National Examinations - December 2018

# 16-Elec-A3, Signals and Communications

3 hours duration

Notes:

1) If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumption made.

2) "Closed-Book" - An approved Casio or Sharp calculator is permitted.

3) Answer all 5 questions.

4) All 5 questions are of equal value.

1. Consider the signal $x(t) = 4\cos(2\pi f_0 t)$, where $f_0 = 120$ Hz. This signal is input to a threshold device which gives the output $y(t)$ as follows: if $x(t) \geq 2$ then $y(t) = x(t)$, whereas if $x(t) < 2$ then $y(t) = 0$.

a) Determine the fundamental frequency of $y(t)$.

b) Write $y(t)$ as a Fourier series (i.e. the real Fourier series).

c) If the signal $y(t)$ is input to an ideal band-pass filter with center frequency 500 Hz and bandwidth 250 Hz, determine the output signal $z(t)$.

d) Determine the average power of the signal $y(t)$ and the signal $z(t)$.

2) A PCM system with uniform quantization is used to transmit a speech signal. The bandwidth of the signal is equal to 8 KHz. Assume that the signal has a dynamic range that varies between -2 and 2 volts (i.e. peak to peak value equal to 4V). Upon reconstruction of the signal assume that the quantization noise can be modelled as a sinusoid of amplitude A_n.

a) Model the signal as a sinusoid and determine the SNR for the reconstructed signal in terms of A_n.

b) Determine the value of A_n if the required SNR is 60 dB.

c) Determine the number of quantization levels required to achieve the above SNR.

d) Determine the number of bits per sample.

e) Determine the bit rate of the quantized signal.

3) In a modulation scheme the message signal is given by $m(t) = \cos(2\pi f_m t)^3 + \dfrac{\sin(\pi f_m t)}{\pi f_m t}$

and the carrier is equal to $A \cos(2\pi f_c t)$, where $f_c = 30 f_m$.

a) Plot the spectrum of the message signal. What is the bandwidth?

b) Plot the spectrum of the modulated signal assuming DSB modulation. What is the bandwidth of the modulated signal?

c) Plot the spectrum of the signal assuming lower-sideband SSB. What is the bandwidth of the modulated signal?

d) Give a block diagram of a system to recover the message signal exactly from the DSB signal. The system should work for arbitrary message signals with the same message signal bandwidth.

e) Give a block diagram of a system which takes the DSB signal in b) and outputs a DSB signal with carrier frequency equal to $35 f_m$.

4) A discrete time linear system is described by the following block diagram:
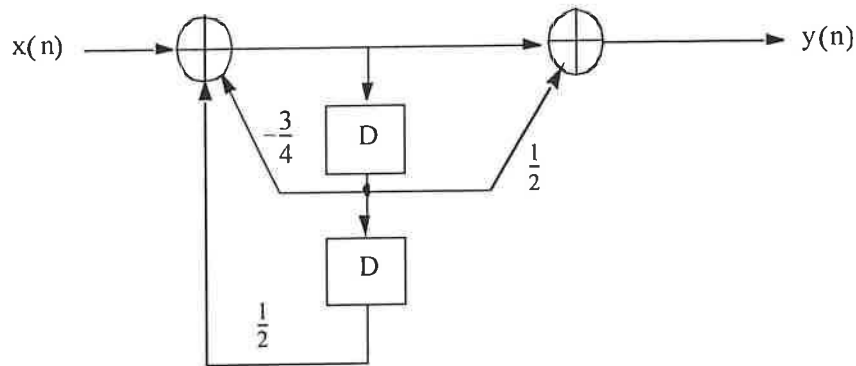
a) Determine the transfer function of the system.

b) Determine the impulse response of the system.

c) Determine the frequency response of the system.

d) Assume that we sample an analog signal at the rate of 10 KHz to obtain the sampled signal $x(n)$ as in the above Figure. The filtered signal, $y(n)$, is then reconstructed to produce a filtered analog signal. The overall system will then implement an analog filter. For which frequency will the amplitude gain of this analog filter be a maximum?

5) A frequency downconverter is implemented using a square-law device as follows:
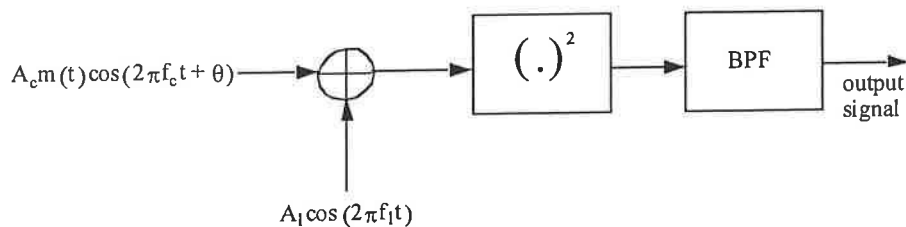
The band-pass filter has a center frequency $f_i = |f_c - f_l|$ (also known as the intermediate frequency, IF). Assume that the bandwidth of the message signal $m(t)$ is equal to B Hz.

a) Determine the smallest possible IF frequency so that there is no distortion in the output signal.

b) For a given IF frequency what is the smallest bandwidth of the band-pass filter (BPF) so that there is no distortion in the output signal?

c) For a given IF frequency what is the largest bandwidth of the BPF so that there is no distortion in the output signal?