Rmr

UNIVERSITY OF CALGARY

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

BIOMEDICAL SIGNAL ANALYSIS

ENEL 563

MIDTERM EXAM
Friday, November 5th, 2004
3:00 p.m. – 4:00 p.m.
ICT 116

Total: 20 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

3 1. Describe two cardiac abnormalities that cause changes in the shape of the QRS complex. Draw the ECG waveforms for the two cases and compare their features with those of a normal ECG waveform.

2. A biomedical signal sampled at 500 Hz contains power-line interference at 60 Hz.

3 (a) Design a notch filter to remove the artifact.

2 (b) Derive the input-output difference equation of the filter.

1 (c) What is the effect of the filter if a signal sampled at 200 Hz is applied as the input?

Marks

3. A researcher uses a combination of the following two digital filters in cascade (series):

Filter 1: The output is the first derivative or difference of the input.

Filter 2: The output is the average of the current input sample and the preceding input sample.

1 (a) Give the input-output relationship in the time domain (difference equation) for each filter.

1 (b) Derive the transfer function H(z) for each filter.

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

1 (d) Derive the transfer function H(z) of the complete system.

1 (e) Does it matter which filter is placed first? Explain.

2 (f) Compute the gain of the complete system at 0, $f_s/4$, and $f_s/2$, where f_s is the sampling frequency.

4 4. A noisy signal **x** (n) is expressed in vector notation as

x (n) = **d** (n) + **η** (n)

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where **d** (n) is the original (ideal) signal and **η** (n) is random noise that is statistically independent of the signal. All signals are assumed to be second-order stationary.

Derive an expression for the autocorrelation function (ACF) matrix of **x** in terms of the ACF matrices of **d** and **η**. Explain each step of your derivation.

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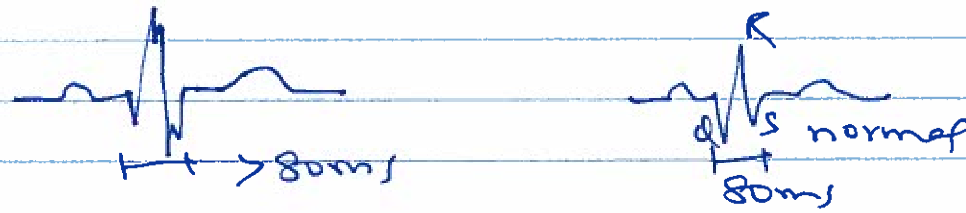
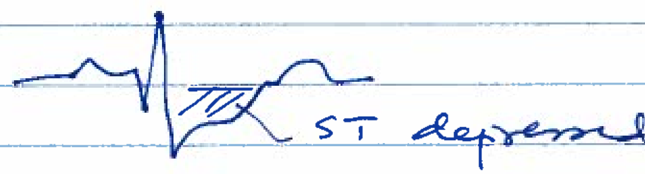
Fall 2004 MidTerm

1 a) Bundle-branch Block - wider, distorted QRS

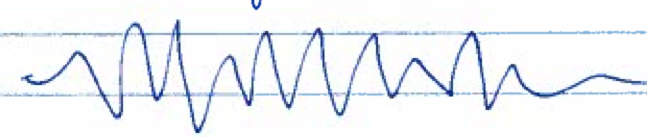


b) PVCs - ectopic focus firing

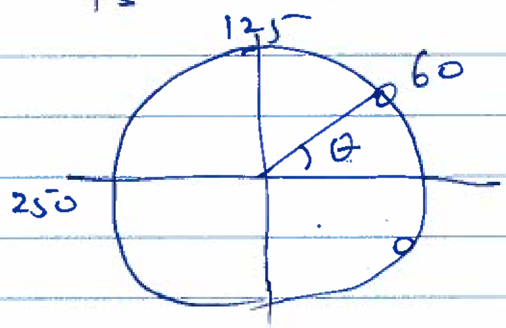
c) myocardial ischemia - ST segment depressed or elevated



d) ventricular fibrillation



2. $f_s = 500$ Hz



magnitude of zeros = 1

$\theta = \frac{60}{250} \times 180 = 43.2^\circ$

$\cos\theta = 0.73$

$\sin\theta = 0.68$

zeros at $0.73 \pm j\,0.68$

$H(z) = (1 - z^{-1}z_1)(1 - z^{-1}z_2)$

$= (1 - 2\cos\theta\, z^{-1} + z^{-2})$

3

$= 1 - 1.46 z^{-1} + z^{-2}$

Gain not normalized

$y(n) = x(n) - 1.46\,x(n-1) + x(n-2)$

2

If the same filter is used at f_s = 200 Hz,

the frequency of the zero is

1

$+ \frac{\theta \times 180^\circ}{180} = \underline{24 \text{ Hz}}$

Therefore, the filter will suppress the components at $\underline{24 \text{ Hz}}$.

3. 7 marks

Filter 1 : $y(n) = [x(n) - x(n-1)]\frac{1}{T}$

Filter 2 : $y(n) = \frac{1}{2}[x(n) + x(n-1)]$

$$H_1(z) = \frac{1}{T}[1 - z^{-1}]$$

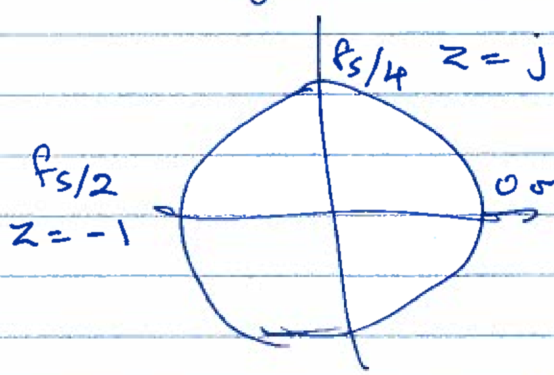
$$H_2(z) = \frac{1}{2}(1 + z^{-1})$$

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

$$h(n) = \frac{1}{2T}[\delta(n) - \delta(n-2)]$$

or $\{\frac{1}{2T}, 0, -\frac{1}{2T}\}$ or $\{1, 0, -1\}$

sequence does not matter $\therefore$ linear shift-invariant systems : $H(z) = H_1(z)\,H_2(z)$



Gain at DC : $|H(z)|_{z=1} = \left|\frac{1}{2T}(1-1)\right| = 0$

at $f_s/2$ $|H(z)|_{z=-1} = \left|\frac{1}{2T}(1-1)\right| = 0$

at $f_s/4$ $|H(z)|_{z=j} = \left|\frac{1}{2T}\left(1 - \frac{1}{-1}\right)\right| = \frac{2}{2T}$ ~~$= f_s$~~

or $\underline{1}$.

4. $\underline{\Phi}_x = E[\underline{x}(n)\underline{x}^T(n)]$

$= E[\{\underline{d}(n) + \underline{\eta}(n)\}\{\underline{d}(n) + \underline{\eta}(n)\}^T]$

Given that $\underline{d}$ and $\underline{\eta}$ are statistically independent and have zero means, we have

$E[\underline{d}(n)\underline{\eta}^T(n)] = 0$

and $E[\underline{\eta}(n)\underline{d}^T(n)] = 0$

$\therefore \underline{\Phi}_x = E[\underline{d}(n)\underline{d}^T(n) + \cancel{\underline{\eta}(n)\underline{d}^T(n)} + \cancel{\underline{\eta}(n)\underline{d}^T(n)} + \underline{\eta}(n)\underline{\eta}^T(n)]$

$= E[\underline{d}(n)\underline{d}^T(n)] + E[\underline{\eta}(n)\underline{\eta}^T(n)]$

$= \underline{\Phi}_d + \underline{\Phi}_\eta$

$\therefore$ The ACF of $\underline{x}$ is the sum of the ACFs of $\underline{d}$ and $\underline{\eta}$.