Name..ID...........................Section...............Seat No.............

Sirindhorn International Institute of Technology
Thammasat University

Final Examination: Semester 1 / 2016

Course Title: ECS332 (Principles of Communications)

Instructor: Asst. Prof. Dr.Prapun Suksompong

Date/Time: December 21, 2016 / 13:30-16:30

Instructions:

- This examination has ....11.... pages (including this cover page).
- Conditions of Examination:

  ....Closed book

  (No dictionary, ☐ No calculator ☑ Calculator (e.g. FX-991MS) allowed)

  ....Open book

  .....✓.....**Semi-Closed book** (......1........sheet(s) ☐ 1 page ☑ both sides of A4 paper note)

  This sheet must be hand-written. It should be **submitted with the exam**.
  Indicate your name and ID in the upper-right corner of each page (in portrait orientation).
- **Read these instructions and the questions carefully**.
- Students are not allowed to be out of the examination room during examination. Going to the restroom may result in score deduction.
- Turn off all communication devices (mobile phone, etc.) and place them with other personal belongings in the area designated by the proctors or outside the test room.
- Write your name, student ID, section, and seat number clearly in the spaces provided on the top of this sheet. Then, write your **first name and the last three digits of your ID** in the spaces provided on the top of each page of your examination paper, starting from page 2.
- The back of each page will not be graded. If necessary, it can be used for calculations of problems that do not require explanation.
- The examination paper is not allowed to be taken out of the examination room. Violation may result in score deduction.
- Unless instructed otherwise, ***write down all the steps*** that you have done to obtain your answers.
  - When applying formula(s), state clearly which formula(s) you are applying before plugging-in numerical values.
  - You may not get any credit even when your final answer is correct without showing how you get your answer.
  - Formula(s) not discussed in class can be used. However, derivation must also be provided.
  - **Exceptions**:
    - Problems that are labeled with "ENRPr" (Explanation is not required for this problem.)
    - Parts that are labeled with "ENRPa" (Explanation is not required for this part.)

    These problems/parts are graded solely on your answers. There is no partial credit and it is not necessary to write down your explanation.
- When not explicitly stated/defined, all notations and definitions follow ones given in lecture.
  - For example, the sinc function is defined by $\text{sinc}(x) = (\sin x)/x$; time is denoted by t and frequency is denoted by f. The unit of t is in seconds and the unit of f is in Hz.
- Some points are reserved for *accuracy* of the answers and also for reducing answers into their *simplest* forms. Watch out for roundoff error.
- Points marked with * indicate challenging problems.
- Do not cheat. Do not panic. **Allocate your time wisely**.

Problem 1. (11 pt) Consider an AM transmitter whose transmitted signal is constructed from the message by

$$x_{\mathrm{AM}}(t) = 5\cos(100\pi t) + m(t)\cos(100\pi t).$$

(a) (9 pt, ENRPr) We consider three cases with different modulation indexes. Their values are specified in the first column of the table below.

Suppose the message is $m(t) = \alpha\cos(10\pi t)$.

(i) (3 pt) For each case, find the value of α which yields the specified modulation index. Put your answer in the second column of the table.

(ii) (3 pt) In the third column of the table, indicate (by writing a Y(es) or an N(o)) whether phase reversal occurs in each case.

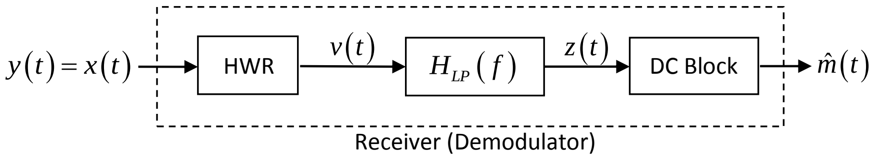
(iii) (3 pt) In the fourth column, calculate the corresponding value of the power efficiency.

Mod. index	α	Phase Reversal	Power Eff.
75%			
100%			
125%			

(b) (1 pt) Suppose $m(t) = \cos(10\pi t) + 2\cos(30\pi t)$. What is the value of the modulation index?

(c) (1 pt) What is the best value of power efficiency that we can achieve without phase reversal?

Problem 2. (5 pt) Consider an AM receiver shown in the figure below:



Suppose the received signal $y(t)$ is the same as the transmitted signal which is given by

$$x(t) = (6 + 16m(t))\cos(2\pi f_c t) \quad \text{where} \quad f_c = 10^5 \text{ Hz}.$$

As usual, the message is band-limited to $B \ll f_c$. The half-wave rectifier input-output relation is described by a function $w(x) = \begin{cases} x, & x \geq 0, \\ 0, & x < 0. \end{cases}$

The frequency response of the filter is $H_{LP}(f) = \begin{cases} g, & |f| \leq B \\ 0, & \text{otherwise.} \end{cases}$

(a) (2 pt) The receiver above is a *rectifier detector*. To recover $m(t)$ back by this receiver, state the restriction that we need to impose on the message $m(t)$.

(b) (3* pt) Assume that appropriate restriction was made in part (a).

(i) (2 pt) Find $z(t)$. (Your answer will still depend on the constant g.)

(ii) (1 pt) Find the constant g which makes $\hat{m}(t) = m(t)$.

Problem 3. (5 pt, ENRPr) In QAM system, the transmitted signal is of the form

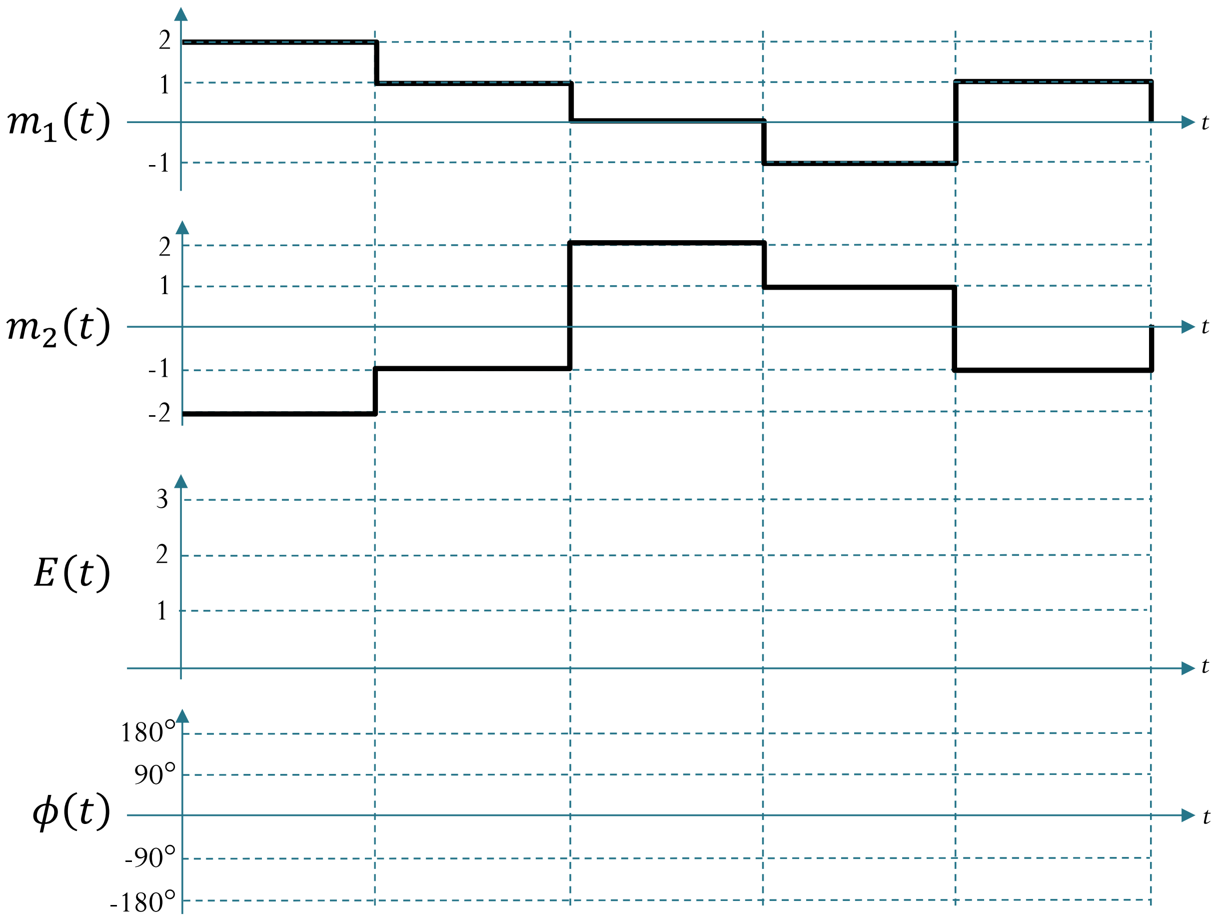
$$x_{\text{QAM}}(t) = m_1(t)\sqrt{2}\cos(2\pi f_c t) + m_2(t)\sqrt{2}\sin(2\pi f_c t).$$

Here, we want to express $x_{\text{QAM}}(t)$ in the form

$$x_{\text{QAM}}(t) = \sqrt{2}E(t)\cos(2\pi f_c t + \phi(t)),$$

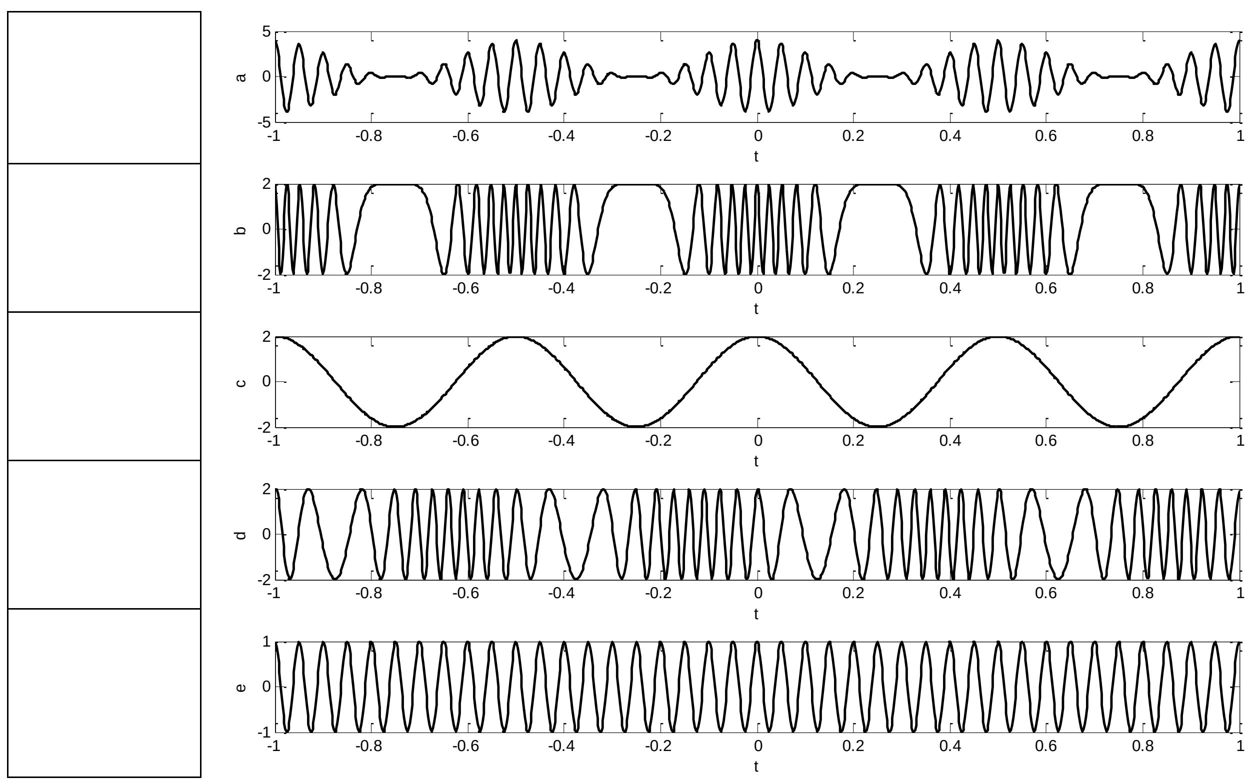
where $E(t) \geq 0$ and $\phi(t) \in (-180°, 180°]$.

Consider $m_1(t)$ and $m_2(t)$ plotted in the figure below. Draw the corresponding $E(t)$ and $\phi(t)$.



Problem 4. (7 pt) Consider the five plots below. One of them is the baseband message signal $m(t)$. One of them is the sinusoid $\cos(2\pi f_c t)$ at the carrier frequency f_c. The message modulates the carrier signal $A\cos(2\pi f_c t)$, producing the other three plots which are the modulated signals $x_{\mathrm{AM}}(t)$, $x_{\mathrm{FM}}(t)$, and $x_{\mathrm{PM}}(t)$.

(a) (5 pt, ENRPa) In the boxes provided below, write down appropriate signal name ($m(t)$, $\cos(2\pi f_c t)$, $x_{\mathrm{AM}}(t)$, $x_{\mathrm{FM}}(t)$, and $x_{\mathrm{PM}}(t)$) to the left of its corresponding plot.



(b) (2 pt) What is the value of the modulation index μ used in $x_{\mathrm{AM}}(t)$?

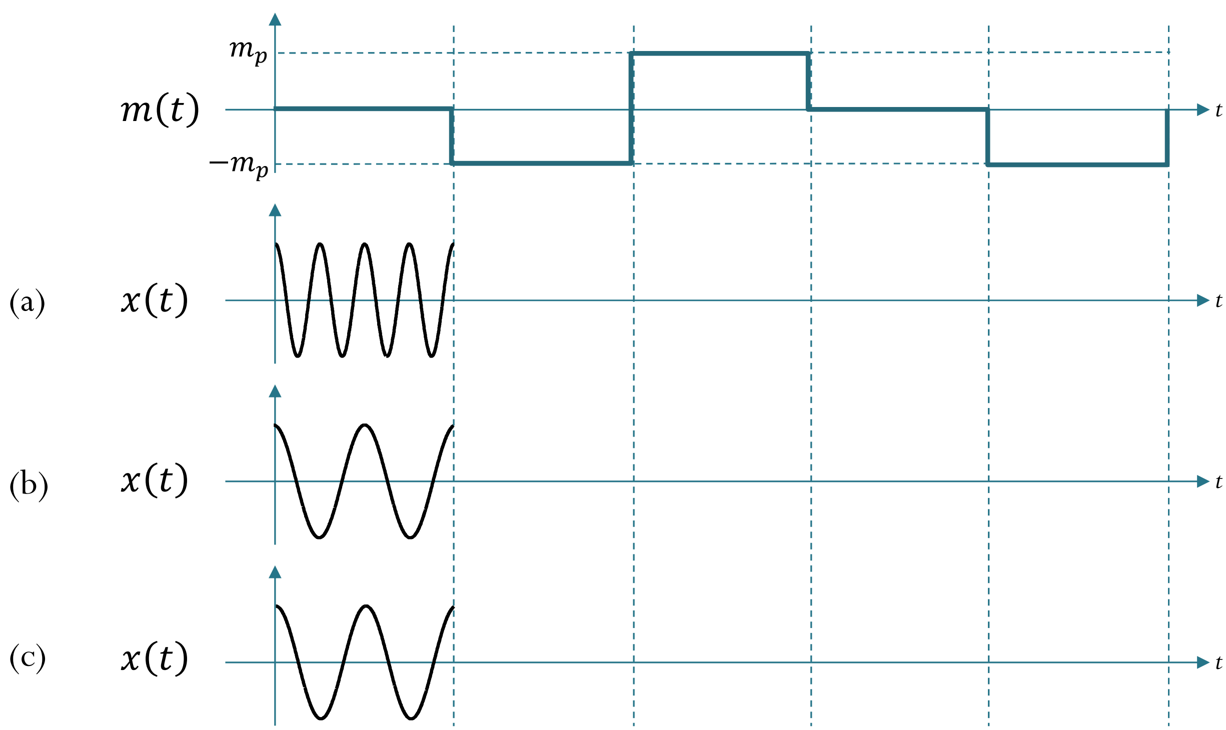
Problem 5. (13 pt, ENRPr) Consider the message $m(t)$ plotted below. For each part, ((a), (b), and (c)) below, your task is to carefully draw the remaining parts of the plots of the transmitted signals $x(t)$. The values of $x(t)$ during the first time interval were shown. Assume that

in part (a), the transmitted signal is generated using FM,

in part (b), the transmitted signal is generated using PM with $k_p = \frac{\pi}{m_p}$,

in part (c), the transmitted signal is generated using PM with $k_p = \frac{\pi}{2m_p}$.

For parts (b) and (c), you do not have to work on the last two intervals.



Make sure that the important "features" of the graphs are emphasized and labeled clearly.

Problem 6. (6 pt, ENRPr) Determine the Nyquist sampling rate R_{Nyquist} for the signals in the table below.

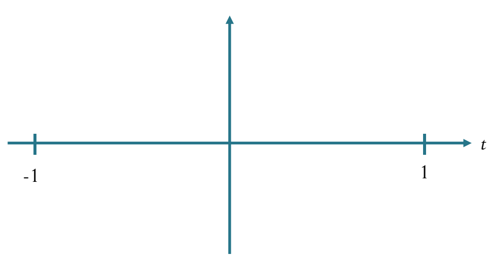
	R_{Nyquist}
$G(f) = \begin{cases} 1, & \lvert f \rvert \le 100, \\ 0, & \text{otherwise.} \end{cases}$	
$g(t) = \sin(300\pi t)$	
$g(t) = \text{sinc}(300\pi t)$	
$g(t) = \text{sinc}^2(300\pi t)$	
$g(t) = \text{sinc}(300\pi t) + \text{sinc}^2(180\pi t)$	
$g(t) = \text{sinc}(100\pi t)\,\text{sinc}(200\pi t)$	

Problem 7. (10 pt, ENRPr) Find the "perceived" frequency when we sample each of the following signals at sampling rate $f_s = 33$ [Sa/s].

$g(t)$	"perceived" frequency
$\cos(2\pi(123456)t)$	
$\cos(2\pi(12345)t)$	
$e^{j2\pi(1234)t}$	
$e^{j2\pi(123)t}$	
$e^{-j2\pi(123)t}$	

Problem 8. (2* pt) Simplify the expression and plot the signal

$g_r(t) = \sum\limits_{n=-\infty}^{\infty} \cos\left(\frac{100\pi n}{49}\right) \text{sinc}\left(49\pi t - n\pi\right)$ for $t \in (-1, 1)$.



Problem 9. (10 pt) Consider a signal $g(t) = \text{sinc}(2\pi t)$.

(a) (1 pt) Is $g(t)$ time-limited?

(b) (1 pt) Is $g(t)$ band-limited?

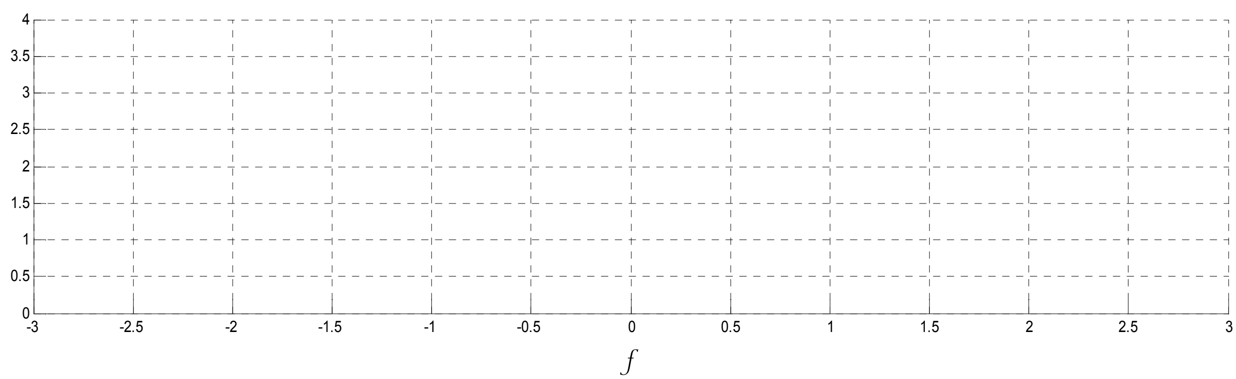
(c) (2 pt) Carefully sketch its Fourier transform $G(f)$.

(d) (2 pt) Find the Nyquist sampling rate.

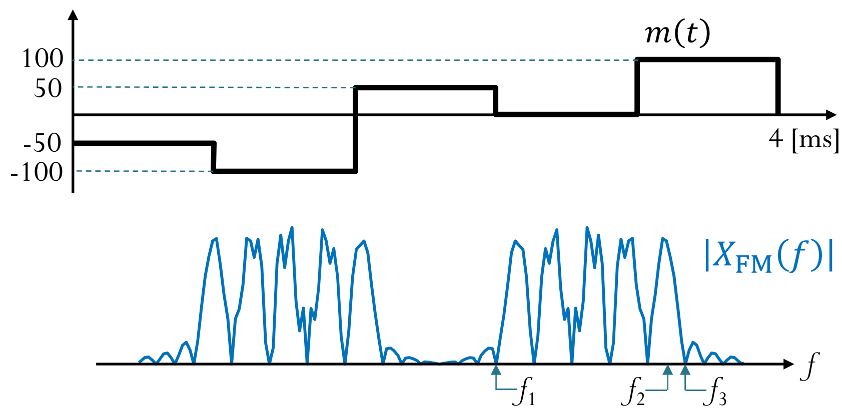
(e) (4 pt) Recall that the instantaneous sampled signal $g_\delta(t)$ is defined by

$$g_\delta(t) = \sum_{n=-\infty}^{\infty} g[n]\delta(t - nT_s)$$

where T_s is the sampling interval. Assume $T_s = 2/3$ [sec]. Let $G_\delta(f)$ be the Fourier transform of $g_\delta(t)$. Sketch $G_\delta(f)$ from $f = -3$ Hz to $f = 3$ Hz.



Problem 10. (6 pt, ENRPr) Consider the signal $x_{\mathrm{FM}}(t)$ where $f_c = 10$ [kHz], $A = 3$, and $k_f = 50$. (Recall that $x_{\mathrm{FM}}(t) = A\cos(2\pi f_c t + \phi + 2\pi k_f \int_{-\infty}^{t} m(\tau)d\tau)$.) The message $m(t)$ and the magnitude spectrum $|X_{\mathrm{FM}}(f)|$ of the modulated signal are shown below. Find the values of f_1, f_2, and f_3.



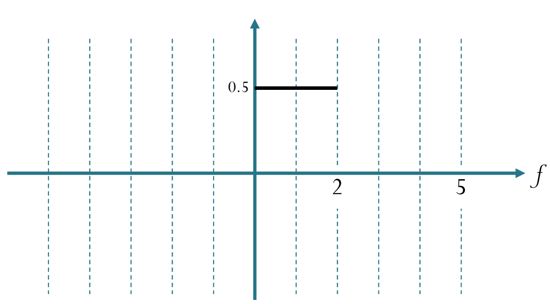
$f_1 =$ ________

$f_2 =$ ________

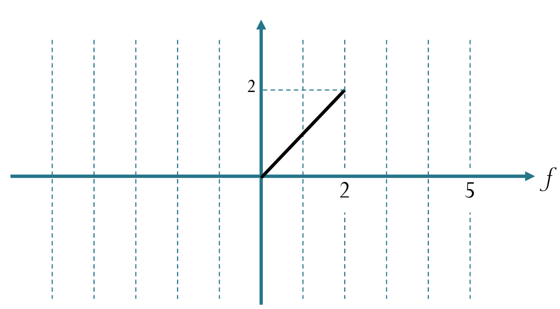
$f_3 =$ ________

Problem 11. (6 pt, ENRPr) In each part below, we want to find a Nyquist pulse $P(f)$ when the symbol "duration" is $T = \frac{1}{4}$. The value of $P(f)$ is given only in the frequency domain from $f = 0$ Hz to $f = 2$ Hz. Outside of the interval $[0, 2)$, you need to assign value(s) to $P(f)$ so that it becomes a Nyquist pulse. For simplicity, we also require that $p(t)$ is real-valued and even.

(a) Sketch a Nyquist pulse $P(f)$ with $P(f) = 0.5$ on $[0, 2)$.



(b) Sketch a Nyquist pulse $P(f)$ with $P(f) = f$ on $[0, 2)$.



Problem 12. (6 pt) In a PCM system, an analog message is sampled at $5,000$ [Sa/s] and then uniformly quantized into 128 different levels.

(a) (1 pt) What is the (theoretical) maximum frequency of the analog message that can be used under such system without aliasing?

(b) (2 pt) Calculate the bit rate of this system.

(c) (1 pt) Calculate the minimum required baseband transmission bandwidth.

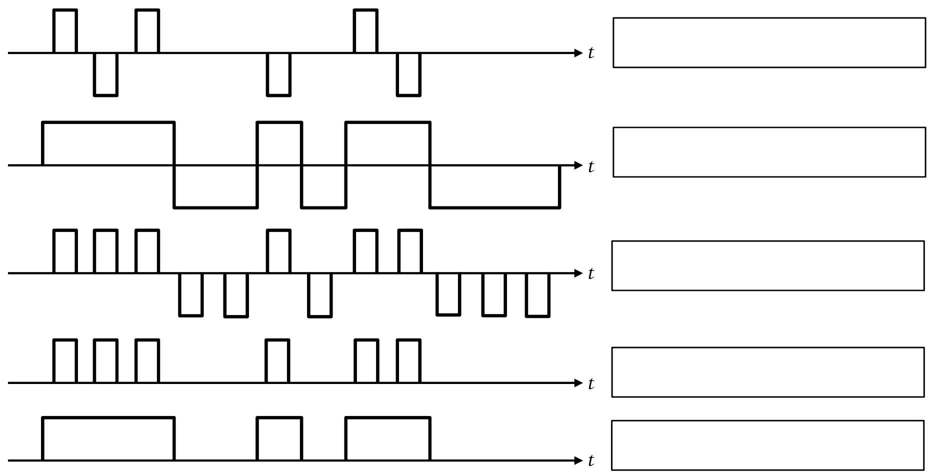
(d) (2 in) Determine the signal-to-quantization-noise power ratio in dB when the message is a full-load sinusoidal modulating wave.

Problem 13. (3 pt) In a digital PAM system, equally-likely message symbols are selected from an alphabet set $\mathcal{A} = \{-8, 8\}$. The pulse used in the transmitted signal is a Nyquist pulse. The additive white noise at each particular time instant is Gaussian with mean 0 and standard deviation 16. The noise and the message are independent. For each part below, leave your answer in terms of Q function(s) with positive argument(s).

(a) (2 pt) Find the symbol error probability when 0 is used as the threshold level for the decoding decision at the receiver.

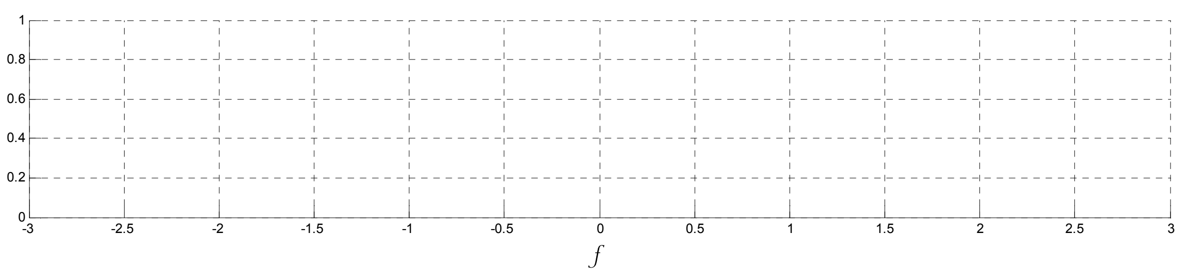
(b) (1* pt, ENRPa) Find the probability that the value of the received signal (the transmitted signal combined with the noise) at a particular time is > 8.

Problem 14. (5 pt, ENRPr) For each of the plots below, indicate which type of line code is being used. Put your answer in the provided box to the right of each plot. In all cases, the bit sequence used is 1 1 1 0 0 1 0 1 1 0 0 0.



Possible answers are "Unipolar RZ", "Unipolar NRZ", "polar RZ", "polar NRZ", "bipolar RZ", "bipolar NRZ", "Manchester"

Problem 15. (4 pt, ENRPr) Consider a raised cosine pulse $p_{\mathrm{RC}}(t;\alpha)$ and its Fourier transform $P_{\mathrm{RC}}(f;\alpha)$. Assume the rolloff factor $\alpha = 0.5$ and the symbol "duration" $T = 0.5$. Carefully sketch $P_{\mathrm{RC}}(f;\alpha)$.



Problem 16. (1 pt)

(a) (1 pt) Do not forget to submit your study sheet with your exam.

(b) Reminder: The (second) online self-evaluation form for this course is due by the end of today.