Student Name: ______________________
Student Number: ____________________

ELECTRICAL ENGINEERING 4BD4 (ELEC ENG 4BD4)

DAY CLASS **Dr. H. de Bruin**

DURATION OF EXAMINATION: 3 hours
McMaster University Final Examination **December 2013**

THIS EXAMINATION PAPER INCLUDES 3 PAGES AND 2 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR

SPECIAL INSTRUCTIONS: In your answers, make use of diagrams whenever possible.
The CASIO-FX 991 only is permitted

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1. Answer five of the following (10 marks each)

(I) Describe how Doppler-shift ultrasound can be used to estimate blood flow in an artery lying near the skin surface (e.g. carotid artery). Describe the continuous Doppler-shift instrumentation used to obtain this estimate. What are the factors that determine depth and spread of the ultrasound wave? What ultrasound frequency would you choose for the above?

(II) What is a strain gauge? Describe in detail the physical and electrical principles of transduction. How would you use this technology to measure large forces (>10 kg) exerted by an adult's muscles? Describe the necessary technology to present a time varying voltage signal representing the instantaneous force to the inputs of an amplifier stage.

(III) What is a piezoelectric transducer and what can it be used for? Give the simplified equivalent circuit for a piezoelectric transducer attached to an amplifier, listing what each component represents. What is resonance and how can you avoid it in a measurement system? When can we make use of resonance of piezoelectric crystals?

(IV) Explain the physical and operating principles of a pulse oximeter. How can we accommodate darker pigmentation or thicker tissue in transmission oximeters? List two sources of noise in the measurement.

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(V) Describe the pH sensor, its principles of operation and output characteristics (specifications). What should be the specifications of the input amplifier that can process its signal?

(VI) In diagnostic electrophysiology we stimulate nerves or groups of neurons by direct electrical stimulation or through stimulation of sensory channels (e.g. sensory nerve fibers in the fingers or the brainstem response to auditory stimuli). The evoked response can be very small (< 2 μvolt) but has higher frequency content (40 Hz – 3 KHz). Unfortunately stimulus artifact, instrumentation and other additive noise exist in the same bandwidth with higher amplitude range. What noise reduction technique is commonly used and describe its principles of operation? What types of noise can it remove? How can this technique be modified to make it more efficient when the noise may include large occasional signals such as EMG or other spikes?

(VII) Describe the single electrode demand/inhibit (synchronous) pacemaker. Why is it the most common form of pacemaker used? Give the block diagram representation of the pacemaker, describing each block.

(VIII) Describe three possible sources of noise in an ECG signal and briefly explain how good instrumentation or experimental design can remove each noise. Use electrical equivalent circuits in your explanations.

2 Answer two of the following (25 marks each)

In your answers use block schematics and present the details for each block including a brief description of the theory of operation of your system where necessary. If your designs include transducers (sensors) describe these in detail and where they are placed in/on the body. Also consider patient safety and comfort, equipment reliability, cost and noise immunity in your design.

(I) During sleep some people suffer from sleep apnea (shortness of breath). Design a system to measure the ratio of theta and delta EEG power to total EEG power using two electrodes (C3 and C4), breathing rate and amount of breathing noise (e.g. snoring), and record and display the average of this data for each minute during 8 hours of sleep.

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(II) In a research study a subject is seated in a chair and asked to maintain a force of 75% MVC (maximum voluntary contraction) of elbow flexion using his biceps brachii (upper arm muscle) until fatigue sets in and he/she can no longer maintain this force. The force will be applied against a fixed bar attached to the chair arm. The researcher is interested in studying the effects of strong sustained contractions (up to 2 min) on neuromuscular control and the response of the heart. Does EMG (2 mV, 10 to 300 Hz) increase to maintain a constant force (i.e. are more motor units recruited) as the muscle fatigues and does the heart rate increase throughout the contraction? Design an experiment and instrumentation system to first measure maximum voluntary contraction (MVC) force on the bar during a 5 second maximum contraction. Your system will then continuously display 75% of this force signal to the subject as a target during the sustained contraction. Your instrumentation will measure the force exerted on the bar during the sustained contraction, display it to the subject as feedback to maintain the 75% level and store it for up to 2 min together with the heart rate (from ECG 2 mV, .05 – 150 Hz) and an EMG amplitude measure. Pick suitable averaging windows for the three different signals. How will you display the results?

(III) Design a patient device for an above-knee amputee to assist him in learning to walk with an artificial leg. When the patient first learns to stand he or she is supported at the arms and with the guidance of a physiotherapist must learn to transfer weight to the artificial leg until full body weight can be supported. During this training your device should give out an audible tone, with the base (0 weight supported) pitch (frequency) at 200 Hz and then increasing proportionally with increased support until full body weight is supported by the artificial leg. The device should also give a brief auditory signal when his heel hits the floor, while learning to walk. Incorporate in the device a counter which will record the number of steps taken by the patient during the day and which can be read and reset by a physiotherapist. As well the device should record and display the average of all the body weight signals (body weight supported as a function of time during a step) recorded for all steps taken during the day.

THE END