basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

**NATIONAL
SENIOR CERTIFICATE**

GRADE 12

ELECTRICAL TECHNOLOGY

NOVEMBER 2015

MARKS: 200

TIME: 3 hours

This question paper consists of 13 pages and a 2-page formula sheet.

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 answers 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 attached at the end of this question paper.

9.   Write neatly and legibly.

QUESTION 1: OCCUPATIONAL HEALTH AND SAFETY

1.1   State ONE unsafe act that may lead to an accident in an electrical technology workshop.   (1)

1.2   Define the term *dangerous practices* with reference to workshop practice.   (2)

1.3   Name TWO unsafe conditions that may exist in an electrical workshop.   (2)

1.4   Explain the term *human rights* in the workplace with reference to the protection of a worker.   (2)

1.5   Explain why risk management is important for ensuring safety in a workshop.   (3)
                                                                                       [10]

QUESTION 2: THREE-PHASE AC GENERATION

2.1   Describe the term *active power*.   (2)

2.2   Draw a neatly labelled phasor diagram of the voltages generated by a three-phase AC system. Indicate the direction of rotation.   (5)

2.3   A three-phase star-connected motor has an output power of 50 kW and draws a current from a 380 V/50 Hz supply at a power factor of 0,95 lagging. Assume there are no losses.

        Given:

        P   =   50 kW
        V_l =   380 V
        Cos ϴ   =   0,95 lagging

        Calculate the:

        2.3.1   Line current   (3)

        2.3.2   Apparent power   (3)

2.4   State TWO advantages of power-factor correction in AC systems.   (2)

2.5   State the function of a wattmeter.   (2)

2.6   Two wattmeters that are used to measure the input power are connected to a balanced three-phase circuit and indicate 2 500 W and 500 W respectively. Calculate the total input power.
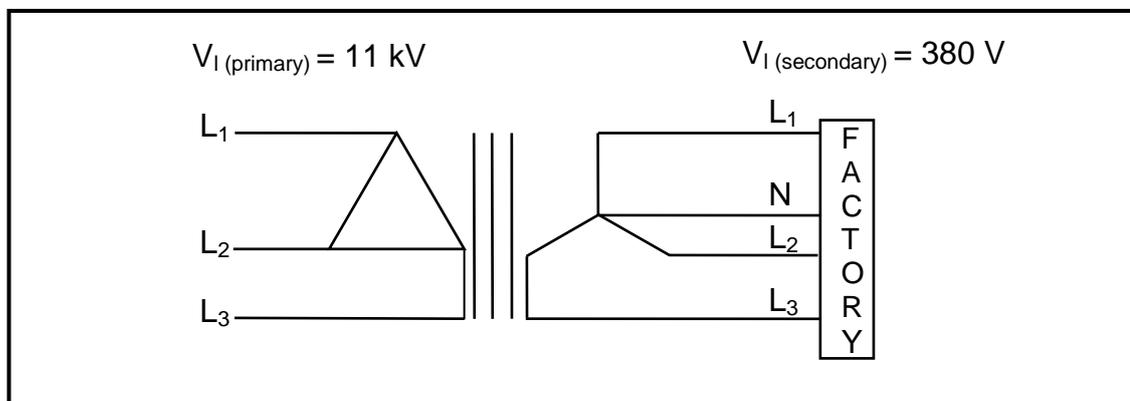
        Given:

        P_1 =   2 500 W
        P_2 =   500 W   (3)
                                                                                       [20]

QUESTION 3: THREE-PHASE TRANSFORMERS

3.1   Name ONE protection device used in transformers.   (1)

3.2   State ONE negative impact of losses in transformers.   (1)

3.3   Name THREE methods of cooling transformers.   (3)

3.4   Describe the effect on the primary current of a transformer if the load
        is increased.   (3)

3.5   The delta-star-connected transformer in FIGURE 3.1 supplies a factory
        with 60 kW. The current lags the voltage by 36,87°. The primary line voltage
        is 11 kV and the secondary line voltage is 380 V.

$V_{l\,(primary)}$ = 11 kV $V_{l\,(secondary)}$ = 380 V

FIGURE 3.1: DELTA-STAR-CONNECTED TRANSFORMER

Given:

P_{out} =   60 kW
Θ   =   36,87° lagging
$V_{l\,(primary)}$ =   11 kV
$V_{l\,(secondary)}$ =   380 V

Calculate the:

3.5.1   Secondary line current   (3)

3.5.2   Primary line current   (3)

3.5.3   Apparent power   (3)

3.5.4   Reactive power   (3)
                                                                                [20]

QUESTION 4: THREE-PHASE MOTORS AND STARTERS

4.1   Name TWO parts of a three-phase squirrel-cage induction motor.   (2)

4.2   State TWO advantages of a three-phase motor when compared to a single-phase motor.   (2)

4.3   Describe why it is important to carry out electrical inspections on a motor after installation and before energising.   (2)
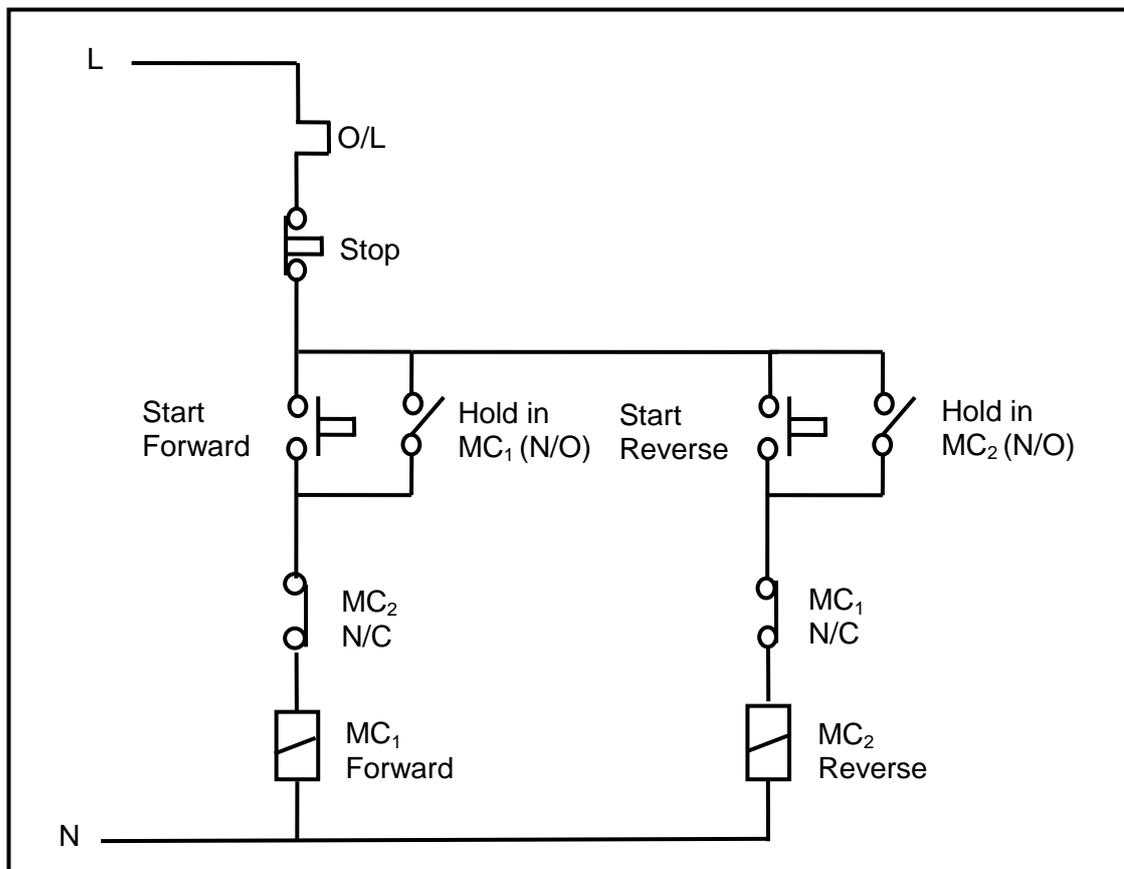
4.4   Refer to the circuit diagram in FIGURE 4.1.

FIGURE 4.1: CONTROL CIRCUIT OF A FORWARD-REVERSE STARTER

        4.4.1   Describe how the contact O/L protects the motor.   (3)

        4.4.2   Describe how interlocking is used in the starter.   (5)

4.5   Describe the function of a star-delta starter.   (3)

4.6   Describe the function of a no-volt coil in a motor starter.   (3)

4.7   State how the direction of rotation of a three-phase motor may be reversed.   (2)

4.8   The name plate on a three-phase motor provides important information about the motor. List THREE types of information it provides.   (3)

4.9   A three-phase motor is connected to a 380 V/50 Hz supply. The motor has six pole pairs and a slip of 4%.

Given:

V_s =   380 V
f   =   50 Hz
S   =   4%
p   =   6

Calculate the:

4.9.1   Synchronous speed   (3)

4.9.2   Rotor speed   (3)

4.10   A three-phase delta-connected motor is connected to a 380 V/50 Hz supply. The motor develops 29,7 kW at full load. It has a power factor of 0,85 and an efficiency of 90%.

Given:

P_{out} =   29,7 kW
V_l =   380 V
Cos Θ   =   0,85
η   =   90%

Calculate the:

4.10.1   Input power   (3)

4.10 2   Input line current   (3)

4.11   Explain what will happen to the current drawn by a motor if the power factor of the motor is improved.   (3)

[40]

QUESTION 5: RLC

5.1 Calculate the capacitive reactance of a 120 µF capacitor when it is connected to a 240 V/50 Hz supply.

Given:

C   =   120 µF
V_s =   240 V
f   =   50 Hz (3)

5.2 Describe why the current in an RLC series circuit is at maximum at resonant frequency. (4)

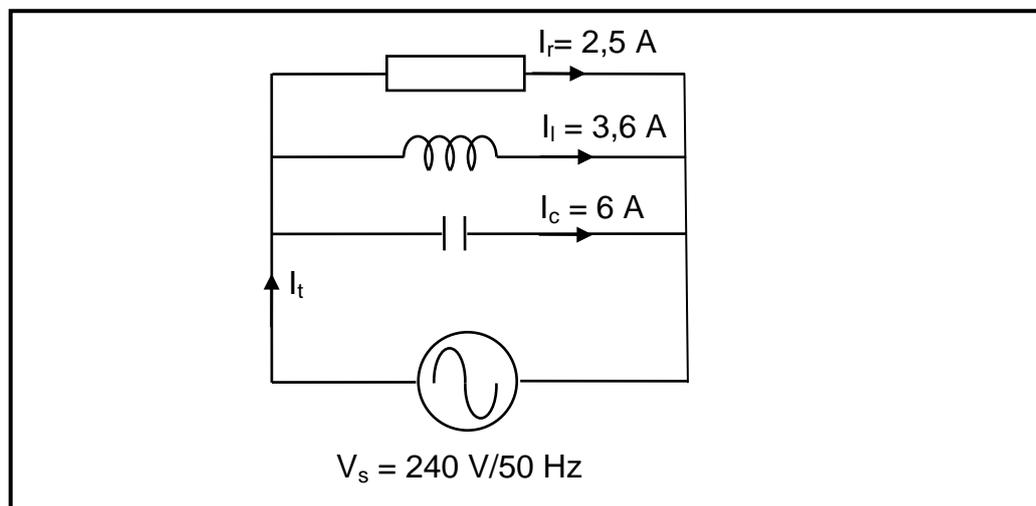5.3 Refer to the circuit diagram in FIGURE 5.1 and answer the questions that follow.

FIGURE 5.1: PARALLEL RLC CIRCUIT

Given:

I_r =   2,5 A
I_l =   3,6 A
I_c =   6 A
V_s =   240 V
f   =   50 Hz

5.3.1 Calculate the total current in the circuit. (3)

5.3.2 Calculate the inductive reactance of the coil. (3)

5.3.3 Describe what will happen to the current through the coil if the frequency of the supply is increased. (3)

5.4 Define the term *Q-factor* with reference to a parallel circuit. (4)

[20]

QUESTION 6: LOGIC

6.1   Study FIGURE 6.1 which shows a typical PLC scan cycle and answer the questions that follow.

```
┌──────────────────────────────────────────────────────┐
│   ┌──────────────────────────────────────────────┐    │
│   │                                              │    │
│   │  ┌──────────┐    ┌──────────┐    ┌──────────┐│    │
│   └─▶│ STEP 1   │───▶│ STEP 2   │───▶│ STEP 3   │┘    │
│      │ Input    │    │ Process  │    │ Output   │     │
│      └──────────┘    └──────────┘    └──────────┘     │
│                                                        │
└──────────────────────────────────────────────────────┘
```
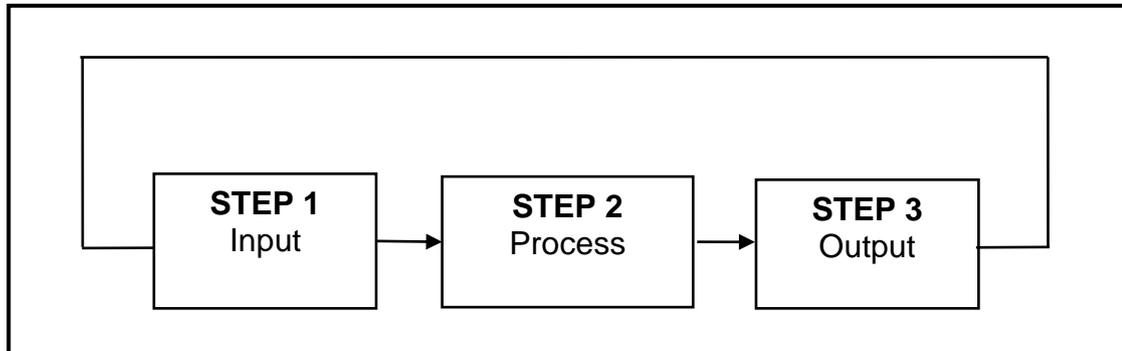
FIGURE 6.1: PLC SCAN CYCLE

6.1.1   Name TWO input devices that may be connected in Step 1.   (2)

6.1.2   List THREE programming languages that may instruct the PLC in Step 2.   (3)

6.1.3   Describe how EACH step in FIGURE 6.1 is used to run a PLC program.   (6)

6.1.4   Explain why heavy-current devices cannot be connected directly to the output of a PLC that uses a transistor output.   (3)

6.1.5   Describe how the problem in QUESTION 6.1.4 is solved in industrial applications.   (3)

6.2   Describe why relay control systems (hard-wired systems) are replaced by PLC control systems.   (2)

6.3   Refer to the following Boolean equation to answer the questions that follow:

$$X = \overline{A}\,\overline{B}\,\overline{C}D + \overline{A}BCD + \overline{A}B\overline{C}D + AB\overline{C}D + A\overline{B}\,\overline{C}D$$

6.3.1   Draw a Karnaugh map and show the grouping.   (9)

6.3.2   Write down the simplified expression that can be extracted from the Karnaugh map.   (3)
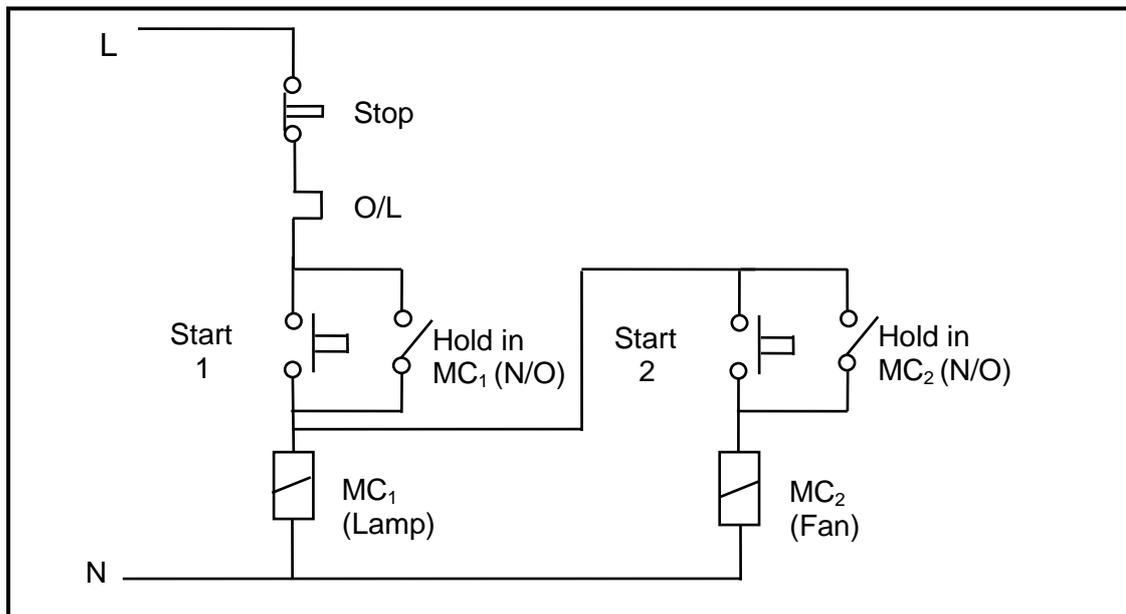
6.4   Refer to the circuit in FIGURE 6.2.

FIGURE 6.2: CONTROL CIRCUIT OF A SEQUENCE STARTER

6.4.1 MC_1 switches on a lamp and MC_2 closes a contactor that energises a fan.

Draw the PLC ladder diagram that would execute the same function of the relay control circuit in FIGURE 6.2.   (8)

6.4.2   State what programming function must be included in the ladder diagram to automate the starting of the fan (MC_2).   (1)

[40]

QUESTION 7: AMPLIFIERS

7.1   List THREE characteristics of an ideal operational amplifier (op amp).   (3)

7.2   Describe the term *bandwidth* in relation to op amps.   (3)

7.3   Give TWO reasons why negative feedback is used in op-amp circuits.   (2)

7.4   Describe the term *positive feedback*.   (3)

7.5   Describe the term *stability* in relation to op amps.   (2)

7.6   Study FIGURE 7.1 and answer the questions that follow.

R_{in} = 5 kΩ
R_f = 15 kΩ
V_{in} = 1,5 V
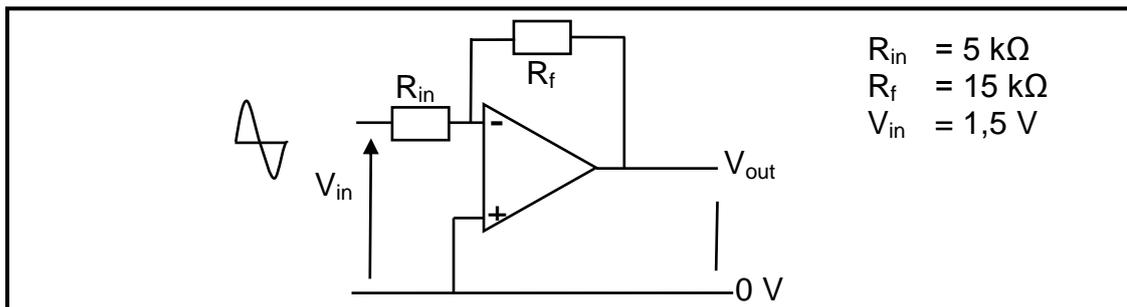
FIGURE 7.1: OP-AMP CIRCUIT

7.6.1   Identify the op-amp circuit in FIGURE 7.1.   (1)

7.6.2   Draw the input and output waveforms on the same y-axis and label
         the waveforms.   (3)

7.6.3   Calculate the voltage gain if the feedback resistor has a value of
         15 kΩ and the input resistor has a value of 5 kΩ.   (3)

7.6.4   Calculate the output voltage if an input signal of 1,5 V is applied to
         the op amp.   (3)

7.7   Study FIGURE 7.2 and answer the questions that follow.
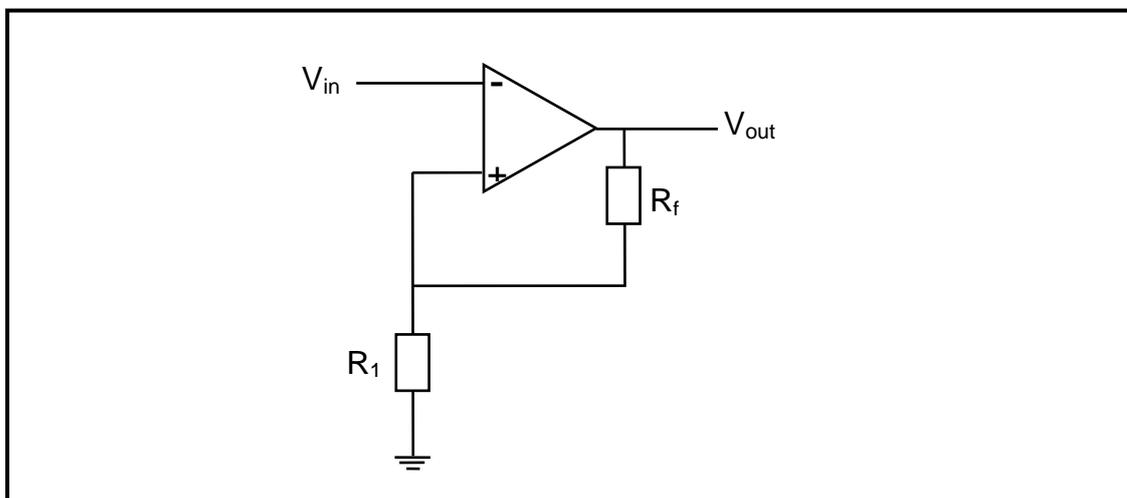
FIGURE 7.2: INVERTING SCHMIDT TRIGGER

7.7.1   State TWO applications of the op-amp circuit in FIGURE 7.2.   (2)

7.7.2 Redraw the input waveform shown in FIGURE 7.3 and directly below it draw the output waveform.
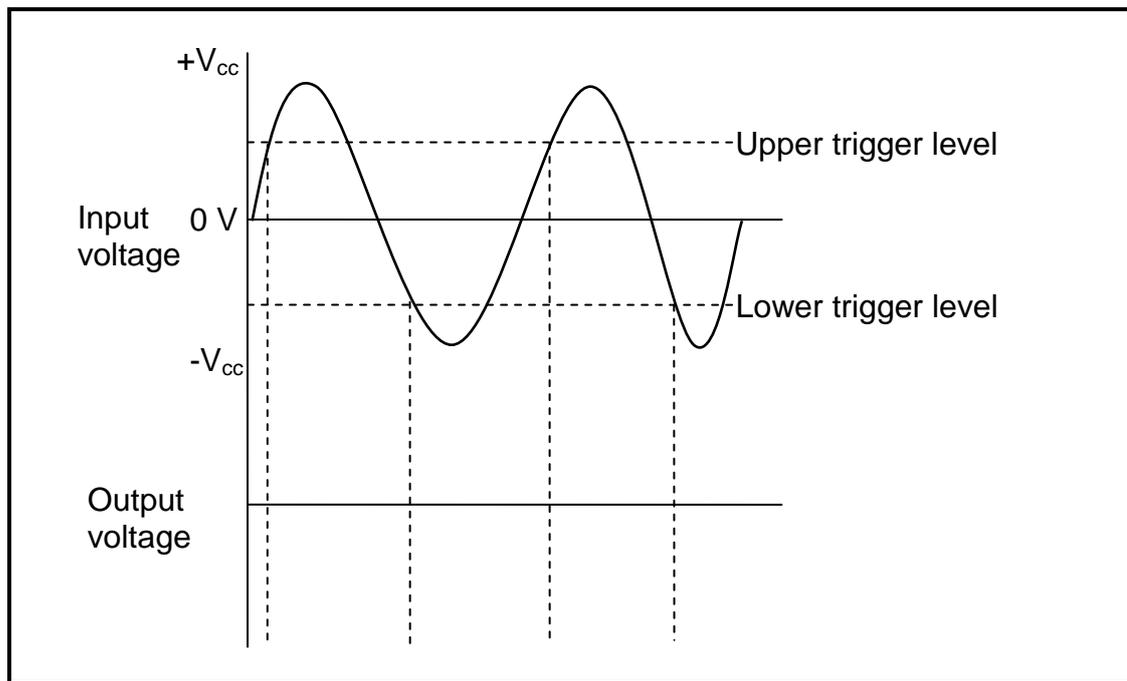
FIGURE 7.3: INPUT WAVEFORM TO AN INVERTING SCHMIDT TRIGGER (6)

7.8 Calculate the resonant frequency of a Hartley oscillator consisting of two coils of 40 mH each and a capacitor of 0,65 µF. The tank circuit of the Hartley oscillator is shown in FIGURE 7.4.
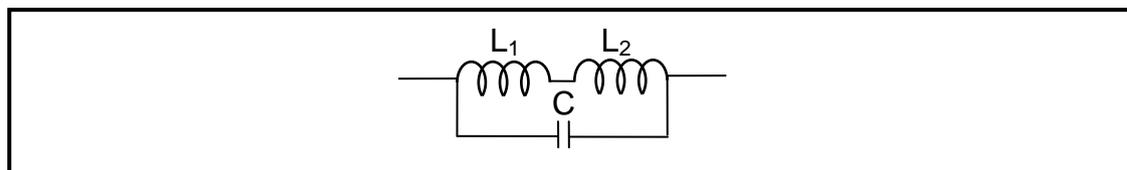

FIGURE 7.4: TANK CIRCUIT OF A HARTLEY OSCILLATOR

Given:

C = 0,65 µF
L_1 = 40 mH
L_2 = 40 mH (3)

7.9 Study FIGURE 7.5 and answer the questions that follow.
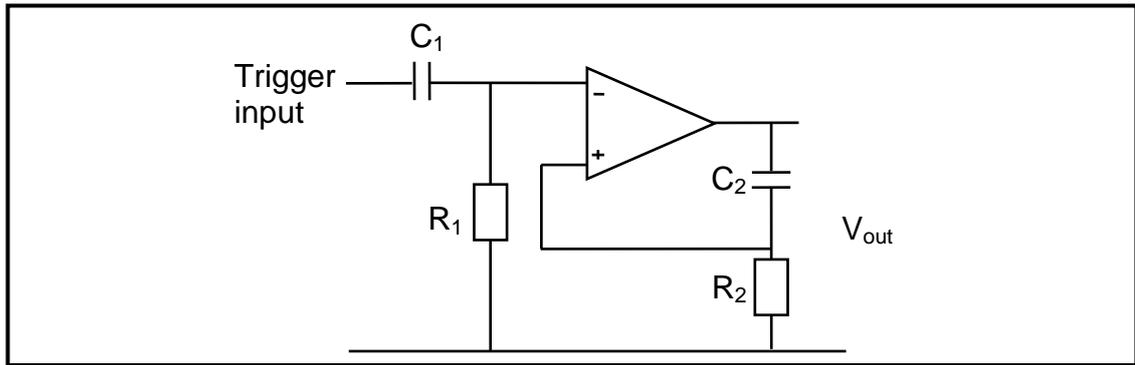
FIGURE 7.5: OP-AMP CIRCUIT

Given:

C_1 = 1 μF
C_2 = 22 nF
R_1 = 1,5 kΩ
R_2 = 550 kΩ

7.9.1 Identify the op-amp circuit in FIGURE 7.5. (1)

7.9.2 State ONE practical application of this type of op amp. (1)

7.9.3 Calculate the time the multivibrator will remain in the set state after it has received a trigger pulse. (3)

7.9.4 Redraw the input waveform shown in FIGURE 7.6 and directly below it draw the output waveform. Show the time calculated in QUESTION 7.9.3 on the output waveform.
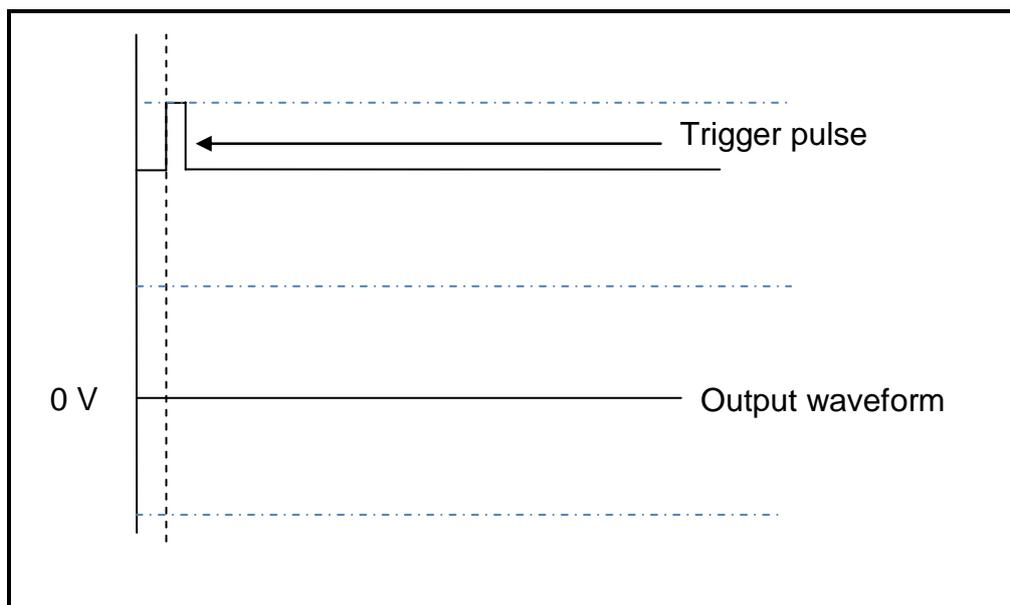

FIGURE 7.6: INPUT TRIGGER PULSE FOR FIGURE 7.5 (5)

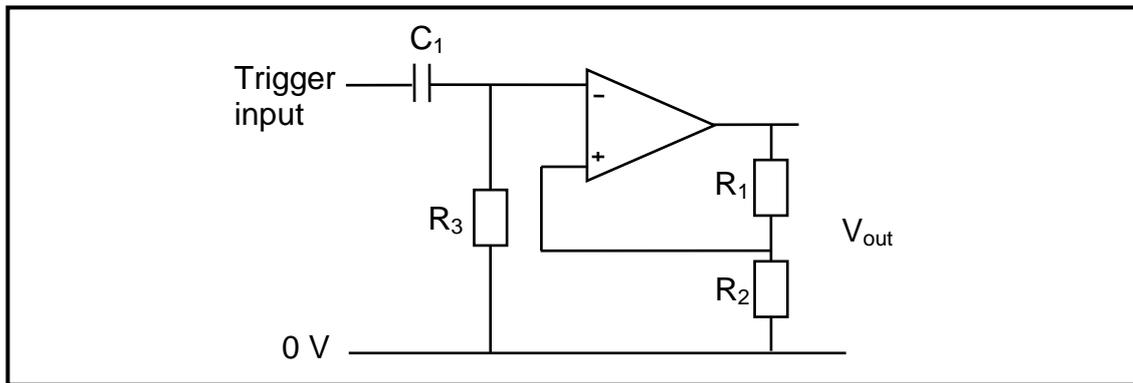7.10 Study FIGURE 7.7 and answer the questions that follow.

FIGURE 7.7: BI-STABLE MULTIVIBRATOR

7.10.1 State ONE application of a bi-stable multivibrator. (1)

7.10.2 If the input trigger pulse is negative, describe what value the output would move to. (2)

7.11 Describe the function of the dual DC supply in op-amp circuits. (3)

[50]

TOTAL: 200

FORMULA SHEET

THREE-PHASE AC GENERATION	RLC CIRCUITS

THREE-PHASE AC GENERATION

Star

$V_l = \sqrt{3}\, V_p$

$I_l = I_p$

Delta

$I_l = \sqrt{3}\, I_p$

$V_l = V_p$

$P = 3V_p I_p \cos\theta$

$P = \sqrt{3} V_l \times I_l \cos\theta$

$S = \sqrt{3}\, V_l\, I_l$

$Q = \sqrt{3}\, V_l\, I_l\, \sin\theta$

$Cos\theta = \dfrac{P}{S}$

$Z_p = \dfrac{V_p}{I_p}$

Two wattmeter method

$P_t = P_1 + P_2$

OPERATIONAL AMPLIFIERS

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

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

$f_r = \dfrac{1}{2\pi\sqrt{L_t C}}$ Hartley oscillator

$f_{rc} = \dfrac{1}{2\pi\sqrt{6}\, RC}$ RC phase-shift oscillator

$V_{out} = (V_1 + V_2 + ... V_n)$

RLC CIRCUITS

$X_l = 2\pi fL$

$X_c = \dfrac{1}{2\pi fC}$

$f_r = \dfrac{1}{2\pi\sqrt{(LC)}}$

Series

$I_t = I_r = I_c = I_l$

$Z = \sqrt{R^2 + (X_l \simeq X_c)^2}$

$V_l = I X_l$

$V_c = I X_c$

$V_t = I Z$

$V_t = \sqrt{V_r{}^2 + (V_l \simeq V_c)^2}$

$I_t = \dfrac{V_t}{Z}$

$Cos\theta = \dfrac{R}{Z}$

$Cos\theta = \dfrac{V_r}{V_t}$

$Q = \dfrac{X_l}{R}$

Parallel

$V_t = V_r = V_c = V_l$

$I_r = \dfrac{V_r}{R}$

$I_c = \dfrac{V_c}{X_c}$

$I_l = \dfrac{V_l}{X_l}$

$I_l = \sqrt{I_r{}^2 + (I_l \simeq I_c)^2}$

$Cos\theta = \dfrac{I_r}{I_t}$

$Q = \dfrac{X_l}{R}$

THREE-PHASE MOTORS AND STARTERS	THREE-PHASE TRANSFORMERS
Star $V_l = \sqrt{3}\, V_p$ $I_l = I_p$	**Star** $V_l = \sqrt{3}\, V_p$ $I_l = I_p$
Delta $I_l = \sqrt{3}\, I_p$ $V_l = V_p$	**Delta** $I_l = \sqrt{3}\, I_p$ $V_l = V_p$
Power $P = 3V_p I_p \cos\theta$ $P = \sqrt{3}\, V_l\, I_l \cos\theta$ $S = \sqrt{3}\, V_l\, I_l$ $Q = \sqrt{3}\, V_l\, I_l \sin\theta$	**Power** $P = 3V_p I_p \cos\theta$ $P = \sqrt{3}\, V_l\, I_l \cos\theta$ $S = \sqrt{3}\, V_l\, I_l$ $Q = \sqrt{3}\, V_l\, I_l \sin\theta$ $\cos\theta = \dfrac{P}{S}$ $\dfrac{V_{p\,(primary)}}{V_{p\,(secondary)}} = \dfrac{N_p}{N_s} = \dfrac{I_{p\,(secondary)}}{I_{p\,(primary)}}$
$\text{Efficiency}\,(\eta) = \dfrac{P_{out}}{P_{in}}$ $P_{out} = P_{ln} - \text{losses}$ $\quad = S \times \cos\theta \times \eta$ $n_s = \dfrac{60 \times f}{p}$ $\text{Slip}_{per\ unit} = \dfrac{n_s - n_r}{n_s}$ $n_r = n_s \left(1 - S_{per\ unit}\right)$ $\%\text{slip} = \dfrac{n_s - n_r}{n_s} \times 100\%$	$\text{Efficiency}\,(\eta) = \dfrac{P_{out}}{P_{in}}$ $P_{out} = P_{in} - \text{losses}$ $\quad = S \times \cos\theta \times \eta$