BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Department of Electrical and Computer Engineering

Communication Systems ENEE 339

Instructor: Dr. Wael Hashlamoun

Midterm Exam

First Semester 2018-2019

Date: Sunday 18/11/2018 Time: 75 minutes

Name: Student #:

Opening Remarks:

- Calculators are allowed, but mobile phones, books, notes, formula sheets, and other aids are not allowed.
- You are required to show all your work and provide the necessary explanations everywhere to get full credit.

Problem 1: 25 Points

The Fourier transform, $G(f)$, of a signal g(t) is given by:

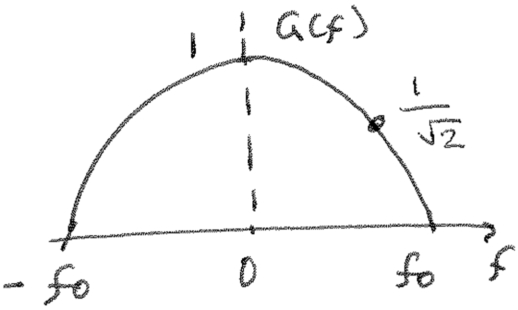
$$G(f) = \begin{cases} \sqrt{1 - \left(\frac{f}{f_0}\right)^2} & -f_0 \le f \le f_0 \\ 0 & |f| > f_0 \end{cases}; \; f_0 = 1000\,Hz$$

9 a. Find the 3-dB bandwidth of g(t).

9 b. If g(t) is passed through an ideal low pass filter with bandwidth $f_0/2$ and unity gain, find the energy of the signal at the filter output.

7 c. The signal $s(t) = g(t)cos2\pi(1000t)$ is passed through an ideal low pass filter with bandwidth 1000 Hz, sketch the spectrum of s(t).

a.



$G(0) = 1$

$-3 = 20\log\frac{G(B)}{G(0)} = 20\log\sqrt{1-\left(\frac{B}{f_0}\right)^2}$

$-3 = 10\log\left(1-\left(\frac{B}{f_0}\right)^2\right)$

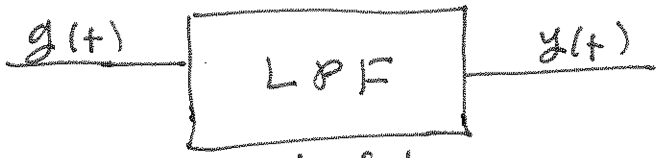
$-0.3 = \log\left(1-\left(\frac{B}{f_0}\right)^2\right) \Rightarrow 10^{-0.3} = 1-\left(\frac{B}{f_0}\right)^2$

$\frac{B}{f_0} = \sqrt{1-10^{-0.3}} = \sqrt{0.498} = 0.706$

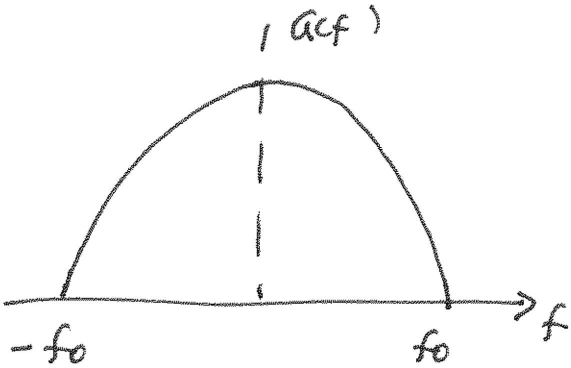
$\Rightarrow \boxed{B = 0.706 f_0 = 706\,Hz}$

Problem 1

b.

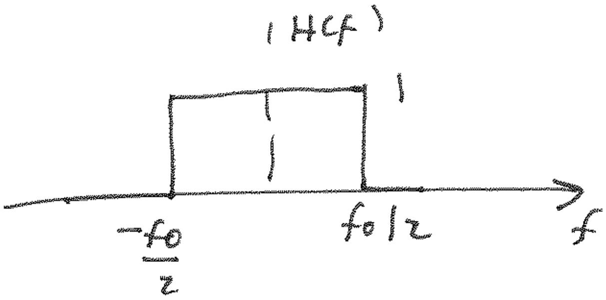


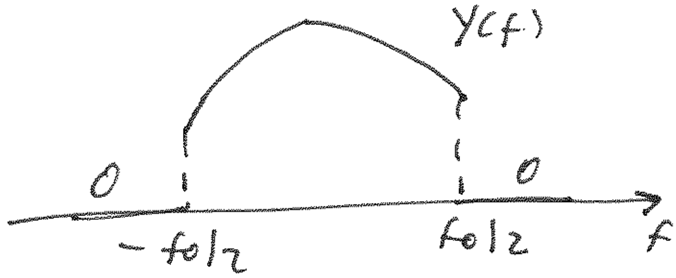
B.W = $f_0/2$



$$Y(f) = G(f)\,H(f)$$

$$|Y(f)|^2 = |G(f)|^2 |H(f)|^2$$





$$E_y = \int_{-f_0/2}^{f_0/2} |G(f)|^2\,df$$

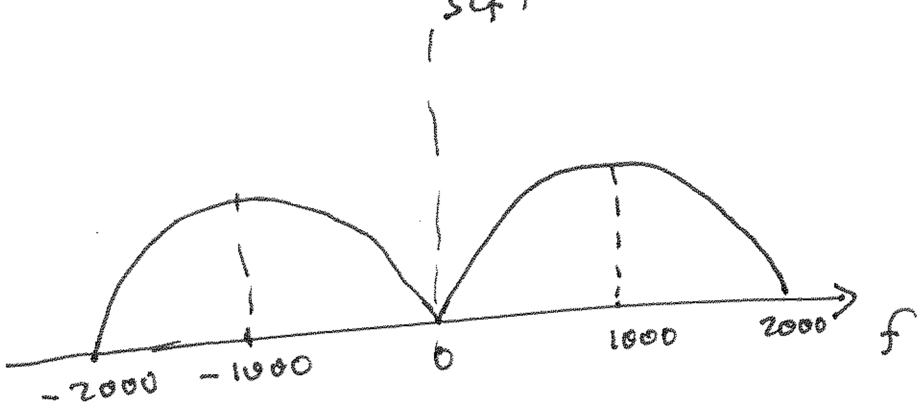
$$= 2\int_0^{f_0/2} \left(1 - \left(\frac{f}{f_0}\right)^2\right) df$$

$$= 2\left[f - \frac{f^3}{3f_0^2}\right]_0^{f_0/2}$$

$$= 2\left[\frac{f_0}{2} - \frac{f_0^3}{24 f_0^2}\right] = 2\left[\frac{f_0}{2} - \frac{f_0}{24}\right]$$

$$= f_0 - \frac{f_0}{12} = \boxed{\frac{11}{12} f_0 = \frac{11}{12} * 1000 = 916.6}$$

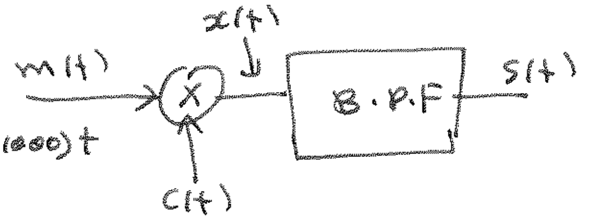
c.



Problem 2: 25 Points

The message $m(t) = 2\cos(2\pi 100t)$ along with the carrier $c(t) = 10\cos(2\pi 1000t)$ are applied to an upper single sideband modulator, which uses the frequency discrimination method, to generate the modulated signal s(t).

6 a. Find the average power in m(t).
6 b. If $c(t)$ is applied to an ideal envelope detector, sketch the signal observed at its output.
6 c. Find the time-domain expression for the modulated signal s(t).
7 d. If s(t) is applied to a coherent demodulator consisting of a multiplier, which uses the signal $c'(t) = \cos(2\pi 1000t + \varphi)$, followed by a low pass filter with bandwidth 120 Hz and unity gain, find the filter output.



$x(t) = 20\cos 2\pi(100)t \cos 2\pi(1000)t$

$x(t) = 10\cos 2\pi(1100)t + 10\cos 2\pi(900)t$

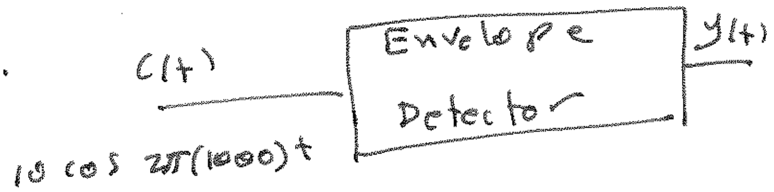
The B.P.F removes lower band

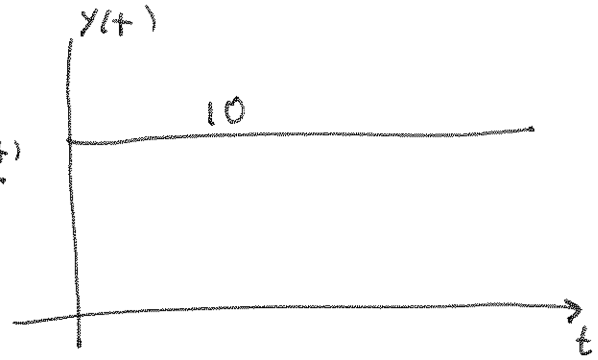
$\Rightarrow$

c. $\boxed{s(t) = 10\cos 2\pi(1100)t}$

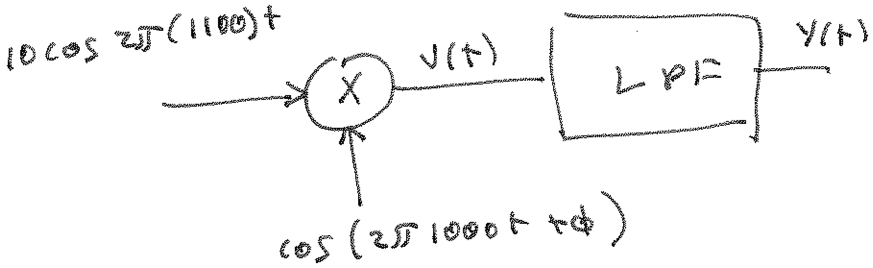
a. $\langle m(t)^2 \rangle = \frac{(2)^2}{2} = 2$

b.





d.



$v(t) = 10\cos 2\pi(1100)t \cdot \cos(2\pi 1000t + \phi)$

$= 5\cos(2\pi 2100t + \phi)$

$+ 5\cos(2\pi 100t \; \phi)$

$\boxed{y(t) = 5\cos(2\pi 100t + \phi)}$

$\boxed{y(t) = 5\cos\phi \cos 2\pi(100)t - 5\sin\phi \sin 2\pi(100)t}$

Problem 3: 25 Points

The Fourier transform of a message m(t) is given as:

$$M(f) = \begin{cases} 5|f| & -W \le f \le W \\ 0 & |f| > W \end{cases} ; W = 1000$$

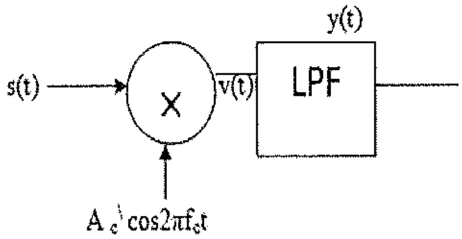
This message is applied to a double sideband suppressed carrier modulator along with the carrier $c(t) = 10\cos(2\pi(f_c)t)$ to produce the modulated signal $s(t)$

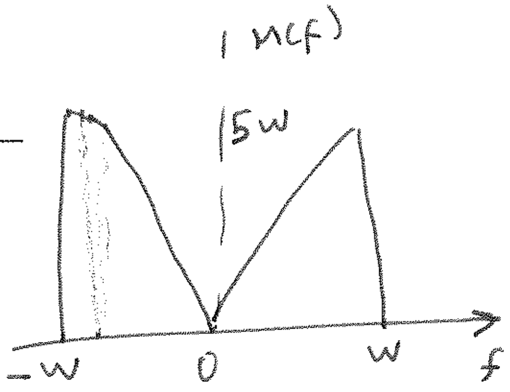
6 a. Find and sketch $S(f)$, the Fourier transform of $s(t)$, for an arbitrary value of f_c.

6 b. Find the transmission bandwidth of s(t).

6 c. Find the minimum required value of f_c in terms of W.

7 d. Show that the receiver in the figure below can demodulate m(t) from s(t) without distortion (you do not have to find what m(t) is).

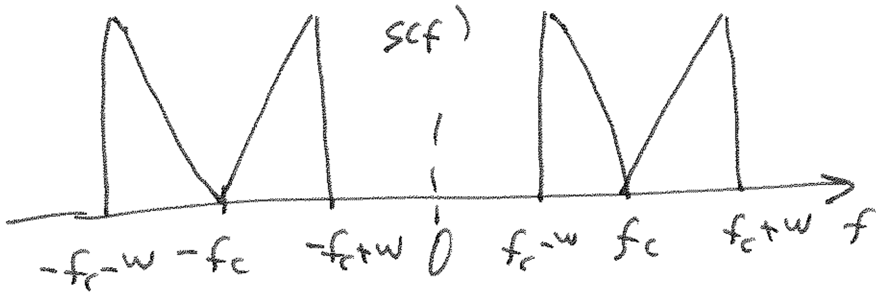




$s(t) = 10 \cos 2\pi f_c t \; m(t)$

$S(f) = 5 \; M(f - f_c)$
$+ 5 \; M(f + f_c)$

a. ⟶



b.

$B.W = 2W$

$\boxed{B.W = 2(1000) = 2000 \text{ Hz}}$

c. $f_c - W \geq 0 \Rightarrow \boxed{f_c \geq W = 1000 \text{ Hz}}$

d. $v(t) = 10(\cos 2\pi f_c t)\, m(t) \cdot A_c' \cos 2\pi f_c t$

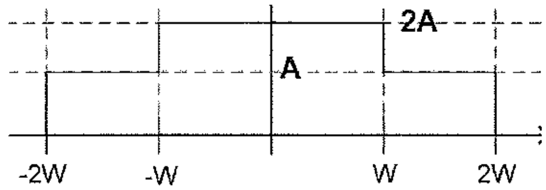
$= 5A_c' m(t)[\cos 4\pi f_c t + 1]$

$\Rightarrow \boxed{y(t) = 5A_c' m(t)}$

Problem 4: 25 Points

Consider the message signal g(t), shown in the figure below

$$g(t) = \begin{Bmatrix} 2A & -W \le t \le W \\ A & W \le |t| \le 2W \\ 0 & |f| > 2W \end{Bmatrix}; A = 1, W = 1$$



g(t) is applied to an FM modulator with sensitivity $k_f = 20\ Hz/V$ to produce an FM signal s(t). The unmodulated carrier frequency is 1000 Hz.

8.5 a. Use the time-bandwidth relationship to find the equivalent rectangular bandwidth of g(t).

5 b. Find and plot the instantaneous frequency of s(t) versus time.

5 c. Find the peak frequency deviation of s(t).

7.5 d. Find the time domain representation for the modulated signal s(t) for all time t.

a. $$T_{eq} = \frac{\left(\int_{-\infty}^{\infty} |g(t)|\,dt\right)^2}{\int_{-\infty}^{\infty} |g(t)|^2\,dt}$$

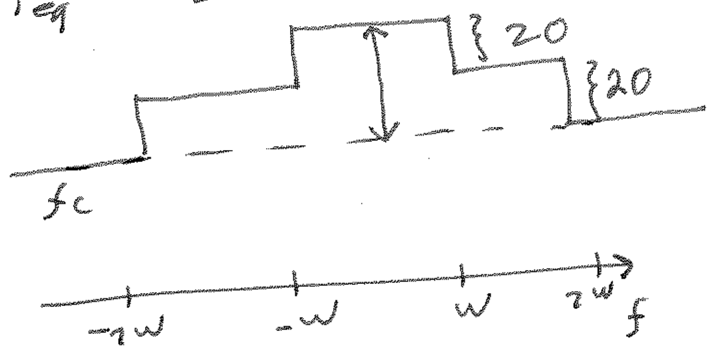
$$\int_{-2W}^{2W} |g(t)|\,dt = 2AW + 2W(2A) = 6AW = 6$$

$$\int_{-2W}^{2W} |g(t)|^2\,dt = (A^2)(2W) + 4A^2(2W) = 10A^2W = 10$$

$$\Rightarrow T_{eq} = \frac{(6)^2}{10} = \frac{36}{10} = 3.6\frac{A^2W^2}{A^2W} = 3.6W$$

$$B_{eq}T_{eq} = \frac{1}{2} \Rightarrow B_{eq} = \frac{1}{2T_{eq}} = \frac{1}{2 * 3.6} = 0.138$$

b. $\longrightarrow$



c. $\Delta f_{max} = 40\ Hz$

d. $$s(t) = \begin{cases} A_c \cos 2\pi f_c t & t < -2W,\ t \geq 2W \\ A_c \cos 2\pi (f_c + 20) t & -2W \leq t < -W,\ W < t \leq 2W \\ A_c \cos 2\pi (f_c + 40) t & -W \leq t \leq W \end{cases}$$