FIJI NATIONAL UNIVERSITY

COLLEGE OF ENGINEERING, SCIENCE AND TECHNOLOGY

School of Electrical & Electronics Engineering

Bachelor of Engineering (Electronics & Instrumentation)

EEE723 – Industrial Electronics

FINAL EXAMINATION

Semester 1, 2017

Date: As per Exam Time Table

Time: As per Exam Time Table

Venue: As per Exam Timetable

Duration of Exam: 3 Hours 10 Minutes

Instructions to Students

1. You are allowed an extra ten (10) minutes of reading time during which you are NOT allowed to write.
2. Attempt all questions from section A and select any two questions from section B.
3. Write your answers in the answer booklet provided.
4. Write your Student ID number on each page used.
5. Begin each Section on a fresh page and use both sides of the answer sheet.
6. You may use calculators provided they are non-programmable.
7. Clearly number the questions in your answer paper in their correct sequence and write legibly. Show all working.
8. Attach any extra sheets used to your answer booklet securely with the string provided.

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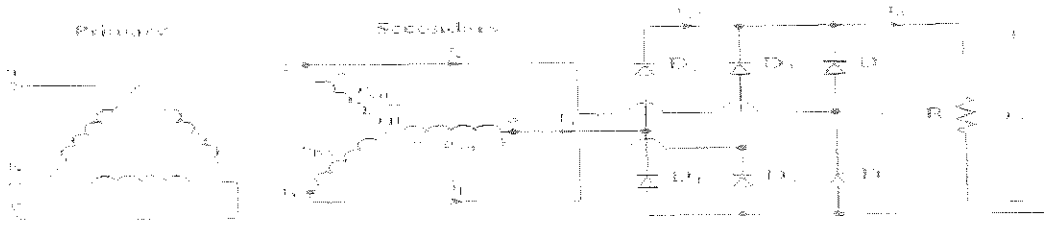
Section A: (compulsory) (50 marks)

Question 1: Industrial Power Control Devices/Circuits and Power supplies (30 marks)

a) Sketch the volt-ampere (V-I) characteristic curve for the thyristor (SCR) and describe its operation. ***(3 marks)***
b) Define the Safe Operation Area (SOA) of power transistors and describe its secondary breakdown phenomenon. ***(3 marks)***
c) Outline the characteristics of Insulated Gate Bipolar Transistor (IGBT). ***(3 marks)***
d) Describe two-switch specification you are required to consider while selecting switches. ***(3 marks)***
e) With the help of switching characteristics curve of GTO thyristor, explain why switching losses are high in GTO thyristor when compared with SCR thyristor. ***(3 marks)***
f) Outline the purpose of isolating control circuits from power circuits. ***(2 marks)***
g) Design a PUT based firing circuit which could be used to trigger an SCR. PUT parameters are $V_s = 25V$, $I_G = 1.8mA$. The frequency of oscillation is f = 1.2kHz. The triggering pulse width is $t_g = 30\mu s$ and the peak voltage of the triggering pulse is equal to 6V. Use C = 0.5μF. ***(4 marks)***
h) Design a series voltage regulator using an operational amplifier and a 5.1 V zener diode to maintain a regulated output of 15 V. Assume that the unregulated input varies between 10 V and 30 V and that the current through the zener diode must be at least 30mA to keep it in its break down region. ***(5 marks)***
i) Compare switching regulator with series and shunt regulators. ***(2 marks)***
j) Outline the desirable features of 723-integrated-circuit regulator. ***(2 marks)***

Question 2: Single-phase & Three-phase controlled/uncontrolled Rectifiers (20 marks)

a) Outline the requirements of rectifier circuit design and list two important parameters used to measure the performance of rectifier circuits. ***(2 mark)***
b) Design a battery charger circuit using half-wave rectifier circuit to charge a battery of 20V. The average charging current should be 5A. The primary input voltage is 120V, 60 Hz and the transformer turns ratio is 2:1. ***(5 marks)***
c) A three-phase bridge rectifier has a purely resistive load R as shown in Figure below:



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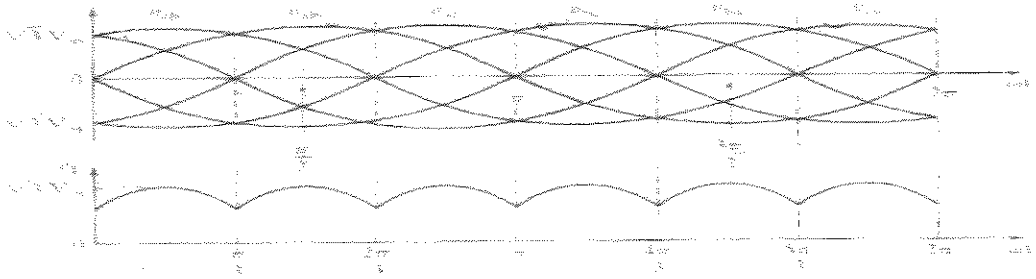

i) For the output voltage waveform, assuming a cosine wave from $\pi/6$ to $\pi/3$, derive the equation for average output voltage V_{DC} and rms output voltage V_{rms}. ***(4 marks)***

ii) Determine the Efficiency, form factor and ripple factor of the three-phase bridge rectifier given above. ***(2 marks)***

iii)For purely resistive load, peak current through a diode is $I_m = \sqrt{3}V_m/R$, *rms* value of the diode current is $I_{rms} = 0.5518I_m$, and *rms* current of the transformer secondary is $I_s = 0.7804I_m$, *rms* voltage of the transformer secondary $V_s = 0.707V_m$, find the transformer utilization factor (*TUF*). ***(2 mark)***

d) For a single-phase full-wave converter (controlled rectifier) operated from 120-V, 60-Hz supply and a highly inductive load is connected. (Load current is continuous and ripple free).

i) Sketch the circuit diagram, input and output waveforms with delay angle of α. ***(3 marks)***

ii) Determine the delay angle, which would give average output voltage of 35% of maximum possible average output voltage. ***(2 marks)***

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Section B (Select and answer any two questions from this section). (50 marks)

Question 1: Converters and Inverters (25 marks)

a) Power flow can be controlled by controlling the ac voltage applied to the load, outline the two types of control methods. ***(3 marks)***
b) Outline the principle of operation of cycloconverters and compare it with AC voltage controllers. ***(4 marks)***
c) With aid of a circuit diagram, describe a Four-quadrant dc-dc converter and outline its application. ***(4 marks)***
d) With an aid of circuit diagram, explain the operation of boost dc-dc regulator. ***(3 marks)***
e) For a single-phase bridge voltage source inverter (VSI), draw the circuit diagram and output waveforms with a resistive load of R and explain its operation. ***(5 marks)***
f) The output of practical invertors contain harmonics, name and describe the performance measures normally used to analyse the quality of an inverter. ***(3 marks)***
g) For industrial application, a variable voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. On the other hand, if the dc input voltage is fixed, then variable output voltage can be obtained by varying the gain of the inverter. Outline and explain one of method to control to the gain. ***(3 marks)***

Question 2: Process Control and Feedback systems (25 marks)

a) Define process control and outline its important components. ***(3 marks)***
b) Name and describe the three basic characteristics important to understand process control system. ***(3 marks)***
c) Describe the on-off controller mode and illustrate the concept using an example of temperature control using op-amp based on-off controller. ***(3 marks)***
d) Explain proportional, integral and derivative control methods and its effect on system response. ***(5 marks)***
e) Describe and compare electric and pneumatic controllers. ***(3 marks)***
f) Discuss and describe the features of transducers that need to be considered when selecting a transducer. ***(3 marks)***
g) Design an op-amp based circuit for implementing a PI-controller with transfer function:

$$G_c(s) = -2\left(1 + \frac{1}{0.30s}\right)$$

Draw the required op-amp based circuit and select suitable component values. Assume that a 0.3μF capacitor is to be used. ***(5 marks)***

Please Turn Over

Question 3: Motor Control (25 marks)

a) Describe the basic characteristics of dc motors and outline various ways of controlling speed of separately excited dc motor. ***(3 marks)***
b) A 20-hp, 220-V, 3000-rpm separately excited dc motor controls a load requiring a torque of T_L=45N-m. The field circuit resistance is R_f =147 ohms, the armature circuit resistance is R_a=0.25 ohms and the voltage constant of the motor is K_v=0.7032 V/A rad/s. The field voltage is V_f=220V. The viscous friction and no-load losses are negligible. The armature current may be assumed continuous and ripple free. Determine:
   i) Speed of the motor if the back emf E_g = 132V. ***(2 marks)***
   ii) The required armature voltage V_a at the speed calculated in (i) above. ***(2 marks)***
   iii)The rated armature current of the motor. ***(1 mark)***
c) With a aid of circuit diagram, describe the operating modes of dc motors in variable-speed application. ***(4 marks)***
d) Using an aid of circuit diagram, outline the principles of either regenerative braking or rheostatic braking of dc-dc converter-fed dc motors drives. ***(3 marks)***
e) Outline the principle of operation of three-phase induction motors. ***(3 marks)***
f) Describe the Torque-speed characteristics of induction motors. ***(5 marks)***
g) Outline the various means of speed control of induction motors. ***(2 marks)***

Question 4: Industrial Applications (25 marks)

a) Draw the block diagram of closed-loop control of separately excited dc motor with control features of firing angle adjustments, current regulation and speed regulation and describe its operation. ***(4 marks)***
b) i. Outline the principles of induction heating. ***(4 marks)***
   ii. Compare induction heating and dielectric heating. ***(3 marks)***
c) Draw the block diagram of uninterruptible power supply (UPS), outline its operation and discus various aspects of the following parts used in UPS: Battery, Inverter and Rectifier. ***(5 marks)***
d) i. Outline the properties of ultrasonic waves. **(3 marks)**
   ii Discus the applications of Ultrasonic waves in engineering. ***(3 marks)***
e) Describe use and principles of Pyrometers. ***(3 marks)***

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Formula Sheet

- Period of oscillation using UJTs and PUTs

$$T = RC\ In\left(\frac{1}{1-\eta}\right)$$

- PUT gate current and resistance:

$$I_G = (1-\eta)\frac{V_s}{R_G}$$

$$R_1 = \frac{R_G}{\eta}$$

$$R_2 = \frac{R_G}{1-\eta}$$

- Average and RMS voltage calculations

$$V_{dc} = \frac{1}{T}\int_0^T v_L(t)\,dt$$

$$V_{rms} = \left(\frac{1}{T}\int_0^T {v_L}^2(t)\,dt\right)^{1/2}$$

- DC motor equations

$$e_g = K_v i_f$$

$$T_d = K_t i_f i_a$$

$$T_d = J\frac{dw}{dt} + Bw + T_L$$

- AC motor equations

$$w_s = \frac{2w}{p}$$

$$s = \frac{w_s - w_m}{w_s}$$

$$w_m = w_s\left(1 - \frac{s_m}{2T_{mm}}T_d\right)$$