EECS 120
Midterm 2
Wed. April 9, 2014
1610 - 1730 pm

Name:___________________________
SID:_____________

- Closed book. One 8.5x11 inch page two sides formula sheet (or two single sided). No calculators.
- There are 4 problems worth 100 points total. There may be more time efficient methods to solve problems.

Problem	Points	Score
1	24	
2	28	
3	22	
4	26	
TOTAL	100	

In the real world, unethical actions by engineers can cost money, careers, and lives. The penalty for unethical actions on this exam will be a grade of zero and a letter will be written for your file and to the Office of Student Conduct.

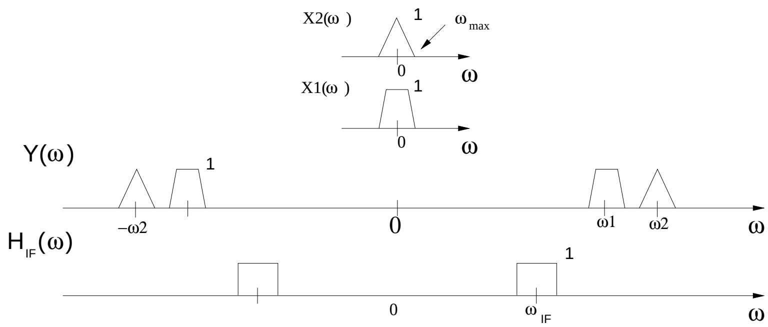
Tables for reference:

$\tan^{-1} 0.1 = 5.7°$	$\tan^{-1} 0.2 = 11.3°$
$\tan^{-1} \frac{1}{2} = 26.6°$	$\tan^{-1} 1 = 45°$
$\tan^{-1} \frac{1}{3} = 18.4°$	$\tan^{-1} \frac{1}{4} = 14°$
$\tan^{-1} \sqrt{3} = 60°$	$\tan^{-1} \frac{1}{\sqrt{3}} = 30°$
$\sin 30° = \frac{1}{2}$	$\cos 60° = \frac{\sqrt{3}}{2}$
$\cos 45° = \frac{\sqrt{2}}{2}$	$\sin 45° = \frac{\sqrt{2}}{2}$

$20 \log_{10} 1 = 0dB$	$20 \log_{10} 2 = 6dB$	
$20 \log_{10} \sqrt{2} = 3dB$	$20 \log_{10} \frac{1}{2} = -6dB$	
$20 \log_{10} 5 = 20db - 6dB = 14dB$	$20 \log_{10} \sqrt{10} = 10$ dB	
$1/e \approx 0.37$	$1/e^2 \approx 0.14$	$\sqrt{2} \approx 1.41$
$1/e^3 \approx 0.05$	$\sqrt{10} \approx 3.16$	$\sqrt{3} \approx 1.73$

Problem 1. Superheterodyne receiver (24 pts)

Two signals $x_1(t)$ and $x_2(t)$ have spectra (Fourier Transforms) $X_1(j\omega)$ and $X_2(j\omega)$ respectively, as shown in the figure below. You are given a signal $y(t)$ with spectrum $Y(j\omega)$, which contains 2 received signals, $x_1(t)\cos(\omega_1 t)$ (from station 1) and $x_2(t)\cos(\omega_2 t)$ (from station 2). A narrow bandpass filter $H_{IF}(j\omega)$ with fixed center frequency $\omega_{IF} < \omega_1$ is used to filter out interference.

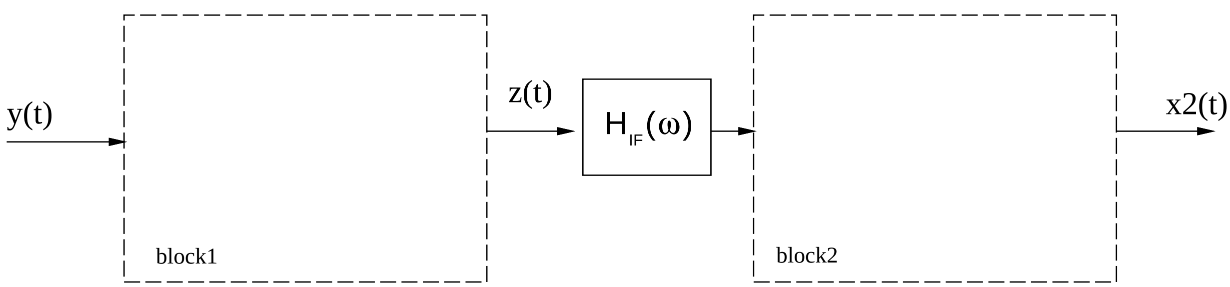


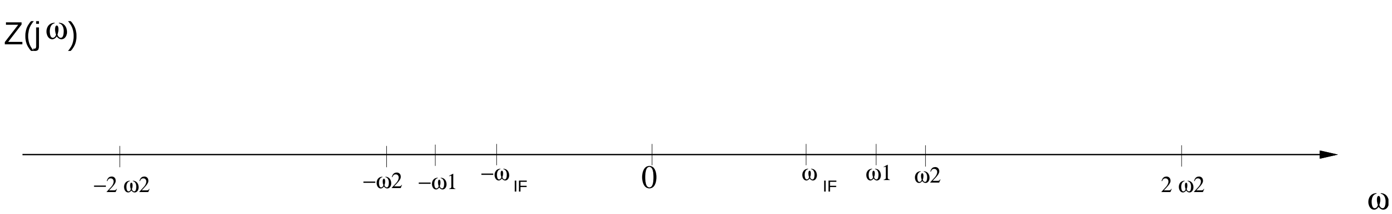
The block diagram below, when completed, should recover the original $x_2(t)$ from $y(t)$.

[7 pts] a. Add signal processing elements as necessary in *block1* such that the output $Z(j\omega)$ will have $X_2(j\omega)$ in the passband of the bandpass filter. For each element, specify amplitudes and frequencies as necessary.

[10 pts] b. For your *block1* system, sketch the spectra $Z(j\omega)$, labelling key frequencies and amplitudes.

[7 pts] c. Add signal processing elements as necessary in *block2* such that the output of *block2* is $x_2(t)$. For each element, specify amplitudes and frequencies as necessary.

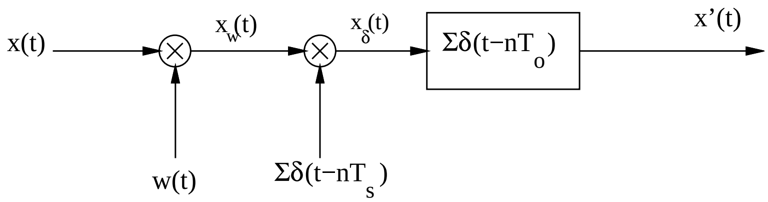




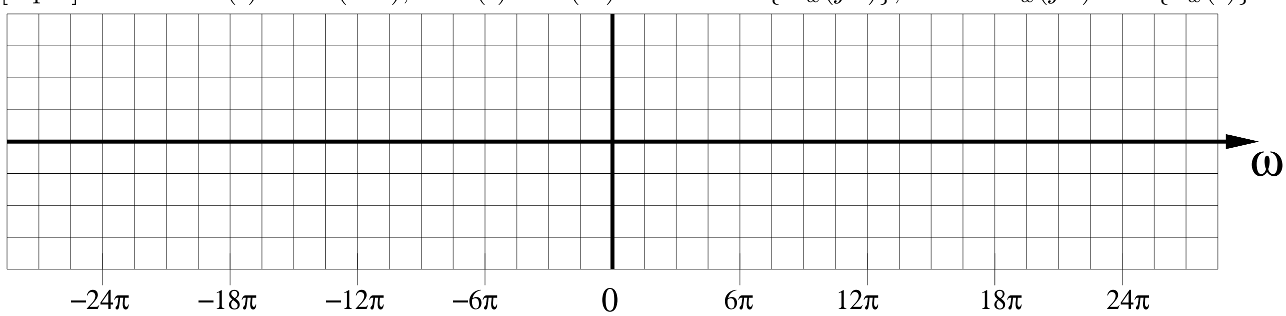
Problem 2. Sampling and Discrete Fourier Transform (28 pts)

For parts a) and b), consider the system below, where $x(t) = \cos(6\pi t)$. Parts a) and b) may have different $w(t), T_s, T_o$ and should be answered independently. Sketch should label peak magnitude, and frequency of zero crossing(s) should match given scale.

Note $\Pi(t) = u(t + 0.5) - u(t - 0.5)$.

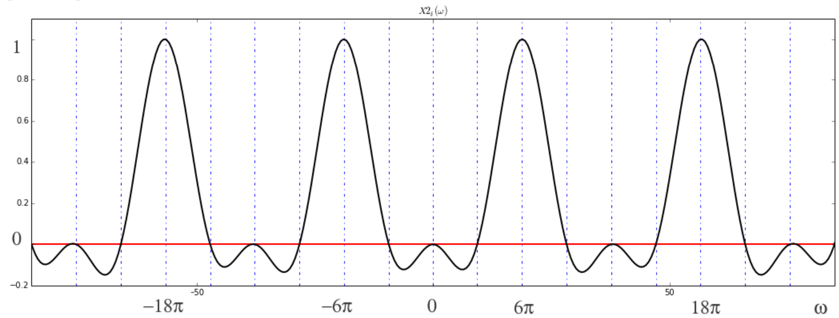


[7 pts] a. Given $x(t) = \cos(6\pi t)$, $w(t) = \Pi(3t)$. Sketch $Re\{X_w(j\omega)\}$, where $X_w(j\omega) = \mathcal{F}\{x_w(t)\}$:

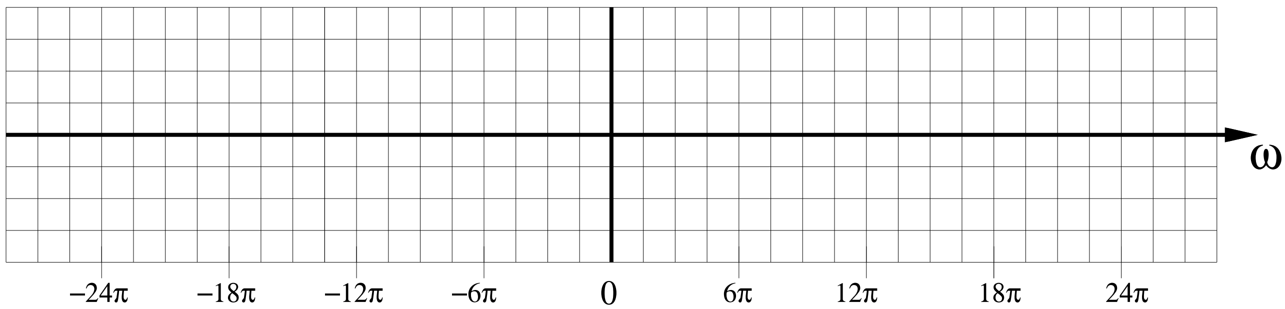


Problem 2. cont.

[7 pts] b. Given a windowed and sampled signal $x_{2\delta}(t)$ with spectrum $X_{2\delta}(j\omega)\}$:

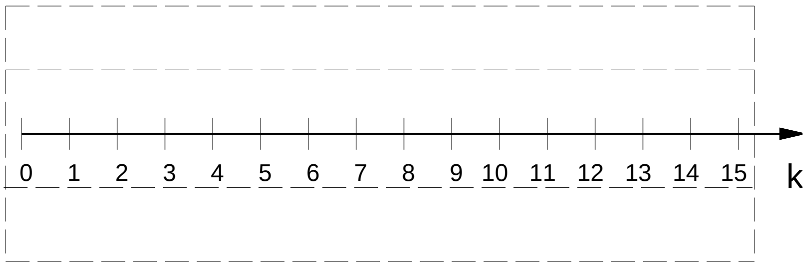


Sketch $Re\{X_2'(j\omega)\}$ where $X_2'(j\omega) = \mathcal{F}\{x_2'(t)\}$, given $T_o = 2/3$ sec.

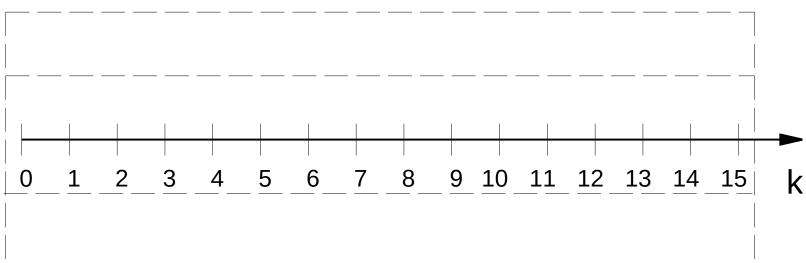


Problem 2. cont.

[7 pts] c. Given $x_3[n] = \cos(\pi n/4)$, sketch $X_3[k]$, the 16 point DFT of $x_3[n]$, labelling amplitudes.



[7 pts] d. Given $x_4[n] = x_3[n] = \cos(\pi n/4)$ for n even, and $x_4[n] = 0$ for n odd, sketch $X_4[k]$, the 16 point DFT of $x_4[n]$, labelling amplitudes.



Problem 3. Laplace Transform (22 points)

A causal system with input $x(t)$ and output $y(t)$ is described by the differential equation:

$$\frac{d^2}{dt^2}y(t) + 5\frac{d}{dt}y(t) + 6y(t) = x(t).$$

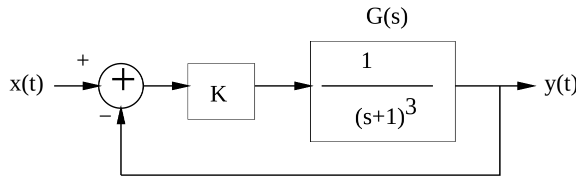
[11 pts] a. Find $Y(s)$ and $y(t)$ for $x(t) = 0$ (ZIR). $y(0^-) = 1, \quad \frac{d}{dt}y(0^-) = 2.$

$Y(s) =$ ____________________ $y(t) =$ ____________________

[11 pts] b. Find $Y(s)$ and $y(t)$ for $x(t) = u(t)$ (ZSR). $y(0^-) = 0, \quad \frac{d}{dt}y(0^-) = 0.$

$Y(s) =$ ____________________ $y(t) =$ ____________________

Problem 4. Feedback System (26 points)



[4 pts] a. Find the transfer function for the system above which has input $x(t)$ and output $y(t)$.

$$H(s) = \frac{Y(s)}{X(s)} = \underline{\hspace{4cm}}$$

[6 pts] b. Find the frequency ω_o at which the phase of $G(s)$ is $-180°$.

$$\omega_o = \underline{\hspace{2.5cm}}$$

[6 pts] c. For the frequency ω_o found above, what is the maximum K which could be used before the closed-loop system is unstable (this is the gain margin).

$$K < \underline{\hspace{2.5cm}}$$

[6 pts] d. Find the sinusoidal steady state response of the closed-loop system with $K = 4$ to the input $x(t) = \cos(t)u(t)$, ignoring any transients. (Hint: phasors).

$$y(t) = \underline{\hspace{4cm}}$$

[4 pts] e. Without explicitly calculating, discuss the steady-state closed-loop response of the system to $x(t) = \cos(\omega_o t)u(t)$ using ω_o from part b and the K value from part c.