Lecture 29

Answering Exam Questions

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?

- Describe how ultrasound frequency and diameter of transducer determine depth of near field and spread. (equations)
- Describe how ultrasound waves bounce off red blood cells and are picked up by receiver
- Describe how red blood cells moving in artery cause doppler shift in received frequency (equations)
- Draw block diagram of continuous Doppler shift instrumentation and label or describe each bloc

(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.

- Describe it as a resistor which has both geometric and piezoresistive properties that change the resistance when strain is applied (equations)
- Idea of isometric device and gauge factor,
- Describe the bonded strain gauge applied to a metal structure that is then put under strain (strain transferred to strain gauge)
- Describe a metal structure that deforms slightly in the elastic range as force is applied
- Describe temperature compensation
- Wheatstone bridge to give zero-based voltage linearly dependent on strain

(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?

- Describe it as a reversible system that produces a voltage difference on opposite faces when placed under strain and deforms when voltage applied to opposite faces.
- Naturally occurring quartz crystal or manmade crystal or polymer film, etc
- Can describe it as a capacitor that produces charge under strain
- Equivalent circuit including transducer electrical characteristics, cable characteristics and amplifier characteristics.
- Describe its force measurement characteristics (bandwidth)
- Describe its resonant properties (crystal osccillator), High frequency sound wave oscillations for ultrasound (MHz). High output- low drive req'd

(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.

- Describe differential absorption characteristics of oxygenated and de-oxygenated hemoglobin over optical frequency range (wavelength), especially for red and infrared
- Describe the reflectance and transmittance method of applying optical energy and measuring remaining energy after absorption.
- Describe constant optical absorption of tissues and fluids not associated with arterial blood.
- Describe how we analyze only that absorption due to pulsatile arterial blood
- Describe the ratio of absorptions and the approximating equation to give SaO2
- Describe autogaining or auto power change to make up for greater or lesser absorption
- Noise: movement artifact, ambient light, other absorbing molecules (drugs) in blood

(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?

- Describe the idea of the semipermeable membrane and the Nernst potential based on differences in ionic concentrations
- Describe the construction and layout of a typical pH electrode including a discussion of the reference electrode
- Discuss the physiological range of pH to be measured and what the output of such an electrode would be
- What characteristics should the first stage amplifier have?

(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?

- Describe the idea of synchronous averaging: requires multiple stimuli with data collection time-locked to stimulus time
- Describe recorded signal as sum of true response +noise, responses being deterministic or consistent, most noise being random w.r.t. signal and w.r.t. to itself for each stimulus
- Describe ensemble averaging which just leaves you with the true signal + some leftover noise
- Describe idea of thresholding out records with large noise spikes
- Describe noise you can't remove such as stimulus artifact which is also time-locked to stimulus and not random w.r.t. each record

(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.

- Describe the idea concept of heart block especially intermittent block
- Describe the need not to stimulate during a naturally occurring T wave to avoid cardiac fibrillation
- Describe how demand/inhibit pacemaker makes sure of this by looking at the ventricular signal to detect a naturally occurring QRS and thus inhibiting sending out a stimulus pulse
- Present the block diagram for the pacemaker, describing each component such as power supply, electrode lead(s) – where placed, how they are made, electrode configuration and material, etc.
- Describe the pacing pulse specifications: duration, current or voltage, shape, default rate
- Can discuss the idea of rate modulation using an activity measuring transducer - accelerometer

(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.

- Same as midterm
- 60 Hz noise using differential amplification to remove common mode signal
- Differential 60 Hz noise from power line capacitive coupling or electrode impedance mismatch removed by cable shielding, twisting leads to reduce magnetic coupling, making sure electrodes are in good contact and have roughly equal impedance
- Motion artifact – taping leads down, having subject avoid moving, using active electrodes, high pass filtering if only interested in QRS
- Muscle artifact – narrow bandpass filtering for QRS detection, not placing electrodes over muscle