ENG01

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) ELECTRICAL & ELECTRONICS ENGINEERING

SEMESTER 1 2023/2024 EXAMINATION

INTERMEDIATE ELECTRICAL PRINCIPLES & ENABLING POWER ELECTRONICS

MODULE NO: EEE5013

Date: Wednesday 10th January 2024 **Time: 10:00am – 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.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

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

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Question 1

a) consider the following signal processing circuit shown on **Figure Q1a**:

[15 marks]

i) Derive an equation for V_{out}, if the applied signal, $\text{Vin}=0.01\sin(1000t)$
ii) Sketch the input and output waveforms, indicating the period/amplitude with appropriate values.
iii) If the calculated value for the output signal is; $Vout = -2\ mV$, calculate the positive value time (t) to achieve this.

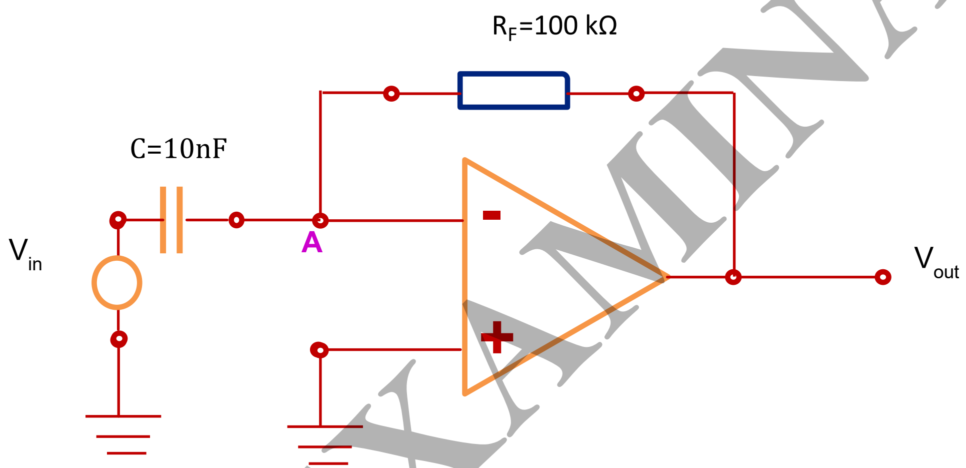

Figure Q1a. Signal processing circuit

Q1 CONTINUES OVER THE PAGE

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Q1 is continued

b) Consider the Integrator Op Amp shown on **Figure Q1b**. Determine **[10 marks]**

i) the cut-off frequency
ii) zero-dB frequency
iii) Explain the suitable frequency for the Op Amp to be used as an integrator.

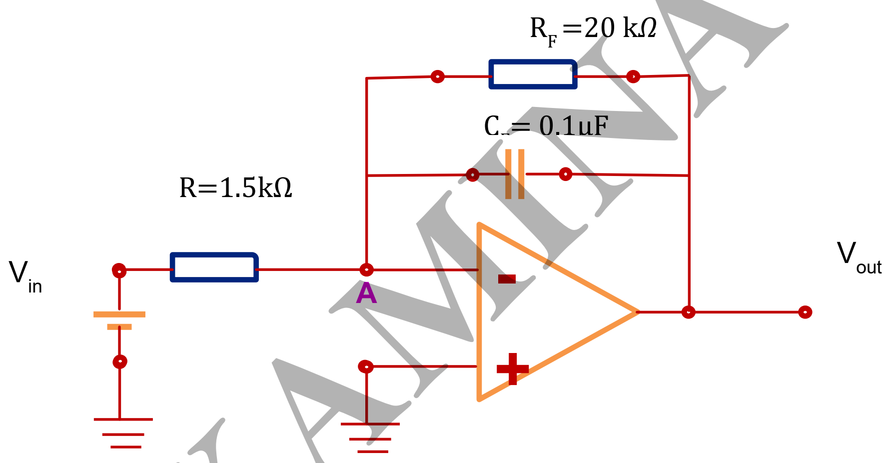

Figure Q1b. Integrator circuit

Total 25 marks

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Question 2

a) Define the heat sink and give its benefits. **[6 marks]**

b) A silicon transistor having a T_{JMAX} rating of 190° C will dissipate 30 W when its case temperature is 70°C, calculate its thermal resistance. **[3 marks]**

c) If the silicon transistor in (part b) is mounted to a heatsink of thermal resistance 3.5° C/W, calculate the maximum collector dissipation by assuming both transistor and heatsink operate at an ambient temperature 25°C. **[4 marks]**

d) Consider a rectangular container is full of a water of density ρ = 1000 kg/m^3. The container dimensions are length (a = 8 cm), width (b = 4 cm) and height (h = 6 cm). The top end of the container is open to atmosphere. Calculate the total power at the:

i) base **[2 marks]**

ii) side of dimensions (a×h) **[6 marks]**

iii) side f dimensions (b×h) **[4 marks]**

Total 25 marks

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Question 3

(a) Explain with the aids of diagrams the operation of a single-phase half-wave rectifier. **[10 marks]**

(b) A half-wave single-phase rectifier circuit is shown in **figure Q3** below. The following are given:

Vs=220 V, f=50 Hz, diode forward voltage drop is assumed to be zero. Load resistor=8 Ω, Determine:

i. The load mean voltage and current **[7 marks]**

ii. The load current ac component and shape for
   1. A pure resistive load of 8 Ω resistor and **[4 marks]**
   2. An inductive load of 0.1 H inductance in series with the 8 Ω resistor

[4 marks]

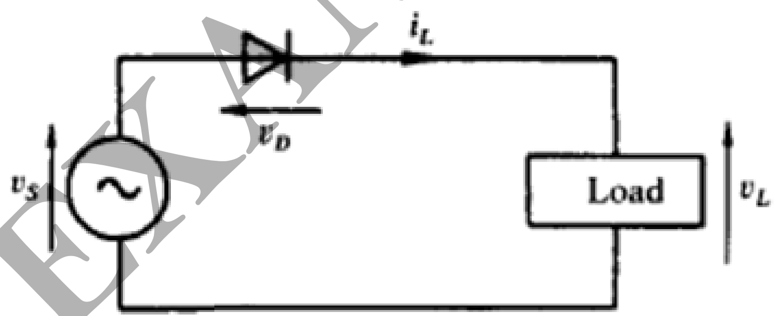

Fig. Q3 A single-phase half-wave rectifier circuit

Total 25 marks

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Question 4

(a) Draw a circuit diagram for a buck converter and derive an expression for $\frac{V_{out}}{V_{in}}$ defining all parameters used in this circuit.

[15 marks]

(b) Prove that the line current of a balanced delta-connect load is equal to the phase current multiplied by square root of 3 and lags it by 30 degrees.

[10 marks]

Total 25 marks

Question 5

(a) Calculate the line voltages and the line currents of a Δ-Y Connection. Given: V_{ab} = 150 ∠30° and V_{bc}=150 ∠ -90°. The system impedance are given as follows:

Z_{line}=0.4+j0.8 Ω, Z_{load}=20+j15 Ω.

[13 Marks]

b) Assume a star-connected load, with each leg Z = 5∠25° Ω, is supplied from a star-connected 3-phase supply with voltage of 0.6 kV (L-L) source. Find:

i. The complex power of the source and load.

[9 marks]

ii. The power factor at the load.

[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:

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

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

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

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

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

$$\text{DPF} = \cos \phi_1$$

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

$$\text{PF} = \frac{1}{\sqrt{1 + \text{THD}_i^2}} \text{DPF}$$

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

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

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

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

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

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

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

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

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

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

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

$$S = \sqrt{3}VI \quad V.A,\ P = \sqrt{3}VIcos\theta\ \ W.,Q = \sqrt{3}VIsin\theta\ \ V.A.r$$

$$Q_C = \sqrt{3}VI_C\ \ V.A.r,\ \ X_C = \frac{V}{\sqrt{3}I_C}\ \ \Omega$$

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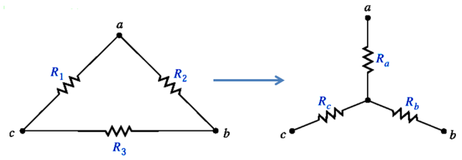
Three-phase systems

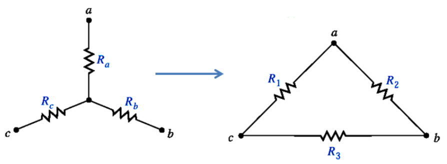


Delta to Star conversion:

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

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

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



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:

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

$$\theta = \frac{\Delta T}{P}$$

Output voltage of a differentiator circuit:

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

Compressibility relationship:

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

General manometer:

$$\Delta P = |\, \Delta\rho\, g\, \Delta h \,|$$

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Venturi meter:

$$v_{\text{in}} = C_D \sqrt{\frac{2\,\Delta P}{\rho_f\left[\left(\frac{d_{\text{large}}}{d_{\text{small}}}\right)^4 - 1\right]}}$$

Force on a submerged wall:

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

Drag coefficient:

$$C_{Drag} = \frac{F_D}{\frac{1}{2}\rho v^2 A}$$

Flow through a small hole:

$$Q = C_D \sqrt{\frac{2\,\Delta P}{\rho}}\, A$$

Flow through a rectangular slit:

$$Q = \frac{2}{3} C_D\, W \sqrt{2g}\left[(Ho + L)^{\frac{3}{2}} - Ho^{\frac{3}{2}}\right]$$

Tank draining:

$$h^{\frac{1}{2}} = h_0^{\frac{1}{2}} - \frac{C_D a \sqrt{2g}}{2A} t$$

Flow over a rectangular weir:

$$Q = \frac{2}{3} C_D W \sqrt{2g}\; H^{\frac{3}{2}}$$

Flow over a V-notch weir:

$$Q = \frac{8}{15} C_D \tan\left(\theta/2\right)(2g)^{\frac{1}{2}} H^{\frac{5}{2}}$$

Poisseuille's Law:

$$Q = -\frac{\pi}{128\mu}\frac{dP}{dx} D^4$$

Darcy's Law:

$$\Delta P = \frac{2 f L \rho \bar{u}^2}{D}$$

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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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