National Exams - May 2019

16-Elec-A3, Signals and Communications

3 hours duration

Notes:

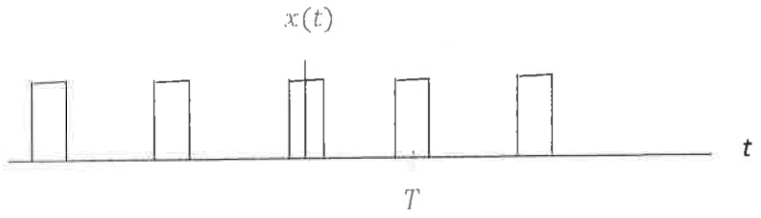
1) If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumption made.

2) This is a Closed-Book exam - One of two calculators is permitted - any Casio or Sharp approved model.

3) Answer all 5 questions.

4) All 5 questions are of equal value.

1. Consider a signal that is a periodic pulse train as in the following Figure where the duty cycle is 20%, and $T = 100\ \mu s$.



This signal is input to a first order (RC) low-pass filter with time constant $RC = T$, in cascade with an ideal low-pass filter with bandwidth $B = 25$ KHz (note cascade means that the output of the first filter is connected to the input of the second filter).

a) Determine the Fourier series coefficients of $x(t)$ if the amplitude of $x(t) = 2$.

b) Determine the output of the ideal low-pass filter, $y(t)$.

c) Determine the average power of the signal $y(t)$.

2. An audio signal $m(t)$ is to be digitized using a non-uniform PCM encoding scheme. The bandwidth of the signal is 10 KHz, and the signal is to be quantized using a uniform quantization scheme for each of two ranges of the signal but with a different step size. Let $m_p = \max|m(t)|$ be the peak value of $m(t)$, and let $m_s = m(kT)$ be a sample of $m(t)$. If $|m_s| \leq m_p/2$ then the quantization error should be less than 0.1% of the peak, m_p, otherwise the quantization error should be less than 0.4% of the peak.

a) Determine a quantization scheme by listing all the threshold values; that is, specify the characteristics of the quantizer by giving the the output quantized level versus the input analog voltage level for each value of the sample.

b) Assign a unique binary code to the quantized levels. What is the number of bits per sample?

c) Determine the bit rate for the digitized speech signal assuming a 20% oversampling rate in order to facilitate the filtering during signal reconstruction.

3. Consider a message signal given by $m(t) = \cos(2\pi f_m t) + \sin(2\pi f_m t)$ where $f_m = 2$ KHz. This signal is to be modulated with a carrier with frequency 100 KHz.

a) Assume DSB modulation, give an expression for the modulated signal in the time domain and plot it

b) Give an expression for the spectrum of the modulated signal in a) and plot it.

c) Assume AM modulation with a modulation index of 0.5 give an expression for the AM signal in the time domain and plot it.

d) Give an expression for the spectrum of the modulated signal in c) and plot it.

e) Assume upper sideband SSB modulation and give an expression for the modulated signal in the time domain and plot the spectrum.

4. An angle-modulated signal is given (in Volts) by

$$x(t) = \begin{cases} 10\cos(12000\pi t) & 0 < t \leq 2 \\ 10\cos(8000\pi t + 6000\pi) & 2 < t \leq 4 \\ 10\cos(10000\pi t) & \text{elsewhere} \end{cases}$$

The carrier frequency is 5 KHz.

a) Assuming a frequency-modulated (FM) signal with frequency deviation constant $f_d =$ 1 KHz/Volt, determine the message signal $m(t)$.

b) Draw the block diagram for a generic FM demodulator not using a phase-lock loop.

5. A discrete time linear system is described by the following difference equation: $y(n) = a_1 y(n-1) + a_2 y(n-2) + x(n) + x(n-1)$, where $x(n)$ is the input, $y(n)$ is the output and $a_1 = a_2 = 1/2$.

a) Give the transfer function for the system, and give the frequency response assuming a sampling frequency of 10 KHz. The expression for the frequency response must be accurate so that we can use it to create a plot.

b) Find the impulse response of the system.

c) Give a block diagram for the filter implementation that minimizes the number of delay elements.