



basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY

NOVEMBER 2014

MARKS: 200

TIME: 3 hours

This question paper consists of 12 pages and 2 formula sheets.

INSTRUCTIONS AND INFORMATION

1. This question paper consists of SEVEN questions.
2. Answer ALL the questions.
3. Sketches and diagrams must be large, neat and fully labelled.
4. Show ALL calculations and round off correctly to TWO decimal places.
5. Number the answers correctly according to the numbering system used in this question paper.
6. You may use a non-programmable calculator.
7. Show the units for all answers of calculations.
8. A formula sheet is provided at the end of this question paper.
9. Write neatly and legibly.

QUESTION 1: OCCUPATIONAL HEALTH AND SAFETY

- 1.1 Name ONE unsafe condition that may cause an electric shock when working in an electrical technology workshop. (1)
- 1.2 State ONE unsafe act in an electrical technology workshop. (1)
- 1.3 State ONE procedure that must be followed when assisting an injured person in an electrical technology workshop. (1)
- 1.4 Describe how a person's human rights may be compromised if a co-worker is using drugs when working in an electrical technology workshop. (2)
- 1.5 Discuss why team work is a good work ethic. (2)
- 1.6 Describe why a risk analysis must be done to improve safety in an electrical technology workshop. (3)
- [10]**

QUESTION 2: THREE-PHASE AC GENERATION

- 2.1 Explain why the secondary winding of a three-phase transformer supplying high-voltage transmission lines is connected in delta. Take economic factors into consideration. (2)
- 2.2 Describe the purpose of a power factor meter in an AC circuit. (2)
- 2.3 State TWO advantages of a three-phase distribution system over a single-phase distribution system. (2)
- 2.4 Power in a 380 V system is measured using the two wattmeter method. The readings on the meters are 420 W and -260 W respectively.
- Given:
- $V_L = 380 \text{ V}$
 $P_1 = 420 \text{ W}$
 $P_2 = -260 \text{ W}$
- 2.4.1 Calculate the active power. (3)
- 2.4.2 State TWO advantages of this method of power measurement over other methods. (2)

- 2.5 A star-connected alternator generates 560 kW at a voltage of 380 V. The alternator has a power factor of 0,85 at full load.

Given:

$$\begin{aligned} V_L &= 380 \text{ V} \\ P &= 560 \text{ kW} \\ \text{Cos } \phi &= 0,85 \end{aligned}$$

- 2.5.1 Calculate the current drawn at full load. (3)
- 2.5.2 Draw the voltage phasor diagram of the alternator. (6)
- [20]**

QUESTION 3: THREE-PHASE TRANSFORMERS

- 3.1 State TWO types of three-phase transformer connections. (2)
- 3.2 Explain the basic operation of a transformer. (5)
- 3.3 State the purpose of a Buchholtz relay in a transformer. (2)
- 3.4 Study FIGURE 3.1 below and answer the questions that follow.

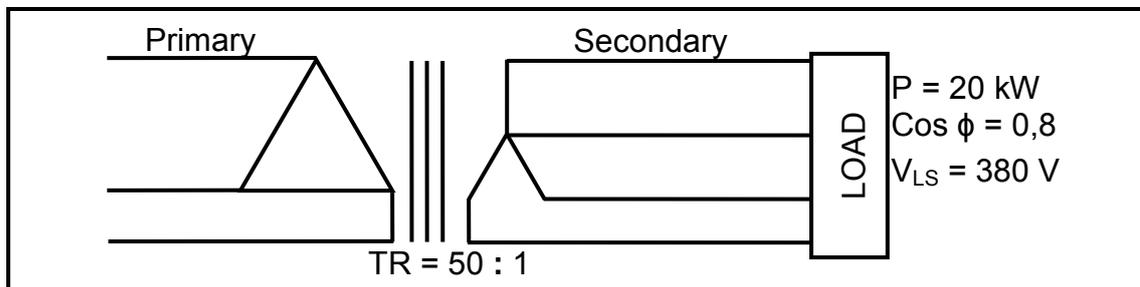


FIGURE 3.1: THREE-PHASE TRANSFORMER

- 3.4.1 Calculate the secondary phase voltage. (3)
- 3.4.2 Calculate the primary phase voltage. (3)
- 3.4.3 Explain, with a reason, whether the transformer is a STEP-UP or STEP-DOWN TRANSFORMER. (2)
- 3.4.4 Describe what would happen to the primary current of the transformer if the load was increased. (3)
- [20]**

QUESTION 4: THREE-PHASE MOTORS AND STARTERS

- 4.1 State ONE application of a three-phase induction motor. (1)
- 4.2 Name ONE advantage of a three-phase induction motor over a single-phase motor. (1)
- 4.3 Explain the principle of operation of a three-phase squirrel-cage induction motor. (8)
- 4.4 Name ONE mechanical inspection that should be done on a motor after installation and before energising. (1)
- 4.5 Name ONE electrical inspection that should be done on a motor after installation and before energising. (1)
- 4.6 Explain the following terms with reference to the speed of an induction motor:
- 4.6.1 Rotor speed (1)
- 4.6.2 Synchronous speed (1)
- 4.7 A three-phase 12-pole motor is connected to a 380 V/50 Hz supply. The motor has 4% slip.

Given:

$$\begin{aligned} V_L &= 380 \text{ V} \\ f &= 50 \text{ Hz} \\ \text{Slip} &= 4\% \\ p &= 2 \end{aligned}$$

Calculate, in r/min, the:

- 4.7.1 Synchronous speed (3)
- 4.7.2 Rotor speed (3)
- 4.8 FIGURE 4.1 below represents the terminals of a three-phase induction motor.

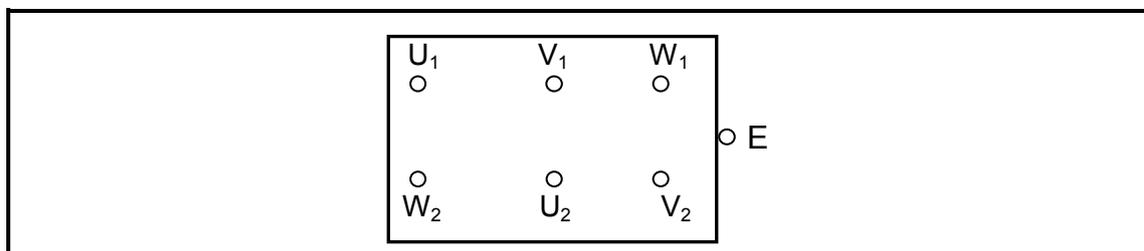


FIGURE 4.1: TERMINALS OF A THREE-PHASE INDUCTION MOTOR

- 4.8.1 Redraw the exact configuration showing the motor terminals connected in delta to the supply. (4)
- 4.8.2 A megger, set on the insulation resistance setting, is connected across W_2 and E. State the type of reading that can be expected and explain why. (3)

- 5.3 Study the circuit diagram in FIGURE 5.1 below and answer the questions that follow.

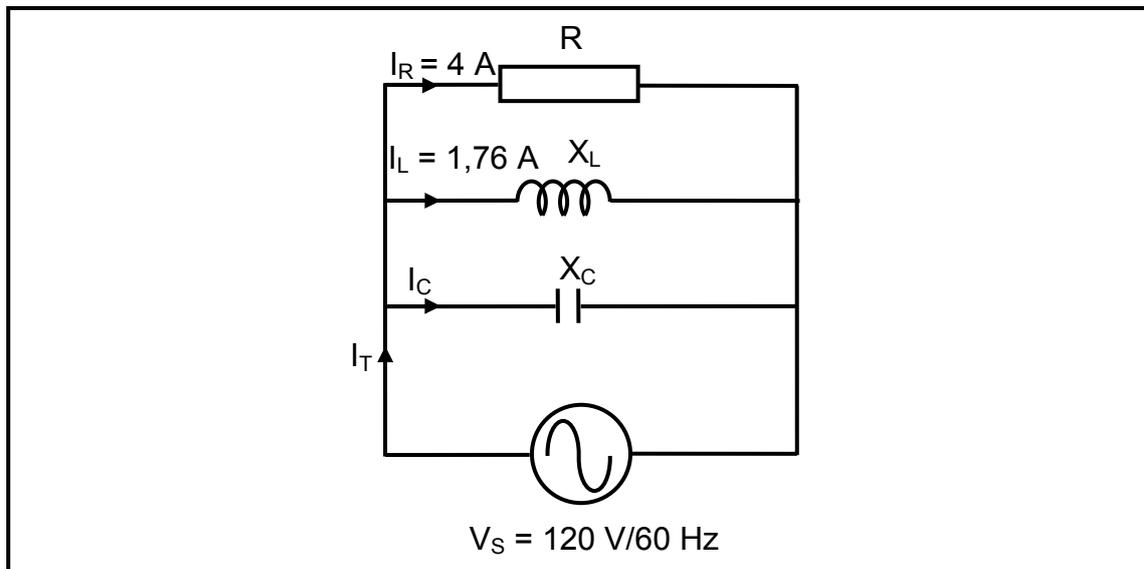


FIGURE 5.1: RLC PARALLEL CIRCUIT

Given:

$$\begin{aligned} X_C &= 26 \Omega \\ V_S &= 120 \text{ V} \\ I_R &= 4 \text{ A} \\ I_L &= 1,76 \text{ A} \\ f &= 60 \text{ Hz} \end{aligned}$$

Calculate the:

- 5.3.1 Current flowing through the capacitor (3)
- 5.3.2 Total current flow (3)
- 5.3.3 Phase angle. State whether it is LEADING or LAGGING. (4)
- [20]**

QUESTION 6: LOGIC

- 6.1 Answer the following questions with reference to programmable logic controllers.
- 6.1.1 Define a *programmable logic controller* (PLC). (3)
- 6.1.2 Describe why relays cannot be entirely replaced by PLCs. (3)
- 6.1.3 State THREE advantages of a PLC over other electrical control systems. (3)
- 6.1.4 State ONE advantage of the use of functional blocks over ladder logic in PLC programming. Give a reason for the answer. (2)

6.2 FIGURE 6.1 below shows a typical PLC system.

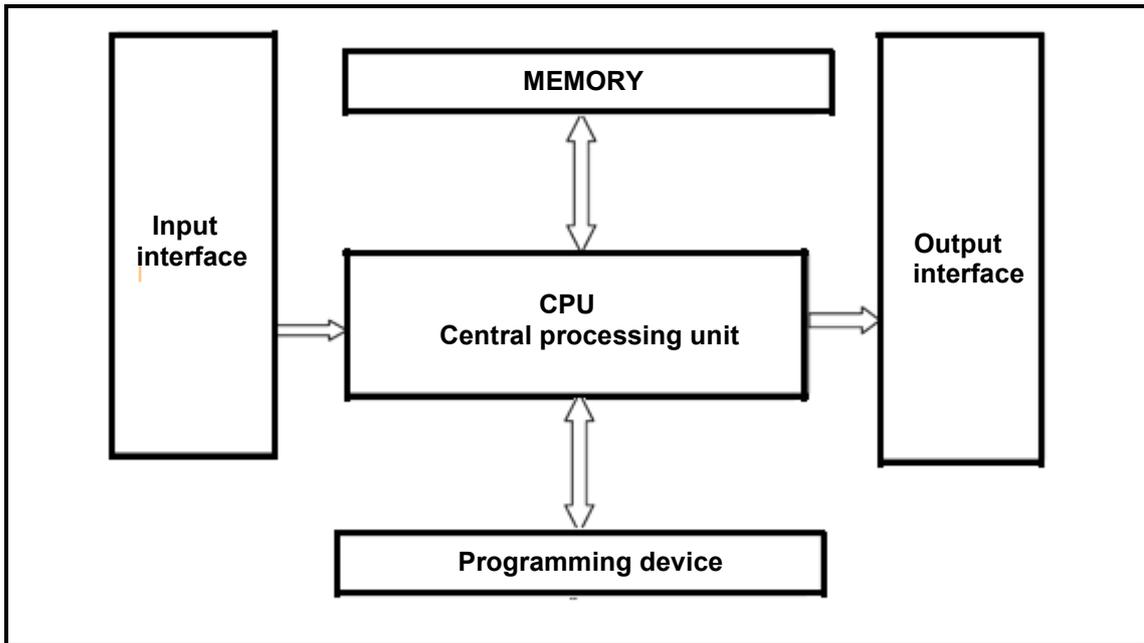


FIGURE 6.1: PLC SYSTEM

6.2.1 Explain the function of a programming device. (3)

6.2.2 Name TWO devices used to programme the central processing unit (CPU). (2)

6.3 Study the circuit in FIGURE 6.2 below and answer the questions that follow.

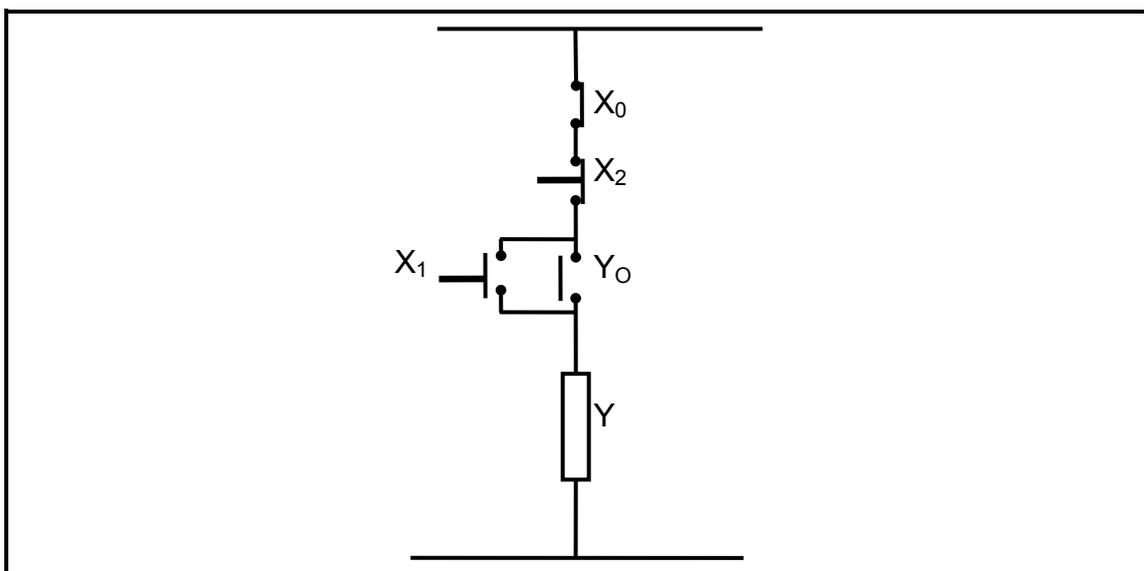


FIGURE 6.2: CONTROL CIRCUIT

6.3.1 Derive the equivalent Boolean equation for the circuit. (5)

6.3.2 Design an equivalent ladder logic diagram of the circuit. (5)

6.4 Refer to the circuit in FIGURE 6.3 below and derive the Boolean expression at the following points:

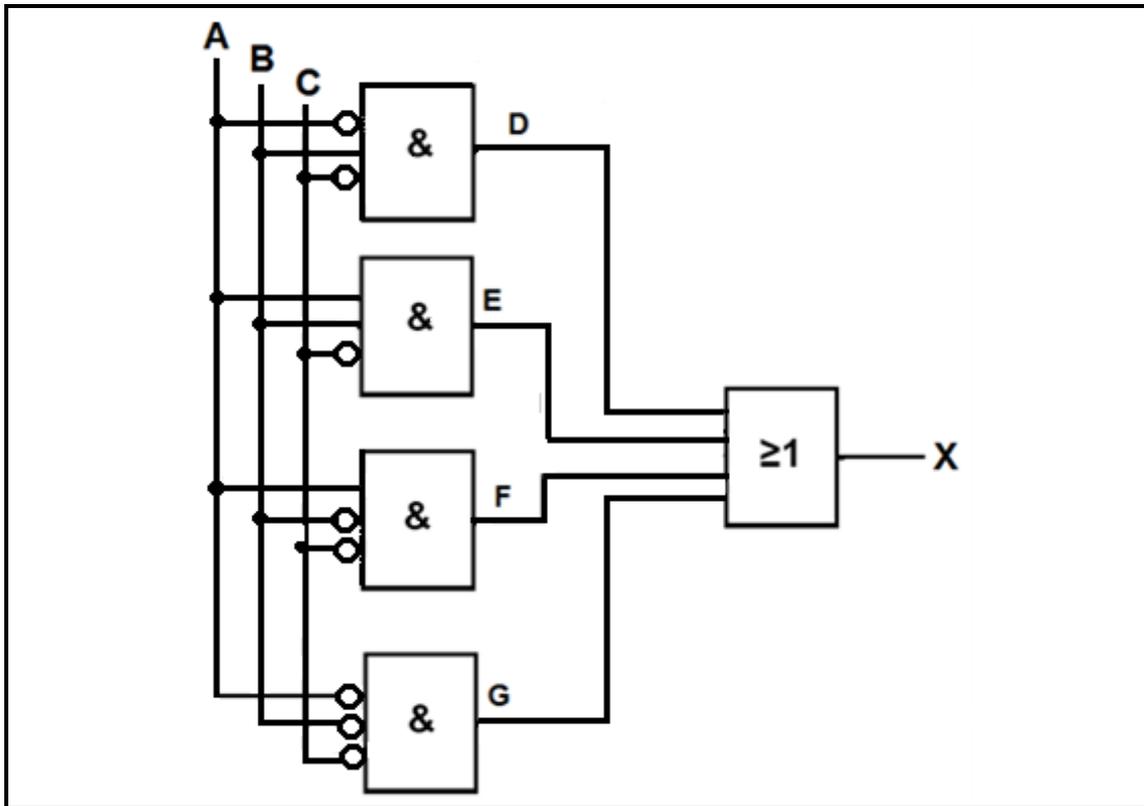


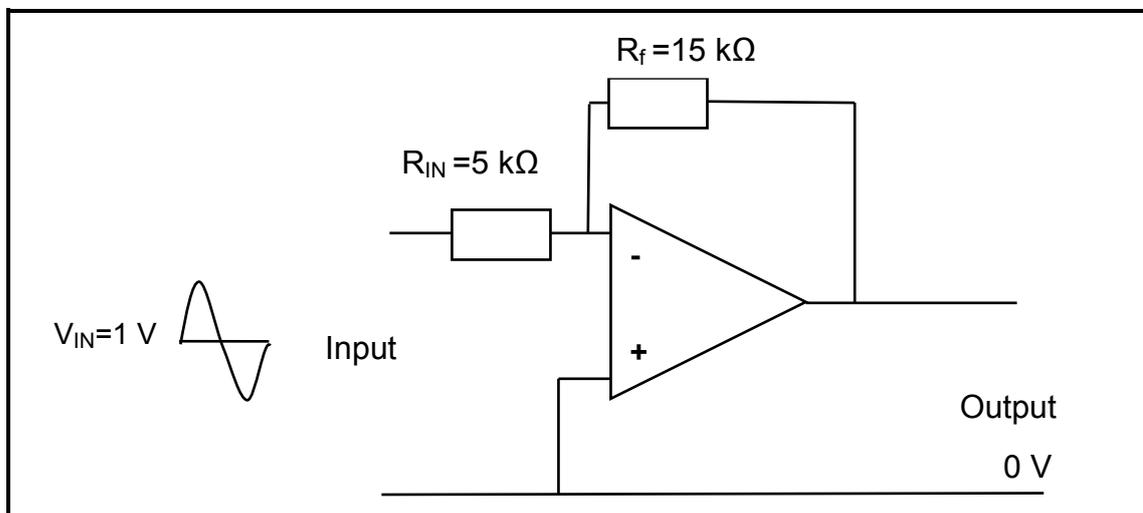
FIGURE 6.3: LOGIC CIRCUIT

- 6.4.1 D (1)
- 6.4.2 E (1)
- 6.4.3 F (1)
- 6.4.4 G (1)
- 6.4.5 X (1)
- 6.4.6 Use the Karnaugh map method to simplify the output (X). (6)

6.5 Safety is of paramount importance in the industry. Explain why a PLC system is safer when testing automation in a factory. (3)
[40]

QUESTION 7: AMPLIFIERS

- 7.1 List THREE characteristics of an ideal op amp (operational amplifier). (3)
- 7.2 Describe how a differential amplifier forms the basis of an op amp. (2)
- 7.3 Draw and label a basic block diagram of an op amp showing a negative feedback network. (4)
- 7.4 State TWO advantages of negative feedback in an op amp circuit. (2)
- 7.5 Explain why op amp circuits are supplied with a dual DC supply. (3)
- 7.6 Study FIGURE 7.1 below and answer the questions that follow.

**FIGURE 7.1: OP AMP**

- 7.6.1 Identify the op amp circuit in FIGURE 7.1. (1)
- 7.6.2 Draw the input and output waveforms (signals) of the op amp. (2)
- 7.6.3 What would happen to the voltage gain of the amplifier if the value of the feedback resistor was decreased? (2)
- 7.6.4 Calculate the gain of the op amp circuit. (3)
- 7.6.5 Calculate the output peak voltage of the op amp. (3)

7.7 Study FIGURE 7.2 below and answer the questions that follow.

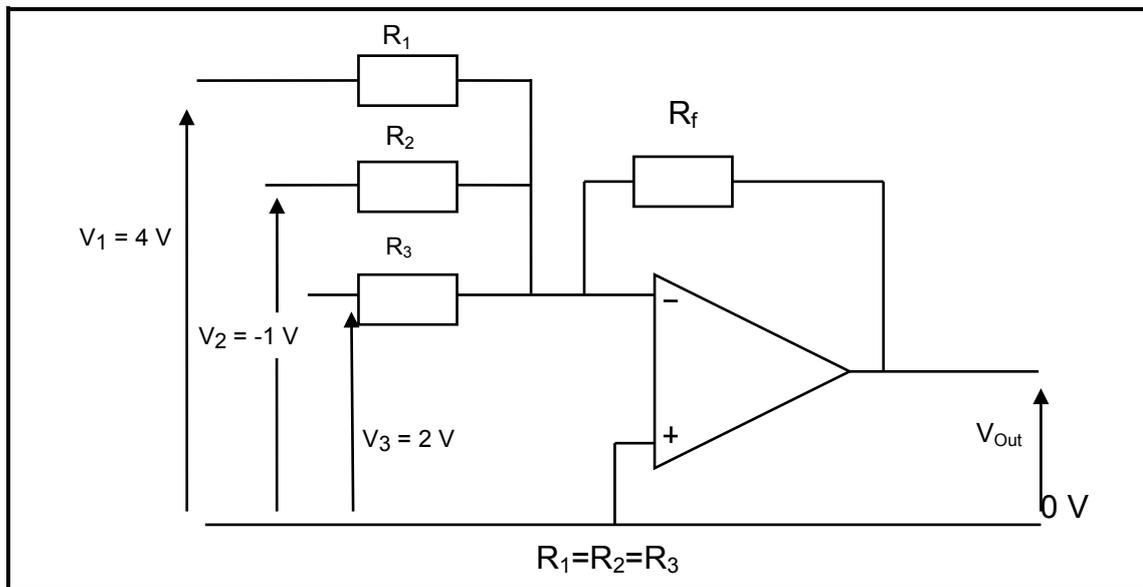


FIGURE 7.2: OP AMP CIRCUIT

- 7.7.1 Identify the op amp circuit in FIGURE 7.2. (1)
- 7.7.2 Describe ONE practical application of this type of op amp. (3)
- 7.7.3 Calculate the voltage output of the op amp. (3)

7.8 The circuit diagram in FIGURE 7.3 below is an op amp connected in the astable multivibrator configuration.

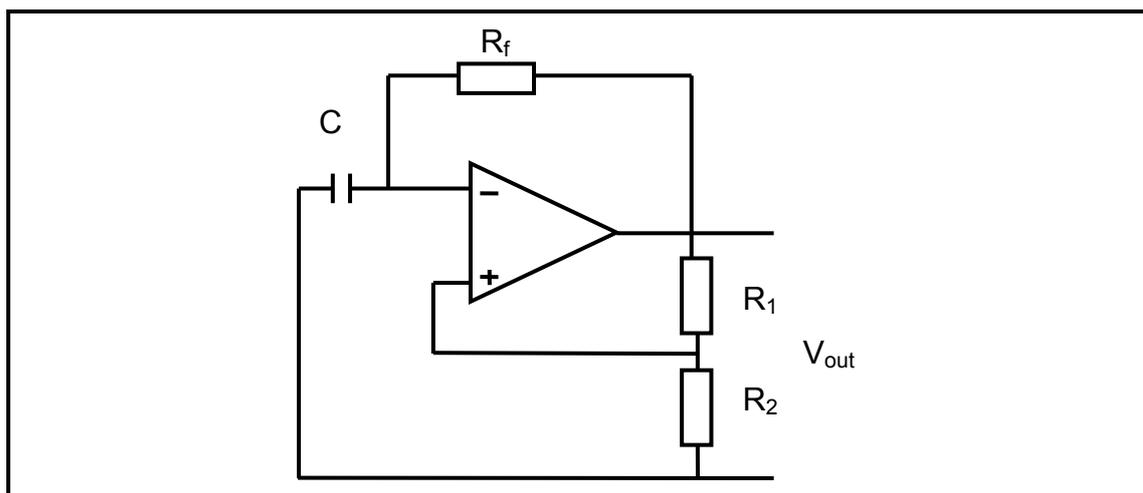


FIGURE 7.3: ASTABLE MULTIVIBRATOR

- 7.8.1 State TWO applications of the circuit. (2)
- 7.8.2 Draw the output waveform that the circuit generates. (3)

7.9 Answer the following questions with reference to an op amp connected in a Schmitt trigger configuration.

7.9.1 Describe ONE practical application of a Schmitt trigger op amp. (3)

7.9.2 Redraw all the time intervals illustrated in FIGURE 7.4 in the ANSWER BOOK and draw the output of the Schmitt trigger from the input signal shown in FIGURE 7.4 below. Label ALL the parts.

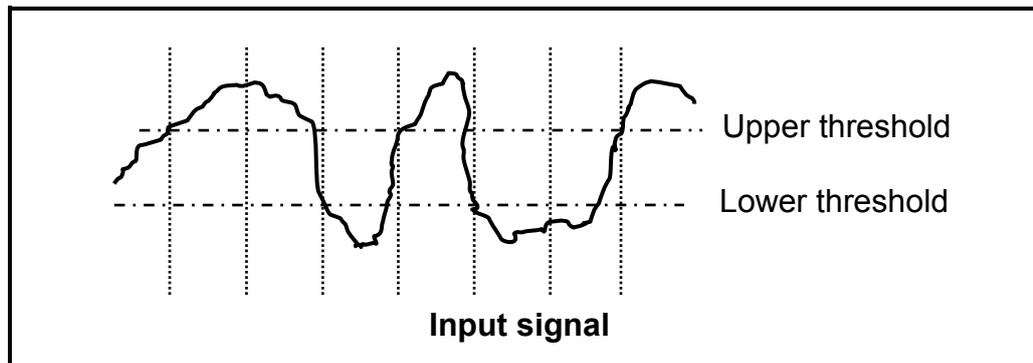


FIGURE 7.4: INPUT SIGNAL OF A SCHMITT TRIGGER OP AMP (4)

7.10 State the type of feedback that oscillators use. (1)

7.11 Describe the type of feedback named in QUESTION 7.10. (2)

7.12 Calculate the oscillation frequency of the RC phase-shift oscillator in FIGURE 7.5 below.

Given:

$$R_1 = R_2 = R_3 = 8 \text{ k}\Omega$$

$$C_1 = C_2 = C_3 = 120 \text{ nF}$$

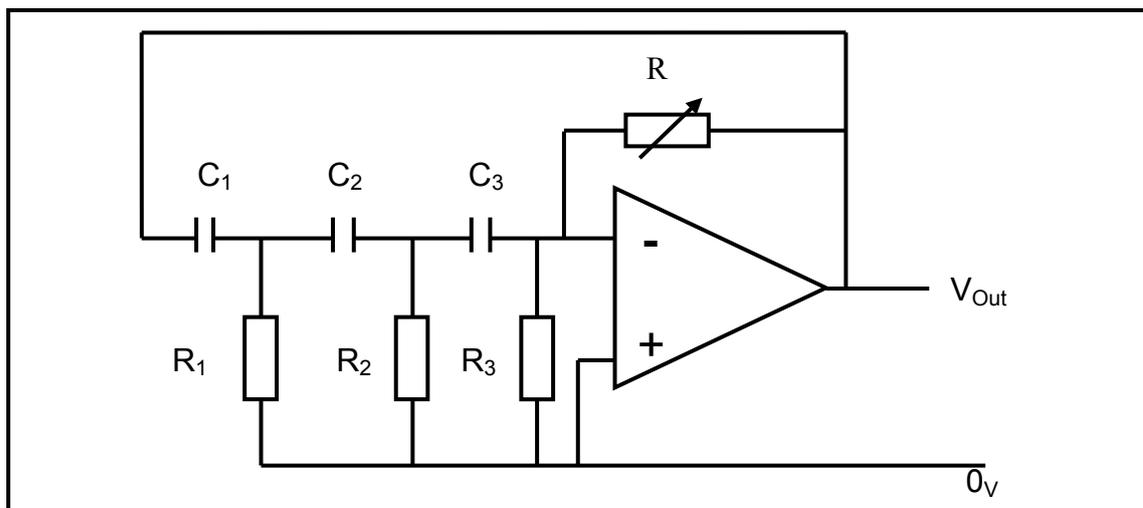


FIGURE 7.5: RC PHASE-SHIFT OSCILLATOR (3) [50]

TOTAL: 200

FORMULA SHEET

THREE-PHASE AC GENERATION**Star**

$$V_L = \sqrt{3} V_{PH}$$

$$I_L = I_{PH}$$

Delta

$$I_L = \sqrt{3} I_{PH}$$

$$V_L = V_{PH}$$

$$P = \sqrt{3} V_L \times I_L \cos \theta$$

$$S = \sqrt{3} V_L I_L$$

$$Q = \sqrt{3} V_L I_L \sin \theta$$

$$\cos \theta = \frac{P}{S}$$

$$Z_{PH} = \frac{V_{PH}}{I_{PH}}$$

Two wattmeter method

$$P_T = P_1 + P_2$$

THREE-PHASE TRANSFORMERS**Star**

$$V_L = \sqrt{3} V_{PH}$$

$$I_L = I_{PH}$$

Delta

$$I_L = \sqrt{3} I_{PH}$$

$$V_L = V_{PH}$$

$$P = \sqrt{3} V_L I_L \cos \theta$$

$$S = \sqrt{3} V_L I_L$$

$$Q = \sqrt{3} V_L I_L \sin \theta$$

$$\cos \theta = \frac{P}{S}$$

$$\frac{V_{PH(p)}}{V_{PH(s)}} = \frac{N_p}{N_s} = \frac{I_{PH(s)}}{I_{PH(p)}}$$

RLC CIRCUITS

$$X_L = 2\pi fL$$

$$X_C = \frac{1}{2\pi fC}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Series

$$I_T = I_R = I_C = I_L$$

$$Z = \sqrt{R^2 + (X_L \approx X_C)^2}$$

$$V_L = I X_L$$

$$V_C = I X_C$$

$$V_T = I Z$$

$$V_T = \sqrt{V_R^2 + (V_L \approx V_C)^2}$$

$$I_T = \frac{V_T}{Z}$$

$$\cos \theta = \frac{R}{Z}$$

$$\cos \theta = \frac{V_R}{V_T}$$

$$Q = \frac{X_L}{R}$$

Parallel

$$V_T = V_R = V_C = V_L$$

$$I_R = \frac{V_R}{R}$$

$$I_C = \frac{V_C}{X_C}$$

$$I_L = \frac{V_L}{X_L}$$

$$I_T = \sqrt{I_R^2 + (I_L \approx I_C)^2}$$

$$\cos \theta = \frac{I_R}{I_T}$$

$$Q = \frac{X_L}{R}$$

THREE-PHASE MOTORS AND STARTERS**Star**

$$V_L = \sqrt{3} V_{PH}$$

$$I_L = I_{PH}$$

Delta

$$I_L = \sqrt{3} I_{PH}$$

$$V_L = V_{PH}$$

Power

$$P = \sqrt{3} V_L I_L \cos \theta$$

$$S = \sqrt{3} V_L I_L$$

$$Q = \sqrt{3} V_L I_L \sin \theta$$

$$\text{Efficiency } (\eta) = \frac{P_{in} - \text{losses}}{P_{in}}$$

Speed

$$n_s = \frac{60 \times f}{p}$$

$$\text{Slip}_{\text{Per Unit}} = \frac{n_s - n_r}{n_s}$$

$$n_r = n_s (1 - S_{\text{Per Unit}})$$

$$\% \text{ slip} = \frac{n_s - n_r}{n_s} \times 100\%$$

OPERATIONAL AMPLIFIERS

$$\text{Gain } A_v = -\frac{V_{out}}{V_{in}} = -\left(\frac{R_f}{R_{in}}\right) \text{ inverting op amp}$$

$$\text{Gain } A_v = \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_{in}} \text{ non - inverting op amp}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \text{ Hartley - oscillator}$$

$$f_{RC} = \frac{1}{2\pi\sqrt{6RC}} \text{ RC - phase - shift oscillator}$$

$$V_{Out} = (V_1 + V_2 + \dots V_N)$$