OLLSCOIL NA hÉIREANN, CORCAIGH
THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

SUMMER EXAMINATIONS, 2005

B.E. (ELECTRICAL)
B.E. (MICROELECTRONICS)
M.ENG.SC. (MICROELECTRONICS)
H.DIP. (MICROELECTRONICS)

Medical Electronic Systems
EE4012

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Time Allowed: *3 hours*

Answer *five* questions.

All questions carry equal marks.
The use of a Casio fx570w or fx570ms calculator is permitted.

1. (a) Define and describe the cardiac cycle. [*10 marks*]

   (b) Define and describe what is a gaseous exchange. [*10 marks*]

2. (a) Draw a circuit diagram of a standard instrumentation amplifier for medical applications based on three operational amplifiers (op-amps) and derive a formula for the voltage gain of the circuit. [*9 marks*]

(b) A patient is connected to two channels (A and B) of an ECG monitor as follows: The left arm is connected to channel A, the right arm is connected to channel B and the right leg is grounded. There is significant skin/electrode contact resistance denoted by Z_{LA} at the left arm, Z_{RA} at the right arm and Z_{RL} at the right leg. The input channels of the ECG monitor each have an input impedance of Z_{IN}. Stray capacitive coupling to nearby mains wiring causes a small mains-induced current, i_p, to flow through the patients' body to ground via the right leg (Z_{RL}).

i. Derive an expression for the differential voltage ($V_A - V_B$) between terminals A and B, caused by the stray current i_p. [*8 marks*]

ii. If $Z_{IN} = 5M\Omega, Z_{RL} = 50k\Omega, Z_{LA} = 20k\Omega, Z_{RA} = 40k\Omega$ and $i_p = 1\mu$A (rms) determine $V_A - V_B$. [*3 marks*]

3. (a) Briefly describe the most important signal properties of ECG and EEG signals and how these affect the choice of a suitable ADC (Analog to Digital Converter) for ECG/EEG instrumentation. [*5 marks*]

(b) Show a block diagram of a Sigma-Delta ADC based on a 1-bit quantizer and a loop filter of order n and derive an expression for the Signal-to-Noise Ratio (SNR) of this converter. [*12 marks*]

(c) A Sigma-Delta converter uses a 1-bit quantizer and a 1^{st}-order loop filter. Determine the sampling rate that must be used to give an SNR equivalent to a conventional 20-bit ADC if the Nyquist sampling rate for the input signal is 15kHz. [*3 marks*]

4. (a) In the Nervus EEG machine a FIR high pass filter is used to eliminate artefacts between 2.0 and 5.0Hz. Describe the method used to design this filter. [*10 marks*]

(b) A second order bandstop digital filter (Notch Filter) has a frequency response of the form :

$$H_{BS}(\omega) = \frac{1+\alpha}{2}\frac{1-2\beta e^{-j\omega}+e^{-2j\omega}}{1-\beta(1+\alpha)e^{-j\omega}+\alpha e^{-2j\omega}}$$

The 3-dB notch bandwidth of the filter is given by:

$$\Delta\omega_{3dB} = \cos^{-1}\left(\frac{2\alpha}{1+\alpha^2}\right)$$

Determine the Constant Coefficient Difference Equation and the frequency response of a digital notch filter to eliminate 50Hz mains noise when the sampling frequency is 256 Hz. A 3-dB notch bandwidth of 0.1π radians is required. [*10 marks*]

5. (a) Explain the Bartlett method of spectral estimation. Compare the Bartlett method to the Periodogram in terms of Bias, Variance and Resolution. The Periodogram is an asymptotically unbiased estimate, but it is not a consistent estimate as: $var\{\hat{P}_{xx}(f)\} \approx P_{xx}^2(f)$ [*10 marks*]

(b) i. Explain how zero padding is used in filtered back-projection tomographic imaging algorithms, and for what purpose.

[*4 marks*]

ii. For a parallel-beam geometry consisting of 161 rays equally spaced over 320mm, determine the maximum frequency and resolution that can be obtained in the Fourier domain. Calculate the improvements obtained when the Radon transform is zero padded to 256 samples.

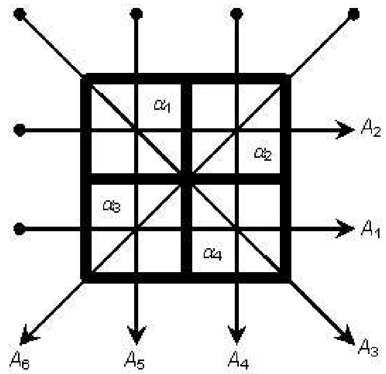
[*4 marks*]

iii. Determine the minimum number of rays required to image a 5mm diameter tumour without aliasing, clearly stating the necessary criterion. [*2 marks*]

6. (a) State the iterative linear ART algorithm and the magnitude of the normalised error criterion used to test for its convergence, clearly explaining all terms.

[*4 marks*]

(b) An area containing four pixels with four unknown absorption contrasts $\alpha_1, \ldots, \alpha_4$ has been interrogated by six rays as shown below. The total measured absorptions are as follows: $A_1 = 13, A_2 = 7, A_3 = 5, A_4 = 8, A_5 = 12, A_6 = 15$



Using the iterative linear ART algorithm, determine the values of the four unknown absorption contrasts after three iterations, showing all workings and clearly stating the initial conditions. [*13 marks*]

(c) Calculate the magnitude of the normalised error for rays 2, 3 and 4 after the second iteration. [*3 marks*]

7. Explain in detail, how control engineering techniques can contribute to either of the following medical applications;

either,

(a) Functional electrical stimulation to restore muscle function, with application to unsupported standing, cardiovascular exercise and cycling.

or,

(b) Noninvasive monitoring and regulation in Type I Diabetic patients.

[*20 marks*]