Instructor Initials	M.H.
Department Head Initials	

THE UNIVERSITY OF CALGARY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ENEL 471 - Introduction to Communications Systems and Networks
(Winter 2019)

Instructor: Dr. M. Helaoui

FINAL EXAMINATION

Date: April 15, 2019
Time: 3:30 – 6:30 PM
Location: KN AUX

Student ID#: _____

Instructions:

1. ***This is a closed-book examination.***
2. ***Answer all questions.***
3. ***Non-programmable calculators are permitted during the examination.***

Marks:

Question	Marks	
1		**/8**
2		**/10**
3		**/8**
4		**/10**
5		**/8**
6		**/6**
TOTAL		**/50**

EXAMINATION RULES AND REGULATIONS

STUDENT IDENTIFICATION

Each candidate must sign the Seating List confirming presence at the examination. All candidates for final examinations are required to place their University of Calgary I.D. cards on their desks for the duration of the examination. (Students writing mid-term tests can also be asked to provide identity proof.) Students without an I.D. card who can produce an acceptable alternative I.D., e.g., one with a printed name and photograph, are allowed to write the examination.

A student without acceptable I.D. will be required to complete an Identification Form. The form indicates that there is no guarantee that the examination paper will be graded if any discrepancies in identification are discovered after verification with the student's file. A Student who refuses to produce identification or who refuses to complete and sign the Identification Form is not permitted to write the examination.

EXAMINATION RULES

(1) Students late in arriving will not normally be admitted after one-half hour of the examination time has passed.

(2) No candidate will be permitted to leave the examination room until one-half hour has elapsed after the opening of the examination, nor during the last 15 minutes of the examination. All candidates remaining during the last 15 minutes of the examination period must remain at their desks until their papers have been collected by an invigilator.

(3) All inquiries and requests must be addressed to supervisors only.

(4) Candidates are strictly cautioned against:

(a) speaking to other candidates or communicating with them under any circumstances whatsoever;

(b) bringing into the examination room any textbook, notebook or memoranda not authorized by the examiner;

(c) making use of calculators and/or portable computing machines not authorized by the instructor;

(d) leaving answer papers exposed to view;

(e) attempting to read other student's examination papers.

The penalty for violation of these rules is suspension or expulsion or such other penalty as may be determined.

(5) Candidates are requested to write on both sides of the page, unless the examiner has asked that the left hand page be reserved for rough drafts or calculations.

(6) Discarded matter is to be struck out and not removed by mutilation of the examination answer book.

(7) Candidates are cautioned against writing in their answer book any matter extraneous to the actual answering of the question set.

(8) The candidate is to write his/her name on each answer book as directed and is to number each book.

(9) A candidate must report to a supervisor before leaving the examination room.

(10) Answer books must be handed to the supervisor-in-charge promptly when the signal is given. Failure to comply with this regulation will be cause for rejection of an answer paper.

(11) If during the course of an examination a student becomes ill or receives word of a domestic affliction, the student should report at once to the supervisor, hand in the unfinished paper and request that it be cancelled. If physical and/or emotional ill health is the cause, the student must report at once to a physician/counsellor so that subsequent application for a deferred examination is supported by a completed Physician/Counsellor Statement form. Students can consult professionals at University Health Services or University Counselling Services during normal working hours or consult their physician/counsellor in the community.

Should a student write an examination, hand in the paper for marking, and later report extenuating circumstances to support a request for cancellation of the paper and for another examination, such a request will be denied.

(12) Smoking during examinations is strictly prohibited.

Question 1 [*8 pts***]**

The message signal $m(t)$, whose spectrum is shown in Figure 1 below, is passed through the system in Figure 2 below, where $f_c = 100\,kHz$, $f_a = 1kHz$, $f_b = 5\,kHz$ and $f_0 = \left(f_a + f_b\right)/2 = 3\,kHz$. The low-pass filters are identical with a cutoff frequency equal to $\left(f_b - f_a\right)/2 = 2\,kHz$.

a- Sketch the frequency spectra of the signals $x_1(t)$, $y_1(t)$, $x_2(t)$, $y_2(t)$. **Indicate all the center frequencies, bandwidths, and amplitudes of interest for all the components of these signals**. *[2 pts]*

b- Sketch the frequency spectra of the output signal $s(t)$. **Indicate all the center frequencies, bandwidths, and amplitudes of interest for all the components of these signals**. *[2 pts]*

c- What type of modulation is obtained at the output? *[2 pts]*

d- Propose a demodulator block diagram that allows to obtain the message $m(t)$ from the signal $s(t)$. *[2 pts]*

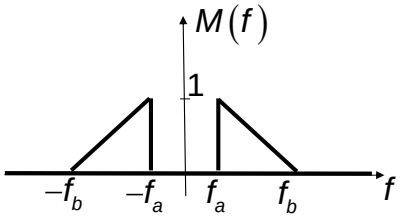

Figure 1

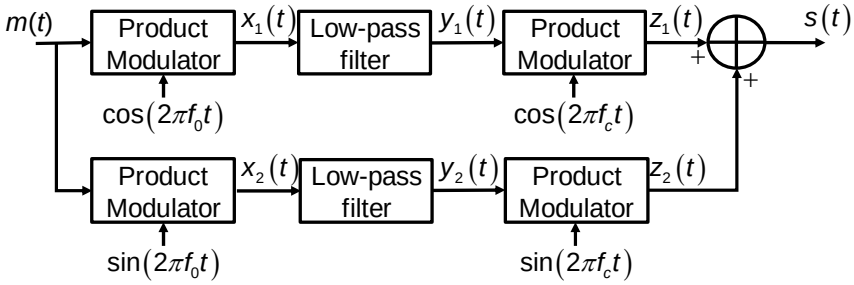

Figure 2

Question 2 [*10 pts***]**

A modulated signal is given by:

$$s(t) = 10\cos\left(2\pi f_c t\right) - 2\sin\left(2\pi\left(f_c - f_m\right)t\right) + 2\sin\left(2\pi\left(f_c + f_m\right)t\right)$$

where, the carrier frequency is $f_c = 1$ MHz the message frequency is $f_m = 10$ kHz .

a- Sketch the phasor diagram of this modulated signal. **Indicate all amplitudes and phases of interest.** *[2 pts]*

b- What type of modulation is this? (AM or FM). *[2 pts]*

c- Determine the modulation index of this modulation. *[2 pts]*

d- Calculate the ratio of the power in the sidebands to the power in the carrier (assuming $1\ \Omega$ resistor). *[2 pts]*

e- Propose a block diagram of a system that performs the demodulation operation of this signal. *[2 pts]*

Question 3 [*8 pts***]**

A FM modulation system has a modulation index $\beta = 5\ rad$.

a- The SNR_C at the input of the FM receiver is equal to 20 dB. What is the SNR at the output of the FM receiver if no pre-emphasis and de-emphasis filters are used? *[2 pts]*

This FM modulation system uses a pair of pre-emphasis and de-emphasis filters defined by:

$$H_{pe}(f) = 1 + j\frac{f}{f_0} \quad \text{and} \quad H_{de}(f) = \frac{1}{1 + j\frac{f}{f_0}}$$

where $f_0 = 2.5\,kHz$, the message bandwidth $W = 15\,kHz$.

b- What is the value of the improvement factor *I* in the output signal-to-noise ratio of the FM receiver produced by using this pair of pre-emphasis and de-emphasis filters? *[2 pts]*

c- What is the SNR at the output of the FM receiver taking into account the effect of the pre-emphasis and de-emphasis filters? *[2 pts]*

d- By how many decibels this FM system is superior to a DSB system? *[2 pts]*

Question 4 [*10 pts***]**

To generate a wideband FM signal, the system in Figure 3 is used. First a narrowband FM signal with frequency sensitivity of 0.1 kHz per volt is generated from a cosine modulating message $m(t) = 2\cos(2000\pi t)$. Then frequency multiplications are used to spread the signal bandwidths. The output frequency from the oscillator is f_0 = 100 kHz.

a. Determine the time domain expression and sketch the phasor diagram of $v_1(t)$. *[3 pts]*

b. Determine the expression of the frequency domain representation and sketch the frequency spectrum of the narrowband modulated signal $v_1(t)$. *[3 pts]*

c. Determine the values of *N* and *M* that are necessary to generate an FM signal at a carrier frequency of $f_c = 40\,MHz$ and modulation index of $\beta = 4$ rad. *[2 pts]*

d. What filter needs to be used at the output of this system to obtain the desired FM signal? **(Provide the type of filter and its passband frequencies)** *[2 pts]*

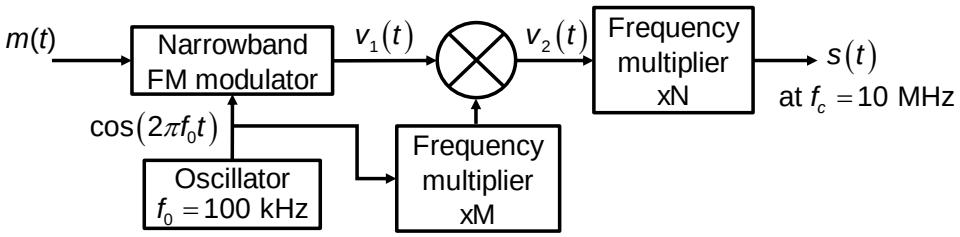

Figure 3

Question 5 [*8 pts*]

For practical considerations, a pulse $g(t)$ in a PAM signal is assumed to have the shape shown in Figure 3. The amplitude is $A=1$, and the pulse duration is $T=4$ *ms*.

a. Determine the impulse response $h(t)$ of a filter matched to this signal and sketch it. *[2 pts]*

b. What is the peak value of the matched filter output? *[2 pts]*

c. What is the expression of the peak-pulse signal-to-noise ratio if a white noise with double-sided power spectral density of $N_o/2=10^{-4}\ W/Hz$ is added to the signal before the matched filter? *[2 pts]*

d. Compare the peak-pulse signal-to-noise ratio in this case to the ideal case where the pulse has zero rising and falling times, the same amplitude ($A=1$), and the same pulse duration ($T=4$ *ms*). *[2 pts]*

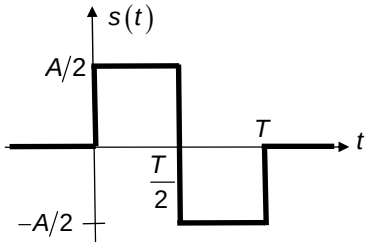

Figure 4

Question 6 [*6 pts***]**

The FM signal $s(t)$ is applied to the discriminator shown in the Figure below. The discriminator is composed of an RC filter followed by an envelope detector. The resistance R is much smaller than the reactance of the capacitor for all significant frequencies. The envelope detector is assumed to be ideal and with infinite input impedance (does not load the filter).

a- Determine the transfer function $H(f)$ of the RC filter. *[3 pts]*

b- Determine the resulting signal at the envelope detector output., assuming that $|k_f m(t)| < f_c$ for all values of t. *[3 pts]*

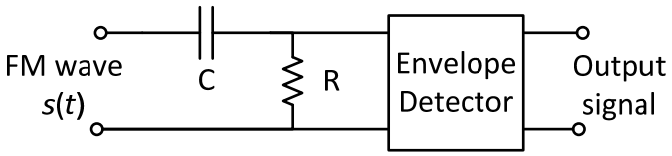

Figure 5

Trigonometric Identities

$$\cos(a+b)=\cos(a)\cos(b)-\sin(a)\sin(b)$$
$$\cos(a-b)=\cos(a)\cos(b)+\sin(a)\sin(b)$$
$$\sin(a+b)=\sin(a)\cos(b)+\cos(a)\sin(b)$$
$$\sin(a-b)=\sin(a)\cos(b)-\cos(a)\sin(b)$$
$$\cos(a)\cos(b)=\frac{1}{2}\left[\cos(a-b)+\cos(a+b)\right]$$
$$\sin(a)\sin(b)=\frac{1}{2}\left[\cos(a-b)-\cos(a+b)\right]$$
$$\sin(a)\cos(b)=\frac{1}{2}\left[\sin(a+b)+\sin(a-b)\right]$$
$$\cos\left(a+\frac{\pi}{2}\right)=-\sin(a)$$
$$\cos\left(a-\frac{\pi}{2}\right)=\sin(a)$$
$$\sin\left(a+\frac{\pi}{2}\right)=\cos(a)$$
$$\sin\left(a-\frac{\pi}{2}\right)=-\cos(a)$$

First Order Taylor Series Approximations

If $a \ll 1$ rad

Then: $\cos(a)\simeq 1$

$\sin(a)\simeq a$

Fourier Transform

$$\text{rect}\left(\frac{t-T/2}{T}\right)\xrightarrow{\mathcal{F}}T\,\text{sinc}\left(\pi fT\right)\text{e}^{-j\pi fT}$$
$$\frac{d\left(g(t)\right)}{dt}\xrightarrow{\mathcal{F}}j2\pi f\cdot G(f)$$

Indefinite Integrals

$$\int\frac{x^2dx}{a^2+b^2x^2}=\frac{x}{b^2}-\frac{a}{b^3}\tan^{-1}\left(\frac{bx}{a}\right)$$