National Exams Dec 2012

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. It is well known that the EEG pattern (0.5 to 32 Hz, 30 µvolt), as well as the core body temperature (35 to 40 ^{0}C as measured in the ear canal) changes during the sleep cycle. Design a system to measure the degree of correlation (linear dependence) between percent of power in the theta (4 – 7 Hz) and delta (1 – 3.5 Hz) EEG bands compared to the total signal power, and the core temperature. Pick a reasonable window length to average the data and obtain these averages for a maximum of 8 hours. How are you going to store and display the results? The principal noise sources will be EMG of the scalp muscles and movement artifact. Your instrumentation should be safe and comfortable and able to recognize and/or remove this noise. 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 ambient EEG of question 1). 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

3. A subject is asked to maintain a maximum voluntary contraction of the biceps brachii (large upper arm muscle that bends the elbow) until he/she can no longer produce any force. Muscle activity can be measured by attaching a pair of electrodes over the belly of the muscle and recording the myoelectric (EMG) signal. During such fatiguing contractions the power spectrum of the surface EMG signal (20 - 250 Hz, 0 – 2 mV) shifts to lower frequencies and the amplitude (linear envelope or mean absolute value) increases. Design a system to continuously measure, display and record the force output and EMG amplitude of the muscle and to record and calculate the power in the 20 to 100 Hz band <u>relative</u> to the power in the 100 to 250 Hz band. These measurements should be made for each 5 seconds of contraction until no force output can be detected. Give a block diagram of the measurement system, including specifications and function for each block, from sensors or transducers to the final displays. 25 marks

4. In patients, heart sounds are produced when heart valves close abruptly or blood flow is turbulent. Physicians detect these sounds with a stethoscope during normal breathing. You are asked to design a system that more accurately measures and displays these sounds (measures both amplitude and duration) and correlates them with the electrical events of the heart and the arterial blood pressure waveform as obtained directly by a pressure transducer attached to flexible tubing with a hollow needle inserted into an artery in the arm. Describe your design including specifications and function for each block in a block diagram from measurement transducers to final signal display. Identify any possible sources of noise in your signals, and approaches to removing them. Also consider patient safety.

25 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. 5 marks

(ii) Why could a patient or subject be at greater risk from electrical shock in a hospital or laboratory environment? Think of patient attached or introduced 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, So_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