

**Association of Professional Engineers of Ontario**

Annual Examinations  
07-Elec-A3, December 2014

Signals and Communications

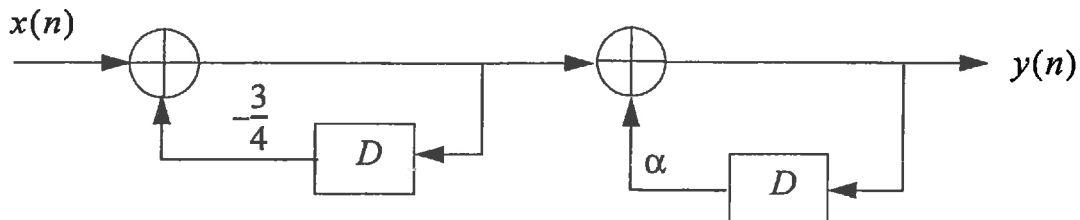
3 hours duration

**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" - no aids other than a standard non-programmable (no text storage) calculator are permitted.
- 3) Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
- 4) All questions are of equal value.

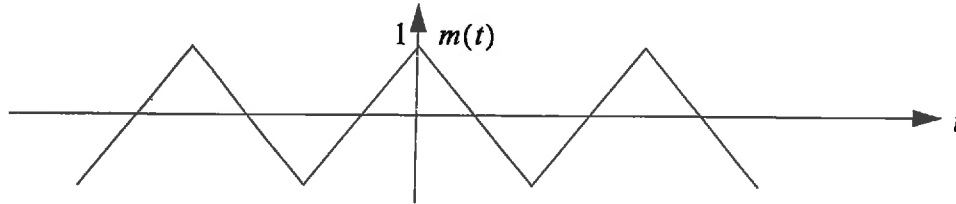
- 1) Consider the signal  $x(t) = u(t-2)e^{-2t}$ , where  $u(t)$  is the step function.
  - a) Determine the Fourier transform of  $x(t)$  in terms of a frequency variable in Hertz.
  - b) Determine the amplitude spectrum and phase spectrum for the signal  $x(t)$ .
  - c) Determine the energy spectral density for the signal  $x(t)$ . What is the energy of  $x(t)$ ?
  - d) If the signal  $x(t)$  is input to a filter with impulse response  $h(t) = u(t) - u(t-1)$  determine the output of the filter. Do the evaluation in the time domain.
  
- 2) A signal  $x(t) = A \cos(2\pi f_0 t)$  is passed through a half-wave rectifier and then input to a circuit that blocks the d.c. component (i.e. a.c. coupling). The signal is then input to an integrator with unity gain.
  - a) Plot the output of the integrator, specifying all the parameters (assume steady state operation).
  - b) If the integrator output is input to a low-pass filter with bandwidth  $2.5f_0$  give the output of the filter in terms of the parameters  $A$  and  $f_0$ .
  
- 3) An audio signal is to be transmitted using PCM in a baseband channel. The bandwidth of the signal is equal to 8 KHz and the signal has a dynamic range of 2V peak to peak. The signal is to be reconstructed using a low pass filter that has a transition region (from the passband to the stopband) equal to 10% of the bandwidth of the passband of the filter. The reconstructed signal must have a quantization noise that is less than 1 mv rms. Assume that the frequency response of the filter is constant within the passband.
  - a) What is the required sampling rate so that we can reconstruct the signal with zero distortion except for quantization noise?
  - b) Find the smallest number of bits required to represent each sample of the signal.
  - c) What is the bit rate of the resulting PCM signal?
  - d) Suppose 10 of the above PCM signals (as in c)) are to be multiplexed and transmitted through a baseband channel using a binary transmission scheme. What is the minimum bandwidth required for the channel assuming optimum filtering of the transmitted pulses?

- 4) Consider a modulation process where the information signal is a zero mean square wave with unit amplitude. Sketch the modulator signal output and give block diagrams for the corresponding demodulator for each of the following types of modulation. (Assume typical values for any parameter not specified).
- AM with a modulation index of  $a = 0.5$
  - DSB with suppressed carrier.
  - Frequency modulation.
  - Phase modulation with modulator constant  $k_p = \frac{\pi}{2}$  radians/volt.
- 5) A superheterodyne receiver uses an intermediate frequency stage with center frequency equal to 800 KHz. It is to be tuned to an input RF AM signal with carrier frequency equal to 2 MHz and bandwidth equal to 20 KHz.
- Determine two possible tuning frequencies for the local oscillator. Which one is preferable if we design the radio to demodulate a block of channels (i.e. ability to tune to any channel in a block of channels).
  - For the preferable tuning frequency in a) what is the image frequency corresponding to the signal in a) with carrier frequency equal to 2 MHz?
  - The above radio utilizes a fixed RF front-end filter and is designed to receive a number of AM stations over an AM broadcasting band centered at 2 MHz. Determine the range of frequencies of this AM band and the number of broadcasting stations that we can have in this system.
- 6) A discrete time causal system is described by the following block diagram



- Give a difference equation for the output  $y(n)$  in terms of the input  $x(n)$ .
- Give the transfer function of the system.
- Find the impulse response for the system.
- For what range of values of  $\alpha$  is the system stable?

- 7) An AM signal has a modulation index  $a = 0.8$  and a peak to peak value of 4 V. The message is a triangular wave with frequency equal to 5 KHz as in the plot below. The carrier frequency is 10 MHz.



- Give an expression for the AM signal in the time domain in terms of  $m(t)$ , and plot it.
- Plot the spectrum of the AM signal (exact values of line spectra are not required - specify the computation procedure). Neglect AM signal components corresponding to message signal harmonics greater than the fourth.
- Plot the envelope of the AM signal. Give all the parameters.
- Give the diagram for an electronic circuit that will demodulate the AM signal. Specify suitable values for any components.
- Give the block diagram for a coherent detector that will demodulate the AM signal.