Assignment 2

Due date: 8th October 2013

Value: 20%

Marking scheme

The distribution of marks is given in the table below.

The student should provide some explanation of how he/she arrives at an answer. This explanation can be in the form of an equation that the student states or it could be in the form of a brief description of his/her reasoning.

The student will score full marks (as per the table below) if he/she gives the right answer together with a correct explanation (or equation).

For each part, the student can lose up to 35% of the marks if the answer is right, but no explanation is given or the explanation is inadequate.

For each part, the student will be able to score up to 80% of the marks if the answer is wrong but the explanation is correct or partly correct.

Question	(a)	(b)	(c)	(d)	(e)	Total
1	5	5	5	5		**20**
2	4	4	4	4	4	**20**
3	4	4	4	4	4	**20**
4	5	5	5	5		**20**
5	5	5	5	5		**20**
6	5	5	5	5		**20**
7	10	10				**20**
8	5	5	5	5		**20**
9	4	4	4	4	4	**20**
10	4	4	4	4	4	**20**
					Total marks	**200**

Question 1

This question relates mainly to **Module 7** phase-controlled thyristor converters and the third objective in the course specification.

Use the waveform template given in your introductory book.

Refer to **figure 7.10** of your study book.

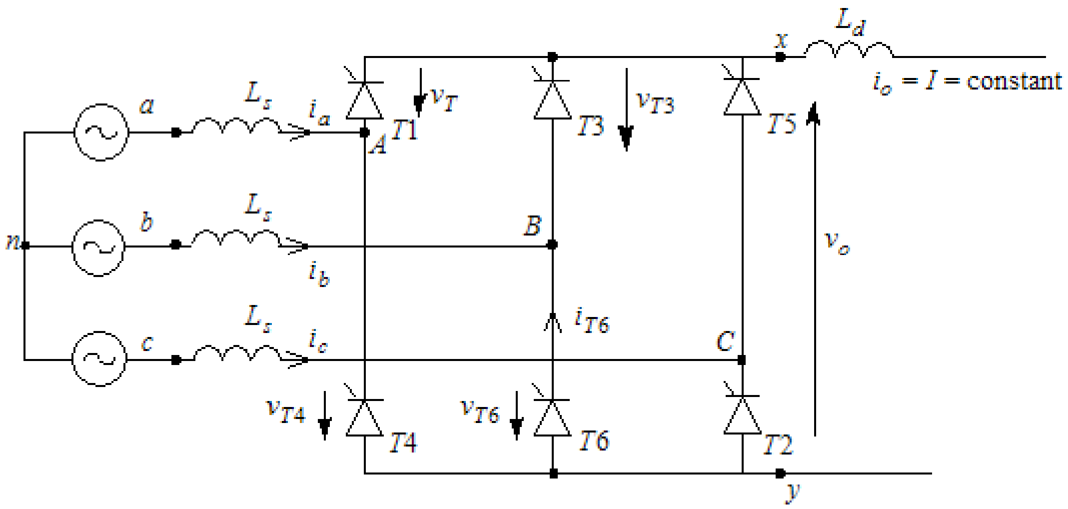


Figure 7.10: Three-phase thyristor converter (L_s – supply inductance)

Assume all components are ideal.

$$v_{an} \text{ (in volts)} = 155.6 \sin \omega t$$

$$\omega = 120\,\pi \text{ rad/s}$$

$$I = 20 \text{ A}$$

$$\alpha = \text{delay angle} = 75°$$

For L_s = 0 mH

(a) Calculate the mean value of v_o

(b) Sketch waveform for v_o, v_{T3} and i_{T5}

For L_s = 0.5mH

(c) Calculate the mean value of v_o

(d) Sketch waveform for v_o, v_{T3} and i_{T5}

Question 2

This question relates mainly to **Module 7** phase-controlled thyristor converters and the third objective in the course specification.

Refer to **figure 7.24** of your study book.

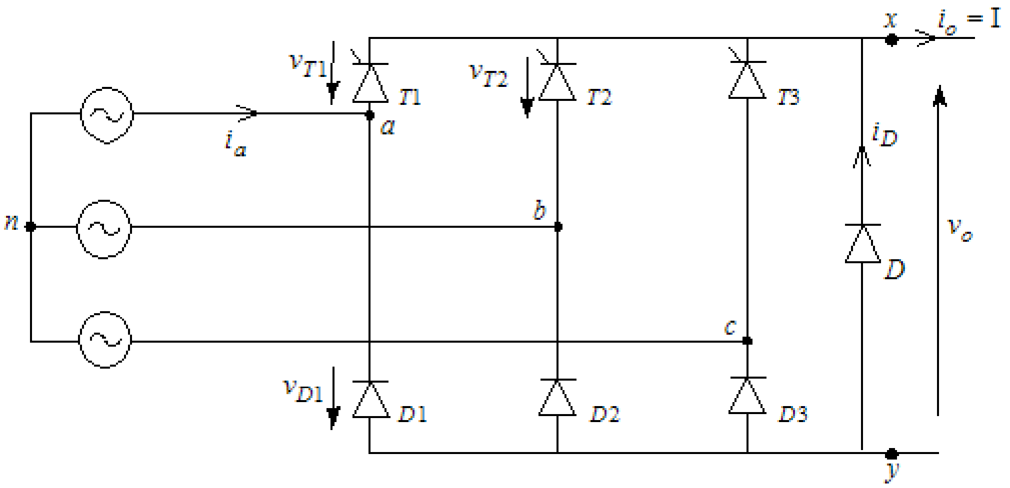


Figure 7.24: Three-phase half controlled rectifier

Assume all components are ideal.

v_{an} (Volts) = 311 sin ωt

ω = 100 π rad/s

I = 20 A

α = delay angle

For delay angle $\alpha = 30°$ sketch waveforms for:

(a) v_o *and* v_{T1}

(b) i_a and i_D

For delay angle $\alpha = 105°$ sketch waveforms for:

(c) v_o *and* v_{T1}

(d) i_b and i_D

(e) Calculate the rms value of i_D for delay angle $\alpha = 105°$.

Question 3

This question relates mainly to **Module 8** switch-mode inverters and the third objective in the course specification.

Refer to the circuit in **figure 8.12** of the study book.

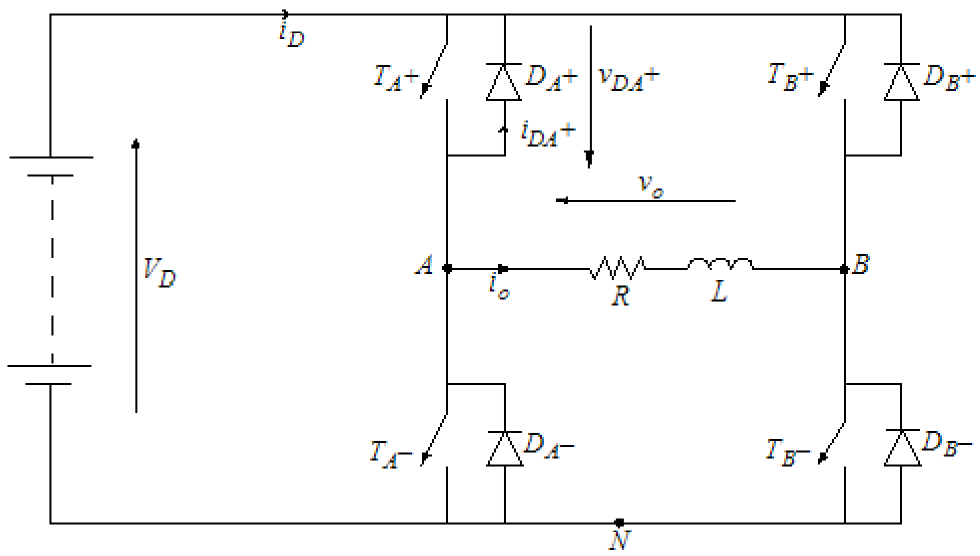


Figure 8.2: Single-phase square wave bridge inverter – R-L load

Assume all components are ideal and v_o is a square wave (unmodified).

V_D = 400 V; R = 10 Ω; L/R = 25 ms; T = 10 ms

(a) Calculate $\hat{I}_o$

(b) Sketch waveforms for the current through the diode D_B+

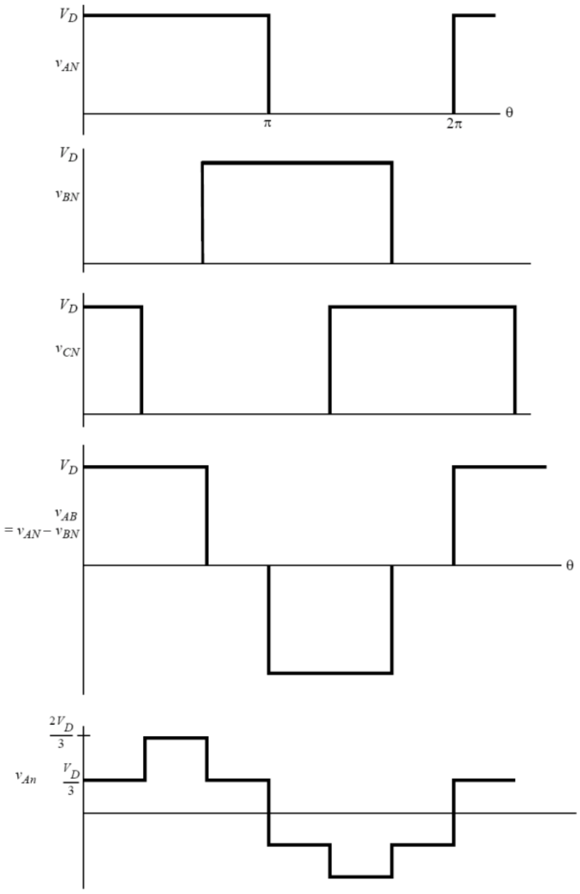
(c) Sketch waveforms for the voltage across the diode D_B+

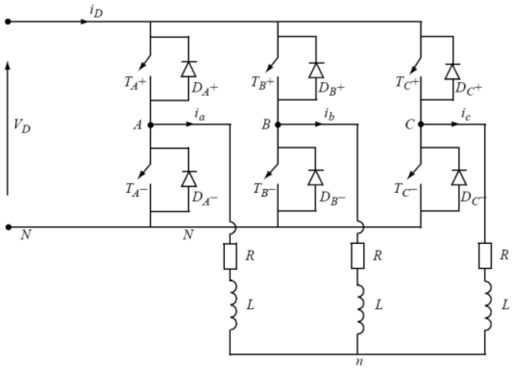
(d) For what fraction of the period does D_B+ conduct?

(e) Calculate the rms value of the fundamental component of i_o .

Question 4

This question relates mainly to **Module 8** switch-mode inverters and the third objective in the course specification.
Refer to the circuit in **figure 8.12(a)** of the study book. The voltage waveforms in **figure 8.13** are applicable. Circuit operation is at steady state. The mean values of i_a, i_b and i_c are all equal to zero.





(a) R-L load

V_D = 220 V, period = 20 ms

For R = 0, L = 0.1 H,

(a) Sketch waveforms for v_{Cn} and i_c.

(b) Calculate the peak value of i_c and the rms value of the fundamental component of i_c

For R = 20Ω, L = 0H,

(c) Sketch waveforms for v_{Cn} and i_c

(d) Calculate the peak value of i_c and the rms value of the fundamental component of i_c

Question 5

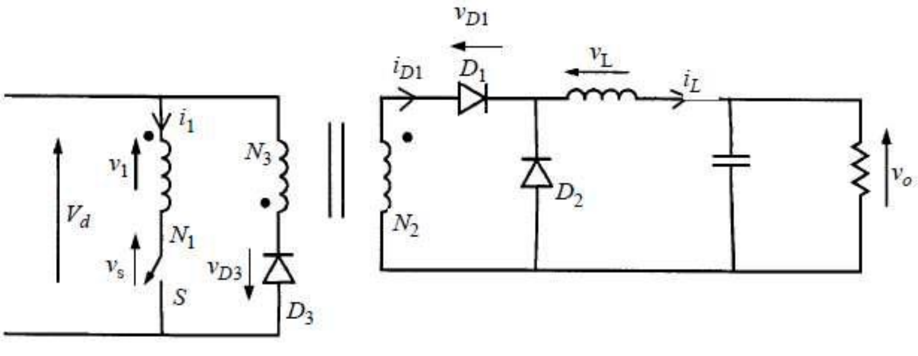


Figure 9.5

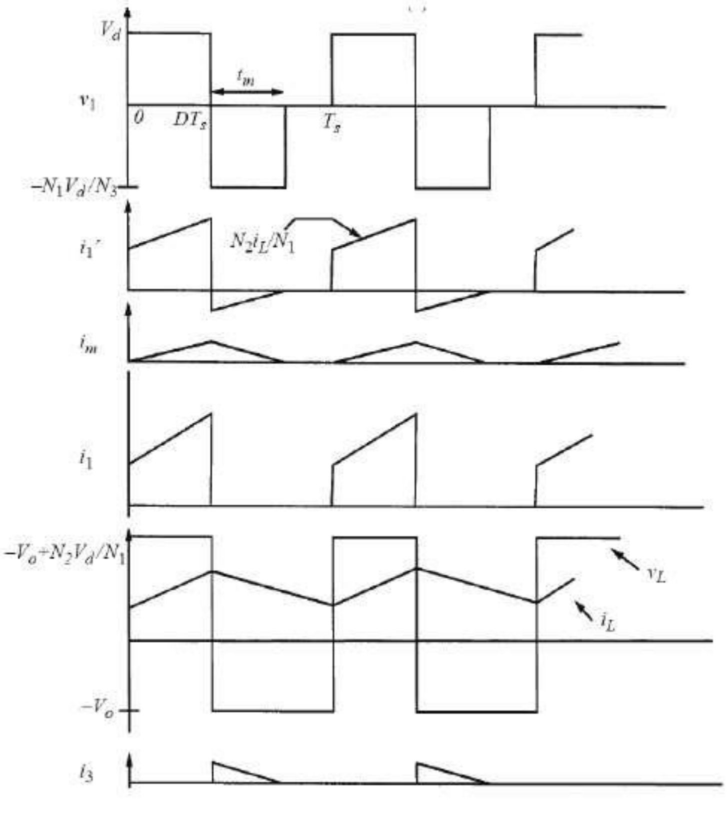


Figure 9.7 (b)

V_d = 230V; V_o =80V; 1/ T_s = 15kHz; $N_3 = N_1$; L = 200μH; C = 18μF.

(a) Calculate the minimum allowable value of N_2/N_1

(b) Estimate the peak to peak ripple in vo. Assume $N_1 = N_2$

(c) Sketch waveforms for v_{D3}

(d) Sketch waveforms for i_{D3}.

Question 6

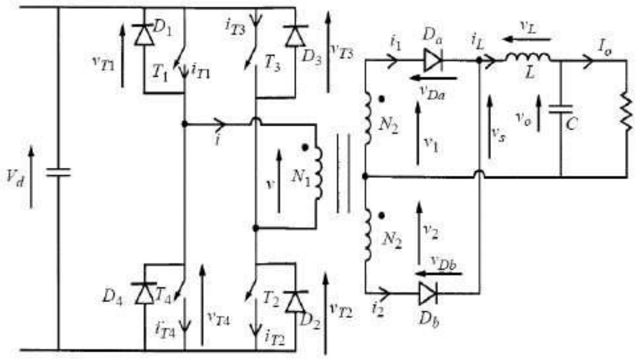


Figure 9.13

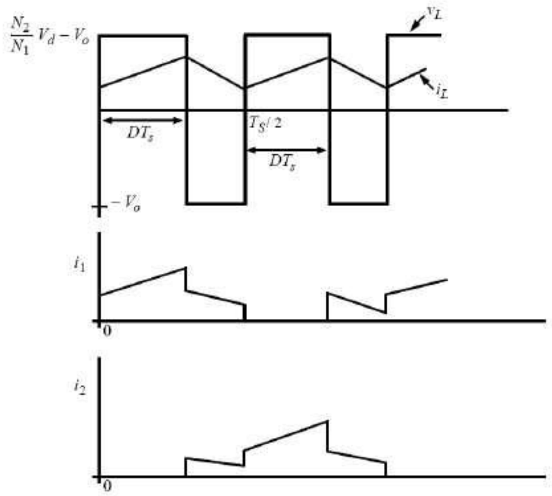


Figure 9.13c

V_d = 300V; I_0 = 5A; V_0 = 48V; 1/ T_s = 20 kHz; N_2/N_1= 0.25

(a) Calculate the value of *D*.

(b) Calculate the minimum value of *L*, if the peak to peak ripple content in i_L is to be maintained below 15% of I_L.

(c) Sketch waveforms for v_{T2}.

(d) Sketch waveforms for i_{T2}. Indicate the peak value of i_{T2}.

You may assume equal sharing of voltages by the transistors when all of them are off.

Assume *L* = 1.5mH.

Question 7

Part (a)
This question relates mainly to **Module 10** drives overview and the fourth objective in the course specification.

A motor is operated at full load and at rated speed for **6 minutes** and then it is operated at no-load for **12 minutes**.

This operating cycle is continuously repeated resulting in motor insulation temperature changing periodically.

As a first approximation the thermal behaviour of the insulation can be modelled as that of a first order system with a thermal time constant τ of **30 minutes** and a thermal resistance of **0.2° C/W**.

Motor power losses at full load = 550 W

Motor power losses at no-load = 220 W

Insulation temperature rise above ambient while the motor is loaded is given by:

$$T = T_1 \; T_2 e^{-t/\tau}$$

where t = 0 at the instant load is applied to the motor.

T_1 is the insulation temperature rise above ambient that would be reached if the motor was to be left fully loaded for a very long time (i.e. t approaches infinity).

Insulation temperature rise above ambient while the motor is running idle is given by:

$$T = T_3 \; T_4 e^{-t/\tau}$$

where at the instant load is removed from the motor.

T_3 is the insulation temperature rise above ambient that would be reached if the motor was to be left energised but unloaded for a very long time (i.e. approaches infinity).

Calculate the values of T_1, T_2, T_3, T_4. Deduce the peak value of the insulation temperature. Sketch motor insulation temperature rise against time.

Part (b)

This question relates mainly to **Module 10** drives overview and the fourth objective in the course specification.

One cycle of the motion profile of a purely inertial load is described below:

Time	**Description of motion**
0 – 5 s	constant acceleration from 0 rad/s to 300 rad/s
5 s – 10 s	constant speed at 300 rad/s
10 s –15 s	constant deceleration from 300 rad/s to 150 rad/s
15 s – 25 s	constant deceleration from 150 rad/s to 0 rad/s
25 s – 30 s	stationary

Combined moment of inertia = 12 kgm^2.

Neglecting all losses; The load is directly coupled to the motor.

(a) Calculate the peak torque required from the motor.

(b) Calculate the rms value of the motor torque.

Question 8

This question relates mainly to **Module 11**. DC adjustable speed drives and the fifth objective in the course specification.

Refer to the circuit in **figure 11.6** of the study book.

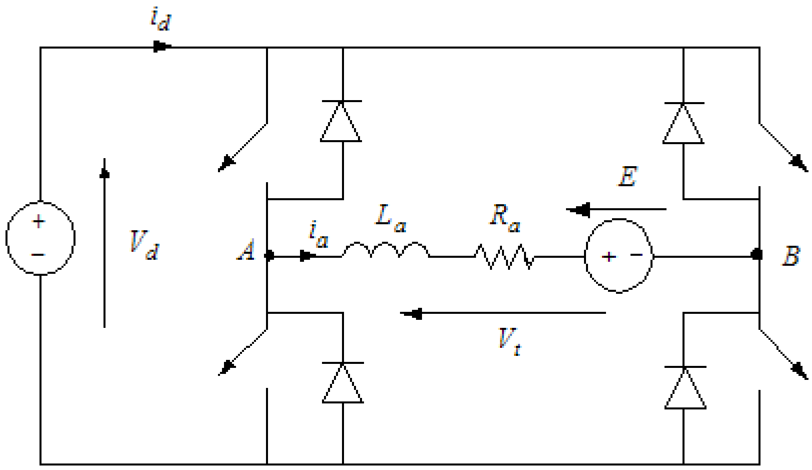


Figure 11.6: Four quadrant DC drive (ϕ_f constant)

Assume all components in the converter are ideal.

V_d = 200 V; K_E = 0.6 V/(rad/s); L_a = 15 mH; R_a = 0.5 Ω

The unipolar control method is used to operate the bridge. Transistor switching frequency is 1.5 kHz.

If speed is 1500 r/min and I_a is 0A draw waveforms for:

(a) v_t and

(b) i_a .

If speed is 1500 r/min, but in reverse direction compared to the above, and I_a is **20 *A***.

The motor is in regenerative braking mode, draw waveforms for:

(c) v_t and

(d) i_a . Indicate maximum and minimum values of i_a .

Question 9

This question relates mainly to **Module 11**. DC adjustable speed drives and the fifth objective in the course specification.

Consider the circuit in **figure 11.14(a)** of the study book.

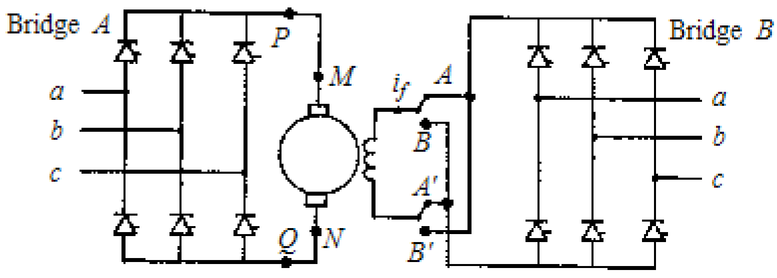


Figure 11.14(a)

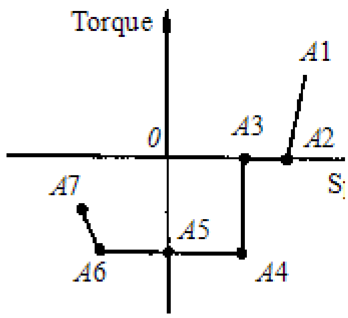


Figure 11.14(b)

The line to line voltage of the three phase AC supply is **415 V**. While motoring at point **A1**, **figure 11.14(b)**, the load torque, including friction torque is equal to **50 Nm** and the speed is equal to **1000 r/min**. Current limit, positive or negative, is set at **50 A**. Values for some of the motor parameters are given below:

K_E = 1.2 V/(rad/s); K_T = 1.8Nm/A; R_a = 0.75 Ω

The values of K_E and K_T correspond to rated field current.

While motoring at **point A7, figure 11.14(b)**, the load torque is 20 **Nm** and the speed is **1250 r/min**. Compared to operation at **point A1**, field current has reversed, but its magnitude is unchanged. The magnitude of the field current is equal to its rated value at all times, except during reversal between **point A2** and **point A3** in **figure 11.14(b)**.

Neglect the effect of supply inductance. Assume that there is no speed drop or rise from points **A1** to **A2**, **A3** to **A4** and **A6** to **A7**. There is a ten per cent speed drop from **A2** to **A3**.

Determine the delay angles of **bridge A** during operation at points:

(a) A1

(b) A4

(c) A5

(d) A6 and

(e) A7.

Question 10

This question relates mainly to the sixth objective in the course specification.

A 22kW, 440V, 50Hz, 4-pole cage induction motor is part of an adjustable speed drive system. At the base voltage and frequency, the full-load slip is 0.05. It can be assumed that the torque-speed characteristic of the motor is linear in the slip frequency range from
–5 Hz to 5 Hz.

Combined moment of inertia of motor and load = 12kgm^2.

Load torque in Nm = 5ω where ω is in rad/s.

The steady state operating speed ranges from 900r/min to 1400r/min.

Acceleration is required to be constant at 30rad/s^2 and deceleration is required to be constant at 60 rad/s^2.

The drive consists of a voltage source inverter with a three-phase diode rectifier at the front end. The supply voltage may be assumed to be 440V.

Estimate:

(a) steady state-slip when speed is 1400r/min.

(b) steady state slip when speed is 900r/min.

(c) required electromagnetic torque during acceleration and during deceleration.

(d) maximum DC input current to the inverter during acceleration (assume efficiency of motor-inverter combination is 91%).

(e) acceleration time from zero speed to 1400r/min.