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

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

AUTUMN 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 briefly describe the Doppler ultrasound test. [*10 marks*]

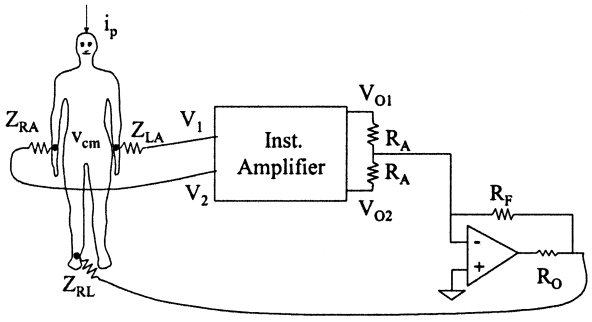
   (b) Define and briefly describe what is a synapse [*10 marks*]

2. (a) Briefly describe the signal properties of ECG and EEG signals including their expected amplitude and frequency ranges and how these affect the choice of a suitable A/D converter for automated monitoring. [*10 marks*]

   (b) Briefly define the following ECG-related terms, illustrating your definition by means of simplified diagrams:

   i. Einthoven Triangle. [*2 marks*]
   ii. Wilson Resistor Network [*2 marks*]
   iii. Lead I Connection [*2 marks*]
   iv. Lead II Connection [*2 marks*]
   v. Lead III Connection [*2 marks*]

3. An ECG system is connected with right-leg feedback as shown below. Due to stray capacitances, a mains-induced stray current, i_p, flows through the patients' body causing an undesired common-mode voltage, v_{cm}.



(a) Assuming that the instrumentation amplifier and the op-amp have very high input impedances and also that $V_{O1} = V_1$ and $V_{O2} = V_2$, derive an expression for v_{cm} in terms of i_p and the circuit elements.

[*15 marks*]

(b) If $Z_{RL} = 50k\Omega$, $R_A = 25k\Omega$, $R_F = R_O = 5M\Omega$, $i_p = 1\mu A$, determine v_{cm}.

[*5 marks*]

4. (a) In the Nervus EEG machine a FIR low pass filter is used to eliminate artefacts greater than 40Hz. 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 0.12π radians is required.

[*10 marks*]

5. (a) Explain the Welch method of spectral estimation. Compare the Welch 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*]

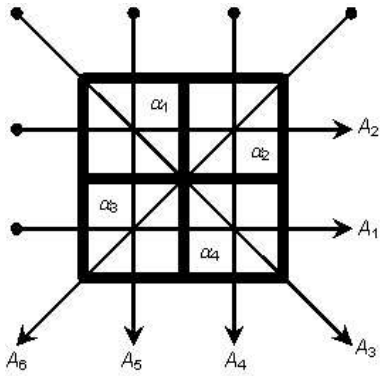
(b) Explain in detail how Fourier transforms and magnetic gradients are used in a typical MRI scanner to localise the signal source in 3-dimensions

[*10 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: $A_1 = 15, A_2 = 3, A_3 = 12, A_4 = 11, A_5 = 7, A_6 = 6$



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*]