[ENG14]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) ELECTRICAL & ELECTRONICS ENGINEERING

EXAMINATION SEMESTER 1 - 2022/2023

INTERMEDIATE ELECTRICAL PRINCIPLES & ENABLING POWER ELECTRONICS

MODULE NO: EEE5013

Date: Tuesday 10th January 2023 **Time: 10:00 – 12:30**

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).**

School of Engineering
B.Eng (Hons) Electrical and Electronic Engineering
Semester One Examination - 2022/2023
Intermidiate Electrical Principles & Enabling Power Electronics
Moduel No.: EEE5013

Question 1

Fleming Digital LTD is a digital electronic manufacturing company based in the UK. You have applied to the company for an opportunity of an internship, but the company requires you go through a test. In your test, the company describes that they are looking to develop a suitable circuit that could be included on a computer system that they are building. Your tasks include:

a) Using Op Amp, you are required to design an electronic circuit that would calculate arithmetic mean of any N number of input data. **[8 marks]**

b) Show how the circuit design calculates the arithmetic mean. **[8 marks]**

c) If the input data are supplied through the inverting input port of the Op-Amp, using a suitable diagram, show how the signal inversion would be removed. **[9 marks]**

Total 25 marks

School of Engineering
B.Eng (Hons) Electrical and Electronic Engineering
Semester One Examination - 2022/2023
Intermidiate Electrical Principles & Enabling Power Electronics
Moduel No.: EEE5013

Question 2

a) State the Stefan-Boltzmann's law of thermal radiation. **[2 Marks]**

b) Modern Unmanned Aerial Vehicles (UAV) are being equiped with Solar Energy Harvesting Systems to enhance battery life. The power electronic part of the system requires to operate within tolerable temperature for safe operations of the switching devices such as MOSFETs or ICs. Consider a TPS54325 device for a buck converter operated without a heatsink, if the thermal resistance from Junction-Ambient is 44.5°C/W and maximum junction temperature is 125°C with $\theta_{JC} = 3$°C/W; assuming a room temperature.

ii. Calculate the maximum power dissipation **[3 Marks]**

iii. Determine the power derating factor **[3 Marks]**

iv. Supposing that a heatsink is desired, determine the heatsink parameters if the thermal resistivity of the heatsink is 142.24×10^{-2}°Cm/W, thickness is 5.08×10^{-5}m and contact area is 23.23×10^{-5}m^2. **[10 Marks]**

c) By letting water fall from a height, electricity can be generated. Similarly, regular floor tiles can be made to generate electricity by simply walking around on them.

i. Identify any two forms of energy involved in the energy generation **[2 Marks]**

ii. Ferdinand is a man weighing 125 kg and completes an average of 34 steps in one minute, calculate the amount of energy harvested from Ferdinand if he causes a 5 mm displacement on the floor tiles per step and also the total power in one minute. **[5 Marks]**

Total 25 marks

PLEASE TURN THE PAGE…

School of Engineering
B.Eng (Hons) Electrical and Electronic Engineering
Semester One Examination - 2022/2023
Intermidiate Electrical Principles & Enabling Power Electronics
Moduel No.: EEE5013

Question 3

a) A 240 V, 50 Hz ideal single-phase source supplies power to a load resistor of 100 Ohms via a single ideal diode. Calculate:

i. The average and rms values of the load current and the power dissipation. **[5 marks]**

ii. The circuit power factor and the ripple factor **[5 marks]**

iii. The rating of the diode. **[2 marks]**

b) Draw the circuit of a basic single-phase square-wave inverter and illustrate the concept of AC waveform generation. Draw the waveform across the load and the diodes. **[13 marks]**

Total 25 marks

Question 4

a) A simple DC chopper is operating at a frequency of 2 kHz from a 96 V DC source to supply a load resistance of 8 Ohms. The load time constant is 6 milliseconds. If the average load voltage is 57.6 V, Find:

i. the ON period of the chopper **[5 marks]**

ii. the average load current **[5 marks]**

iii. the magnitude of the ripple current and its rms value. **[6 marks]**

b) Enumerate four of the objectives of a grounding system. **[4 marks]**

c) Define clearly what is meant by apparent, active, and reactive powers. How mathematically you express each one of these terms in terms of voltage, current and load power factor angle. Draw the power triangle and comment.

[5 marks]

Total 25 marks

School of Engineering
B.Eng (Hons) Electrical and Electronic Engineering
Semester One Examination - 2022/2023
Intermidiate Electrical Principles & Enabling Power Electronics
Moduel No.: EEE5013

Question 5

a) Find the rms value of the neutral line current I_o in the unbalanced three-phase circuit given below in Figure Q5a. Assume Z_n=10 Ohms.

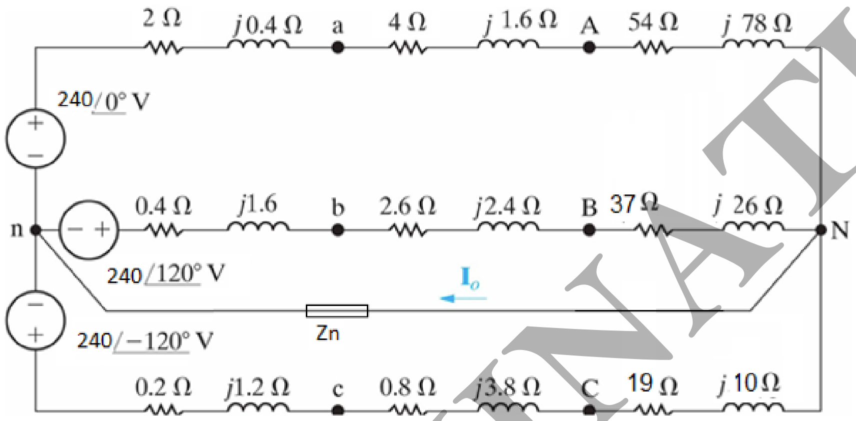


Figure Q5a

[12 Marks]

b) A three-phase line has an impedance of 0.1+ j0.8 Ω per phase. The line feeds two balanced three-phase loads connected in parallel. The first load is absorbing a total of 210 kW and 280 kVAr magnetizing vars. The second load is Y-connected and has an impedance of 15.36-j4.48 Ω per phase. The line-to-neutral voltage at the load end of the line is 4000 V. What is the magnitude of the line voltage at the source end of the line? What is needed to bring the load power factor to unity. Suggest an extra added circuit element in parallel and find its value for frequency of 50 Hz. **[13 marks]**

Total 25 marks

END OF QUESTIONS

Formula Sheet follows over the page

PLEASE TURN THE PAGE…

School of Engineering
B.Eng (Hons) Electrical and Electronic Engineering
Semester One Examination - 2022/2023
Intermidiate Electrical Principles & Enabling Power Electronics
Moduel No.: EEE5013

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:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

PLEASE TURN THE PAGE…

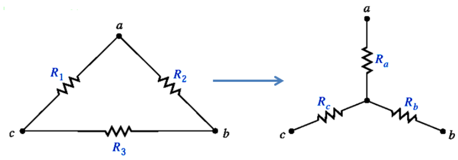
$$V_{ph} = \frac{V}{\sqrt{3}}\ , I_{ph} = I \quad for\ star\ connection,\ V_{ph} = V,\quad I_{ph} = \frac{I}{\sqrt{3}} \quad for\ delta\ connection$$

School of Engineering
B.Eng (Hons) Electrical and Electronic Engineering
Semester One Examination - 2022/2023
Intermidiate Electrical Principles & Enabling Power Electronics
Moduel No.: EEE5013

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

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

Three-phase systems

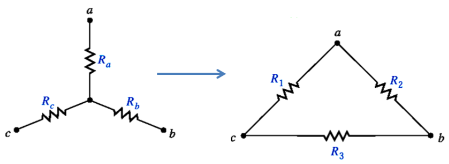


Delta to Star conversion:

$$R_a = \frac{R_1R_2}{R_1+R_2+R_3}$$

$$R_b = \frac{R_2R_3}{R_1+R_2+R_3}$$

$$R_c = \frac{R_3R_1}{R_1+R_2+R_3}$$



Star to Delta conversion:

$$R_1 = \frac{R_aR_b + R_bR_c + R_cR_a}{R_b}$$

$$R_2 = \frac{R_aR_b + R_bR_c + R_cR_a}{R_c}$$

$$R_3 = \frac{R_aR_b + R_bR_c + R_cR_a}{R_a}$$

Gravity:

9.81 m/s

Thermal resistance of the interface material:

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

Output voltage of a differentiator circuit:

$$v_0 = -R_2C_1\frac{dv_I}{dt}$$

Compressibility relationship:

$$K = -V\frac{d\,P}{d\,V}$$

General manometer:

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

PLEASE TURN THE PAGE…

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:

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

Please turn the page

School of Engineering
B.Eng (Hons) Electrical and Electronic Engineering
Semester One Examination - 2022/2023
Intermidiate Electrical Principles & Enabling Power Electronics
Moduel No.: EEE5013

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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