National Exams Dec 2013

04-Bio-B6, Bioinstrumentation

3 hours duration

The following exam includes 6 questions of which you must answer 4. Use block diagrams where appropriate, with specifications and/or function for each block, to aid in your explanations. Detailed electronic circuits are not necessary but could be helpful in your solution. It is expected that most systems will require a mixed analog/digital solution. When using a microcontroller or computer in your solution it is necessary to describe the data acquisition/processing/display functions in a simple flow chart. Each question is worth 25 marks, with marks for each subsection as shown.

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FOUR (4) questions constitute a complete exam paper.
   The first four questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Most questions require diagrams and/or answers in essay format. Clarity and organization of the answer are important.

1. The electroretinogram (ERG) is recorded by placing a ring electrode (gold or stainless steel) on the cornea of the eye with a reference electrode (Ag-AgCl) on the forehead and a ground on the neck. The resulting signal shown in Fig. 1 has an amplitude of 0 – 900 μV and a bandwidth of 0 – 50 Hz (the total time for Fig 1 is 150 ms). The signal is caused by flashing a light (time 0 in Fig 1) of different intensities and colours and recording the response of the retina. The important features are times to the peaks of the a-wave and b-wave and the amplitudes from the baseline of each of these waves. Design a measurement system to record the ERG which removes enough noise to allow us to measure these features and record the signal and results. Use a block diagram approach giving the specifications for each block from transducers to final display(s). Consider patient safety and comfort.

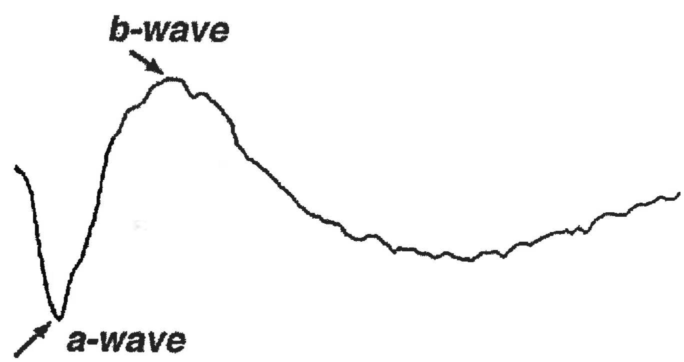

Fig.1 The biphasic waveform of the ERG of a normal patient.

25 marks

2. The BSAEP (Brain Stem Auditory Evoked Potential) is recorded by stimulating the auditory system using sharp clicks. These clicks are presented to the ear using earphones that damp out all external sounds. The resulting brain signal, doesn't change from click to click, and is recorded over the central/parietal area of the brain using surface electrodes with the earlobe as a reference. This evoked signal, lasting 10 ms, is in the 100's of nanovolts to several microvolt amplitude range and bandwidth of 150 to 2500 Hz and is usually totally masked by environmental or other noise (e.g. the background EEG). Each surface electrode has a total skin/electrode impedance of 5K ohms and is connected to the instrumentation by a 2 m flexible wire.

(i) Describe 3 sources of noise other than the ambient EEG including their frequency and amplitude ranges — 6 marks

(ii) Design a front end amplifier/filter system that will take the signal from the subject electrodes and present it to the input of the analog to digital convertor of the data acquisition system. Give all important specifications for the circuit blocks and your reasons for selecting the values, including the sampling rate for the ADC. — 15 marks

(iii) If some of the noise covers the frequency range of the BSAEP, are there any techniques, other than filtering, that can remove some or all of it? Describe briefly. — 4 marks

Total — 25 marks

3. There are three broad categories of noise sources in biological, especially electrophysiological measurements. These categories are: environmental, biological and instrumentation. Describe five of these noise sources and how modern instrumentation system methods and technologies can accommodate or remove the associated noise. The descriptions of the methods or technologies should give detailed explanations or specifications respectively.

5 marks each

Total — 25 marks

4. The piezoelectric sensor is a reversible transducer that is used to generate and measure ultrasound waves in biological tissue as well as measure applied forces.

(a) Give the equivalent circuit model of a piezoelectric transducer attached to an amplifier and used to measure an applied force. Describe each circuit component.

10 marks

(b) How can a single piezoelectric transducer be used to measure blood flow in superficial or deep arteries. Give a block diagram of the instrumentation system and describe the function of each block including the operation of the transducer

15 marks

5. Bioinstrumentation is used extensively in the hospital or other high risk environments where the principle consideration is patient/subject/animal safety rather than instrumentation protection, as it is in industry. Consequently biomedical engineers must be very aware of electromedical standards and safety guidelines.

(i) Describe the difference between macroshock hazard and microshock hazard (when the equipment is still functioning but the ground may be broken). 5 marks

(ii) Why could a patient or subject be at greater risk from electrical shock in a hospital or laboratory environment? Think of the patient having attached or indwelling sensors or instrumentation, and impedances to current flow. 5 marks

(iii) What standards should a professional biomedical engineer be aware of and follow in the design or use of medical or laboratory equipment? 5 marks

(iv) Electrical isolation and isolated circuits are extensively used in bioinstrumentation. Describe the devices and circuits used to accomplish this and the advantages or disadvantages of different approaches. 10 marks

6. One of the most important parameters measured in the operating, emergency, post anesthetic care and intensive care units is the oxygen saturation of arterial blood (the percent of hemoglobin carrying oxygen, SaO_2). In earlier decades this had to be done by drawing blood from an artery and performing a laboratory analysis. Since the 1980's an instrument has been developed based on light absorption called the pulse oximeter that is noninvasive and accomplishes this continuously in real time. This is done by shining light on the skin and measuring either reflected or transmitted light energy.

(i) Describe the biophysical principles underlying the transmitted light technique including the absorption characteristics of the tissues involved. 10 marks

(ii) Describe the instrumentation required to accomplish this from sensor to display. Use a block diagram with each block representing the hardware or data processing element. 8 marks

(iii) How can we accommodate darker pigmentation or thicker tissue in transmission oximeters. 5 marks

(iv) List two sources of noise in the measurement. 2 marks