FIJI NATIONAL UNIVERSITY

COLLEGE OF ENGINEERING, SCIENCE AND TECHNOLOGY

School of Electrical & Electronics Engineering

Trade Diploma in Electronics Engineering

EEE574 – Power Control Electronics

FINAL EXAMINATION

Trimester 2, 2016

Date: As per Exam Time Table

Time: As per Exam Time Table (3 hours)

Venue: As per Exam Timetable

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 in this examination booklet
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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Final Examination

Section A: Short Answer Question [40 marks]

(2 marks each)

1. Draw the *volt-ampere (V-I)* characteristic curve for the thyristor (SCR) and describe the operation of SCR. (*Label the forward blocking region, forward break over region, high conduction region, reverse breakdown voltage and reverse blocking region*).

2. A thyristor can be destroyed, if current rises at very high rate, that is high di/dt. What can be done to operate thyristor within specified safe limit outlined by manufacturer.

3. Describe what is *R-C* snubber circuit and its application in the operation of a thyristor.

4. Describe the difference between line commutation and forced commutation.

5. Discuss the advantage and disadvantage of using GTO (gate-turn-of) thyristor.

6. Draw the structure of *BJT* power transistor (npn type) and sketch the curves for switching operation of the power transistor.

7. Define secondary breakdown phenomenon in relation to power transistors.

8. Draw the Safe Operation Area (SOA) of the BJT power transistors and label the 4 regions.

9. Describe the characteristics of IGBT (Insulated Gate Bipolar Transistor).

10. Define two characteristics of an ideal switch.

11. What is the difference between triggering gate current and holding current of a thyristor.

12. Define rectifier recovery time.

13. Name five important parameters used to measure the performance of rectifier circuits.

14. Explain the principles of phase control rectifiers.

15. Describe the principle of operation of a step-down dc-dc converter (chopper).

16. Describe pulse-width-modulation control of a convertor.

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17. What are the advantages and disadvantages of circulating current mode of operation of dual converters.

18. i) Describe the function on an inverter.
    ii) Define voltage-fed inverters (VFI) and current-fed inverters (CFI).

19. State and discuss the various methods of speed control of dc motors.

20. State and discuss the various methods of speed control of ac induction motors.

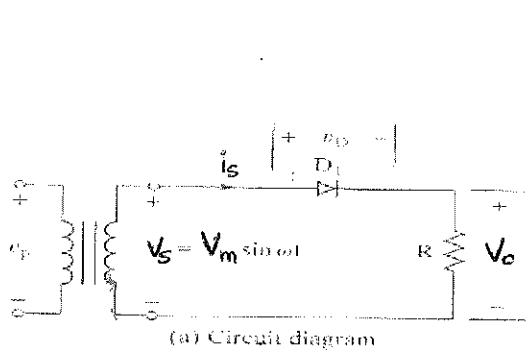
Section B [60 marks]

Part I: Rectifiers (22 marks)

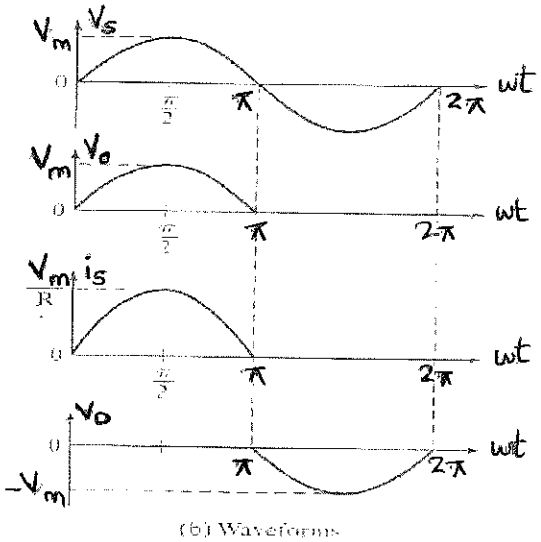
a) Figure below shows the single-phase half-wave rectifier (with purely resistive load R) circuit and input and output waveforms:

i) Derive the equations for average output voltage (V_{DC}), average output current (I_{DC}), root-mean-square (*rms*) output voltage (V_{rms}) and root-mean-square (*rms*) output current (I_{rms}). (4 marks)

ii) Determine the efficiency, form factor and ripple factor of the half wave rectifier. (2 marks)



(a) Circuit diagram



(b) Waveforms

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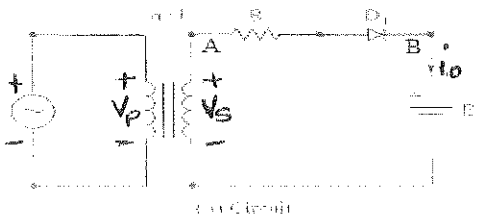
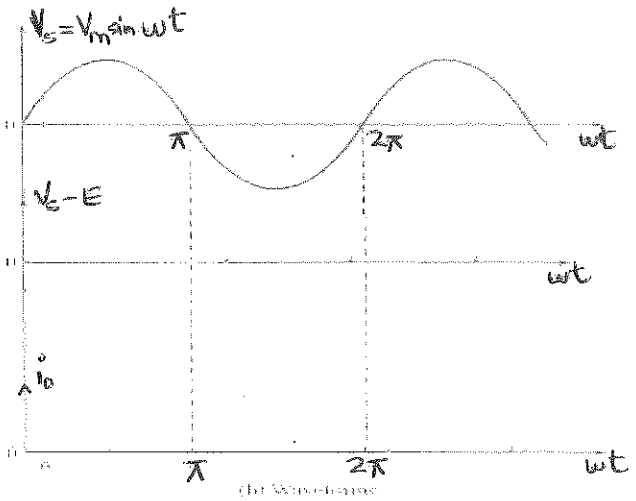
b) The battery voltage in Figure below is E=20V and its capacity is 100WH, the average charging current should be I_{DC} = 5A. The primary input voltage V_p = 120V 60Hz and the transformer turns ratio n=2:1.

i) Draw the waveforms for current i_o and voltage between points A and B. (label the peak amplitudes) (2 marks)

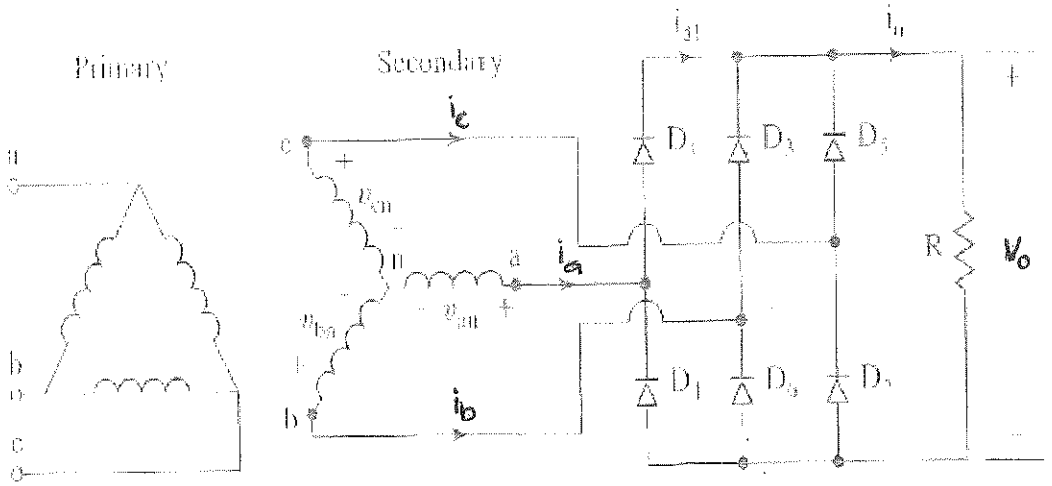
ii) Find the conduction angle α of the circuit. (2 marks)

iii) Drive the formula for average charging current and find the value of current limiting resistor R. (3 marks)





c) A three-phase bridge rectifier has a purely resistive load R as shown in Figure below.



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Final Examination

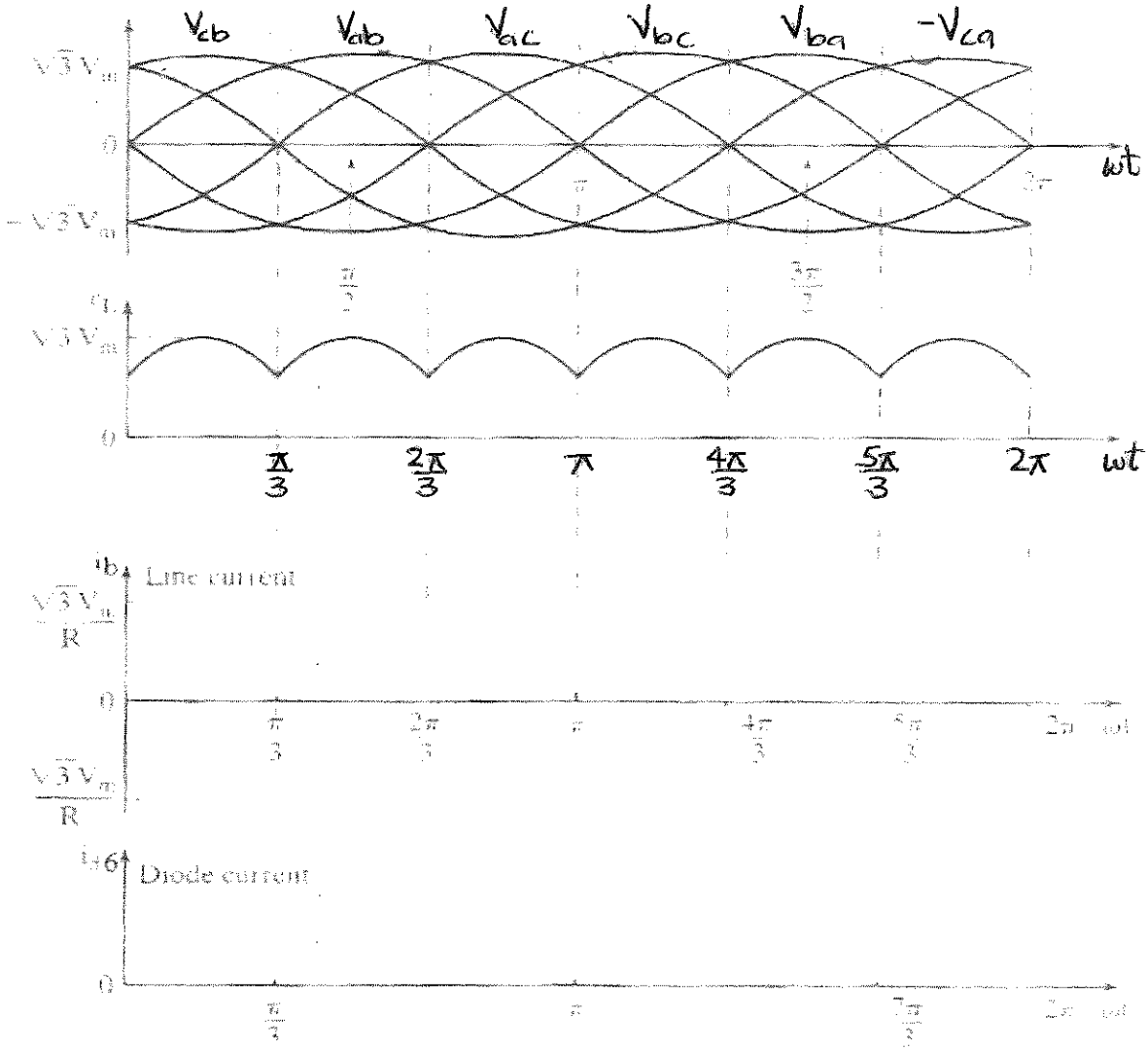
For the three-phase bridge rectifier, Figure below shows the line-to-line voltage and the output voltage waveforms. Do the following:

i) Draw the waveform for line current i_c in Figure below. (2 marks)

ii) Draw the waveform for diode current i_{d5} in Figure below. (2 marks)

iii) 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}. (3 marks)

iv) Determine the efficiency of the three-phase bridge rectifier given above. (2 marks)



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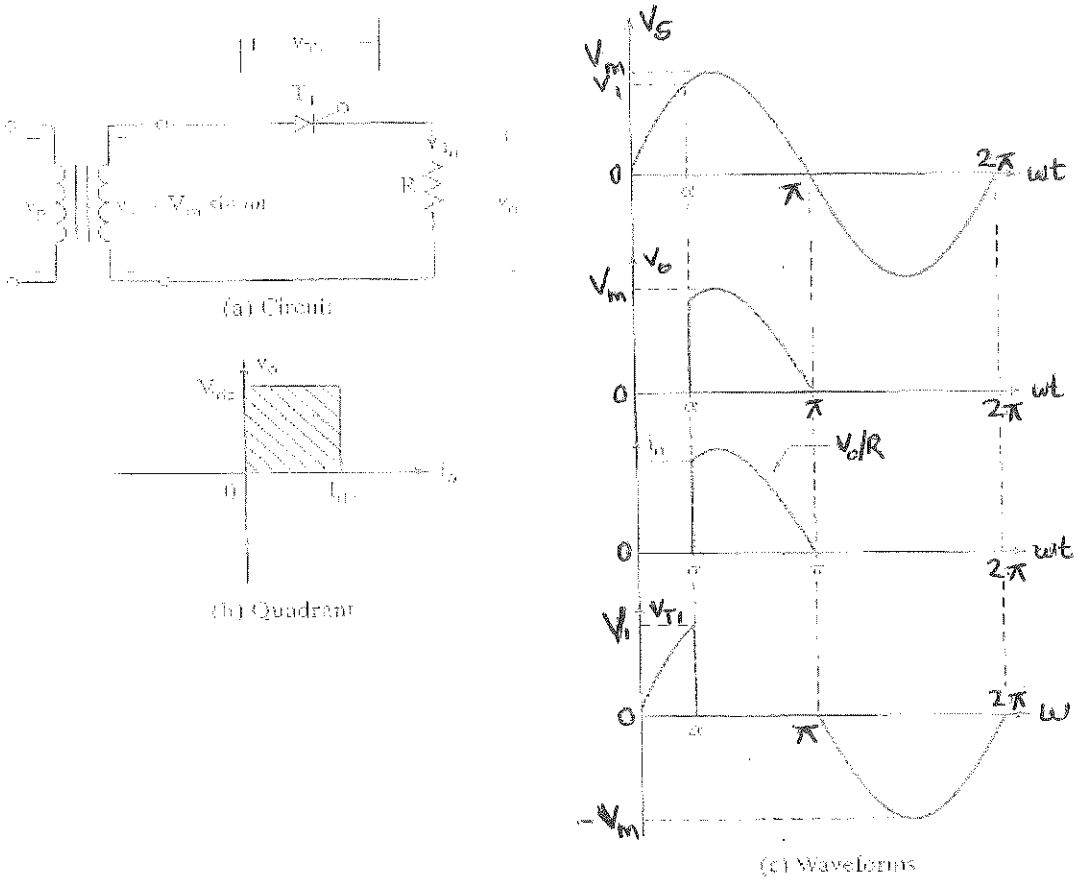
Part II: Control Rectifiers (14 marks)

a) A single-phase half-wave converter given below is operated from a 120V, 60Hz supply. If the resistive load R is R =10 ohms and the delay is $\alpha = \pi/3$, determine: (4 marks)
   i) The efficiency
   ii) The transformer utilization factor



b) A single-phase half-wave converter given in part a is operated from 120V, 60Hz supply and the resistive load R= 10 ohms. If the output voltage is 25% of the maximum possible average output voltage, calculate: (4 marks)
   i) The delay angle
   ii) The rms and average output currents

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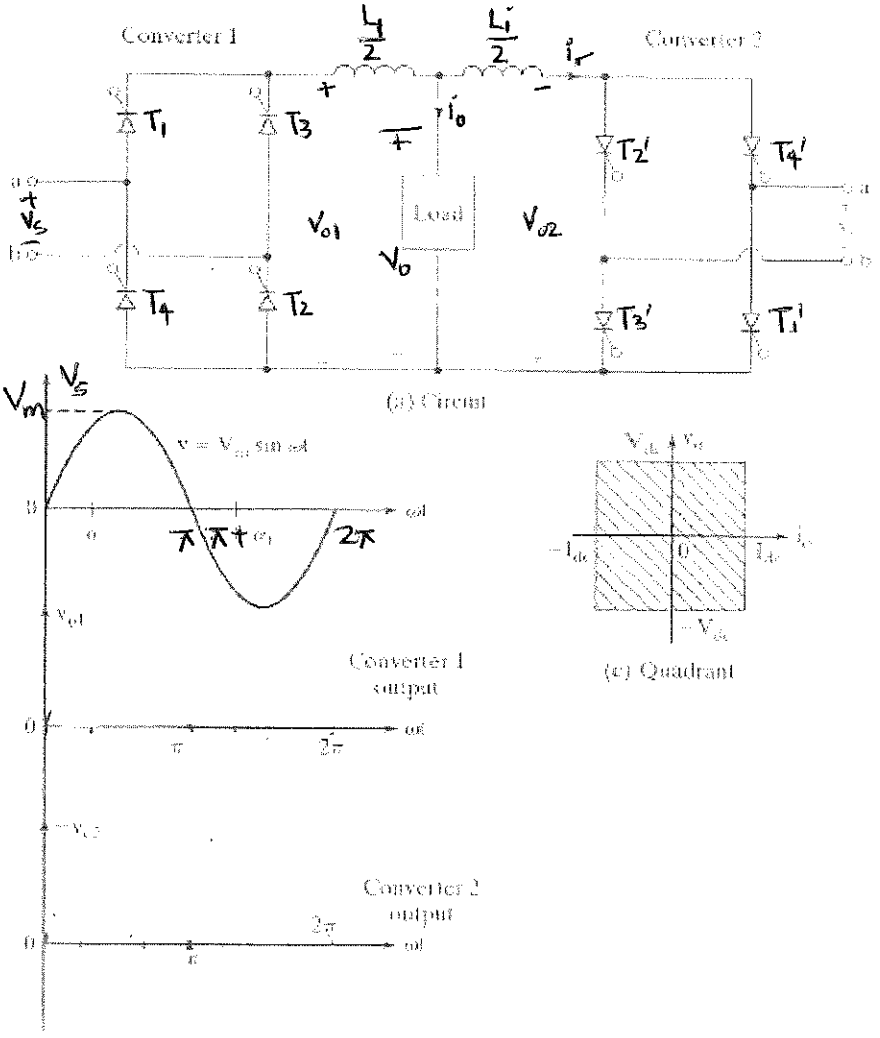
c) A single-phase dual convertor given below is operated from 120V, 60Hz supply and the load resistance is R=10 ohms. The circulating inductance is Lr =40mH; delay angles are $\alpha_1 = 60^0$ and $\alpha_2=120^0$. (6 marks)

i) Draw the output voltage (v_{o1}) waveform with respect to converter 1.
ii) Draw the output voltage (v_{o2}) waveform with respect to converter 2.
iii) Calculate the peak circulating current and the peak current of converter 1.

Circulating current = $i_r = (2V_m/wL_r)\ (cos\alpha 1 - coswt)$
Condition: $i_r > 0$, *if* $0 <= \alpha 1 < \pi/2$
$i_r < 0$, *if* $\pi/2 < \alpha 1 <= \pi$



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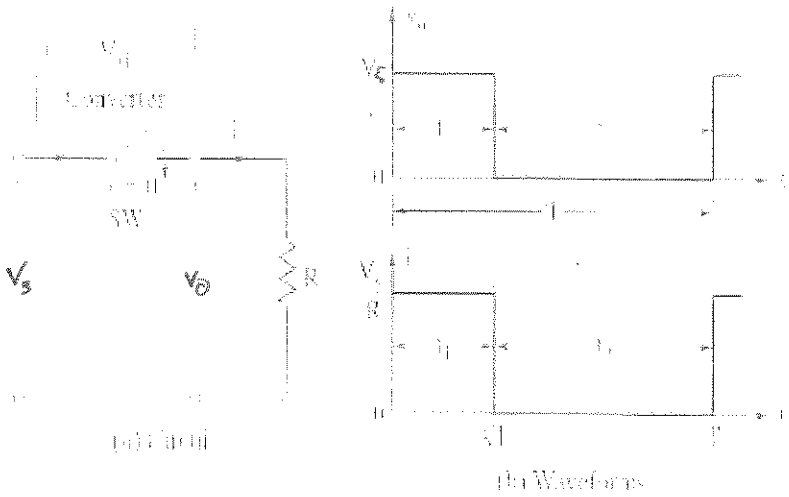
Part III: Choppers and Inverters (12 marks)

a) A dc converter shown below has a resistive load of R =10 ohms and the input voltage V_s=220V. When the converter switch remains on, its voltage drop is v_{ch}=2 V and the chopping frequency is f=1kHz. If the duty cycle is 50%, determine: (5 marks)
   i) The average output voltage.
   ii) The rms output voltage.
   iii) The effective input resistances Ri of the converter.



b) Draw the circuit of Single-phase half-bridge inverter circuit and state the principle of its operation. (3 Marks)

c) The single-phase half-bridge inverter as you have drawn in part b has a resistive load of R= 2.4 ohms and the dc input voltage is V_s=48V. Determine: (4 marks)
   i) The rms output voltage V_{o1} at the fundamental frequency. *($V_{01} = 0.45V_s$ and $V_0=V_s/2$)*
   ii) The output power P_o.
   iii) The average and peak currents of each transistor.

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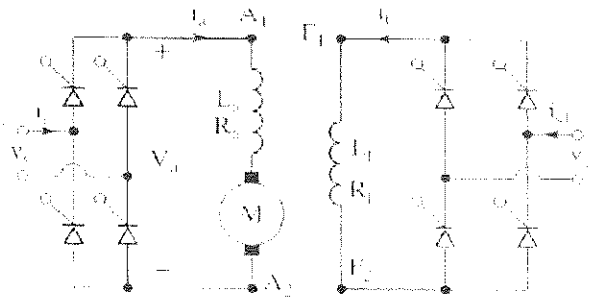
Part IV: Power Electronics Applications (Process Control and Motor speed Control)
(12 marks)

a) Define the following terms: (2 marks)
   i) Process
   ii) Closed loop control system

b) List two power control applications. (1 mark)

c) Draw and explain the close-loop control block diagram of electrical drives. (3 marks)

d) A dc separately excited motor drives a constant toque load of 18 NM. The motor is driven by a full-wave convector through a 120 V ac supply as shown below. Assume that $K_{IF} = 2.5$ and the armature resistance is 2 ohms. Calculate the triggering angle α_a for the motor to operate at 200 rev/min. The motor current is continuous.
(3 marks)



$$V_a = \frac{2V_{max}}{\pi}\cos\alpha_a$$

$$V_f = \frac{2V_{max}}{\pi}\cos\alpha_f$$

$$V_a = E_a + R_a I_a$$

$$E_a = KI_f\omega = KI_f * (2\pi\frac{n}{60})$$

e) Speed of induction motors can be varied by stator voltage control. Draw and explain how ac voltage controllers can be used to control speed of three-phase induction motor.
(3 marks)

THE END

ALL THE BEST FOR THE EXAMINATION