Tutorial 7 – Analog and digital conversion

1. (a) State sampling theorem I.
   (b) A signal, v(t), bandlimited to 3kHz, has a amplitude spectrum shown in Figure T7.1. The signal is sampled by an ideal unit impulse train such that the guardband of the sampled output is 1 kHz.
      i) Determine the sampling frequency and sketch the amplitude spectrum of the sampled signal.
      ii) State how v(t) can be recovered from the samples.
      iii) If the sampling rate is 5000 samples per second, comment on the recovery of v(t).

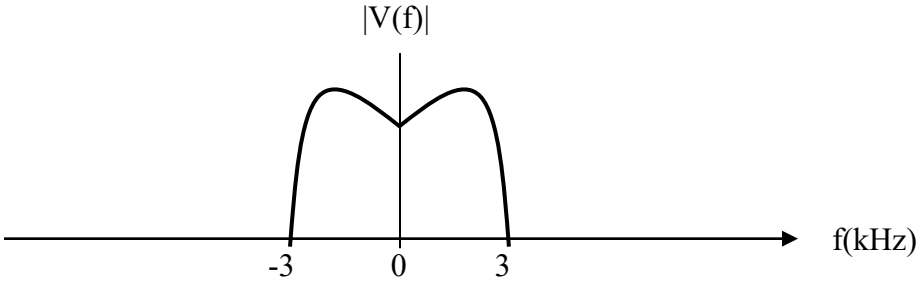


Figure T7.1

2. The bandlimited signal f(t) is ideally sampled at 80 samples per second as shown in Figure T7.2, where f(t) = 100sinc 100t. Draw the amplitude spectrum of the output signal g(t).

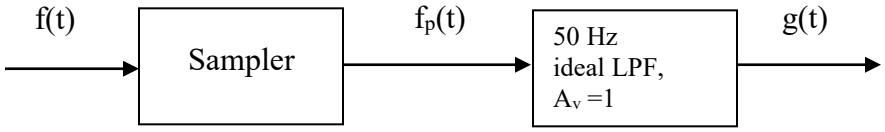


Figure T7.2

3. (a) Sketch the amplitude spectra of the following signals:
   (i) m(t) = 2rect1000t
   (ii) p(t) = $\sum_{n=-\infty}^{\infty} \delta(t - nT_s)$ where p(t) is unit impulse train and T_s = 0.2ms

   (b) The signal m(t) is filtered and then sampled by signal p(t) as shown in Figure T7.3. Sketch the amplitude spectra at points X and Y over a range of $\pm$ 8kHz.

   (c) Explain how to recover signal at point X from the signal y(t) at point Y.

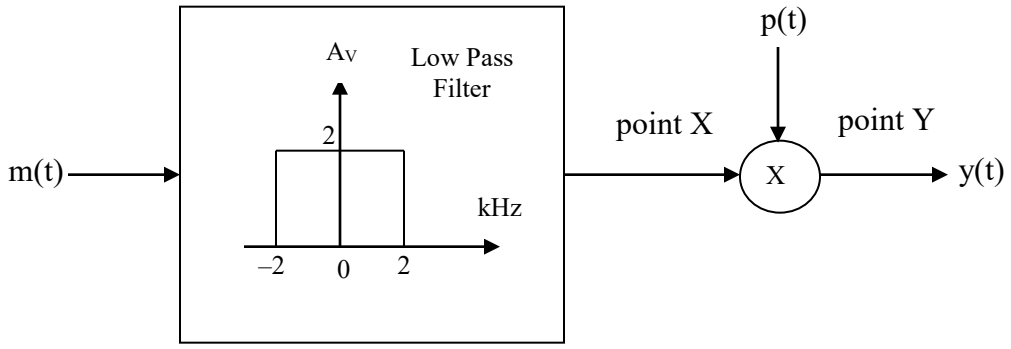


Figure T7.3

4. State two main differences between natural and flat top sampling.

5. Sketch the i/p-o/p characteristics of a 3-bit mid-riser linear quantiser of a PCM system used to digitise analogue signals whose range of amplitudes vary between ± 3.5 volts.

6. A PCM system employs a uniform 5-bit quantiser/encoder. The maximum permissible input voltage to the quantiser is 15 volts peak-to-peak. Calculate the signal-to-quantisation noise ratio (in dB) for the following input signals:
   (a) 7.5 Sin ωt
   (b) 5 Sin ωt

7. Four voice channels plus one music channel are sampled and transmitted through a PCM-TDM system in which 8-bit uniform quantisers are employed. The music signal is bandlimited to 10 kHz and each voice channel is bandlimited to 4 kHz.
   (a) sketch the PCM-TDM commutator system capable of handling both the voice and music signals. Ensure that uniform sampling is achieved. Synchronisation information is needed.
   (b) calculate the gross bit rate of the system

8. A PCM-TDM system is used to multiplex three similar sinusoidal signals, each uniformly quantised and represented by a binary code. The bit duration is 10 μsec. If the maximum signal-to-quantisation noise ratio is to be maintained greater than 1000, determine
   (a) the number of bits required
   (b) the sampling frequency (uniform sampling and `sync' info are required)
   (c) the highest analogue signal frequency allowed
   (d) the minimum transmission bandwidth required

9. A commutator shown in Figure T7.4 is connected to a communication channel with bandwidth of 300 kHz.

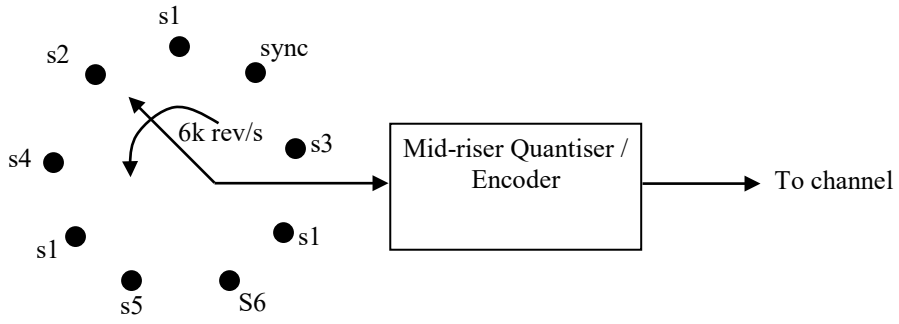
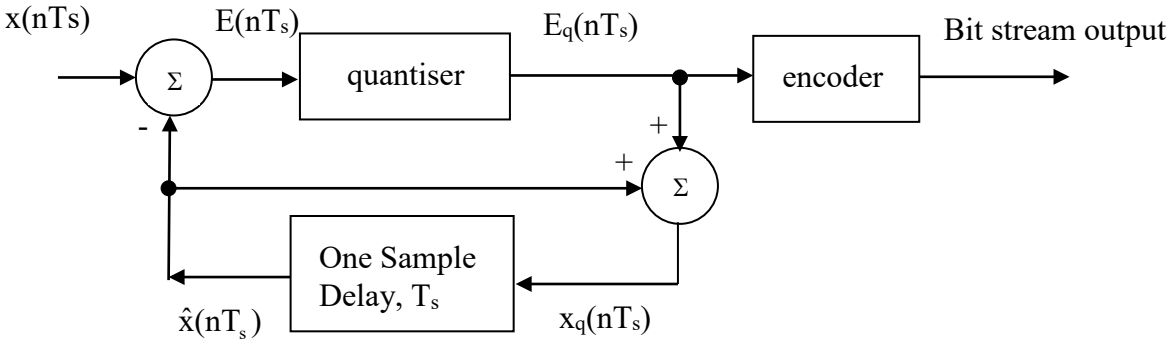


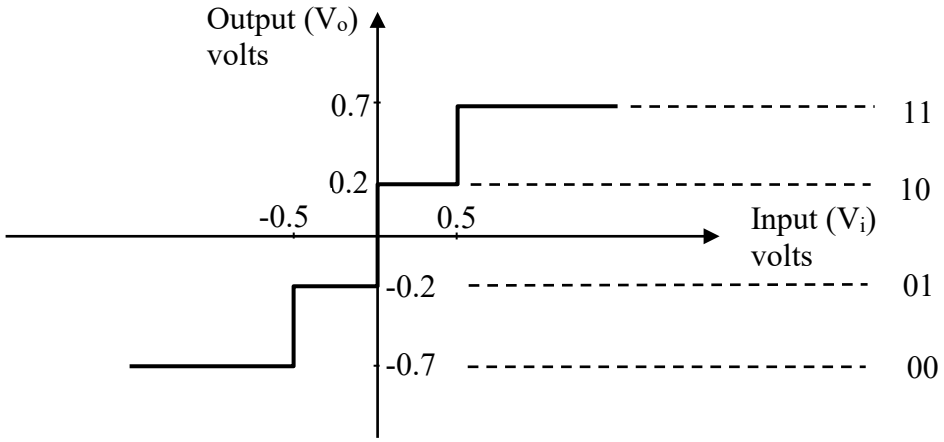
Figure T7.4

   (a) Determine the maximum signal frequency of each input signal s_1 to s_6.
   (b) Show that the maximum number of bits per sample for each signal is 11 bits assuming each sample of the signals is encoded using unipolar NRZ format.

10. (a) A DPCM modulator is shown below. Assume that the input $x(nT_s)$ is given in the table, complete the remaining boxes in the table 7.1. What is the output bit stream?
    (b) Let us now assume that the signal is sent using binary PCM. The quantiser is a uniform quantiser of step size equal to 0.2 volts. The maximum signal swing is ±6 volts. How many quantisation levels are required to code the signal? What is the bandwidth requirement in this case, expressed as a ratio of the bandwidth used in part (a).



(a) DPCM Modulator



(b) Quantizer Characteristic for DPCM Modulator

Quantizer rule V_0 = 0.7V; $0.5V < V_i < \infty$

= 0.2V; $0V < V_i \leq 0.5V$

= -0.2V; $-0.5V < V_i \leq 0V$

= -0.7V; $-\infty < V_i \leq -0.5V$

Time	**$x(nT_s)$**	**$\hat{x}(nT_s)$**	**$E(nT_s)$**	**$Eq(nT_s)$**	**$Xq(nT_s)$**
0	5V	5.1V			
T_s	6V				
$2T_s$	6V				
$3T_s$	6V				
$4T_s$	6V				
$5T_s$	6V				

Table 7.1