National Exams May 2014

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. 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

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 (mean absolute value) increases. Design a system to continuously measure, display and record the force output and EMG of the muscle. The system should then calculate and display over time the above amplitude statistic and power ratio 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 precise specifications and function for each block, from sensors or transducers to the final displays. 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 electro-medical 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