

# ECS 332: In-Class Exercise # 11 - Sol

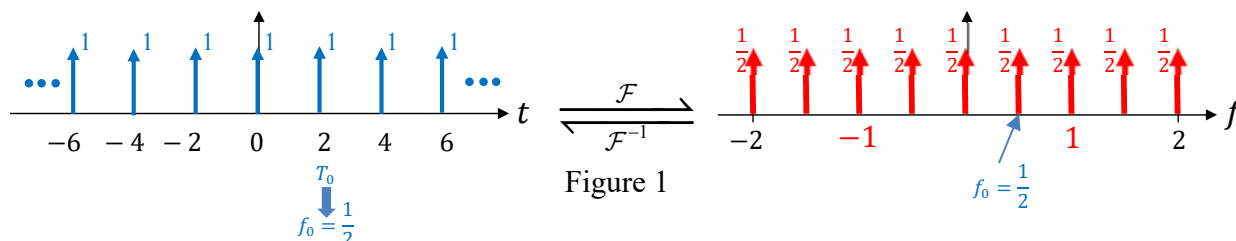
## Instructions

1. Separate into groups of no more than three students each.
2. Explanation is not required for this exercise [ENRE]
3. **Do not panic.**

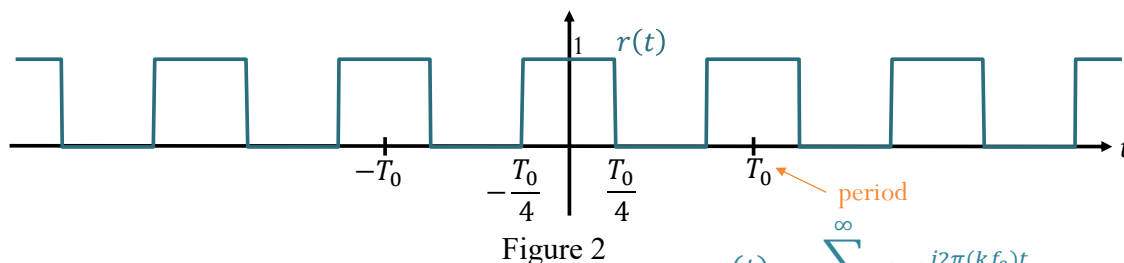
Date: <u>11</u> / <u>10</u> / <u>2019</u>			
Name			ID (last 3 digits)
Prapun			5 5 5

1. Consider the impulse train  $g(t)$  shown on the left in

Figure 1. Plot its Fourier transform  $G(f)$  from  $f = -2$  to  $f = 2$ .



2. Consider the rectangular pulse train  $r(t)$  shown in Figure 2.



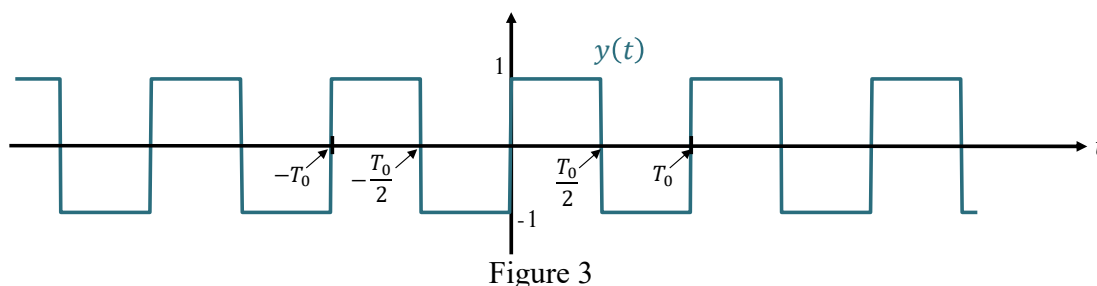
$$r(t) = \sum_{k=-\infty}^{\infty} c_k e^{j2\pi(kf_0)t}$$

Using Fourier series expansion, we can write  $r(t)$  in the form

$$\dots \boxed{\frac{-1}{3\pi}} e^{j2\pi(-3f_0)t} + \boxed{0} e^{j2\pi(-2f_0)t} + \boxed{\frac{1}{\pi}} e^{j2\pi(-f_0)t} + \boxed{\frac{c_0}{2}} + \boxed{\frac{c_1}{\pi}} e^{j2\pi(f_0)t} + \boxed{0} e^{j2\pi(2f_0)t} + \boxed{\frac{c_3}{3\pi}} e^{j2\pi(3f_0)t} + \dots$$

where  $f_0 = \frac{1}{T_0}$ . Write the appropriate Fourier coefficients in the boxes above.

3. Consider the rectangular pulse train  $y(t)$  shown in Figure 3.



Compare with Figure 1. Observe that  $y(t) = \alpha + \beta r(t - \gamma T_0)$ . Find the constants  $\alpha$ ,  $\beta$ , and  $\gamma$ .

$$\alpha = \underline{-1}, \beta = \underline{2}, \gamma = \underline{1/4}$$

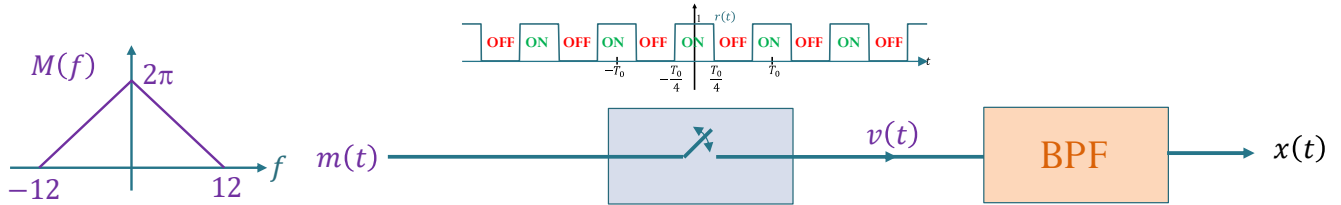
# ECS 332: In-Class Exercise # 12 - Sol

## Instructions

1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. [ENRE] Explanation is not required for this exercise.
3. **Do not panic.**

Date: <u>16</u> / <u>10</u> /2019			
Name	ID (last 3 digits)		
Prapun	5	5	5

1.  $M(f)$  is plotted on the left below. Consider a switching modulator:

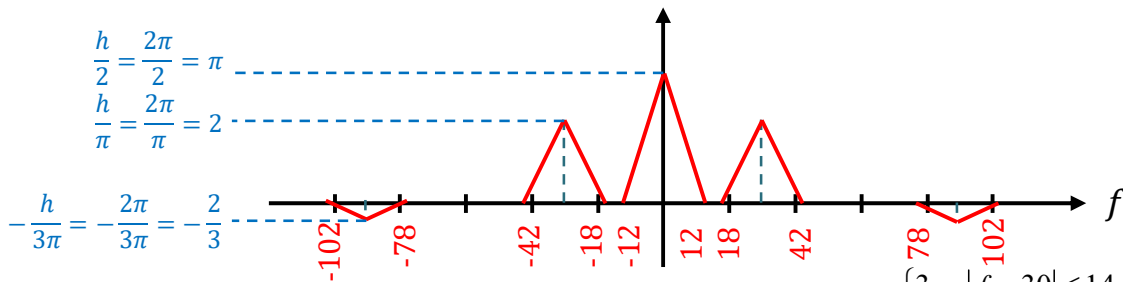


The switching box is operating at frequency 30 Hz with duty cycle 50%.

a. Plot  $V(f)$

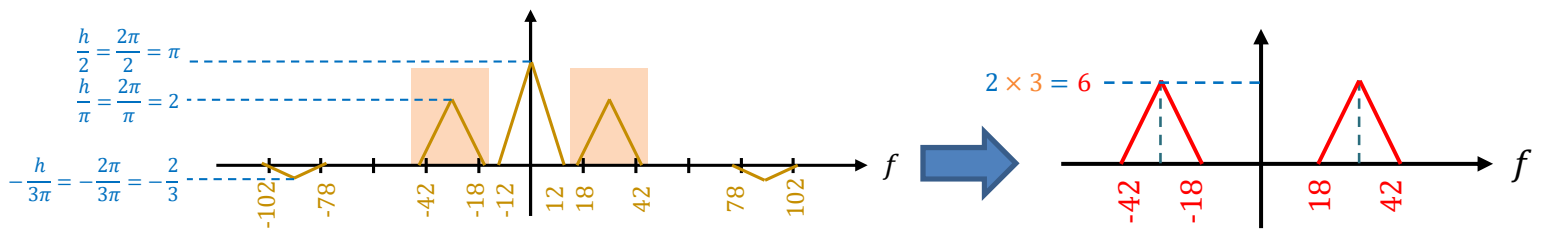
We have seen, in class, that

$$v(t) = m(t) \times r(t) \text{ where } r(t) = \frac{1}{2} + \frac{2}{\pi} \cos(2\pi f_0 t) - \frac{2}{3\pi} \cos(2\pi(3f_0)t) + \frac{2}{5\pi} \cos(2\pi(5f_0)t) + \dots$$

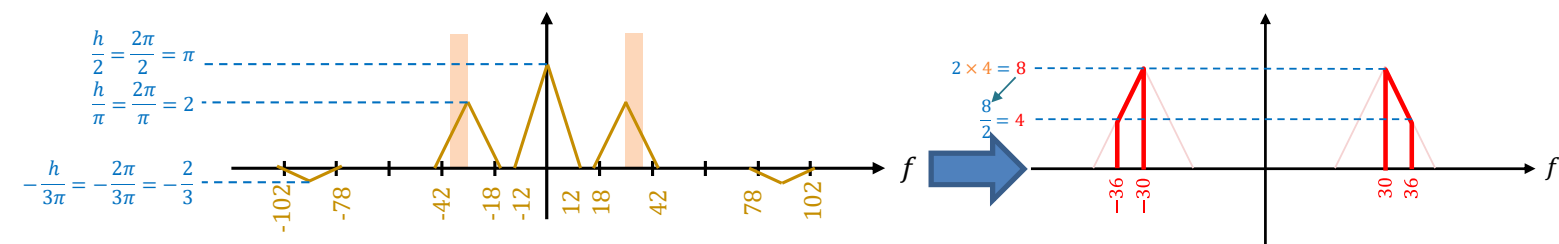


For the BPF, note that  $|f - a| \leq b$  is the same as  $-b \leq f - a \leq b$  which, in turn, is equivalent to  $-b + a \leq f \leq b + a$ .

b. Plot  $X(f)$  when the frequency response of the BPF is  $H(f) = \begin{cases} 3, & |f - 30| \leq 14, \\ 3, & |f + 30| \leq 14, \\ 0, & \text{otherwise.} \end{cases} = \begin{cases} 3, & 16 \leq f \leq 44, \\ 3, & -44 \leq f \leq -16, \\ 0, & \text{otherwise.} \end{cases}$



c. Plot  $X(f)$  when the frequency response of the BPF is  $H(f) = \begin{cases} 4, & |f - 33| \leq 3, \\ 4, & |f + 33| \leq 3, \\ 0, & \text{otherwise.} \end{cases} = \begin{cases} 4, & 30 \leq f \leq 36, \\ 4, & -36 \leq f \leq -30, \\ 0, & \text{otherwise.} \end{cases}$



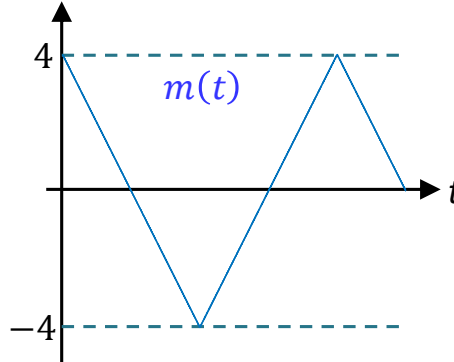
# ECS 332: In-Class Exercise # 13 - Sol

## Instructions

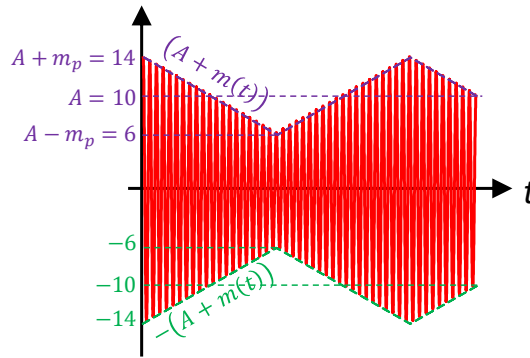
1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. [ENRE] Explanation is not required for this exercise.
3. **Do not panic.**

Date: <u>18</u> / <u>10</u> /2019			
Name			ID (last 3 digits)
Prapun			5 5 5

Consider an AM transmission of the message  $m(t)$  shown below:

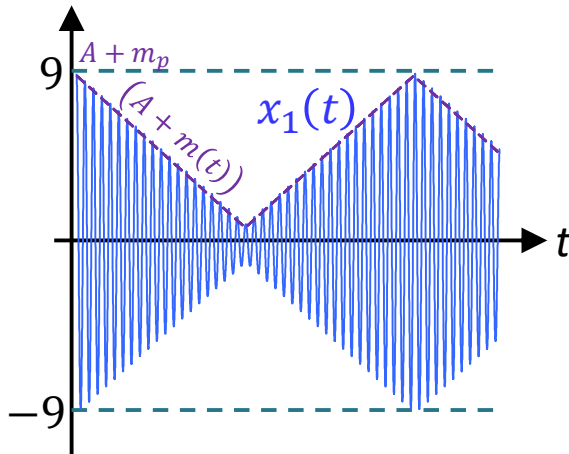


1. Assume that the carrier frequency  $f_c$  is large (enough). Plot the corresponding AM signal  $x_{AM}(t)$  when the modulation index is 40%



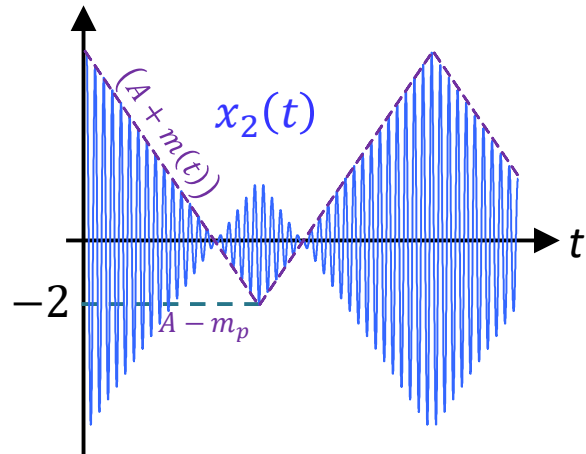
2. In each part below, the AM signal is plotted. Determine the modulation index used in each case.

(a)



$$\begin{aligned}
 A + m_p &= 9 \\
 A + 4 &= 9 \\
 A &= 5 \\
 \mu &= \frac{m_p}{A} = \frac{4}{5} = 0.8 = 80\%
 \end{aligned}$$

(b)



$$\begin{aligned}
 A - m_p &= -2 \\
 A - 4 &= -2 \\
 A &= 2 \\
 \mu &= \frac{m_p}{A} = \frac{4}{2} = 2 = 200\%
 \end{aligned}$$

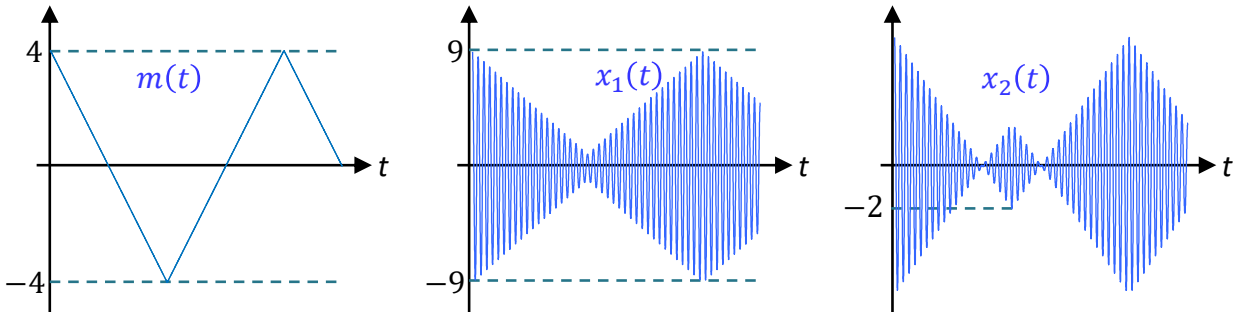
# ECS 332: In-Class Exercise # 14 - Sol

## Instructions

- Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
- Write down all the steps that you have done to obtain your answers. You may not get full credit even when your answer is correct without showing how you get your answer.
- Do not panic.**

Date: <u>25</u> / <u>10</u> / 2019			
Name			ID (last 3 digits)
Prapun			5 5 5

- Continue from the previous in-class exercise. We considered AM transmission of the message  $m(t)$  shown on the left below.



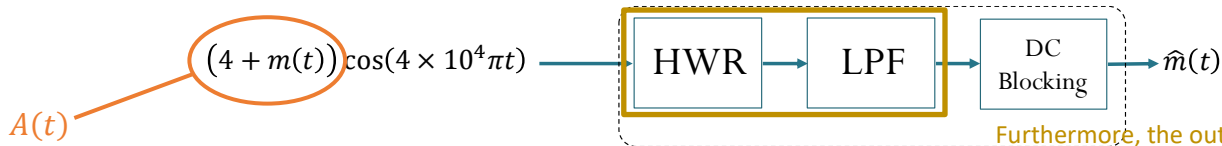
The middle and the rightmost plots show two AM signals  $x_1(t)$  and  $x_2(t)$  produced by using two different values of modulation index. During the previous in-class exercise, we have calculated the values of  $A$  and  $\mu$ . They are summarized in the table below.

Suppose  $m(t)$  is a periodic triangular wave with average power  $\langle m^2(t) \rangle = \frac{16}{3}$ .

Calculate the corresponding value of the power efficiency for each case.

$x_{AM}(t)$	$A$	$\mu$	Power Efficiency
$x_1(t)$	5	80%	$\text{Eff} = \frac{\frac{P_m}{2}}{\frac{A^2}{2} + \frac{P_m}{2}} = \frac{1}{\frac{A^2}{P_m} + 1} = \frac{1}{\frac{5^2}{16/3} + 1} = \frac{16}{91} \approx 0.1758 = 17.58\%$
$x_2(t)$	2	200%	$\text{Eff} = \frac{\frac{P_m}{2}}{\frac{A^2}{2} + \frac{P_m}{2}} = \frac{1}{\frac{A^2}{P_m} + 1} = \frac{1}{\frac{2^2}{16/3} + 1} = \frac{4}{7} \approx 0.5714 = 57.14\%$

- [ENRPr] Consider a rectifier demodulator shown below.



In class, we have shown that, if  $A(t)$  is always nonnegative, this combination is equivalent to a switching demodulator whose ON time is synchronized to the nonnegative part of the incoming sinusoidal signal.

Furthermore, the output is  $\frac{g}{\pi} A(t)$ . Here,

Rectifier Demodulator  $A(t) = 4 + m(t)$ . Therefore, the output of

Assume that  $m(t)$  has 0 average and that it is band-limited to  $B = 5$  kHz. this part is  $\frac{4g}{\pi} + \frac{g}{\pi} m(t)$ .

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

Finally, the DC blocking box removes the DC component. Here, because we assume that  $\langle m(t) \rangle = 0$ , the DC component is

Assume that  $m(t) \geq -4$  at all time.

$$\langle \frac{4g}{\pi} + \frac{g}{\pi} m(t) \rangle = \frac{4g}{\pi} + \frac{g}{\pi} \langle m(t) \rangle = \frac{4g}{\pi}$$

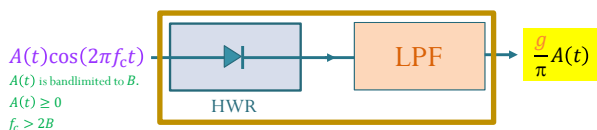
Find the value of the gain  $g$  which makes  $\hat{m}(t) = m(t)$ :

So,

$$g = \underline{\pi}$$

$$\hat{m}(t) = \frac{4g}{\pi} + \frac{g}{\pi} m(t) - \frac{4g}{\pi} = \frac{g}{\pi} m(t)$$

To make  $\hat{m}(t) = m(t)$ , we need  $g = \pi$ .



$A(t)$  is bandlimited to  $B$ .  
 $A(t) \geq 0$   
 $f_c > 2B$

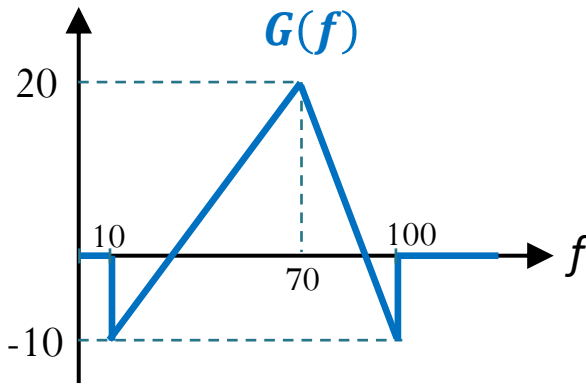
# ECS 332: In-Class Exercise # 15 - Sol

## Instructions

1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. Write down all the steps that you have done to obtain your answers. You may not get full credit even when your answer is correct without showing how you get your answer.
3. **Do not panic.**

Date: <u>30</u> / <u>10</u> /2019			
Name			ID (last 3 digits)
Prapun			5 5 5

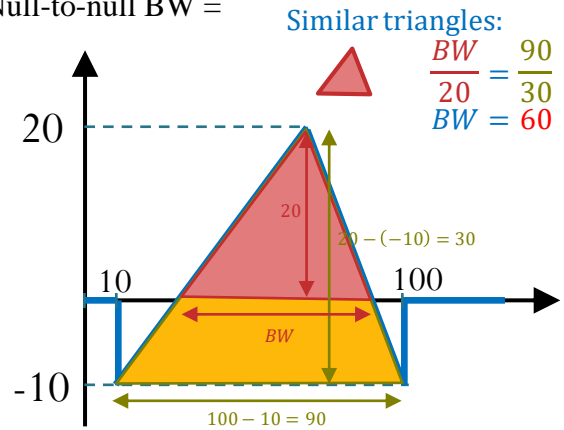
1. Find the bandwidth (BW) values for the signal below.  
Note that the signal is even and real-valued in both domains and therefore we show only the positive-frequency side.



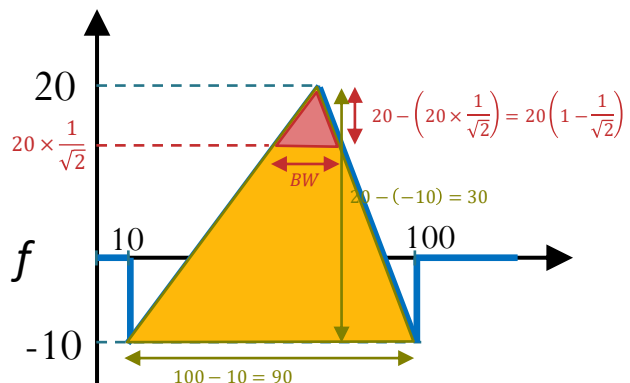
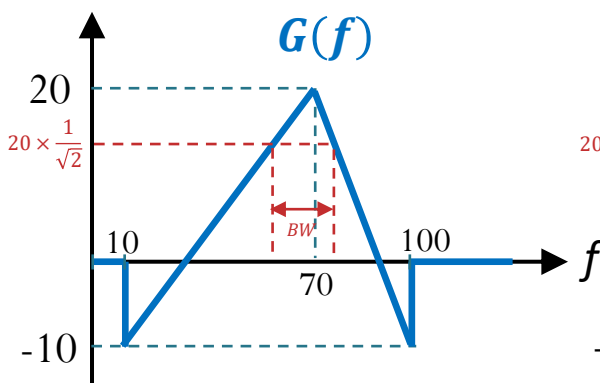
Absolute BW =

$$100 - 10 = 90.$$

Null-to-null BW =



3-dB BW (half-power BW) =



# ECS 332: In-Class Exercise # 16 - Sol

## Instructions

1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. ENRE (Explanation is not required for this exercise.)
3. **Do not panic.**

Date: <u>01</u> / <u>11</u> / 2019			
Name			ID (last 3 digits)
Prapun			5 5 5

1. 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

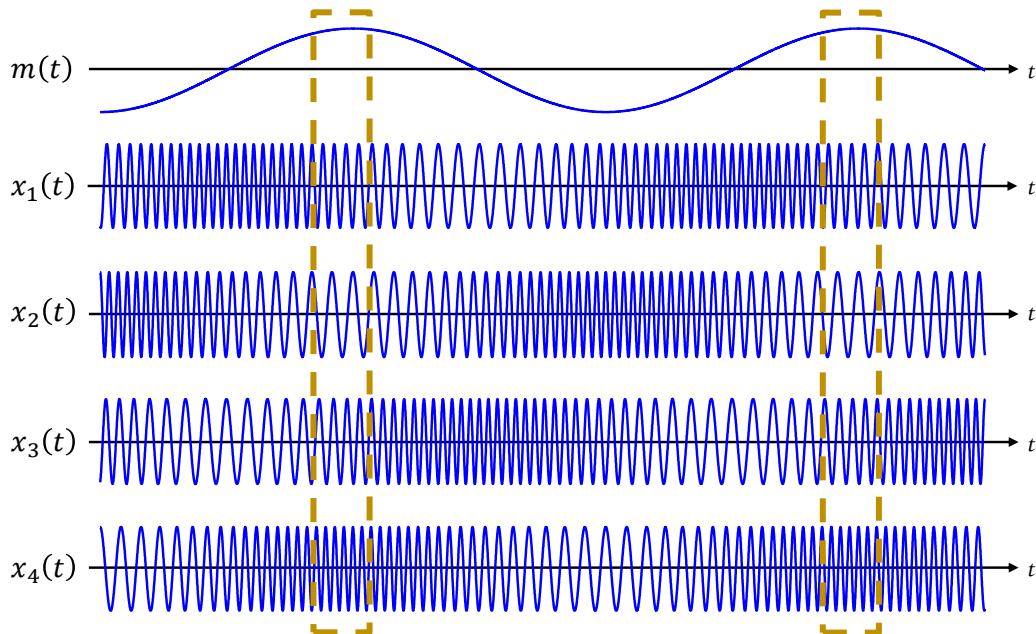
$$x_{\text{QAM}}(t) = \sqrt{2}E(t)\cos(2\pi f_c t + \phi(t)),$$

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

This problem assumes the messages are piecewise constant. Their values during three time intervals are listed below. Find the values of  $E(t)$  and  $\phi(t)$  during the corresponding time intervals.

Intervals	$m_1(t)$	$m_2(t)$	$E(t)$	$\phi(t)$	$m_1 - jm_2$
$0 \leq t < 1$	-1	-1	$\sqrt{2}$	$135^\circ$	$1 + j = \sqrt{2} \angle 135^\circ$
$1 \leq t < 2$	0	5	5	$-90^\circ$	$-5j = 5 \angle -90^\circ$
$2 \leq t < 3$	-3	4	5	$-126.87^\circ$	$-3 - 4j \approx 5 \angle -126.87^\circ$

2. Consider five plots below. The top one is the baseband message signal  $m(t)$  that is used in the modulation to create an FM signal. Identify which plot is  $x_{\text{FM}}(t)$ .



$x_{\text{FM}}(t)$ :  $x_4(t)$

The “frequency” of the FM signal should follow the value of  $m(t)$ .

For example, during the time when  $m(t)$  has highest value should correspond to the time when FM signal has the highest frequency.

# ECS 332: In-Class Exercise # 17 - Sol

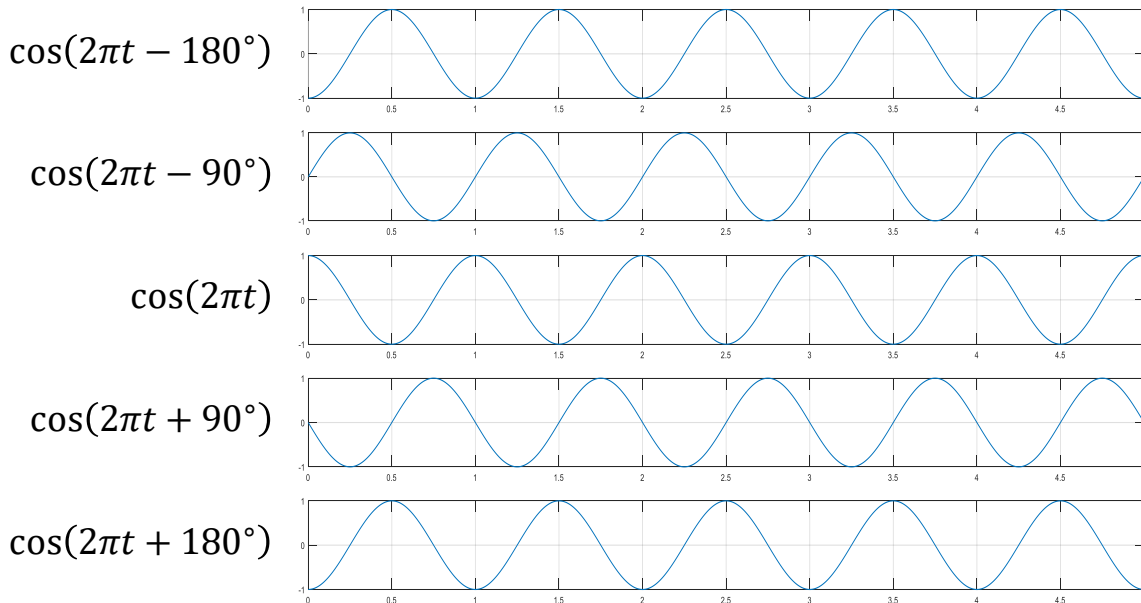
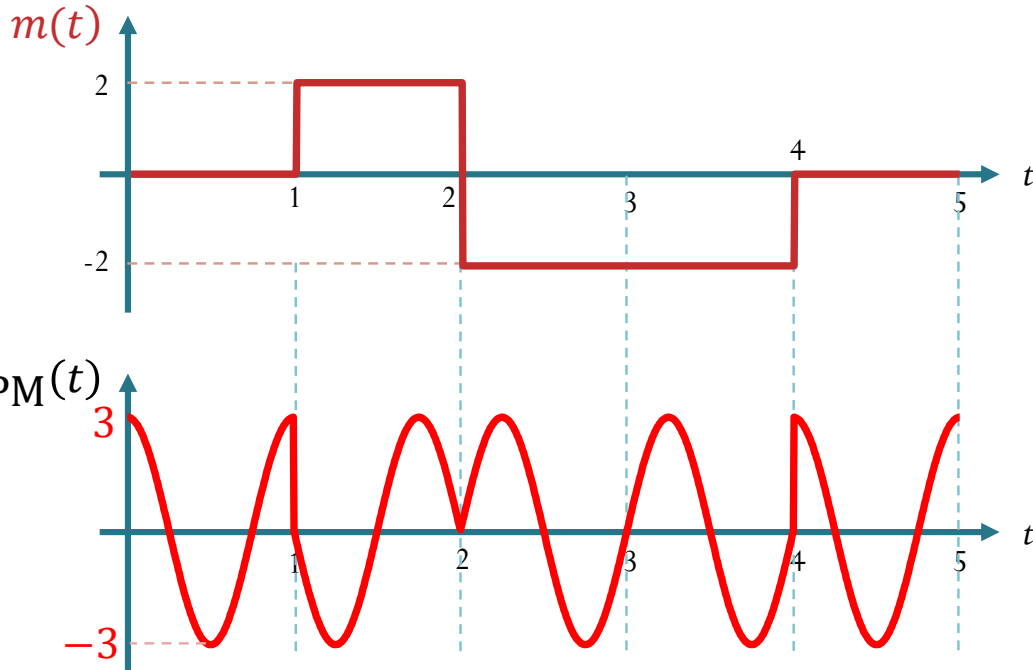
## Instructions

1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. ENRE (Explanation is not required for this exercise.)
3. **Do not panic.**

Date: <u>06</u> / <u>11</u> / 2019			
Name			ID (last 3 digits)
Prapun			5 5 5

1. A PM signal is created from the message  $m(t)$  by  $x_{PM}(t) = 3 \cos(2\pi f_c t + k_p m(t))$ .

Suppose  $f_c = 1$  and  $k_p = \frac{\pi}{4} = 45^\circ$ . For the message  $m(t)$  plotted below. Plot the corresponding  $x_{PM}(t)$ .



# ECS 332: In-Class Exercise # 18 - Sol

## Instructions

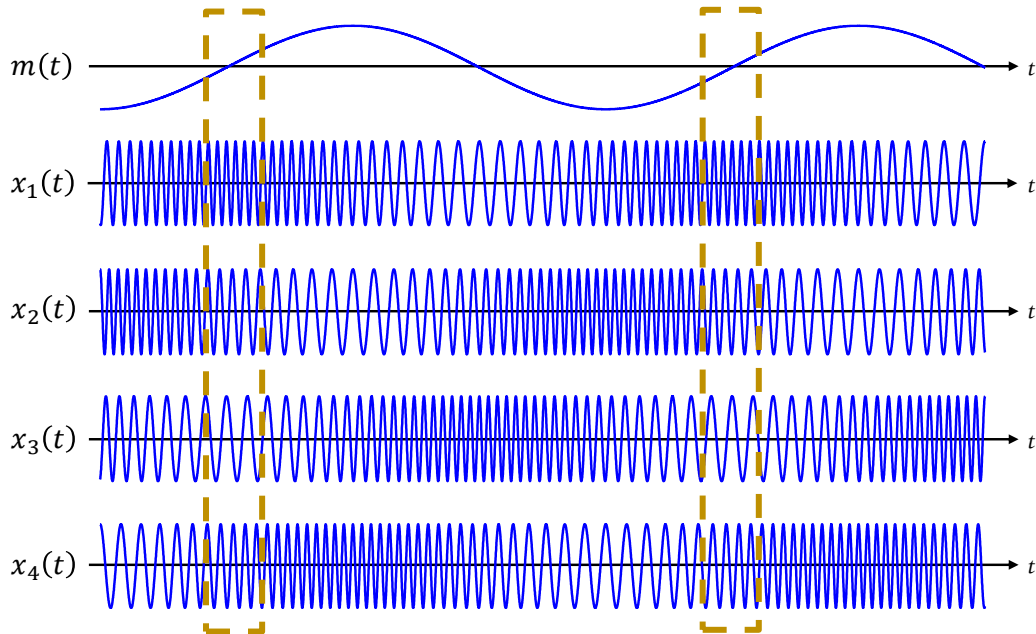
1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. Write down all the steps that you have done to obtain your answers. You may not get full credit even when your answer is correct without showing how you get your answer.
3. **Do not panic.**

Date: <u>08</u> / <u>11</u> / 2019			
Name			ID <small>(last 3 digits)</small>
Prapun			5 5 5

1. Consider a signal  $x(t) = 5 \cos(8\pi t^3 - 12\pi t^2 + 26\pi t)$ .  
Let  $f(t)$  be its instantaneous frequency. Find  $f(1)$ .

$$\begin{aligned} \theta(t) &= 8\pi t^3 - 12\pi t^2 + 26\pi t \\ \frac{d}{dt}\theta(t) &= 24\pi t^2 - 24\pi t + 26\pi \\ f(t) &= \frac{1}{2\pi} \frac{d}{dt}\theta(t) = 12t^2 - 12t + 13 \\ f(1) &= 12 - 12 + 13 = \mathbf{13}. \end{aligned}$$

2. [ENRPa] Consider five plots below. The top one is the baseband message signal  $m(t)$  that is used in the modulation to create a PM signal. Identify which plot is  $x_{\text{PM}}(t)$ .



$x_{\text{PM}}(t)$ :  $x_1(t)$

The "frequency" of the PM signal should follow the value of  $\frac{d}{dt}m(t)$ .

For example, the time when  $\frac{d}{dt}m(t)$  has highest value should correspond to the time when PM signal has the highest frequency.



# ECS 332: In-Class Exercise # 19 - Sol

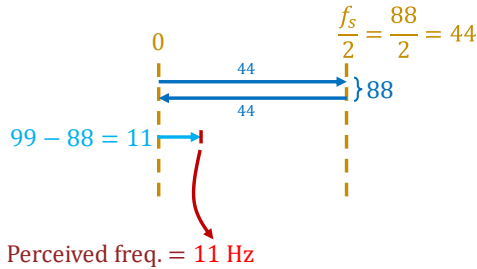
## Instructions

1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. Write down all the steps that you have done to obtain your answers. You may not get full credit even when your answer is correct without showing how you get your answer.
3. **Do not panic.**

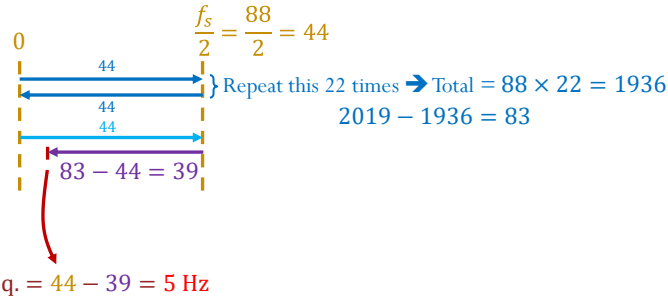
Date: <u>13</u> / <u>11</u> / 2019			
Name			ID (last 3 digits)
Prapun			5 5 5

1. Suppose we input  $\cos(2\pi(f_0)t)$  into plotspect with sampling rate  $f_s = 88$  samples/sec. Find the **“perceived” frequency** (the freq. that plotspect sees) when

a)  $f_0 = 99$

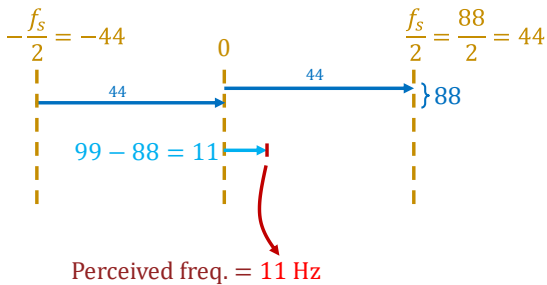


b)  $f_0 = 2019$

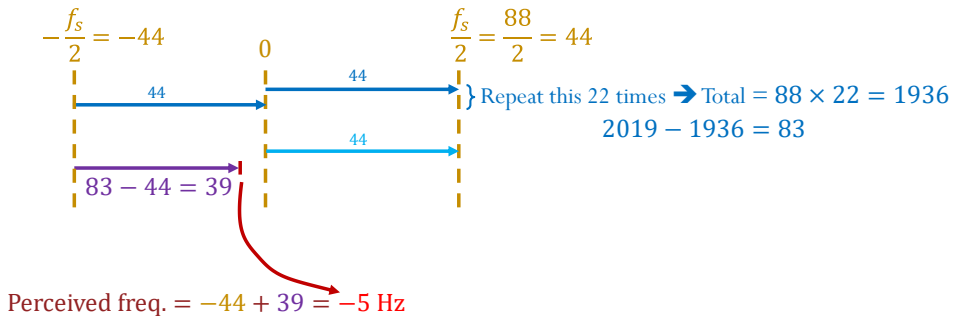


2. Suppose we input  $e^{j(2\pi(f_0)t)}$  into plotspect with sampling rate  $f_s = 88$  samples/sec. Find the **“perceived” frequency** (the freq. that plotspect sees) when

a)  $f_0 = 99$



b)  $f_0 = 2019$



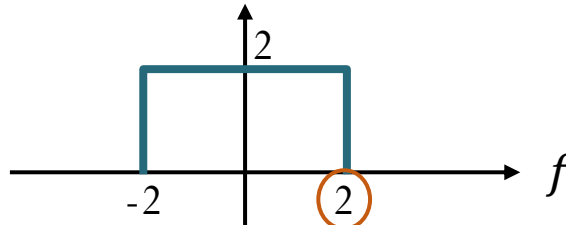
# ECS 332: In-Class Exercise # 20 - Sol

## Instructions

1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. Write down all the steps that you have done to obtain your answers. You may not get full credit even when your answer is correct without showing how you get your answer.
3. **Do not panic.**

Date: <u>15</u> / <u>11</u> / 2019			
Name			ID (last 3 digits)
Prapun			5 5 5

Consider a continuous-time signal  $g(t)$  whose **Fourier transform** is plotted below.



- (a) Find the Nyquist sampling rate for this signal.

Nyquist sampling rate =  $2 \times f_{max} = 2 \times 2 = 4$  [Sa/s]

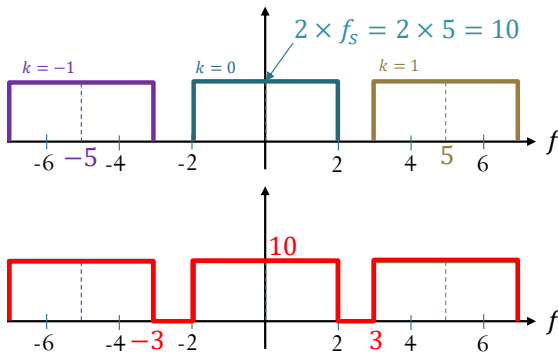
Note that  $f_{max}$  is NOT the frequency at which the spectrum is maximum.

Mathematically,  $f_{max} = \max\{f: G(f) \neq 0\}$ .

- (b) The ideal 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.

Plot the **Fourier transform** of  $g_\delta(t)$  from  $f = -6$  to  $f = 6$ .

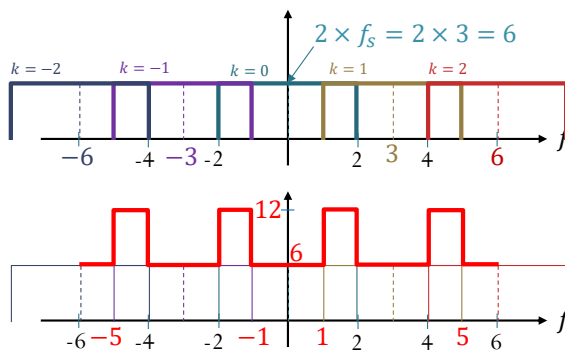
- a. when  $T_s = 1/5$



$$G_\delta(f) = \sum_{k=-\infty}^{\infty} f_s G(f - kf_s)$$

Only  $f_s G(f - kf_s)$  for  $k = -1, 0, 1$  are shown here. The contribution from other  $k$  values are outside of this specified freq. range.

- b. when  $T_s = 1/3$



$$G_\delta(f) = \sum_{k=-\infty}^{\infty} f_s G(f - kf_s)$$

Only  $f_s G(f - kf_s)$  for  $k = 0, \pm 1, \pm 2$  are shown here. The contribution from other  $k$  values are outside of this specified freq. range.

# ECS 332: In-Class Exercise # 21 - Sol

## Instructions

1. Separate into groups of no more than three students each. **The group cannot be the same as any of your former groups after the midterm.**
2. ENRE (Explanation is not required for this exercise.)
3. **Do not panic.**

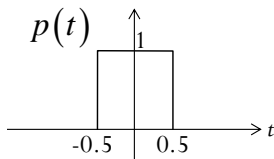
Date: <u>20</u> / <u>11</u> /2019			
Name			ID (last 3 digits)
Prapun			5 5 5

A communication system is using PAM to transmit a three-character message “Gr8”. Each character is first converted to its 7-bit ASCII representation. Then, the 7 bits are further converted to the corresponding decimal number treating the bits as they are in two's complement representation. With such conversions, we see that the three characters correspond to three decimal numbers: -57, -14, 56. These numbers are denoted by  $m[0]$ ,  $m[1]$ , and  $m[2]$ , respectively. Assume  $m[n] = 0$  for other values of  $n$ .

Recall that the PAM signal is constructed from the discrete-time message  $m[n]$  via

$$x_{PAM}(t) = \sum_{n=-\infty}^{\infty} m[n]p(t - nT_s).$$

(a) Plot  $x_{PAM}(t)$  when the pulse below is used and  $T_s = 1$ .

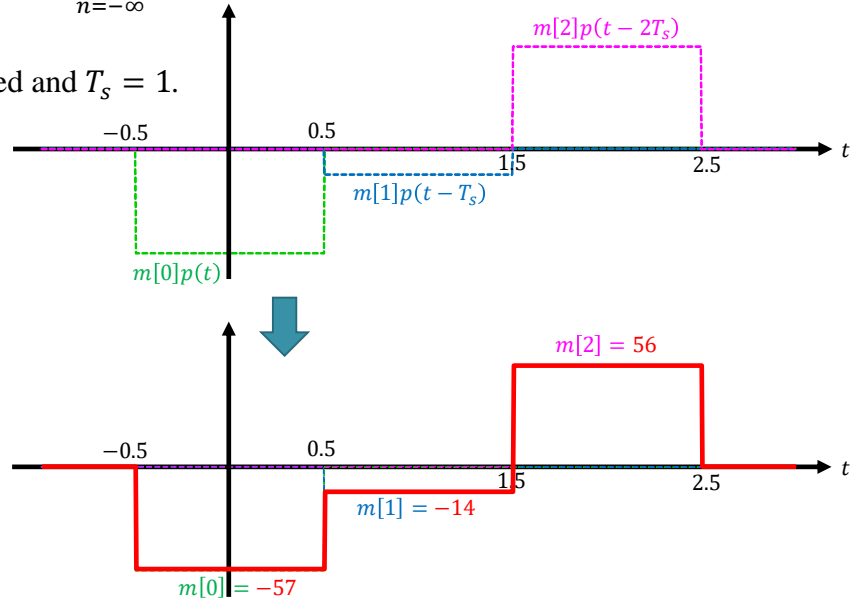


You may assume

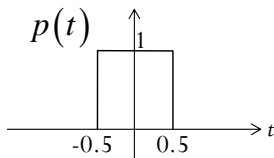
$$p(-0.5) = 1$$

and

$$p(0.5) = 0.$$



(b) Plot  $x_{PAM}(t)$  when the pulse below is used and  $T_s = 0.6$ .



You may assume

$$p(-0.5) = 1$$

and

$$p(0.5) = 0.$$

