higher education & training

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INDUSTRIAL ELECTRONICS N5

(8080175)

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This question paper consists of 5 pages and a formula sheet of 6 pages.

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
INDUSTRIAL ELECTRONICS N5
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer all the questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Start each section on a new page.
5. Use only a black or blue pen.
6. Write neatly and legibly.

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QUESTION 1: ALTERNATING CURRENT THEORY

1.1 Draw a neat, labelled gain-versus-frequency response curve of a simple:

1.1.1 Low-pass filter

1.1.2 High-pass filter

(2 × 2) (4)

1.2 Give TWO applications of resonant circuits. (2)

1.3 An adjustable frequency with a constant voltage of 200 mV is connected over a series RLC-circuit. The frequency is adjusted until there is a maximum current flow of 10 mA at 5 kHz.

Calculate:

1.3.1 The values of R, L and C if the Q-factor is 125 (8)

1.3.2 The voltage across the inductor (2)

[16]

QUESTION 2: POWER SUPPLIES

2.1 An RC-π-filter is connected to a half-wave power supply which is provided with a 60 Hz supply. The serial resistor is 10 Ω, the second filter capacitor is 250 µf and the input ripple voltage is 5 V.

Calculate the ripple factor for a 15 V DC output. (5)

2.2 2.2.1 What is the main function of a voltage-multiplier circuit? (2)

2.2.2 Briefly give the disadvantage of a voltage-multiplier circuit. (2)

2.3 Draw a neat, labelled circuit diagram of a double-voltage power supply which can supply both positive and negative voltages to operational amplifiers. (8)

[17]

QUESTION 3: TRANSISTOR AMPLIFIERS

3.1 Briefly explain the function of each of the following components in a common emitter amplifier:

3.1.1 Emitter resistor (R_E)

3.1.2 Emitter capacitor (C_E)

(2 × 1) (2)

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3.2 The following values of a common emitter are known:

$I_{C(MAX)}$ = 12 mA; R_E = 150 Ω; R_{B1} = 17 kΩ; R_{B2} = 3 kΩ

Calculate each of the following:

3.2.1 $+V_{CC}$

3.2.2 β

3.2.3 V_B

(3 × 3) (9)

3.3 The following information pertains to a fixed-biased voltage amplifier:

h_{ie} = 1 300 Ω; h_{oe} = 20 µA/V; R_L = 10 kΩ

$h_{re} = 2 \times 10^{-4}$; h_{fe} = 250; R_C = 240 Ω

Calculate by means of the precise method:

3.3.1 The current gain A_i (not necessary for the current-divider rule) (4)

3.3.2 The voltage gain A_V (3)

[18]

QUESTION 4: OPERATIONAL AMPLIFIERS

4.1 Give TWO applications of an operational voltage follower. (2)

4.2 4.2.1 Draw a neat, labelled circuit diagram of a differential operational amplifier that will monitor the difference between two voltage levels. (3)

4.2.2 Determine the difference in input voltage if the output voltage is 15 V, the input resistance is 2 kΩ and the feedback resistance is 10 kΩ. (3)

4.3 Calculate the upper cut-off frequency of a low filter if C = 2nf and R = 12 kΩ. (2)

[10]

QUESTION 5: INTEGRATED CIRCUITS

Draw a neat, labelled internal diagram of an integrated 555 precision timer. **[8]**

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QUESTION 6: TRANSDUCERS

6.1 Sketch a neat, labelled circuit diagram of a thermistor temperature control circuit that uses an alternating-current excited bridge circuit. (4)

6.2 The bridge is balanced at 27 °C, A = 7×10^{-11}, B = 9 800 and a 12 V battery is connected across the bridge and R_t = 10 kΩ at 27 °C.

Calculate:

6.2.1 The value of the thermistor at 30 °C (2)

6.2.2 The gain of the amplifier with an output of 10 V (7)

[13]

QUESTION 7: ELECTRONIC PHASE CONTROL

7.1 Indicate whether the following statements are TRUE or FALSE by writing only 'True' or 'False' next to the question number (7.1.1–7.1.3) in the ANSWER BOOK.

7.1.1 An open-loop system is used for speed control of low-power series motors.

7.1.2 An open-loop system is a simple on-off system with feedback network.

7.1.3 In an open-loop system the comparator compares the feedback signal with the input reference signal.

(3 × 1) (3)

7.2 Make a neat, labelled sketch of a trigger circuit for a silicon-controlled rectifier. (2)

[5]

QUESTION 8: TEST EQUIPMENT

Briefly explain the function of the binary counter in a voltmeter. **[3]**

QUESTION 9: OSCILLATORS

Design a switching circuit that will switch a lamp on for ONE minute when an infrared ray is interrupted. The circuit must include an infrared diode, an operational amplifier and a 555 precision timer.

Calculate the value of the resistor in the timer if a capacitor value of 470 µf is used. **[10]**

TOTAL: 100

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FORMULA SHEET

$$I = \frac{V}{R} \qquad P = IV = I^2R = \frac{V^2}{R}$$

$$V_T = V_1 + V_2 + V_3 + ... = I_1R_1 + I_2R_2 + I_3R_3 + ...$$

$$I_T = I_1 + I_2 + I_3 + ... = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + ...$$

$$T = RC \qquad T = \frac{L}{R}$$

$$V_R = RC\frac{dv}{dt} \qquad V_C = \frac{1}{RC}\int v_i dt$$

$$X_L = 2\pi fL \qquad X_C = \frac{1}{2\pi fC}$$

$$Z = R + jX_L \qquad Z = R - jX_C$$

$$Z = R + j(X_L - X_C) \qquad I_T = \frac{V_T}{Z_T}$$

$$V_R = I_T R \qquad V_L = I_T(jX_L)$$

$$V_C = I_T(-jX_C) \qquad f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$Q = \frac{V_L}{V_T} = \frac{V_C}{V_T} = \frac{X_L}{R} = \frac{X_C}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{f_r}{f_2 - f_1}$$

$$BW = f_2 - f_1 \qquad \frac{1}{Z_T} = \frac{1}{Z_1} + \frac{1}{Z_2}$$

$$Z_T = \frac{Z_2Z_2}{Z_1 + Z_2} \qquad I_T = I_1 + I_2 = \frac{V}{Z_1} + \frac{V}{Z_2}$$

$$Z_T = \frac{R(jX_L)}{R + jX_L} \qquad \frac{1}{Z_T} = \frac{1}{R} - \frac{j}{X_L}$$

$$I_T = I_R - jI_L \qquad I_T = \frac{V}{R} - j\frac{V}{X_L}$$

$$Z_T = \frac{R(-jX_C)}{R - jX_C} \qquad \frac{1}{Z_T} = \frac{1}{R} + \frac{j}{X_C}$$

$$I_T = I_R + jI_C \qquad I_T = \frac{V}{R} + j\frac{V}{X_C}$$

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$$\frac{1}{Z_T} = \frac{1}{R} - j\left(\frac{1}{X_L} - \frac{1}{X_C}\right)$$

$$I_T = I_R - j(I_L - I_C) \qquad I_T = \frac{V}{R} - j\left(\frac{V}{X_L} - \frac{V}{X_C}\right)$$

$$a + jb = \sqrt{a^2 + b^2} \,/\, \tan^{-1}\frac{b}{a} = r \,\underline{/\theta}$$

$$r\,\underline{/\theta} = r(\cos\theta + j\sin\theta) \qquad Q = \tan\theta$$

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \qquad Z_d = \frac{L}{CR_1}$$

$$V_{rms} = \frac{1}{\sqrt{2}}V_m = 0{,}707\,V_m \qquad V_{dc} = \frac{2}{\pi}V_m = 0{,}637\,V_m$$

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P} \qquad V_{dc} = \frac{1}{\pi}V_m = 0{,}318\,V_m$$

$$PIV = V_m \qquad PIV = 2\,V_m$$

$$R_{r(rms)} = 0{,}385\,V_m \qquad V_{r(rms)} = 0{,}305\,V_m$$

$$r = \frac{V_{r(rms)}}{V_{dc}} \qquad V_{r(rms)} = \frac{V_{r(p-p)}}{2\sqrt{3}}$$

$$V_{dc} = V_m - \frac{V_{r(p-p)}}{2}$$

$$V_{dc} = V_m - \frac{I_{dc}}{2fC} \qquad V_{dc} = V_m - \frac{I_{dc}}{4fC}$$

$$V_{r(rms)} = \frac{I_{dc}}{2\sqrt{3}fC} = \frac{V_{dc}}{2\sqrt{3}fCR_L} \qquad V_{r(rms)} = \frac{I_{dc}}{4\sqrt{3}fC} = \frac{V_{dc}}{4\sqrt{3}fCR_L}$$

$$r = \frac{I_{dc}}{2\sqrt{3}fCV_{dc}} = \frac{1}{2\sqrt{3}fCR_L} \qquad r = \frac{I_{dc}}{4\sqrt{3}fCV_{dc}} = \frac{1}{4\sqrt{3}fCR_L}$$

$$V'_{dc} = \frac{R_L}{R + R_L}.V_{dc} \qquad V'_{r(rms)} = \frac{X_C}{\sqrt{R^2 + X_C^2}}.V_{r(rms)}$$

$$X_C = \frac{1}{2\pi fC} \qquad X_C = \frac{1}{4\pi fC} \qquad r' = \frac{V'_{r(rms)}}{V'_{dc}}$$

$$V'_{r(rms)} = \frac{X_C}{R}.V_{r(rms)} \qquad r' = rX_C\left(\frac{R + R_L}{R.R_L}\right)$$

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$V'_{dc} = V_{dc} - I_{dc}R_1$

$V'_{dc} = \frac{R_L}{R_L + R_1} . V_{dc}$

$V'_{r(rms)} = \frac{V_{r(rms)}}{(2\pi f)^2 LC}$

$V'_{r(rms)} = \frac{V_{r(rm)}}{(4\pi f)^2 LC}$

$VR = \frac{V_{NL} - V_{FL}}{V_{FL}}$

$\%VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$

$2V_m = V_{c2} = V_m + V_{c1}$

$3V_m = V_{c1} + V_{c3} = V_m + 2V_m$

$S = \frac{\Delta V_o}{\Delta V_i}$

$V_R = V_i - V_z$

$R_{s(\min)} = \frac{V_{i(\max)} - V_z}{I_{z(\max)}}$

$I_z = \frac{P_z}{V_z}$

$R_{L(\min)} = \frac{V_Z}{V_{i(\max)} - V_Z} . R_S$

$V_o = V_r - V_{be}$

$R_c = \frac{V_{cc} - V_{ce}}{I_c}$

$R_b = \frac{V_{cc} - V_{be}}{I_b}$

$\beta = \frac{I_c}{I_b}$

$C_e \geq \frac{10}{2\pi f R_e}$

$V_e = \frac{V_{cc}}{10}$

$R_e = \frac{V_e}{I_e} \simeq \frac{V_e}{I_c}$

$R_c = \frac{V_{cc} - V_{ce} - V_e}{I_c}$

$R_b = \frac{V_{cc} - V_{be} - V_e}{I_b}$

$R_{b1} = \frac{R_{b2}(V_{cc} - V_b)}{V_b}$

$R_{b2} = \frac{1}{10}\beta R_e$

$V_b = V_e + V_{be}$

$V_{be} = h_{ie} i_b + h_{re} V_{ce}$

$i_c = i_{fe} i_b + h_{oe} V_{ce}$

$A_i = \frac{h_{fe}}{1 + h_{oe} Z_L}$

$A_i = h_{fe}$

$A_i = \left(\frac{h_{fe}}{1 + h_{oe} Z_L} \right) \left(\frac{R_b T}{R_{bT} + Z_1} \right) \left(\frac{R_c}{R_c + R_L} \right)$

$A_v = \frac{-h_{fe} Z_L}{h_{ie} + (h_{ie} h_{oe} - h_{fe} h_{re}) Z_L}$

$A_v = \frac{-h_{fe} Z_L}{h_{ie}}$

$Z_1 = h_{ie} - \frac{h_{fe} h_{re} Z_L}{1 + h_{oe} Z_L}$

$Z_1 = h_{ie}$

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$$Z_2 = \frac{1}{h_{oe} - \frac{h_{fe}h_{re}}{h_{ie} + R_s}} \qquad Z_2 = \frac{1}{h_{oe}}$$

$$A_p = \frac{A_i^2 R_L}{R_1} = -A_v A_i \qquad A_p = \frac{{h_{fe}}^2 R_L}{h_{ie}}$$

$$Z_0 = R_C // R_L // Z_2 = Z_L // Z_2$$

$$Z_0 = R_C // Z_2 = Z_L // Z_2 \qquad Z_1 = R_b // Z_1$$

$$Z_i = R_{b1} // R_{b2} // Z_1 \qquad I_1 = \frac{R_{bT} I_i}{R_{bT} = Z_1}$$

$$I_0 = h_{fe} I_b = h_{fe}\left(\frac{R_{b2}(I_i)}{R_{b2} + h_{ie}}\right) \qquad A_i = \frac{I_0}{I_1}$$

For common base, substitute all the 'e' subscripts with a 'b' in the h-parameters.

$$Z_L = R_c // R_L \qquad I_1 = \frac{R_e I_i}{R_e + Z_1}$$

$$CMRR = \frac{A_{dm}}{A_{cm}} \qquad CMRR\ (dB) = 20log\frac{A_{dm}}{A_{cm}}$$

$$I_e = \frac{V_e}{R_e} \qquad I_c = \frac{I_e}{2}$$

$$R_L = \frac{V_{R_L}}{I_C} \qquad g_m R_L = \frac{h_{fe}}{h_{ie}} . R_L$$

$$V_0 = -\left(\frac{R_f}{R_1}\right) . V_i \qquad V_0 = \left(\frac{R_f}{R_1} + 1\right) . V_i$$

$$V_0 = -\left(\frac{R_f}{R_1} . V_1 + \frac{R_f}{R_2} . V_2 + \frac{R_f}{R_3} . V_3\right) \qquad V_0 = -\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right) R_f$$

$$V_0 = -(V_1 + V_2 + V_3) \qquad V_0 = -(I_1 + I_2 + I_3)\, R_f$$

$$V_0(t) = -\frac{1}{RC}\int V_i(t) \qquad V_0(t_b) = -\frac{1}{RC}\int_{t_a}^{t_b} V_i(t_b) + V_c(t_a)$$

$$t = \frac{1}{f} \qquad A_v = -\frac{R_s}{R_1}$$

$$R_2 = \frac{R_1 R_s}{R_1 + R_s} \qquad f_c = \frac{1}{2\pi R_s C}$$

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$$V_0(t) = -RC\frac{dV_i(t)}{dt}$$

$$A = \frac{R_f}{X_c}$$

$$A = -\frac{R_f}{R_s}$$

$$V_0(t) = -R_f C\frac{d}{dt}.v_i \sin \omega t$$

$$t = R_f C$$

$$V_0 = A(V_r - V_i)$$

$$V_0 = \frac{R_f}{R_s}(V_2 - V_1)$$

$$V_0 = V_2 - V_1$$

$$f_0 = \frac{1}{2\pi\sqrt{C_1 C_2 R_1 R_2}}$$

$$f_0 = \frac{1}{2\pi RC}$$

$$f_0 = \frac{1}{2\pi\sqrt{L_T C_1}}$$

$$L_T = L_1 + L_2 + 2M$$

$$f_0 = \frac{1}{2\pi\sqrt{LC_T}}$$

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC_2}}$$

$$f = \frac{1}{2\pi RC\sqrt{6}}$$

$$f_0 = \frac{1{,}5}{RC}$$

$$f_0 = \frac{1}{t} = \frac{1}{t_1 + t_2}$$

$$t_1 = 0{,}7\ R_2 C_1$$

$$t_2 = 0{,}7\ R_1 C_2$$

$$f_0 = \frac{1}{1{,}4RC}$$

$$V_i = I_{c2}R_e + V_{be(ON)}$$

$$t = 1{,}1\ RC$$

$$f_0 = \frac{1{,}443}{(R_A + 2R_B)C}$$

$$t_{low} = 0{,}693\ (R_B)C$$

$$t_{high} = 0{,}693\ (R_A + R_B)C$$

$$t_T = t_{low} + t_{high}$$

$$K = \frac{\Delta R / R}{\Delta l / l}$$

$$\sigma = \Delta l / l$$

$$R = \rho\frac{1}{\pi d^2 / 4}$$

$$\sigma = \frac{S}{E}$$

$$Resolution = \frac{1}{number\ of\ turns}$$

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$$Resolution = \frac{voltage\ drop\ across\ adjacent\ turns}{total\ voltage\ drop}$$

$$R_t = Ae^{B/T} \qquad T = 273 + °C$$

$$V_A = \frac{R_2}{R_1 + R_2}.V_T \qquad V_B = \frac{R_t}{R_t + R_3}.V_T$$

$$V_{AB} = V_A - V_B \qquad A_v = \frac{V_0}{V_i}$$

$$V_{Hall} = kIH$$

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