Professional Engineers Ontario

Annual Examinations

16-Elec-A3, May 2017

Signals and Communications

3 hours duration

Notes:

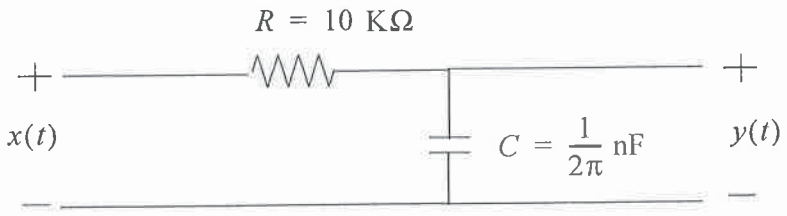
1) If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumption made.

2) "Closed-Book" - no aids other than a standard non-programmable (no text storage) calculator are permitted.

3) Answer all 5 questions.

4) All 5 questions are of equal value.

1. Consider a first order low-pass filter given by the following circuit.



If $x(t)$ is a square wave with frequency equal to 50 KHz, ranging from 0 to 2 volts, and with the origin being such that the maximum value occurs at the origin and the signal is an even function, determine the Fourier series for $x(t)$.

a) Give an expression for the output, $y(t)$, in the time domain.

b) Give an expression for the output, $y(t)$, in the frequency domain.

c) Consider a 40 dB definition of bandwidth, i.e. all out-of-band frequency components are lower than -40 dB relative to the main AC in-band component, what is the bandwidth of the output signal?

d) Determine the average power of the input signal.

e) Determine the average power of the output signal.

2. A discrete linear time invariant system has an impulse response given by $h(n) = 1$ for $0 \le n \le 3$, $h(4) = \frac{1}{2}$, and $h(n) = 0$ elsewhere.

a) If the input is the signal $x(n) = 1 - \frac{|n-6|}{6}$ for $0 \le n \le 12$ and zero elsewhere, determine the output of the system $y(n)$.

b) Give an equation relating the output to the input in the time domain.

c) Give a block diagram of the system for arbitrary inputs.

d) Give the transfer function for the system.

e) Is the system bounded input bounded output stable? Justify your answer.

3) The message signal $m(t) = \cos(2\pi f_m t) + \frac{1}{2}\cos(3\pi f_m t)$, where $f_m = 1$ KHz, is input to a Double Sideband Modulator (DSB) with carrier frequency $f_c = 10 f_m$ KHz.

a) Is the signal $m(t)$ periodic? If so, plot $m(t)$ over one fundamental period.

b) Give an exact expression for the DSB signal in the time domain in terms of the message signal $m(t)$, if the average power of the DSB signal is 10.

c) Assume an AM modulation scheme with the same message, $m(t)$, with modulation index $\mu = 0.8$. Plot the AM signal in the time domain. (Marks will consider neatness). Scale the AM signal so that the average power is 10.

d) What is the power efficiency of the AM modulation scheme in c).

e) Assume that the AM signal in c) is fed into an envelope detector, give (plot) the output signal.

f) Specify the minimum frequency band required to transmit the AM signal (give the center frequency and bandwidth).

4) A voice signal $m(t)$ is to be digitized using a 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. Let m_p be the peak value of $|m(t)|$, and let m_s be a sample of $m(t)$. If $|m_s| < \frac{m_p}{2}$ then the quantization error should be less than 0.1% of the peak, m_p, and if $\frac{m_p}{2} \le |m_s| \le m_p$ then 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 quantizer characteristics - the output quantized level versus the input analog voltage level.

b) What is the number of bits per sample if a binary encoding scheme is used.

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

5) An FM signal has the form $s(t) = A_c \cos(2\pi f_c t + \phi(t))$, where $A_c = 5$ $\phi(t) = a\cos(2\pi f_1 t) + b\cos(2\pi f_2 t)$, $a = 1$, $b = 2$, $f_1 = 2000$ Hz, and $f_2 = 2f_1$.

a) Determine the message signal $m(t)$, assuming that the frequency deviation constant is 5 KHz/volt.

b) What is the average power of the FM signal $s(t)$?

c) Determine the peak frequency deviation of the FM signal.

d) Determine the bandwidth of the FM signal.

e) Give the block diagram of a suitable demodulator.