Professional Engineers Ontario

Annual Examinations
07-Elec-A3, May 2016
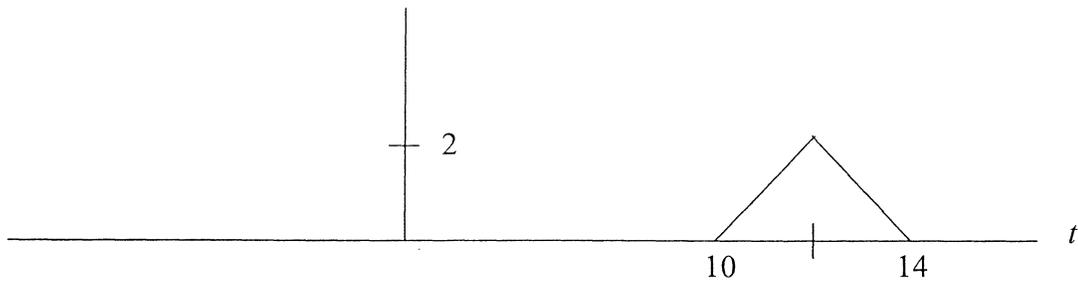
Signals and Communications

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 6 questions are of equal value.

1) Consider the following signal $x(t)$

a) Determine the Fourier transform of $x(f)$.

b) Determine the energy of the signal of $x(t)$.

c) If the signal is input to an ideal low-pass filter with bandwidth equal to 1 Hz plot the output signal in the frequency domain, i.e. plot the spectrum of the output signal.

2) A modulated signal has the following form

$$x(t) = A(1 + m_1(t))\cos(2\pi f_c t) + m_2(t)\sin(2\pi f_c t)$$

where the signals $m_1(t)$ and $m_2(t)$ are two independent message signals with bandwidths $W \ll f_c$, $|m_1(t)| \leq 1$, $|m_2(t)| \leq 1$, and where A is a constant with $A \gg 1$.

a) Give the block diagram of a system to demodulate the two signals $m_1(t)$ and $m_2(t)$ exactly.

b) If the signal $x(t)$ is input to an ideal envelope detector determine the output. If the message signals are audio signals, what does this output sound like?

c) If the envelope detector is used as a demodulator for the signal $m_1(t)$ determine an approximate value of the signal to distortion ratio.

d) Is there an $m_2(t)$ signal component at the envelope detector output? If so, what is the signal to distortion ratio for $m_2(t)$?

3) A digital communication system supports a bit rate of 90 Kb/s. This system is used to transmit an analog signal by using PCM with uniform quantization. The reconstructed signal is to have an SNR that exceeds 50 dB. What is the maximum bandwidth of an analog signal that can be transmitted on this channel. (Assume that the signal is uniformly distributed in $[-V_m, V_m]$).

4) The signal $m(t) = \sqrt{2}(\cos(2\pi f_m t) + \sin(2\pi f_m t))$ is input to an AM modulator with carrier frequency f_c, where $f_m = 1$ KHz and $f_c = 1$ MHz.

a) Plot the signal $m(t)$.

b) Assume that the modulation index is 0.5, give an expression for the AM signal in the time domain, assuming that the maximum value (i.e. the peak value) of the AM signal is 8.

c) Give an expression for the spectrum of the AM signal.

d) What is the bandwidth of the AM signal?

5) A discrete time system is described by the following equation

$y(n) = \frac{1}{3}y(n-1) + 2x(n)$, where $y(n)$ is the output and $x(n)$ is the input, and where

$y(n) = x(n) = 0$ for $n < 0$.

a) Give a block diagram for the system.

b) Determine the transfer function for the system.

c) Give the impulse response for the system?

d) Find the output of the system if the input is $x(n) = u(n)$ where $u(n)$ is the discrete time step function.

6) An FM modulator has the following characteristics: When a 2 volt dc signal is applied as the message input the frequency of the signal changes by 5 KHz from the nominal frequency, f_c (with input grounded).

a) Determine the output of the modulator when the input is equal to $m(t) = \cos(2\pi f_1 t) + 3\sin(4\pi f_1 t)$, where $f_1 = 2$ KHz, i.e. Give the expression for the modulator output. Specify all the parameters.

b) Give an approximate value for the bandwidth of the signal at the modulator output in a).

c) Give the block diagram for a system that demodulates an FM signal. Do not use a phase-lock loop.