Manual for Communication Systems Laboratory (EEE/ECE F311)

Prepared by
Faculty & Laboratory Staff
Dept. EEE

BITS Pilani, Hyderabad

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Experiment 7: Sampling and Reconstruction

Aim: This experiment is intended to make the student to perform experiments on Sampling of Analog Signal, Reconstruction of signal from sampled values, Pulse Amplitude Modulation (PAM), Time Division Multiplexing (TDM) and recovery of signals from TDM stream, using Emona Telecoms-Trainer 101 kit.

Equipment Required: Emona Telecom Trainer Kit 101, Oscilloscope, microphone, headset, connecting patch cards etc.

A – Generation of Sampling Signal and its Properties.

Ideally, sampling of an analog signal is to be done with a train of impulse signals. However, for practical applications, we use pulses of finite durations for sampling the analog signals. In this part of the experiment, the student is expected to use Emona kit to generate the sampling signal and study its properties.

For generating train of pulses with finite time duration, the Emona kit has a *Twin Pulse Generator* block. This block can generate 2 streams of pulses, at a rate decided by the *Inputclock speed* and both of the streams will have pulses of same duration, controlled by the *Width knob*. However, there is a delay between the pulses generated at output ***Q1*** and ***Q2***, controlled by *Delay knob.* The use of 2 streams of pulses will be evident in the following sections.

For generating samples of a source signals, use the connection diagram in Figure 1. We use 8 KHz clock from Master Signal Generator. This implies that the sampling pulses have a rate of 8000 pulses per second. Adjust the width of generated pulse to a minimum, by turning the pulse width control on the Twin Pulse Generator Block. You may keep the delay control to the left most position. We will be using the output ***Q1*** of the twin pulse generator for sampling the analog signal. Display both the 8 KHz clock and the generated pulse wave forms on DSO.

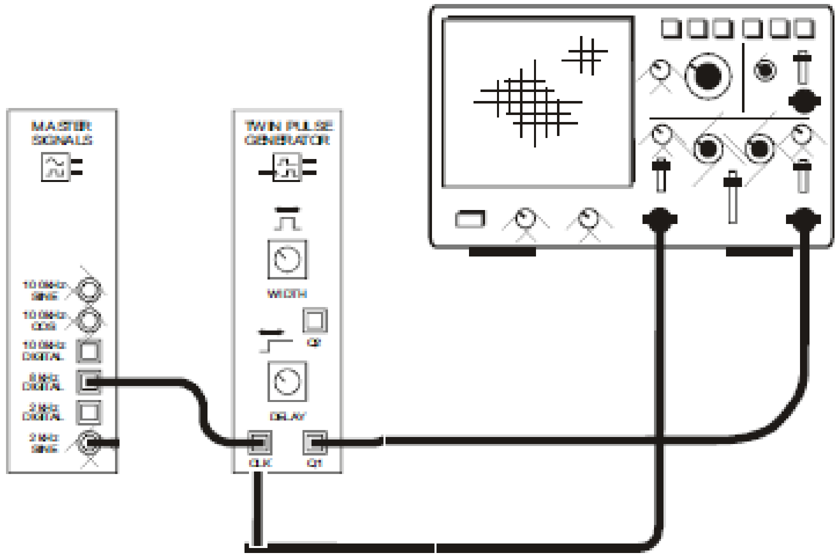

Figure 1: Connection diagram for Generating the Sampling Signal.

First, we will study the properties of the sampling pulses, both in time and frequency domains. Follow the steps given below.

a) Measure the width of the sampling pulse (τ) and also $1/\tau$. Measure the inter pulse duration (T) and corresponding frequency.

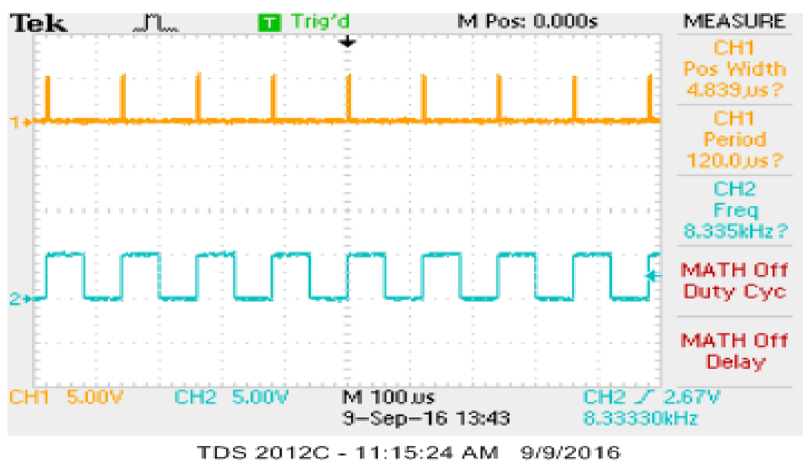

Figure 2: Sampling signal with respect to8 KHz clock signal.

b) Obtain the spectrum of the sampling signal on DSO and answer the following:

i. Adjust the FFT Zoom and frequency scale, so as to observe at least 3 major lobes of the spectra. Note the frequency points at which you observe deep nulls in the spectra? Are these frequency values related to (τ) and $1/\tau$,that you measured in (a)? Tabulate in Table 1.

ii. Increase the width of the sampling pulse, to about twice the previous value. At which frequency point is the deepest dip now? Relate it to the new (τ) and $1/\tau$, and tabulate in Table1.

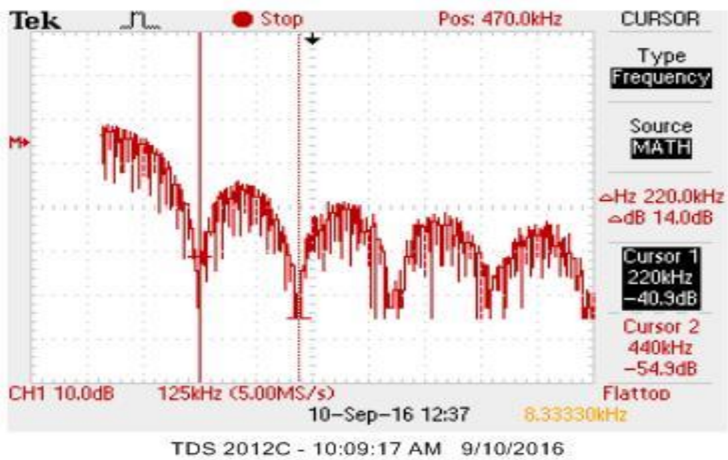

Figure 3: Spectrum of the sampling signal

Table 1: Sampling Signal Parameters

Sl. No	Sampling Pulse width (τ)	Sampling Frequency	$1/\tau$	Spectral Null locations		
1						
2						

iii. Next, adjust the FFT Zoom and frequency scale, so as to zoom further into the first major lobe. You should be able to observe distinct spectral peaks, within the major lobe. What is the separation between the spectral peaks? How is the separation related to T, measured in Step (a)?

iv. Can you relate this spectrum to the Discrete Fourier Spectrum of the pulse train with pulse width as τ and inter pulse period as T?

B – Sampling of a Message Signal.

In this experiment, we sample a 2 KHz sinewave with the sampling pulse sequence, generated in the previous section. For implementing the sampling process, Emona kit provides a Dual Sampling Switch block. You may use the connection diagram as in Figure 2.

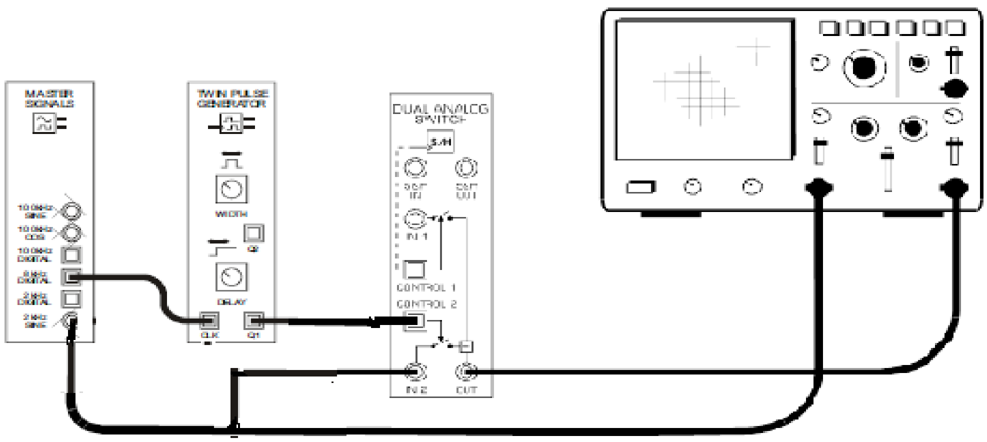

Figure 4: Connection diagram for generating the Sampled Signal.

a) Keep the sampling pulse width to the minimum. Observe the sampled signal on the DSO. How many samples are appearing in one full cycle of the analog signal?

b) Expand one of the samples (in time). Does the top of the sample resemble a Pulse Amplitude Modulated (PAM) signal?

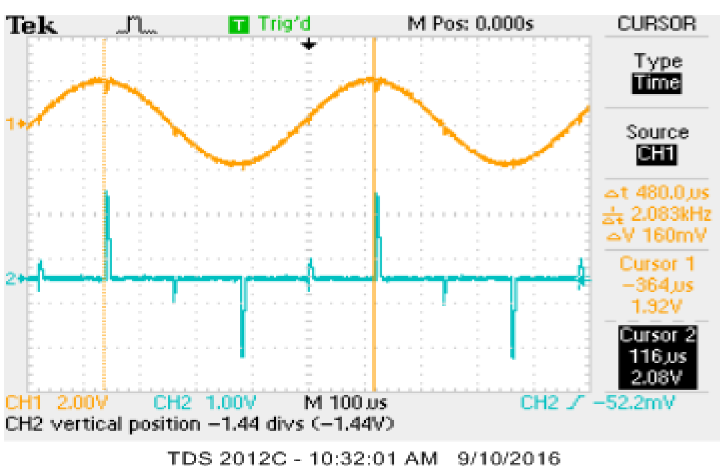

Figure 5: The Sampled Signal.

c) Obtain the spectrum of the sampled signal. Zoom the spectrum enough to observe individual spectral peaks. Note the frequency values of the spectral peaks. How are these frequency values related to the message frequency and parameters of the sampling pulse train?

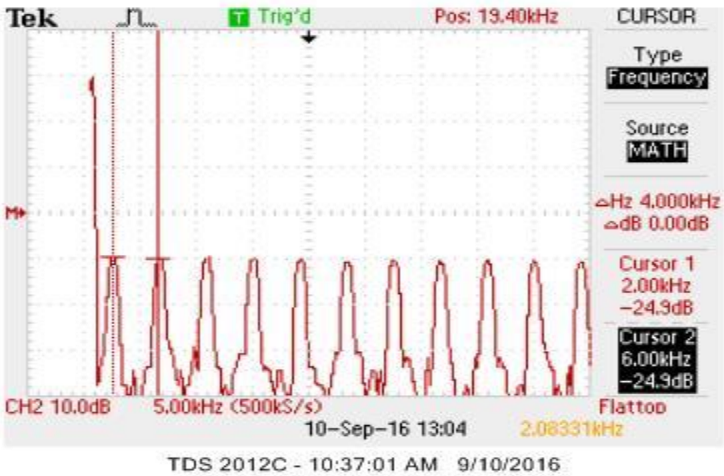

Figure 6: Spectrum of the Sampled Signal.

C– Recovery of Message Signal from its Samples.

a) Recovery of the original signal from its samples requires the samples to be filtered by a low pass filter. Use the connection diagram in Figure 3. Adjust the cutoff frequency of tunable LPF to recover the continuous signal.

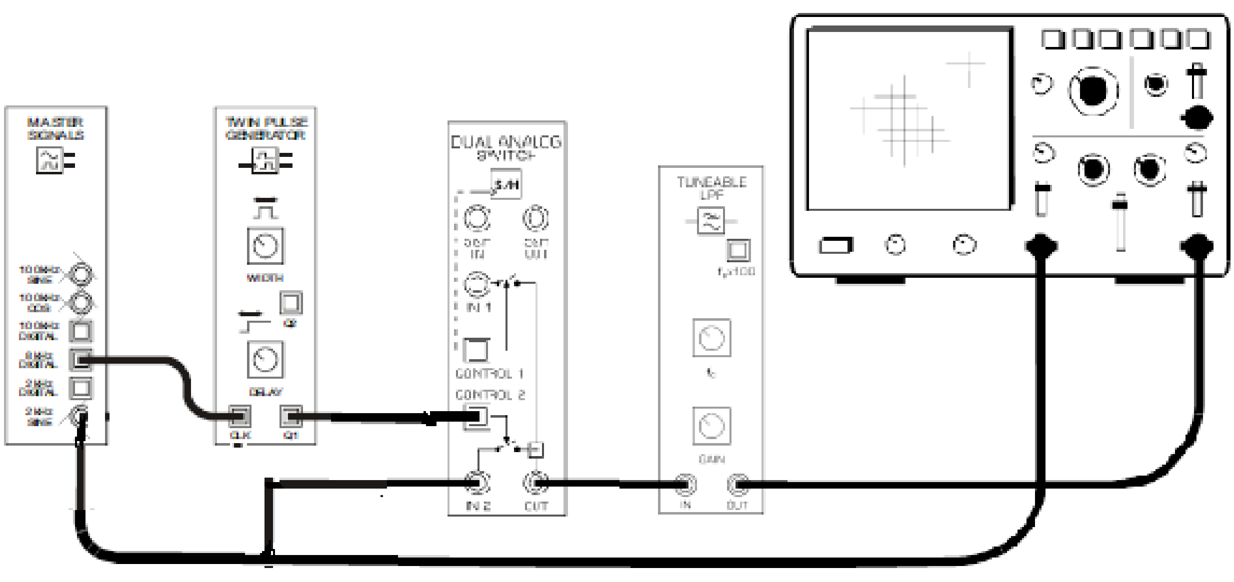

Figure 7: Connection diagram for reconstruction from the Samples.

b) Increase the pulse width to about twice. *Observe and comment on the effect of sampling pulse width on the amplitude of the recovered signal.*

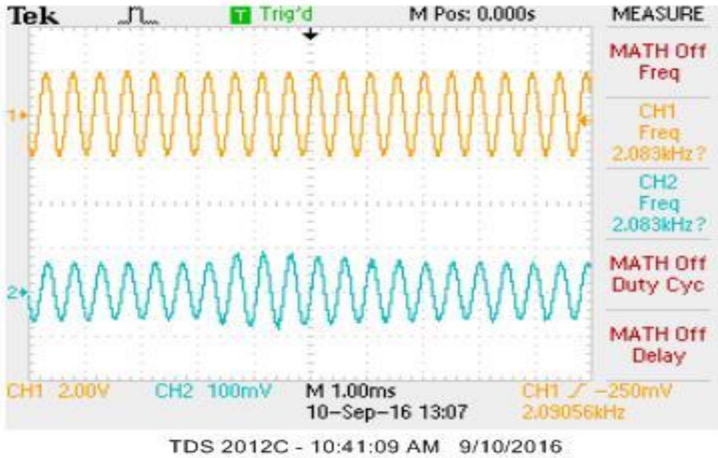

Figure 8: Recovered signal from the sampled signal.

D – Study of Under Sampling and Aliasing.

You may be aware that sampling of a signal, at a rate not satisfied by Nyquist criterion, results into aliasing and thus spoiling the frequency content of the original message signal. Under these under sampled conditions, the recovered signal from its samples does not resemble the original signal. In this experiment, you will be observing this phenomenon.

a) Generate a 1 KHz sine wave signal using ***VCO*** and sample it using 8 KHz sampling signal, keeping the sampling pulse width to minimum. For this you may follow the steps similar to section B. Also connect circuit to recover the analog signal from sampled signal, in a similar way as in section C. Observe the spectrum of the recovered signal on the DSO. What is frequency corresponding to the spectral peak? Tabulate in Table 2.

Table 2: Under Sampling and Aliasing

Sl. No	Message Frequency	Frequencies of the sampled signal	Frequency of the Recovered signal	Remarks on Aliasing effect
1	1Khz			
2	3 Khz			
3	5 Khz			
4	10 Khz			

b) Change the VCO frequency to 3 KHz and observe the spectrum of the recovered signal on the DSO. Tabulate the observations in Table 2. Next, change the VCO frequency to 5 KHz and 10 KHz and observe the spectrum of the recovered signal on the DSO. Do you see any aliased component in the spectrum? What is the frequency of the aliased component?

E- Sampling of a Message Signal with Sample and Hold Scheme.

The sample and hold operation is simple to implement, and is a very commonly used method of sampling in communications systems.In its simplest form the sample is held until the next sample is taken. In natural sampling, during the time that the analog signal is measured, any change in its voltage is measured too. For some digital systems, a changing sample is unacceptable. Figure 9 shows an alternative system where the sample's size is fixed at the instant that the signal measured. This is known as a *sample and hold* scheme.

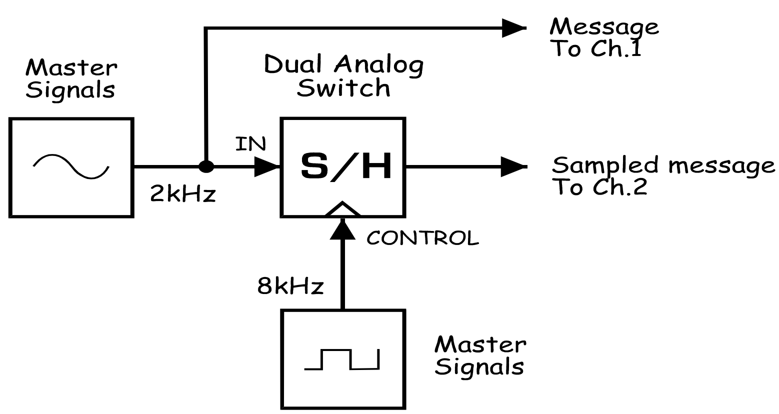

Figure 9: Sampling with sample and hold scheme Block Diagram

You may use the connection diagram as in Figure 10 for generating the sampled signal using sample and hold scheme.

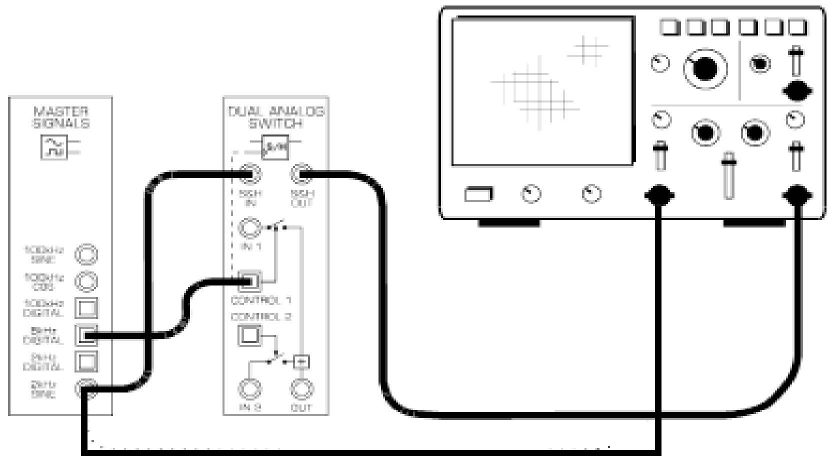

Figure 10: Connection diagram for generating the Sampled Signal.

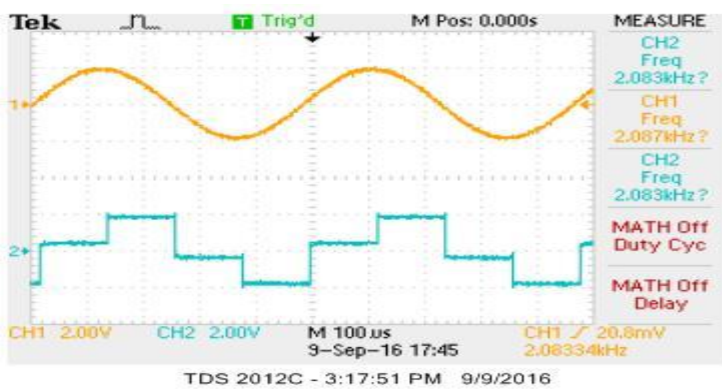

Figure 11:The Sampled Signal suing sample and hold scheme

a) Observe the sampled signal on the DSO and comment on the observation.

b) What two features of the sampled signal confirm that the set-up models the sample and hold scheme?

F – Pulse Amplitude Modulation (PAM) and Time Division Multiplexing / De Multiplexing. (TDM)

TDM involves multiplexing of 2 independent message samples, in the PAM mode. Connect the block diagram as in Figure 12. Keep the pulse width to minimum and adjust the delay to have a clear separation between the twin pulses that get generated. Observe the TDM stream on the Channel 2 of DSO.

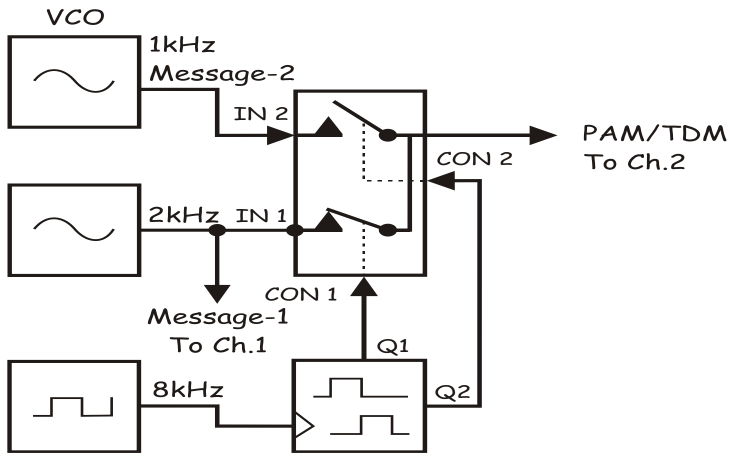

Figure 12: Block Diagram for TDM signal generation.

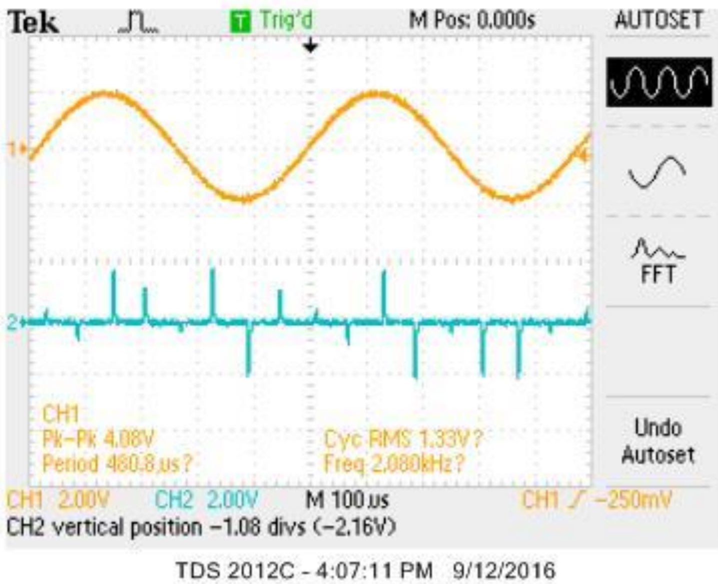

Figure 13:TDM Signal

Connect the blocks as in Figure 14, to de-multiplex and recover one of the messages and recover second message using connections as in Figure 16. Use DC coupled multipliers. Why is this multiplication process required for the recovery?

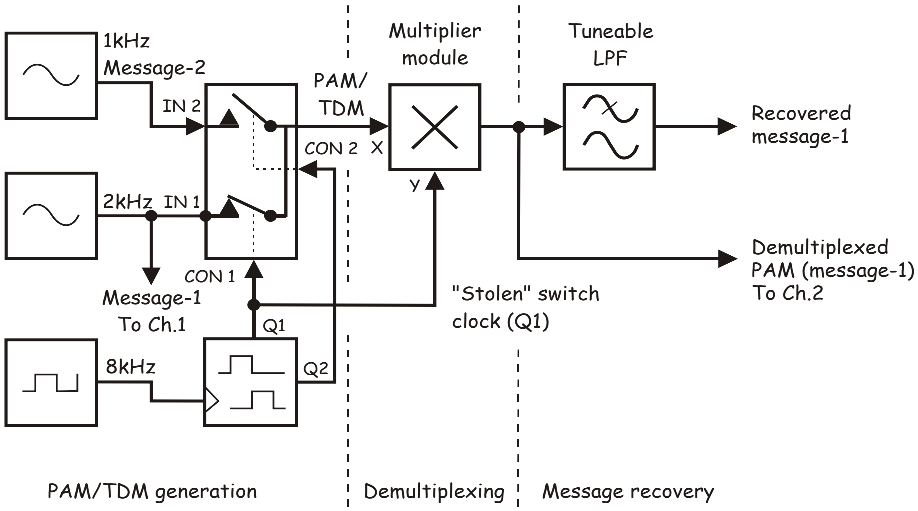

Figure 14: Block Diagram for Recovery from TDM stream (1st Stream)

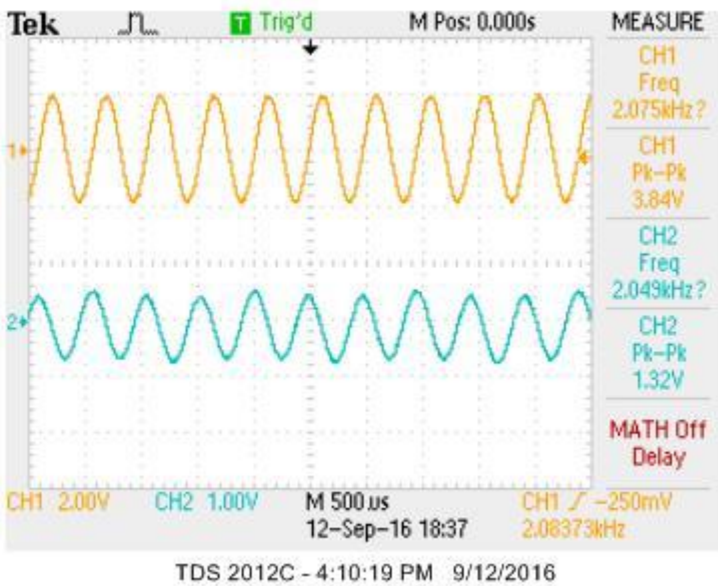

Figure 15: Recovered message signal 1 for TDM stream

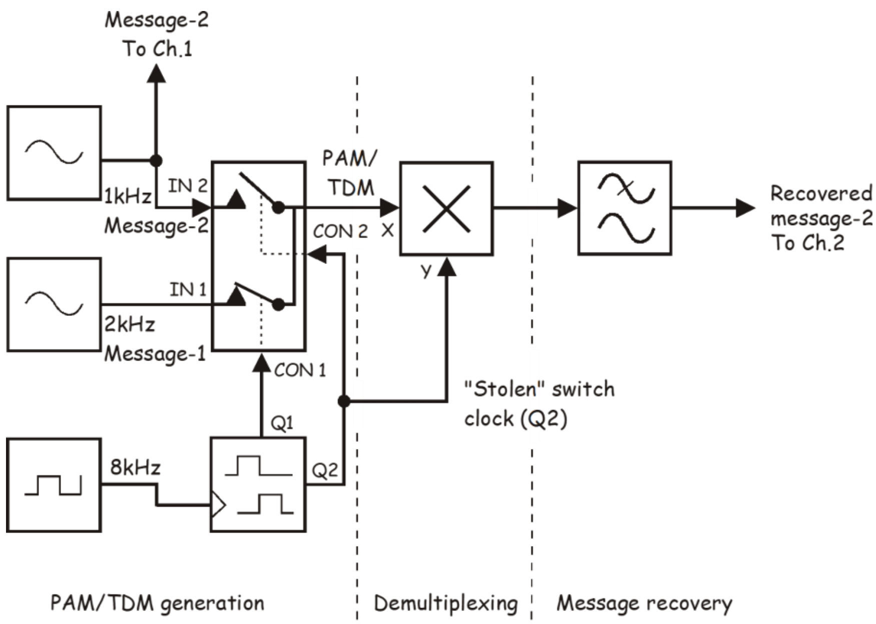

Figure 16: Block Diagram for Recovery from TDM stream (2nd Stream).

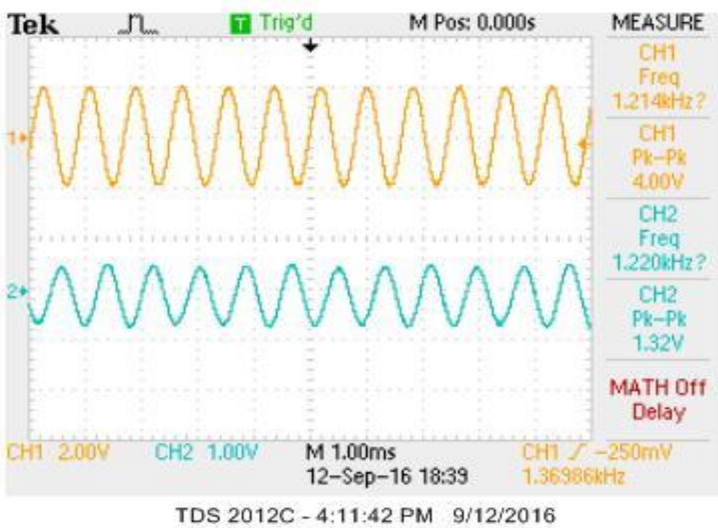

Figure 17: Recovered message signal 2 for TDM stream

G –Conclusions:

1. List out your learnings from the experiments.