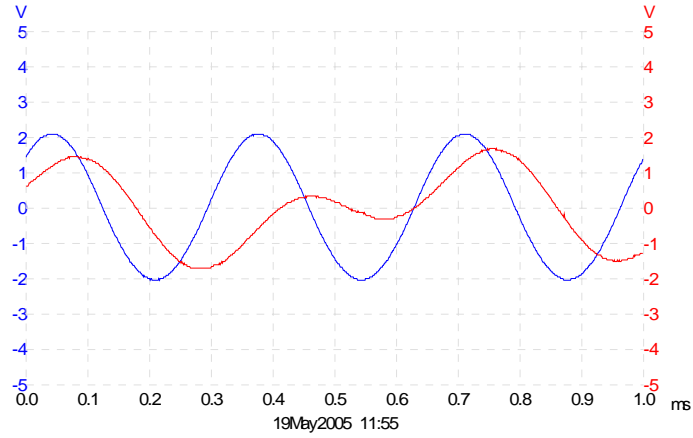


Figure 3