UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING

EXAMINATION SEMESTER 1 - 2024/2025

INTERMEDIATE ELECTRICAL PRINCIPLES & ENABLING POWER ELECTRONICS

MODULE NO: EEE5013

Date: Wednesday 8th January 2025 **Time: 10:00 – 12:30pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

CANDIDATES REQUIRE: **Formula Sheet(attached).**

Question 1

a) An operational amplifier has high input impedance and low output impedance. Briefly explain why this is desirable.

[6 marks]

b) Figure Q1b below is a diagram of a summing inverting negative feedback operational amplifier circuit with two inputs V1 and V2 and an output Vout.
i) Derive an expression for the output Vout of the following circuit in terms of the input voltages $V1$ and $V2$
ii) What is the value of Vout if V1=2 V and V2 = 3 V?

[10 marks]

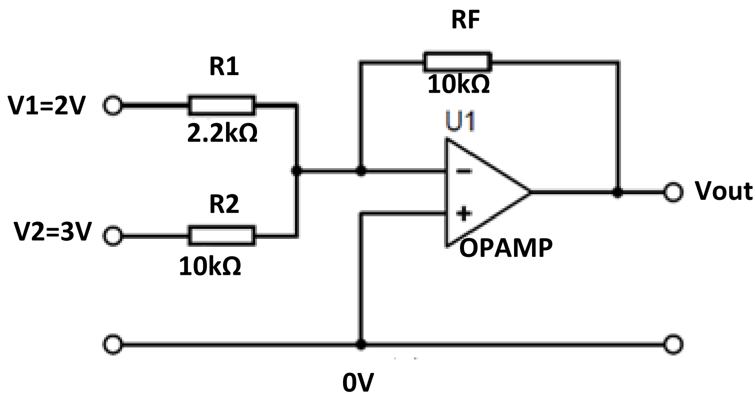

Fig.Q1b: Summing amplifier (has a supply of +/- 12 V)

c) An instrumentation amplifier is often used to obtain a high signal to noise ratio and it achieves this by common-mode rejection. Briefly define the term common mode rejection ratio.

[5 marks]

d) An amplifier has a common mode rejection ratio of 86 dB. Express the common mode rejection ratio as an arithmetic ratio e.g. *x*:1, where *x* is a numerical value.

[4 marks]

Total 25 marks

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Question 2

a) Enumerate the basic grounding system then explain what is meant by static grounding.

[4 marks]

b) For the following two devices if they carry the same load current of 12 A (rms) find their respective junction temperature (T_J), temperature of the junction region of the following semiconductor devices, at steady state. Assume ambient temperature =25°C and $R_{\theta ca}$=3°C/W .$R_{DS(on)}$=drain - source on resistance ,$P_{D(max)}$ = Maximum power dissipation, $R_{\theta ca}$=Thermal Resistance between case-ambient and $R_{\theta jc}$ =Thermal Resistance between junction-case.

	Device 1(IRF531)	Device 2(MTP14N06A)
1. $R_{DS(on)}$	0.18 Ω	0.10 Ω
2. $R_{\theta jc}$	1.67 °C/W	3.12 °C/W
3. $P_{D(max)}$	75W	40W

[14 marks]

c) For a dam in an electro hydro power station with the head on a dam is 4500cm.

I. What is the potential energy for one m^3 of water at the top of the reservoir?

[4 marks]

II. If this passes a turbine in 1 second, what total power does it represent? Ignore friction.

[3 marks]

Total 25 Marks

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Question 3

a) The single-phase half-wave-controlled rectifier shown in **Figure Q3a** supplies a resistive load with an average load current of 1.62 A. If the supply voltage is 240 V, 50 Hz and the average output voltage is 81 V, calculate the following:

I.	The firing angle α	**[4 marks]**
II.	The load resistor R	**[2 marks]**
III.	The rms load voltage	**[3 marks]**
IV.	The rms load current	**[2 marks]**
V.	The DC power and the ripple factor	**[4 marks]**

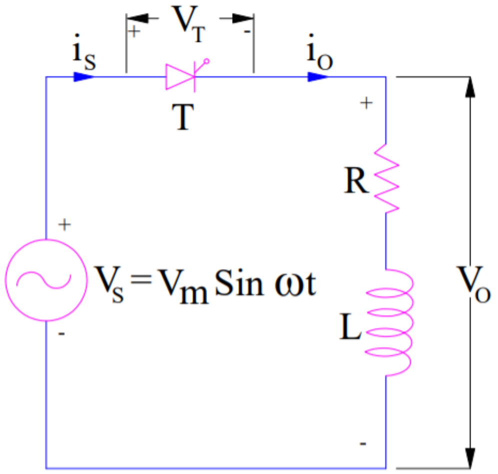

Figure Q3a

b) The Xlinks Morocco-UK Power project is a proposal that is capable of transmitting up to 3.6 GW solar and wind-generated electricity from Morocco to the United Kingdom. If built, the 4,000 km (2,500 miles) cable will be the world's longest undersea power cable, and would supply up to 8% of the UK's electricity consumption.

Analyse whether an AC or DC transmission system would be more suitable for this project, considering at least 3 out of the 4 following factors:

- Line losses
- Installation and maintenance costs

Question 3 continues over the page….

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Question 3 continued….

- Ease of integration with existing grid infrastructure
- Impact on the stability of the power system

[8 marks]

c) What type of DC-DC converter is represented in the circuit diagram shown in Figure Q3c? Choose the correct answer from the four provided options.

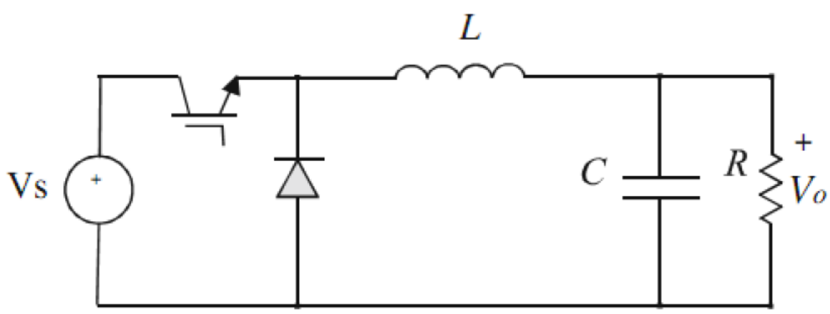

Figure Q3c

(i) Step-up/Boost converter
(ii) Step-down/Buck converter
(iii) Inverter
(iv) Buck-Boost converter

[2 marks]

Total 25 Marks

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Question 4

(a) Calculate the line voltages and the line currents of a Y-Y source-load Connection. Given: $V_{an} = 120\ \angle 60^o$ V . The system is a positive sequence, balanced three-phase system. The system impedances per phase are given as follows:

Z_{source}=0.4+j0.3 Ω , Z_{line}=0.6+j0.7 Ω, and Z_{load}=24+j19 Ω.

[10 Marks]

(b) Assume a delta-connected load, with each leg Z = $100\angle 80^o$ Ω, is supplied from a Y-connected 3-phase supply with voltage of 13.8 kV (L-L) source. Find:

(i) The complex power of the source and load.

[6 marks]

(ii) The power factor at the load.

[4 marks]

(iii) The value of a shunt capacitor that brings the power factor of the load to unity. Assume system frequency is 50 Hz

[5 marks]

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Total 25 Marks

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Question 5

a) A 3-phase, 50 Hz, 215 kV power line is delivering load of 125 MW at 0.8 power factor lagging and has an impedance per phase of $186.78\angle 79.46^{o}\Omega$. Find out what is the value of a series capacitance that compensates 70% of its inductive reactance. **[5 marks]**

b) Draw a circuit diagram for a boost converter using components of inductor, capacitor, switch, load resistor and a diode, and explain its operation in continuous conduction mode (CCM).

[10 marks]

c) For the above boost converter, if the input voltage is 20 V, the switch operates at T_{ON} = 0.36 msec, T_{OFF} = 0.14 msec, calculate the following:

(i) the chopping frequency and the Duty Cycle

[2 marks]

(ii) The average value of the output voltage

[3 marks]

(iii) The average value of the output current, if the resistance load is 10 Ω

[2 marks]

(iv) The changes in inductor current ΔI_L, if the inductance is 10 mH

[3 marks]

Total 25 Marks

END OF QUESTIONS

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Formula sheet

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

Converters:

$$\%THD_i = 100 \times \frac{I_{dis}}{I_{s1}} = 100 \times \frac{\sqrt{I_s^2 - I_{s1}^2}}{I_{s1}} = 100 \times \sqrt{\sum_{h \neq 1}\left(\frac{I_{sh}}{I_{s1}}\right)^2}$$

$$PF = \frac{V_s I_{s1} \cos \phi_1}{V_s I_s} = \frac{I_{s1}}{I_s} \cos \phi_1$$

$$DPF = \cos \phi_1$$

$$PF = \frac{I_{s1}}{I_s} DPF$$

$$PF = \frac{1}{\sqrt{1 + THD_i^2}} DPF$$

$$A_u = \sqrt{2} V_s (1 - \cos u) = \omega L_s I_d$$

$$\cos u = 1 - \frac{\omega L_s I_d}{\sqrt{2} V_s}$$

$$V_d = 0.45 V_s - \frac{\text{area } A_u}{2\pi} = 0.45 V_s - \frac{\omega L_s}{2\pi} I_d$$

$$V_d = 1.35\, V_{LL} cos\alpha - 3\frac{\omega L_s}{\pi} I_d$$

$$\cos(\alpha + u) = \cos\alpha - 2\frac{\omega L_s}{\sqrt{2} V_{LL}}\, I_d$$

$$\gamma = 180 - (\alpha + u)$$

$$V_L = \left[\frac{1}{T}\int_0^T v_L^2(t)dt\right]^{1/2}$$

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

$$\text{TUF} = \frac{P_{dc}}{V_s I_s} = \frac{V_{dc} I_{dc}}{V_s I_s}$$

$$\text{RF} = \frac{V_{ac}}{V_{dc}}$$

$$\sigma = \frac{P_{dc}}{P_L} = \frac{V_{dc} I_{dc}}{V_L I_L}$$

$$\text{FF} = \frac{V_L}{V_{dc}} \quad \text{or} \quad \frac{I_L}{I_{dc}}$$

$$V_{d\alpha} = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_{max}\sin(\omega t)d(\omega t) = \frac{V_{max}}{2\pi}(1+\cos\alpha)$$

$$V_{ph} = \frac{V}{\sqrt{3}} \;, I_{ph} = I \quad for\ star\ connection,$$
$$V_{ph} = V, \quad I_{ph} = \frac{I}{\sqrt{3}} \quad for\ delta\ connection$$

$$V_{ph} = \frac{V}{\sqrt{3}} \;, I_{ph} = I \quad for\ star\ connection,\ V_{ph} = V, \quad I_{ph} = \frac{I}{\sqrt{3}} \quad for\ delta\ connection$$
$$S = \sqrt{3}VI \quad V.A,\ P = \sqrt{3}VIcos\theta\ \ W.,Q = \sqrt{3}VIsin\theta\ \ V.A.r$$
$$Q_C = \sqrt{3}VI_C\ \ V.A.r,\ \ X_C = \frac{V}{\sqrt{3}I_C}\ \ \Omega$$

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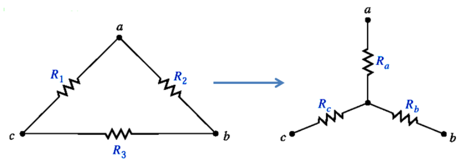
Three-phase systems

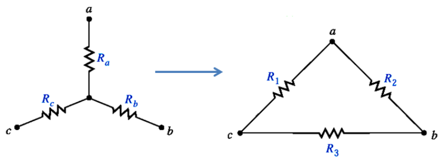


Delta to Star conversion:

$$R_a = \frac{R_1 R_2}{R_1 + R_2 + R_3}$$

$$R_b = \frac{R_2 R_3}{R_1 + R_2 + R_3}$$

$$R_c = \frac{R_3 R_1}{R_1 + R_2 + R_3}$$



Star to Delta conversion:

$$R_1 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b}$$

$$R_2 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$$

$$R_3 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_a}$$

Gravity: 9.81 m/s^2

Thermal resistance of the interface material:

$$\theta_{cs} = \frac{(\rho)(t)}{A}$$

Output voltage of a differentiator circuit:

$$v_0 = -R_2 C_1 \frac{dv_I}{dt}$$

Compressibility relationship:

$$K = -V \frac{dP}{dV}$$

Force on a submerged wall:

$$F = \frac{\rho g a h^2}{2}$$

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Summary of phase and line voltages/currents for balanced three-phase systems.[1]

Connection	Phase voltages/currents	Line voltages/currents
Y-Y	$\mathbf{V}_{an} = V_p\angle 0^\circ$ $\mathbf{V}_{bn} = V_p\angle -120^\circ$ $\mathbf{V}_{cn} = V_p\angle +120^\circ$ Same as line currents	$\mathbf{V}_{ab} = \sqrt{3}V_p\angle 30^\circ$ $\mathbf{V}_{bc} = \mathbf{V}_{ab}\angle -120^\circ$ $\mathbf{V}_{ca} = \mathbf{V}_{ab}\angle +120^\circ$ $\mathbf{I}_a = \mathbf{V}_{an}/\mathbf{Z}_Y$ $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$ $\mathbf{I}_c = \mathbf{I}_a\angle +120^\circ$
Y-Δ	$\mathbf{V}_{an} = V_p\angle 0^\circ$ $\mathbf{V}_{bn} = V_p\angle -120^\circ$ $\mathbf{V}_{cn} = V_p\angle +120^\circ$ $\mathbf{I}_{AB} = \mathbf{V}_{AB}/\mathbf{Z}_\Delta$ $\mathbf{I}_{BC} = \mathbf{V}_{BC}/\mathbf{Z}_\Delta$ $\mathbf{I}_{CA} = \mathbf{V}_{CA}/\mathbf{Z}_\Delta$	$\mathbf{V}_{ab} = \mathbf{V}_{AB} = \sqrt{3}V_p\angle 30^\circ$ $\mathbf{V}_{bc} = \mathbf{V}_{BC} = \mathbf{V}_{ab}\angle -120^\circ$ $\mathbf{V}_{ca} = \mathbf{V}_{CA} = \mathbf{V}_{ab}\angle +120^\circ$ $\mathbf{I}_a = \mathbf{I}_{AB}\sqrt{3}\angle -30^\circ$ $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$ $\mathbf{I}_c = \mathbf{I}_a\angle +120^\circ$
Δ-Δ	$\mathbf{V}_{ab} = V_p\angle 0^\circ$ $\mathbf{V}_{bc} = V_p\angle -120^\circ$ $\mathbf{V}_{ca} = V_p\angle +120^\circ$ $\mathbf{I}_{AB} = \mathbf{V}_{ab}/\mathbf{Z}_\Delta$ $\mathbf{I}_{BC} = \mathbf{V}_{bc}/\mathbf{Z}_\Delta$ $\mathbf{I}_{CA} = \mathbf{V}_{ca}/\mathbf{Z}_\Delta$	Same as phase voltages $\mathbf{I}_a = \mathbf{I}_{AB}\sqrt{3}\angle -30^\circ$ $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$ $\mathbf{I}_c = \mathbf{I}_a\angle +120^\circ$
Δ-Y	$\mathbf{V}_{ab} = V_p\angle 0^\circ$ $\mathbf{V}_{bc} = V_p\angle -120^\circ$ $\mathbf{V}_{ca} = V_p\angle +120^\circ$ Same as line currents	Same as phase voltages $\mathbf{I}_a = \dfrac{V_p\angle -30^\circ}{\sqrt{3}\mathbf{Z}_Y}$ $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$ $\mathbf{I}_c = \mathbf{I}_a\angle +120^\circ$

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