higher education & training

Department:
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REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

INDUSTRIAL ELECTRONICS N5

(8080175)

27 November 2023 (X-paper)
09:00–12:00

Drawing instruments and nonprogrammable calculators may be used.

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. Sketches must be large, neat and fully labelled.
5. Write neatly and legibly.

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QUESTION 1: ALTERNATING CURRENT THEORY

1.1 Draw a graphical representation of the voltage and current versus frequency with respect to resonance in serial circuits. (3)

1.2 In a serial RLC circuit the lower and upper half power frequency is 199,5 kHz and 200,5 kHz respectively. The serial resistor has a value of 10 Ω and the coil has a value of 0,015 H.

If a power supply of 20 V is applied, calculate:

1.2.1 The value of the capacitor at resonance (5)

1.2.2 The voltage drop across each component (6)

1.2.3 The Q-factor (2)
[16]

QUESTION 2: POWER SUPPLIES

2.1 An RC π-filter delivers an output voltage of 12 V. If X_{C2} = 8 Ω; R = 10 Ω; R_L = 300 Ω and $V'_{R(RMS)}$ = 0,8 V;

Calculate:

2.1.1 V_{DC} across the first capacitor (3)

2.1.2 $V_{R(RMS)}$ across the first capacitor (3)

2.1.3 r' across the second capacitor (2)

2.2 Draw a neat, labelled circuit diagram that provides over-voltage protection in a power supply and briefly describe how the circuit operates. (6)
[14]

QUESTION 3: TRANSISTOR AMPLIFIERS

3.1 The following values of a common-emitter amplifier with a silicon transistor are known:

R_{B1} = 15,947 kΩ; R_{B2} = 3 kΩ; R_E = 120 Ω; R_c = 480 Ω; $^+V_{cc}$ = 12 V;
V_{BE} = 0,7 V and β = 250

Calculate the values of V_e, I_c, I_B, V_{ce} and V_B of the amplifiers. (10)

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3.2 Calculate the input impedance (Z_i) and the output impedance (Zo) of the circuit in QUESTION 3.2 using the approximate method if:

$h_{ie} = 1{,}2\ k\Omega$; $h_{re} = 2 \times 10^{-4}$; $h_{fe} = 100$ and $h_{oe} = 20\ \mu A/V$ (Rs = 0) (5)

[15]

QUESTION 4: OPERATIONAL AMPLIFIERS

4.1 If the input signal of the integrator is a square wave form of ± 1 V, 500 Hz and the input resistor and feedback capacitor has values of 10 MΩ and 0,01 μf respectively, calculate the output voltage and draw its waveform (capacitor is initially discharged). (9)

4.2 Draw a neat, labelled circuit diagram of a voltage follower and briefly describe TWO functions of this circuit. (4)

[13]

QUESTION 5: INTEGRATED CIRCUITS

As an electronic technician you were tasked to design the printed circuit board for an electronic control system that uses a 741 operational amplifier. With the aid of a neat, labelled diagram, draw the integrated metal can pack outlay of a 741 operational amplifier and label all terminal assignments. **[4]**

QUESTION 6: ELECTRONIC PHASE CONTROL

Draw a neat, labelled circuit diagram of a light dimmer in which a triac is used. **[6]**

QUESTION 7: TEST EQUIPMENT

Draw a neat, labelled block diagram of a voltage-to-frequency converter. **[6]**

QUESTION 8: OSCILLATORS

8.1 State THREE factors that may destabilise the frequency of an oscillator. (3)

8.2 Draw a neat, labelled circuit diagram of a uni-junction transistor oscillator. (4)

8.3 Name THREE common types of waveforms and give an application of each. (6)

[13]

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QUESTION 9: TRANSDUCERS

9.1 Draw the circuit diagram of a thermistor control circuit in which an operational amplifier and a DC Wheatstone bridge are used. (4)

9.2 If the bridge is balanced at 25 °C; A = 0,2169; β = 3 200 and a 12 V battery is connected across the bridge; R_t = 10 kΩ at 25 °C;

Calculate the following:

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

9.2.2 The gain of the amplifier with an output of 10 V (7)
[13]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$V_R = V_i - V_z$$

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

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

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

$$V_o = V_r - V_{be}$$

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

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

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

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

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

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

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

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

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

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

$$V_b = V_e + V_{be}$$

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

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

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

$$A_i = h_{fe}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$V_0(t) = -RC\frac{dV_i(t)}{dt} \qquad A = \frac{R_f}{X_c}$$

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

$$t = R_f C \qquad V_0 = A(V_r - V_i)$$

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

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

$$f_0 = \frac{1}{2\pi\sqrt{L_T C_1}} \qquad L_T = L_1 + L_2 + 2M$$

$$f_0 = \frac{1}{2\pi\sqrt{LC_T}} \qquad C_T = \frac{C_1 C_2}{C_1 + C_2}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC_2}} \qquad f = \frac{1}{2\pi RC\sqrt{6}}$$

$$f_0 = \frac{1{,}5}{RC} \qquad f_0 = \frac{1}{t} = \frac{1}{t_1 + t_2}$$

$$t_1 = 0{,}7\ R_2 C_1 \qquad t_2 = 0{,}7\ R_1 C_2$$

$$f_0 = \frac{1}{1{,}4RC} \qquad V_i = I_{c2}R_e + V_{be(ON)}$$

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

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

$$t_T = t_{low} + t_{high} \qquad K = \frac{\Delta R / R}{\Delta l / l}$$

$$\sigma = \Delta l / l \qquad R = \rho\frac{1}{\pi d^2 / 4}$$

$$\sigma = \frac{S}{E} \qquad Resolution = \frac{1}{amount\ of\ turns}$$

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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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