ECE 3210 Midterm 2

Week of: November 13, 2023

Student's name: ______________________________

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You have 2 hours for 5 problems.

- Show enough (neat) work in the clear spaces on this exam to convince us that you derived, not guessed, your answers.
- Put your final answers in the boxes at the bottom of the page.

You may use two US letter-style size page of notes, front and back.

Problem	Score	Possible Points
1		20
2		20
3		20
4		20
5		20
Total score		100

1 Short answer

(a) Consider the following discrete-time signals

$$f_k = \{1, 2, 3, 2, 1, -1\}$$
$$g_k = \{1, 1, 1\}.$$

please compute the **8-point circular convolution** of g_k and f_k.

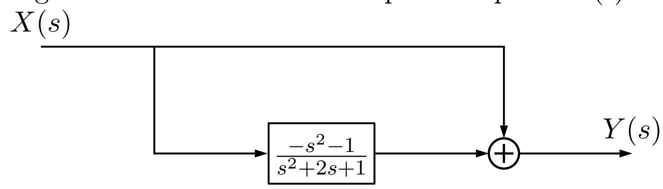
$y_{k,\mathrm{cir}} =$

(b) Given the transfer function

$$H(s) = \frac{2s^2 - 1}{s^3 - 6s + 1}$$

sketch the canonical block diagram below.

(c) Consider the block diagram below. What is its impulse response $h(t)$?



$h(t) =$

2 Differential equations

Consider the following differential equation

$$y''(t) + 3y'(t) + 2y(t) = 2x'(t) - x(t)$$

with initial conditions $y(0^-) = -3$ and $y'(0^-) = 2$ as well as an input $x(t) = u(t)$.

(a) Find the zero-input response using the Laplace transform.

$y_{zi}(t) =$

(b) Find the zero-state response using the Laplace transform.

$y_{zs}(t) =$

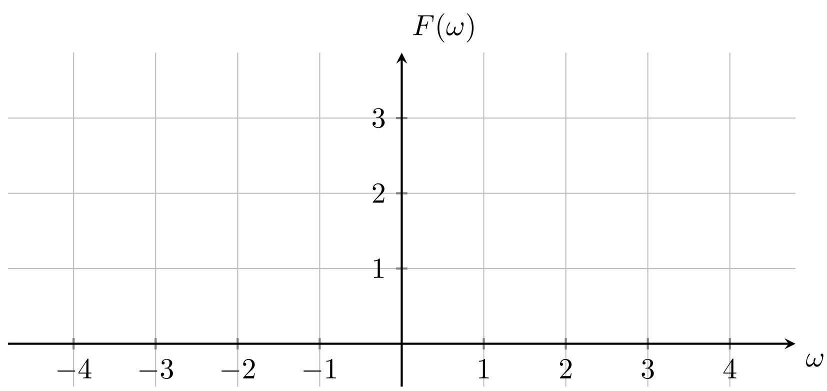
(c) Find the total response.

$y(t) =$

3 Sampling

Consider the signal $f(t) = \frac{1}{\pi}\text{sinc}^2\left(\frac{t}{2}\right)$

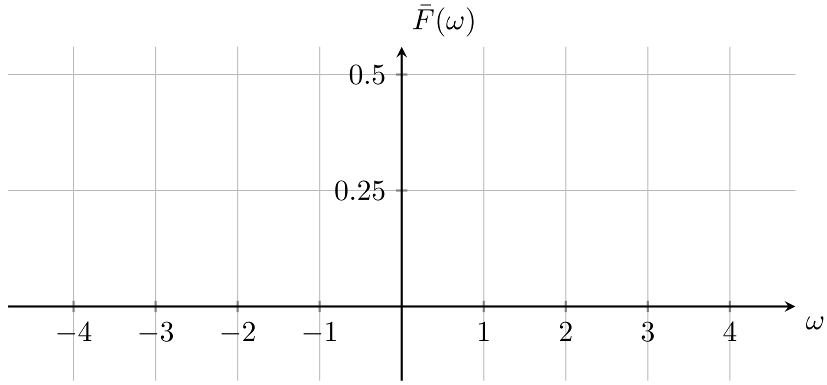
(a) Sketch the Fourier transform $F(\omega)$ below.



(b) What is the bandwidth and Nyquist sampling rate (f_s) for this signal in hertz?

BW= $f_s =$

(c) Suppose we were to sample at one half the Nyquist frequency, sketch the Fourier transform of the resulting signal $\bar{F}(\omega)$.



(d) What is the expression for $\bar{f}(t)$?

$\bar{f}(t) =$

(e) If you were to reconstruct this signal using an ideal low-pass filter $h(t)$ with a cutoff frequency of one quarter the Nyquist sampling rate, what is resulting $f_{\text{recon}}(t)$? (Assume that the low-pass filter has unity gain—i.e., a gain of 1—in the passband.)

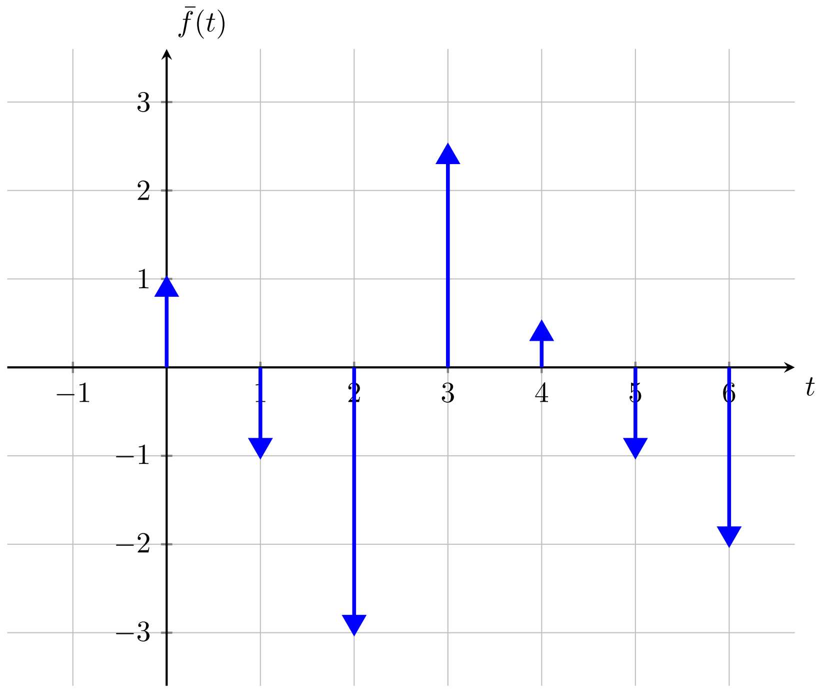
$f_{\text{recon}}(t) =$

4 Reconstruction

(a) A zero-order hold system can be used to reconstruct a signal $f(t)$ from its samples. The impulse response of this circuit is

$$h(t) = \mathrm{rect}\,(t)\,.$$

Consider a sampled signal $\bar{f}(t)$ below. Sketch the system output $f(t)$ on the plot marked $f(t)$. (*Hint:* the system is LTI therefore the system output is $f(t) = h(t) * \bar{f}(t)$.)



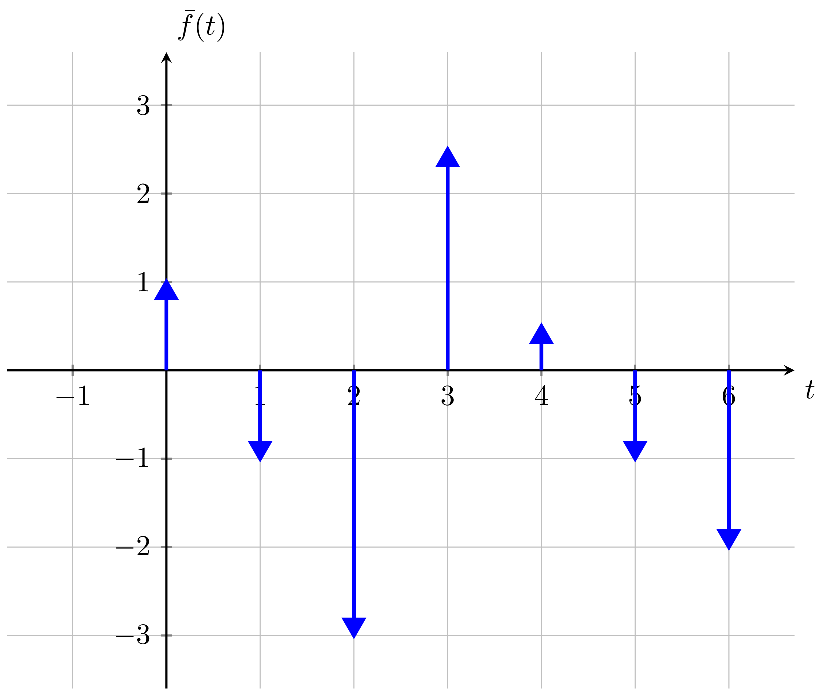
(b) Determine the frequency response $H(\omega)$ of this filter.

$H\,(\omega) =$

(c) This filter, being non-causal, is unrealizable. By delaying its impulse response, the filter can be made realizable. What is the minimum delay required to make the filter realizable?

$T_{\text{delay}} =$

(d) How would this delay affect the reconstructed? Sketch the reconstruction on the plot below with the *delayed* $h(t)$.

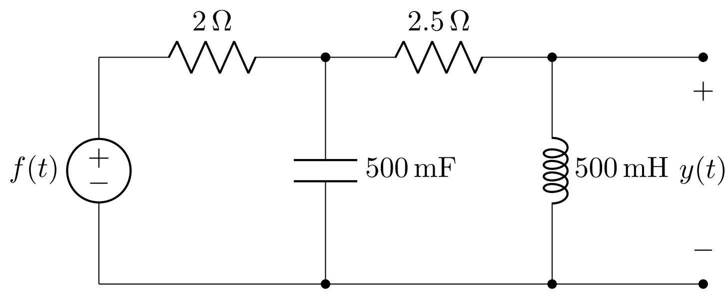


(f) How would this delay affect the system's frequency response? What is the new $H(\omega)$?

$H(\omega) =$

5 Transfer functions

Consider the circuit below.



(a) Draw the circuit in the s-domain.

(b) Derive the transfer function $H(s)$ for this circuit.

Your work continued...

$H(s) =$

(c) Given an input $x(t) = u(t)$, find the zero-state response for $y(t)$.

$y_{zsr}(t) =$