higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

**NATIONAL CERTIFICATE**

# INDUSTRIAL ELECTRONICS N5

(8080175)

**21 November 2022 (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.**

108Q1E2221

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# DEPARTMENT OF HIGHER EDUCATION AND TRAINING
# REPUBLIC OF SOUTH AFRICA

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

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**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. ALL the calculations must be shown.
5. ALL the sketches and diagrams must be large, clear and neat.
6. Keep questions and subsections of questions together.
7. Use only a black or blue pen.
8. Start each question on a new page.
9. Write neatly and legibly.

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## QUESTION 1: ALTERNATING CURRENT THEORY

1.1 In a serial RL circuit it takes 2 μs for the circuit to reach 63,2% of the total current $I_T$. If R = 150 kΩ and $V_T$ = 5 V, calculate:

1.1.1 The value of L (2)

1.1.2 $I_L$ after 2 μs (3)

1.2 Draw a neat, labelled circuit diagram of an RC integrator as well as the frequency response curve thereof. (3)

1.3 A circuit consists of the following components:

$Z_1$ = 120 –j 21,21 Ω

$Z_2$ = 180 +j 25,31 Ω

$Z_3$ = 100 +j 47,31 Ω

All impedances are connected in parallel and to a 250 V/50 Hz supply.

Calculate the total impedance of the circuit. (9)

**[17]**

## QUESTION 2: POWER SUPPLIES

2.1 Calculate the value of the series resistor needed in order to protect a Zener diode that has 750 mW, 12 V in a voltage reference source. The circuit is supplied with the maximum voltage of 20 V. (4)

2.2 Draw a neat, labelled circuit diagram of a parallel voltage regulator and briefly describe its operation. (7)

2.3 Show, with the aid of a neat, labelled circuit diagram, how a 5 V fixed voltage regulator can be used to produce a voltage lower than a fixed voltage regulator. (5)

**[16]**

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## QUESTION 3: TRANSISTOR AMPLIFIERS

3.1 The following information about a common emitter amplifier is known:



Ve = 1,5V; $I_B$ = 40µA; Rc =750 Ω;
β = 250; Re = 120Ω; Vb = 0,6V

3.1.1 Vce (5)

3.1.2 $R_{b1}$ and $R_{b2}$ (4)

3.2 A fixed-bias voltage amplifier has an input impedance of 2 kΩ and an output impedance of 2,5 kΩ.

Calculate the values of the collector resistor and base resistor with the precise method if the following information about the transistor is known:

$h_{ie}$ = 12kΩ; $h_{re} = 2 \times 10^{-4}$;
$h_{fe}$ = 100; and $h_{oe}$ = 20µA/V $R_S$ = 0 (8)
**[17]**

## QUESTION 4: OPERATIONAL AMPLIFIERS

4.1 Explain the term *common-mode rejection ratio.* (2)

4.2 If the input signal is a square waveform of ± 1 V, 500 Hz and the input resistor and feedback capacitor have values of 10 MΩ and 0,01 µF respectively, calculate the output voltage and draw its waveform (the capacitor is initially discharged). (9)
**[11]**



## QUESTION 5: INTEGRATED CIRCUITS

5.1 Name FOUR types of voltage regulators. (4)

5.2 Explain the term *static electricity.* (2)
**[6]**



## QUESTION 6: TRANSDUCERS

6.1 Indicate whether the following statements are TRUE or FALSE by writing only 'True' or 'False' next to the question number (6.1.1–6.1.3) in the ANSWER BOOK.

6.1.1 A strain gauge is used to measure the force applied to aircraft wings, concrete pylons and bridging structures.

6.1.2 An LDR is a device whose resistance changes when it is exposed to light.

6.1.3 In negative temperature coefficient thermistors, the resistance decreases with an increase in temperature.

(3 × 1) (3)

6.2 Draw a neat, labelled circuit diagram of a tacho-generator in a closed-loop system. (4)

6.3 Briefly describe the operating principle of an infrared detector and state ONE application thereof in practice. (4)

**[11]**

## QUESTION 7: ELECTRONIC PHASE CONTROL

Draw a complete circuit diagram of a full-wave DC phase control circuit with two SCRs in the bridge. The potentiometer must also be included in the circuit. **[6]**

## QUESTION 8: TEST EQUIPMENT

Draw a neat, labelled block diagram of a staircase A/D voltmeter. **[6]**

## QUESTION 9: OSCILLATORS

9.1 Draw a neat, labelled circuit diagram of a Hartley oscillator. (4)

9.2 Draw a neat, labelled circuit diagram of a Schmitt trigger. (4)

9.3 Briefly explain the function of the Rozner modification. (2)

**[10]**

**TOTAL: 100**

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## FORMULA SHEET

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$I_T = I_R - j(I_L - I_C)$$

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

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

$$r \angle \theta = r(\cos\theta + j\sin\theta)$$

$$Q = \tan\theta$$

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

$$Z_d = \frac{L}{CR_1}$$

$$V_{rms} = \frac{1}{\sqrt{2}} V_m = 0{,}707\ V_m$$

$$V_{dc} = \frac{2}{\pi} V_m = 0{,}637\ V_m$$

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P}$$

$$V_{dc} = \frac{1}{\pi} V_m = 0{,}318\ V_m$$

$$PIV = V_m$$

$$PIV = 2\,V_m$$

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

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

$$r = \frac{V_{r(rms)}}{V_{dc}}$$

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

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

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

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

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

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

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

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

$$V'_{dc} = \frac{R_L}{R + R_L} \cdot V_{dc}$$

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

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

$$V'_{r(rms)} = \frac{X_C}{R} \cdot V_{r(rms)}$$

$$r' = rX_C\left(\frac{R + R_L}{R.R_L}\right)$$

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

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

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

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

$t = R_f C$

$V_0 = A(V_r - V_i)$

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

$V_0 = V_2 - V_1$

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

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

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

$L_T = L_1 + L_2 + 2M$

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

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

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

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

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

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

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

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

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

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

$t = 1{,}1\ RC$

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

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

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

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

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

$\sigma = \Delta l / l$

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

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

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

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

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

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

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

$V_{Hall} = kIH$

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