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UNIVERSITY OF CALGARY

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

BIOMEDICAL SIGNAL ANALYSIS

ENEL 563

MIDTERM EXAM
Friday, November 4th, 2005
3:00 p.m. – 4:00 p.m.
ICT 114
60 minutes

Total: 15 Marks

NOTE:

1. *This is a closed-book exam.*
2. *Calculators with text/program storage capabilities are not allowed.*
3. *Answer all questions.*
4. *In case of problems requiring numerical or algebraic manipulation, show all steps clearly.*
   In case of problems requiring descriptive answers, provide clear statements in point form; long essays are not required.
   In case of problems requiring algorithms, provide the reason/logic for each step.
5. *Specify units or dimensions when appropriate.*
6. *In drawing plots of signals, spectra, etc. label the axes clearly.*

Marks

1 1. (a) Draw the waveform of a typical, normal ECG over one cardiac cycle. Label the names of the component waves and give their typical durations and intervals.

1 (b) Draw a version of the ECG waveform as above including power-line artifact at 60 Hz. Describe a potential cause of the artifact and a method to prevent or remove the artifact.

1 (c) Draw a version of the ECG waveform as above including high-frequency noise. Describe a potential cause of the artifact and a method to prevent or remove the artifact.

Marks

2. The transfer function of a digital filter is specified as

$$H(z) = \frac{1}{3}\left[1 + z^{-1} + z^{-2}\right]$$

1 (a) Derive and plot the impulse response of the filter.

1 (b) What is the gain of the filter at DC and $f_S/2$, where f_S is the sampling frequency?

1 (c) Draw the signal-flow diagram of the filter.

1 (d) A signal with the samples {3,1,2} is applied as the input to the filter. Compute the output of the filter.

Show all steps in your solutions.

Marks

3. For a signal sampled at f_S= 200 Hz, design a notch filter to reject power-line artifact at 50 Hz. Use only one pair of zeros. Give the following in your solution:

2 (a) The pole-zero plot of the filter. Show the frequencies DC, 50 Hz, and 100 Hz on the plot.

2 (b) The transfer function and impulse response of the filter.

Marks

4. Two filters connected in series (cascade) are specified in terms of their difference equations

$$y_1(n) = x(n) - x(n-1)$$

and

$$y_2(n) = \frac{1}{2}[\,y_1(n) + y_1(n-1)\,],$$

where $x(n)$ is the input to the first filter, $y_1(n)$ is the output of the first filter that is provided as the input to the second filter, and $y_2(n)$ is the output of the second filter.

1 (a) Derive the transfer function of each filter.

1 (b) Derive the transfer function of the combined system.

1 (c) Derive the impulse response of the combined system.

1 (d) Plot the pole-zero diagram of the combined system.

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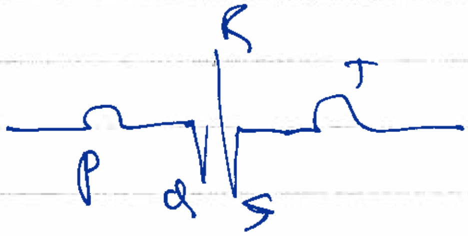
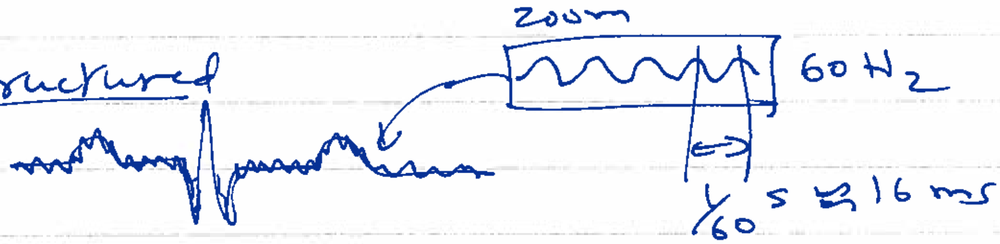
1. a



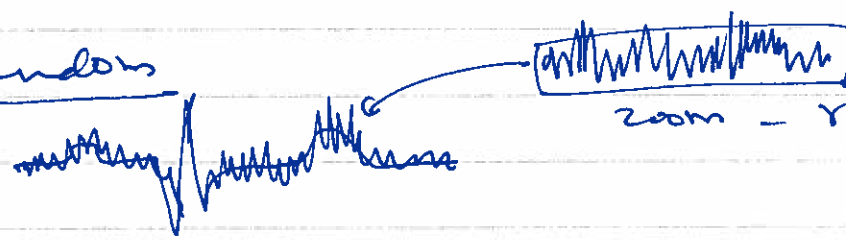
	ms
P	80
P-Q	80
QRS	80
ST	100-120
T	120-160

b. Structured



60 Hz : from power-line leakage -
poor grounding.
use 60 Hz notch filter

c. Random



zoom - random noise

H-F noise : EM interference - bad shielding
EMG due to coughing, breathing
use LPF, cutoff > 70-80 Hz

3

2. $H(z) = \frac{1}{3}[1 + z^{-1} + z^{-2}]$.

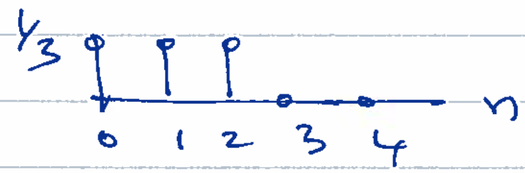
a) $H(z) = \sum_{n=0}^{\infty} h(n) z^{-n}$

$= h(0) + h(1)z^{-1} + h(2)z^{-2} + \cdots$

$\therefore$ Impulse response $= \left\{\frac{1}{3}, \frac{1}{3}, \frac{1}{3}\right\}$; $n = 0, 1, 2$.

I

Not $\uparrow$



$= \frac{1}{3}\delta(n) + \frac{1}{3}\delta(n-1) + \frac{1}{3}\delta(n-2)$

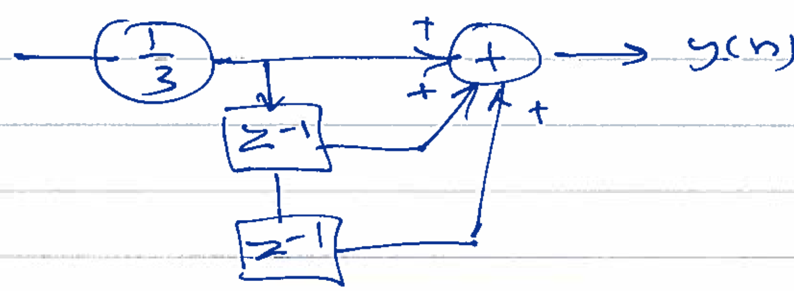
b) DC: $z = 1$

$H(1) = \frac{1}{3}(1+1+1) = 1$.

$f_s/2$: $z = -1$.

$H(-1) = \frac{1}{3}(1 - 1 + 1) = \frac{1}{3}$.

c)



4

d) $x(n) = \{3, 1, 2\}$ $\rightarrow \{1, 4/3, 2, 1, 2/3\}$

$y(n) = x(n) * h(n)$ $= \frac{1}{3}\{3, 4, 6, 3, 2\}$

for $n = 0, 1, 2, 3, 4$

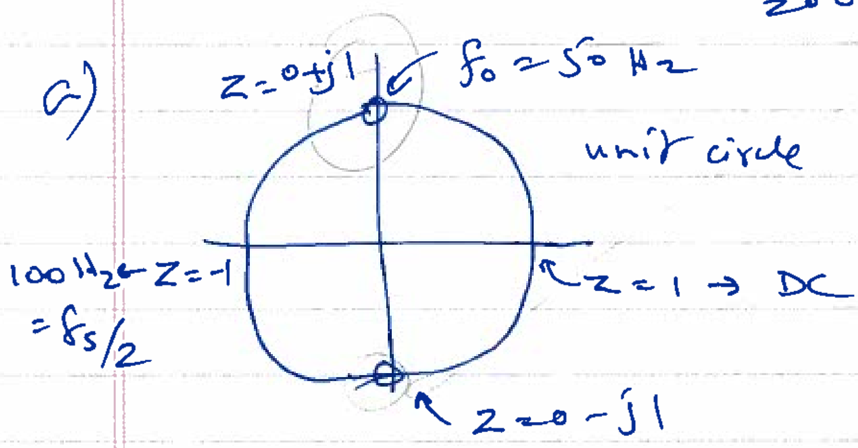
($= 0$ for $n < 0$)

			3	1	2			
$h(-n)$	1	1	1					3
$h(-n+1)$		1	1	1				4
			1	1	1			6
				1	1	1		3
					1	1	1	2

3. $f_s = 200\ Hz = 360°$

$f_0 = 50\ Hz \rightarrow \frac{50}{200} \times 360° = 90°$

a)



ask the students to give these coordinates

ignore poles at $z=0 \rightarrow$ delay only

$\underline{z^{-n}}$

b) $H(z) = G\,[1 + (j1)z^{-1}]\,[1 - (j1)z^{-1}]$

$= G(1 + z^{-2})$

$j = \sqrt{-1}$; $j^2 = -1$;

$-j^2 = +1$

for $H(1) = 1$ at DC,

~~let~~ $G = 1/2$.

impulse response $h(n) = \{1/2, 0, 1/2\}$

$n = 0, 1, 2.$

$= \frac{1}{2}\{\delta(n) + \delta(n-2)\}$

or let $\underline{G = 1}$

4 a) $y_1(n) = x(n) - x(n-1)$

$$Y_1(z) = X(z) - z^{-1}X(z)$$

$$H_1(z) = \frac{Y_1(z)}{X(z)} = (1 - z^{-1})$$

$$y_2(n) = \frac{1}{2}[y_1(n) + y_1(n-1)]$$

$$Y_2(z) = \frac{1}{2}[Y_1(z) + z^{-1}Y_1(z)]$$

$$H_2(z) = \frac{1}{2}(1 + z^{-1}) = \frac{Y_2(z)}{Y_1(z)}$$

b) $H(z) = H_1(z)H_2(z) = \frac{1}{2}(1+z^{-1})(1-z^{-1})$

$$= \frac{1}{2}(1 - z^{-2})$$

c) $h(n) = \{\frac{1}{2}, 0, -\frac{1}{2}\} = \frac{1}{2}\delta(n) - \frac{1}{2}\delta(n-2)$

d) $(1+z^{-1})(1-z^{-1}) = 0 \rightarrow$ zeros at $z=1, z=-1$

ignore poles at $z=0$.