basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: ELECTRONICS

NOVEMBER 2024

MARKS: 200

TIME: 3 hours

This question paper consists of 23 pages, a 1-page formula sheet and a 5-page answer sheet.

INSTRUCTIONS AND INFORMATION

1. This question paper consists of SIX questions.

2. Answer ALL the questions.

3. Answer the following questions on the attached ANSWER SHEETS:

   QUESTIONS 5.4.4, 5.5.1 and 5.9.2
   QUESTIONS 6.2.4, 6.5.3 and 6.6.3

4. Write your centre number and examination number on every ANSWER SHEET and hand them in with your ANSWER BOOK, whether you have used them or not.

5. Sketches and diagrams must be large, neat and FULLY LABELLED.

6. Show ALL calculations and round off answers correctly to TWO decimal places.

7. Number the answers correctly according to the numbering system used in this question paper.

8. You may use a non-programmable calculator.

9. Calculations must include:

   9.1 Formulae and manipulations where needed

   9.2 Correct replacement of values

   9.3 Correct answer and relevant units where applicable

10. A formula sheet is attached at the end of this question paper.

11. Write neatly and legibly.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question numbers (1.1 to 1.15) in the ANSWER BOOK, e.g. 1.16 D.

1.1 A disastrous event, resulting from the use of plant and machinery, or from activities at a workplace, is known as a/an …

A minor incident.
B major incident.
C accident.
D risk. (1)

1.2 The impedance in a RLC series circuit, is minimum when the …

A inductive reactance equals the capacitive reactance.
B inductive reactance is greater than the capacitive reactance.
C capacitive reactance is greater than the inductive reactance. (1)
D resistance is maximum.

1.3 In a pure capacitive circuit that is connected to an AC supply, the …

A voltage leads the current by 90°.
B current leads the voltage by 90°.
C voltage and current are in phase.
D current leads the voltage by 180°. *(1)*

1.4 The quality factor of an RLC parallel circuit is … to the bandwidth.

A inversely proportional
B directly proportional
C equal
D not related (1)

1.5 One advantage the field-effect transistor (FET) has over the bipolar junction transistor (BJT) is …

A a low input impedance.
B the amplification of large signal voltages at the input stage of amplifiers.
C a high input impedance.
D that it draws a large amount of input current. (1)

1.6 A … is a three-terminal semiconductor device that can operate in the negative resistance region of its characteristic curve.

A Darlington transistor
B unijunction transistor
C bipolar junction transistor
D junction-field effect transistor (1)

1.7 A … is a characteristic of an ideal operational amplifier.

A low input impedance
B low voltage gain
C limited bandwidth
D low output impedance (1)

1.8 The gain of the … operational amplifier will be 2 if the values of the feedback resistor and the input resistor(s) are the same.

A integrator
B non-inverting
C inverting
D summing (1)

1.9 The … multivibrator circuit produces a continuous square wave output without any external trigger.

A monostable
B astable
C bistable
D Schmitt trigger (1)

1.10 The output of a 555 monostable multivibrator circuit … after a trigger pulse is applied.

A remains stable until power is turned off
B switches to the other stable state and remains there indefinitely
C remains in the unstable state for a fixed period before returning to its stable state
D continually changes between $+V_{CC}$ and $-V_{CC}$. (1)

1.11 The primary function of a summing operational amplifier circuit is to …

A amplify only the largest signal of multiple input signals.
B subtract multiple input signals to receive one output signal.
C add multiple input signals to receive one output signal.
D compare multiple input signals to receive one output signal. (1)

1.12 The output voltage of an integrator operational amplifier … when a constant long and large input voltage is applied.

A is constant
B increases linearly
C decreases linearly
D oscillates between positive and negative values (1)

1.13 The primary purpose of the coupling capacitors in an RC coupled amplifier is to …

A provide DC to pass through.
B block DC and allow AC signals to pass.
C increase voltage.
D allow DC signals to pass and to block AC signals. (1)

1.14 The disadvantage of a push-pull amplifier is …

A frequency distortion.
B amplitude distortion.
C phase distortion.
D cross-over distortion. (1)

1.15 The transistor in a class C amplifier conducts for … of the input cycle.

A more than 180°
B more than 180° but less than 360°
C less than 180°
D more than 360° (1)
[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 Define the term *workplace* with reference to the Occupational Health and Safety Act, 1993 (Act 85 of 1993). (2)

2.2 Name TWO human rights in the workplace. (2)

2.3 Explain why poor ventilation is an unsafe condition in a workshop. (2)

2.4 State TWO types of victimisation by an employer that are forbidden. (2)

2.5 Explain why a person should not interfere with equipment in the workshop that is provided for safety. (2)
[10]

QUESTION 3: RLC CIRCUITS

3.1 Explain the following terms with reference to RLC circuits:

3.1.1 Inductive reactance (2)

3.1.2 Bandwidth (2)

3.2 FIGURE 3.2 below shows an RLC series circuit with a variable frequency supply. Answer the questions that follow.

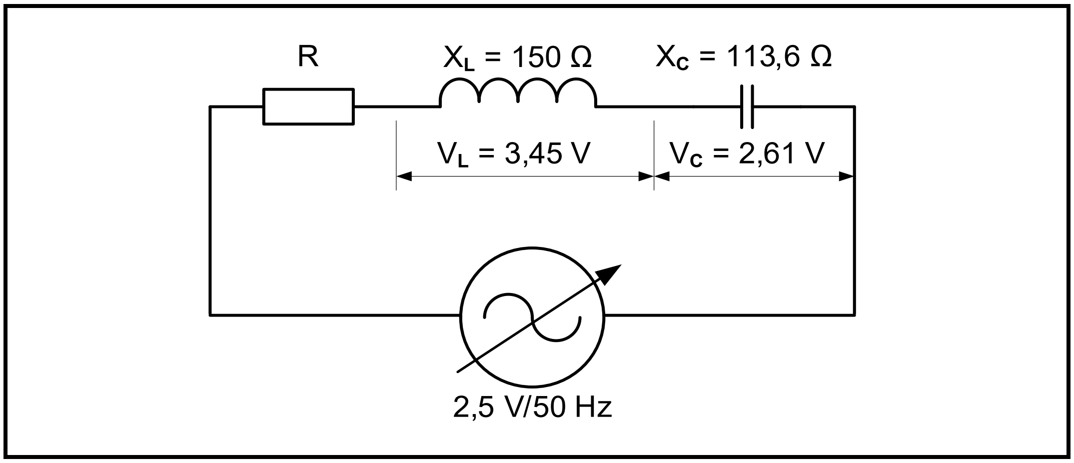

FIGURE 3.2: RLC SERIES CIRCUIT

Given:

X_L = 150 Ω
X_C = 113,6 Ω
V_T = 2,5 V
V_L = 3,45 V
V_C = 2,61 V

3.2.1 State whether the circuit represented in FIGURE 3.2 has a leading or a lagging power factor. (1)

3.2.2 Calculate the current through the inductor. (3)

3.2.3 Calculate the value of the inductor. (3)

3.2.4 Calculate the value of resistor R if the impedance Z = 106,42 Ω. (3)

3.2.5 Complete the phasor diagram in FIGURE 3.2.5 below in your ANSWER BOOK.

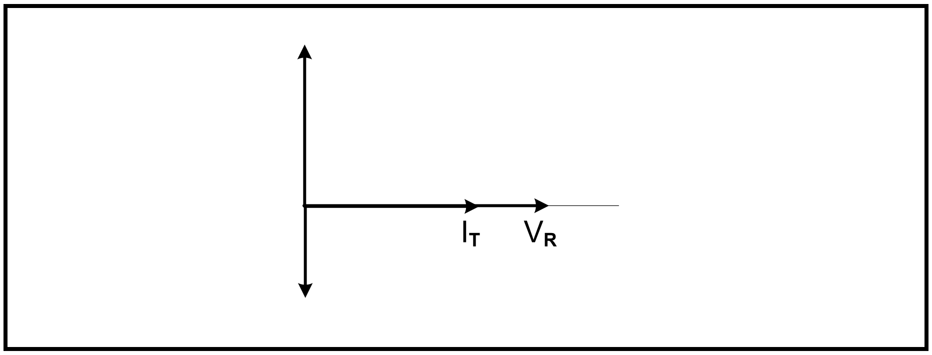

FIGURE 3.2.5: PHASOR DIAGRAM (4)

3.2.6 After decreasing the frequency, the current increased slightly. Explain why this happened. (3)

3.3 FIGURE 3.3 below shows an RLC parallel circuit and its impedance vs frequency response curve. Answer the questions that follow.

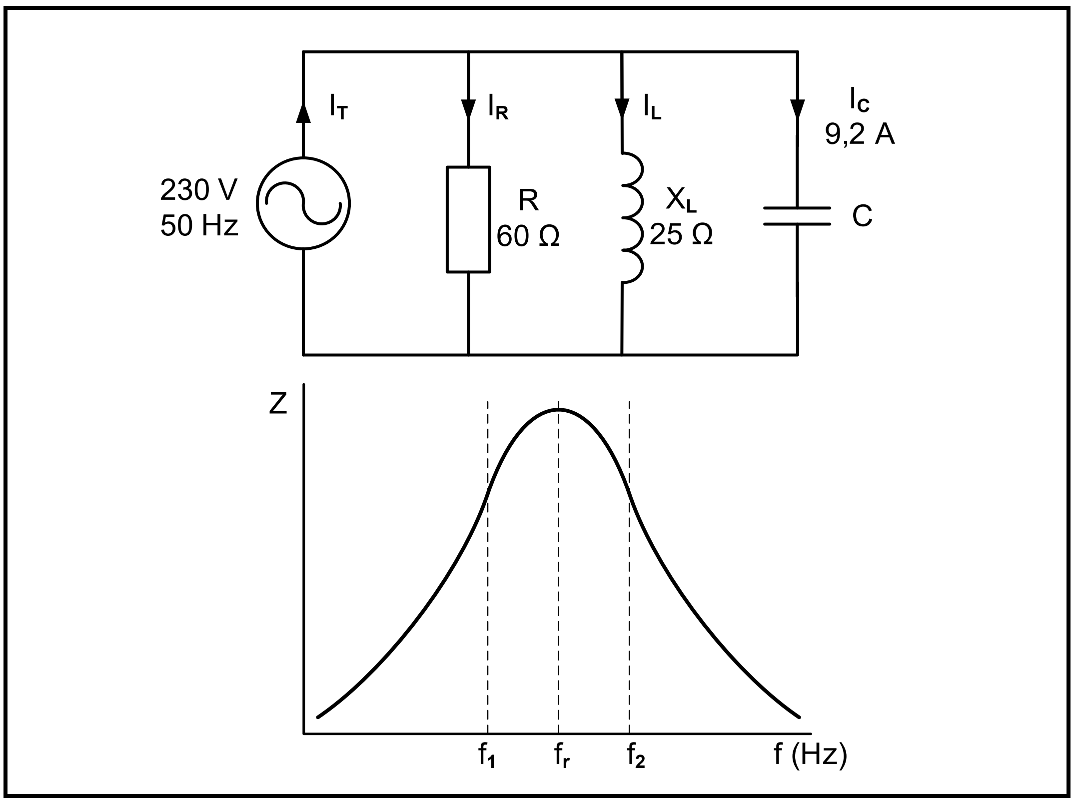

FIGURE 3.3: RLC PARALLEL CIRCUIT AND FREQUENCY RESPONSE CURVE

Given:

V_T = 230 V
I_C = 9,2 A
R = 60 Ω
X_L = 25 Ω
f = 50 Hz

3.3.1 Calculate the current through the resistor. (3)

3.3.2 Calculate the capacitive reactance. (3)

3.3.3 Determine the total current. Give a reason for your answer. (2)

3.3.4 Calculate the Q-factor of the circuit. (3)

3.3.5 Calculate the bandwidth of the circuit. (3)
[35]

QUESTION 4: SEMICONDUCTOR DEVICES

4.1 Identify the MOSFET represented by the symbol in FIGURE 4.1 below.

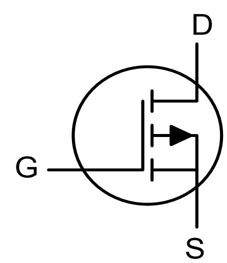

FIGURE 4.1: MOSFET (2)

4.2 Refer to FIGURE 4.2 below and answer the questions that follow.

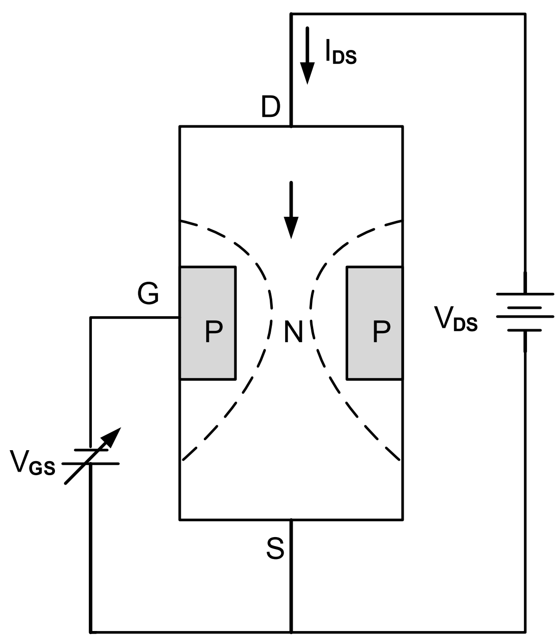

FIGURE 4.2: CONSTRUCTION OF A JFET

4.2.1 Describe how the pinching state is reached in FIGURE 4.2 above. (3)

4.2.2 Explain why the junction field-effect transistor (JFET) has a high input resistance compared to the bipolar junction transistor (BJT). (3)

4.3 Refer to FIGURE 4.3 below and answer the questions that follow.

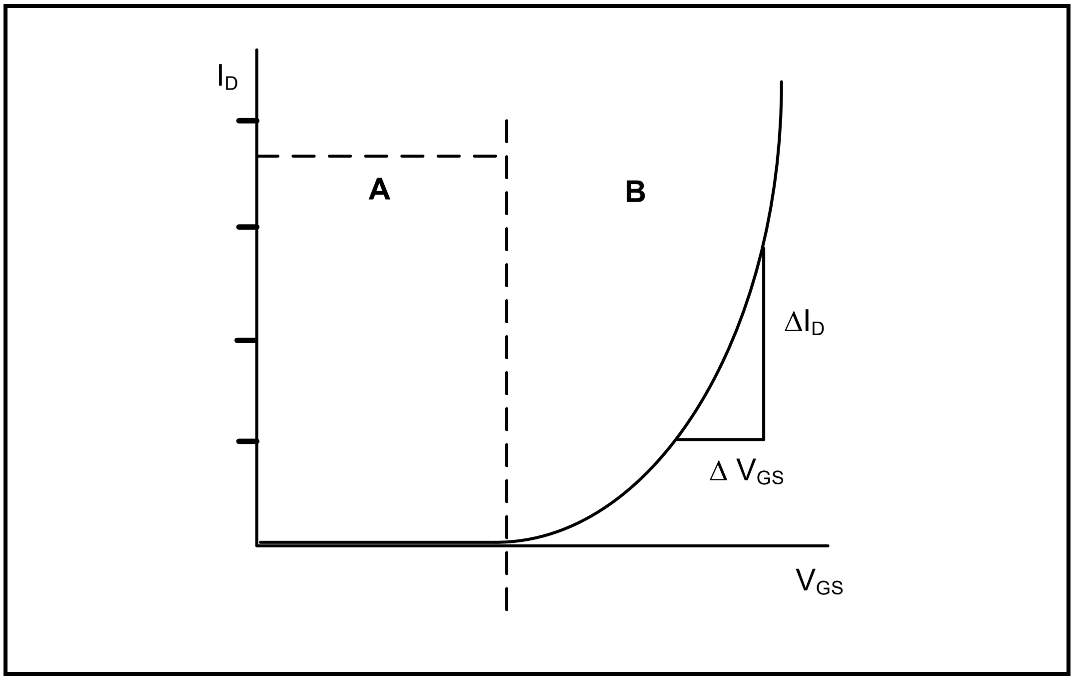

FIGURE 4.3: MOSFET CHARACTERISTIC CURVE

4.3.1 Identify the MOSFET characteristic curve in FIGURE 4.3 above. (1)

4.3.2 Label the regions at **A** and **B**. (2)

4.3.3 Briefly describe the relationship between the gate-source voltage (V_{GS}) and the drain current (I_D), with reference to the characteristic curve. (4)

4.3.4 State TWO applications of a metal-oxide-semiconductor field-effect transistor (MOSFET). (2)

4.4 State the difference between the *junction field-effect transistor (JFET)* and the *metal-oxide-semiconductor field-effect transistor (MOSFET),* with reference to their modes of operation. (1)

4.5 FIGURE 4.5 below shows the circuit diagram of a UJT as a saw-tooth generator. Answer the questions that follow.

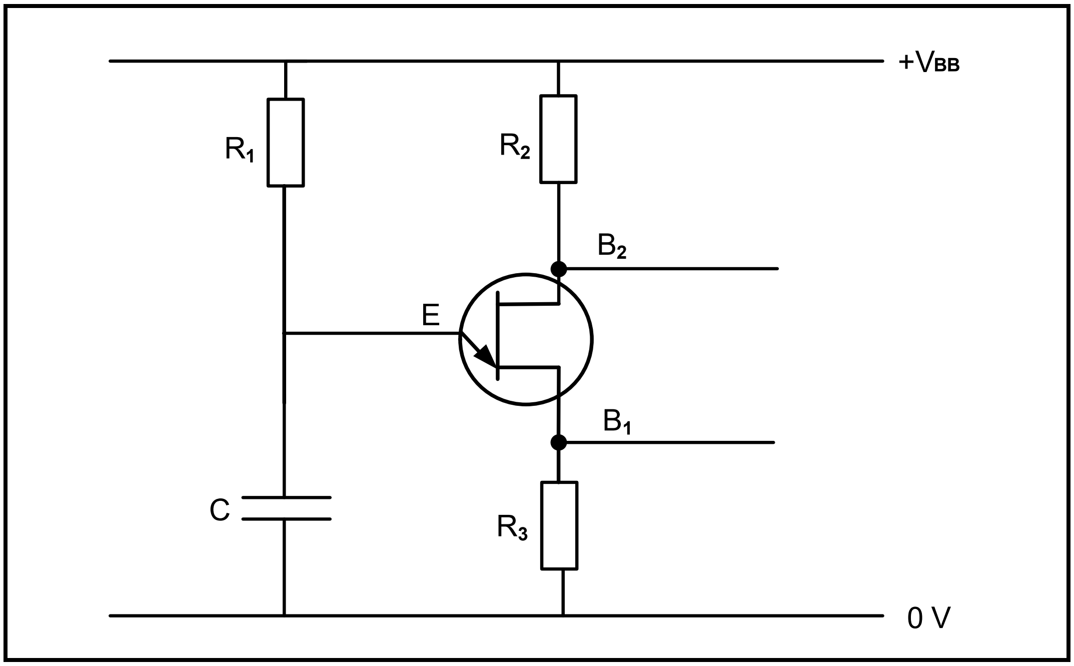

FIGURE 4.5: UJT AS A SAW-TOOTH GENERATOR

4.5.1 Name the polarity of the pulse that would be produced across B_1. (1)

4.5.2 Briefly describe how the UJT reaches the valley point during its operation. (2)

4.5.3 State the difference between a *unijunction transistor (UJT)* and a *bipolar junction transistor (BJT)*, with reference to the following:

(a) Construction (2)

(b) Amplification (2)

4.6 Refer to FIGURE 4.6 below and answer the questions that follow.

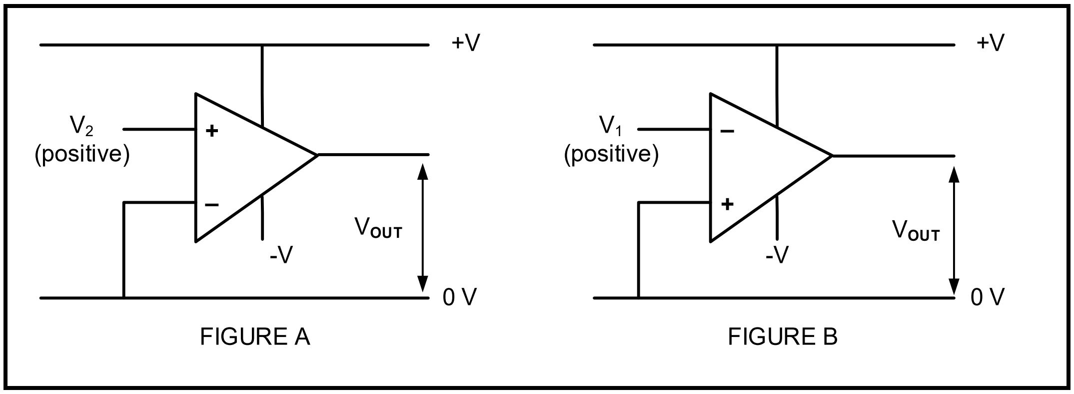

FIGURE 4.6: OPERATIONAL AMPLIFIERS

4.6.1 Determine the state of the output voltages in FIGURE A and FIGURE B. (2)

4.6.2 State TWO advantages of an operational amplifier. (2)

4.6.3 Explain the term *common mode rejection ratio* with reference to operational amplifier characteristics. (1)

4.7 FIGURE 4.7 below is an operational amplifier with an input signal voltage of 2 mV, a feedback resistor R_F = 4,7 kΩ, non-inverting resistor R_1 = 22 kΩ and input resistor R_{IN} = 470 Ω. Answer the questions that follow.

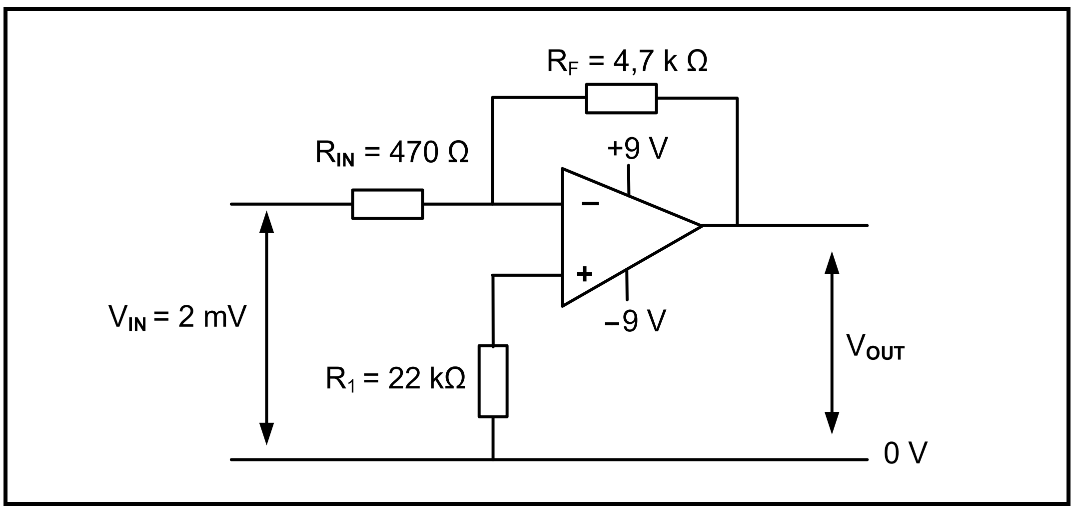

FIGURE 4.7: OPERATIONAL AMPLIFIER

Given:

V_{IN} = 2 mV
R_{IN} = 470 Ω
R_F = 4,7 kΩ
R_1 = 22 kΩ

4.7.1 Name the type of feedback used in FIGURE 4.7 (1)

4.7.2 Calculate the gain. (3)

4.7.3 Calculate the output voltage. (3)

4.7.4 Explain why operational amplifiers require dual power supplies to operate. (2)

4.8 FIGURE 4.8 below shows the internal circuit diagram of a 555 IC. Answer the questions that follow.

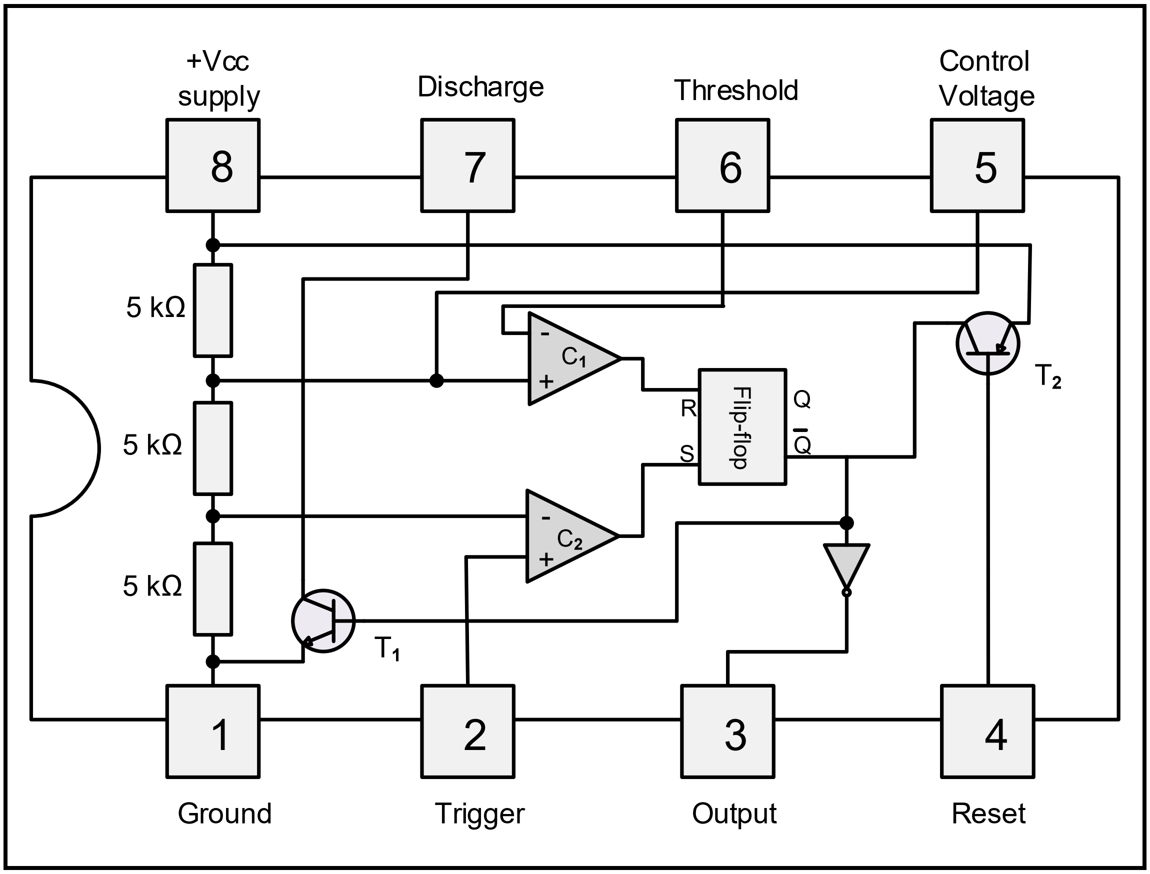

FIGURE 4.8: INTERNAL LAYOUT OF A 555 IC

4.8.1 State ONE industrial application where the 555 IC is used as a timing device. (1)

4.8.2 Explain how the NPN transistor (T_1) can be turned ON when the 555 IC is connected in a circuit. (1)

4.8.3 State the condition of the comparator's output voltage when the inverting terminal voltage is higher than the non-inverting terminal. (1)

4.8.4 State the function of the three 5 kΩ resistors. (1)

4.8.5 Briefly describe what happens when the voltage at Pin 2 falls below ⅓ of the supply voltage. (2)

[45]

QUESTION 5: SWITCHING CIRCUITS

5.1 Explain the concept *negative feedback* with reference to operational amplifiers. (2)

5.2 Name the switching circuit described by EACH of the following statements:

5.2.1 In digital circuits and radio receivers it is used to recover signals that have been polluted by noise. (1)

5.2.2 The output 'remembers' the last input and therefore this circuit is often used as a memory element. (1)

5.2.3 A circuit using a 741 IC receives an input pulse, the output swings to $-V_{CC}$ momentarily and then swings back to its original $+V_{CC}$ output state. (1)

5.3 FIGURE 5.3 below shows the circuit diagram of a 555 IC used as a bistable multivibrator. Answer the questions that follow.

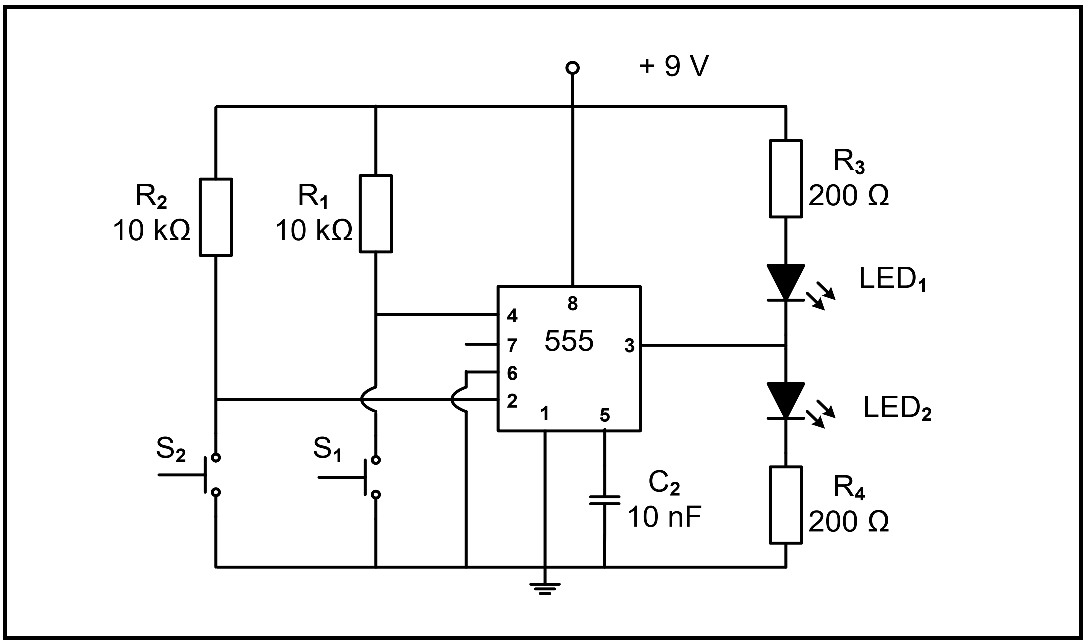

FIGURE 5.3: 555 BISTABLE MULTIVIBRATOR

5.3.1 State the purpose of resistor R_2. (1)

5.3.2 Explain the operation of the circuit when S_2 is pressed. Refer to the inputs and the states of LED_1 and LED_2 in your response. (4)

5.3.3 Explain how the circuit is reset. (2)

5.4 FIGURE 5.4 below shows a monostable multivibrator circuit using a 741 op amp. Answer the questions that follow.

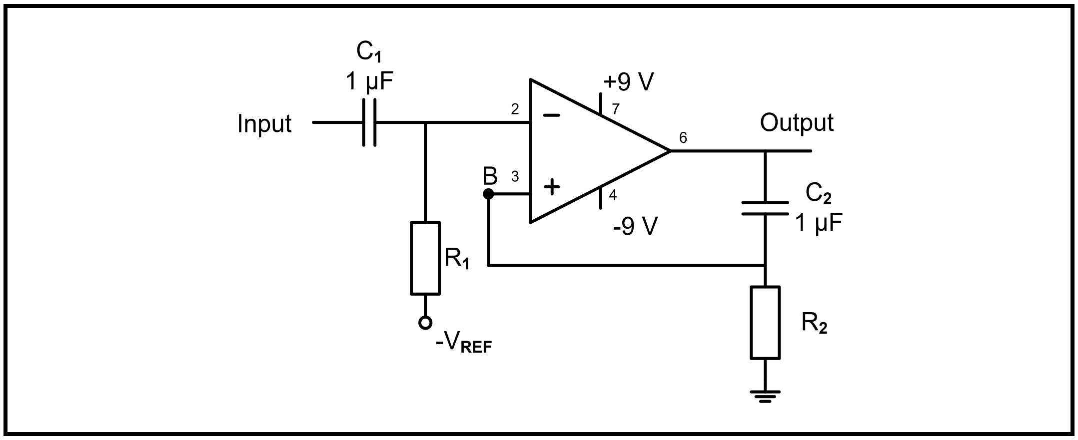

FIGURE 5.4: MONOSTABLE MULTIVIBRATOR

5.4.1 State the voltage at B during the circuit's resting condition. (1)

5.4.2 Explain the purpose of having a negative reference voltage ($-V_{REF}$) in the circuit during its natural resting condition. (2)

5.4.3 Explain the operation of the circuit when a positive trigger input, greater than V_{REF}, is applied to the inverting input. (3)

5.4.4 Draw the output for the circuit on the ANSWER SHEET for QUESTION 5.4.4 if R_2 and C_2 are chosen to create a changed (unstable) state for 3 seconds. (4)

5.5 An astable multivibrator circuit can be constructed by using a 555 IC or a 741 op amp. Answer the questions that follow.

5.5.1 Complete the circuit diagram in FIGURE 5.5.1 on the ANSWER SHEET for QUESTION 5.5.1 to make an astable multivibrator.

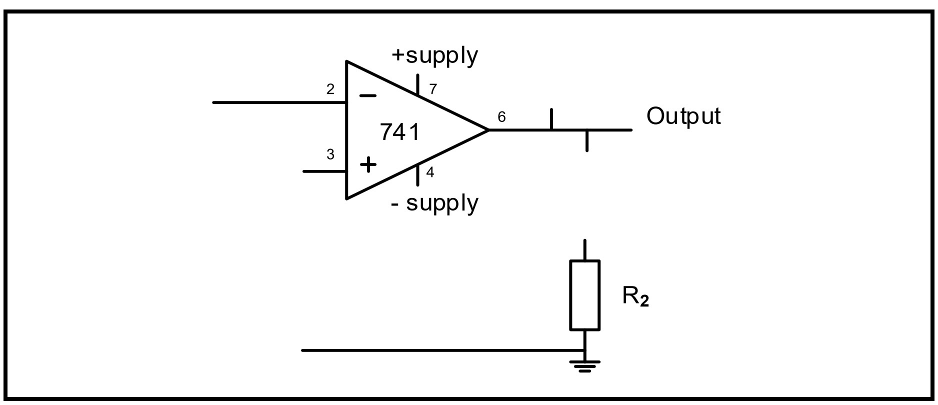

FIGURE 5.5.1: INCOMPLETE CIRCUIT DIAGRAM OF AN ASTABLE MULTIVIBRATOR (4)

5.5.2 Differentiate between the output voltages of an astable multivibrator circuit using a 741 op amp and an astable multivibrator circuit using a 555 IC. (2)

5.6 FIGURE 5.6 below shows a 741 op amp comparator circuit. Answer the questions that follow.

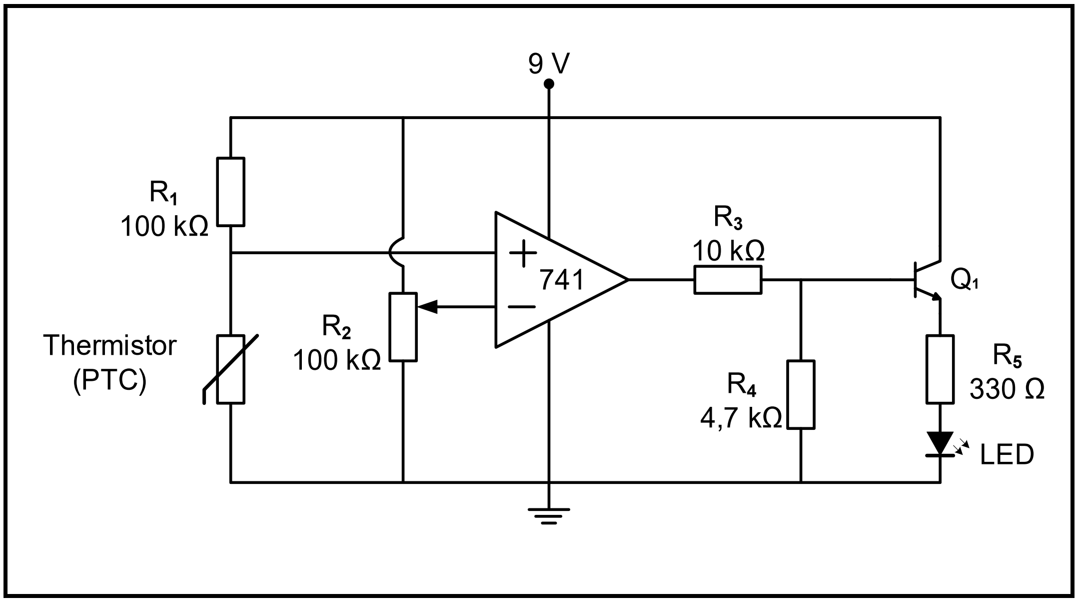

FIGURE 5.6: COMPARATOR AS A TEMPERATURE SENSOR

5.6.1 Name the component that sets the reference voltage in the circuit. (1)

5.6.2 Name TWO components that make up the sensing unit. (2)

5.6.3 Explain how the temperature setting can be changed in the comparator. (2)

5.7 State TWO applications of a Schmitt trigger. (2)

5.8 FIGURE 5.8 below shows the circuit diagram of an inverting summing amplifier. Answer the questions that follow.

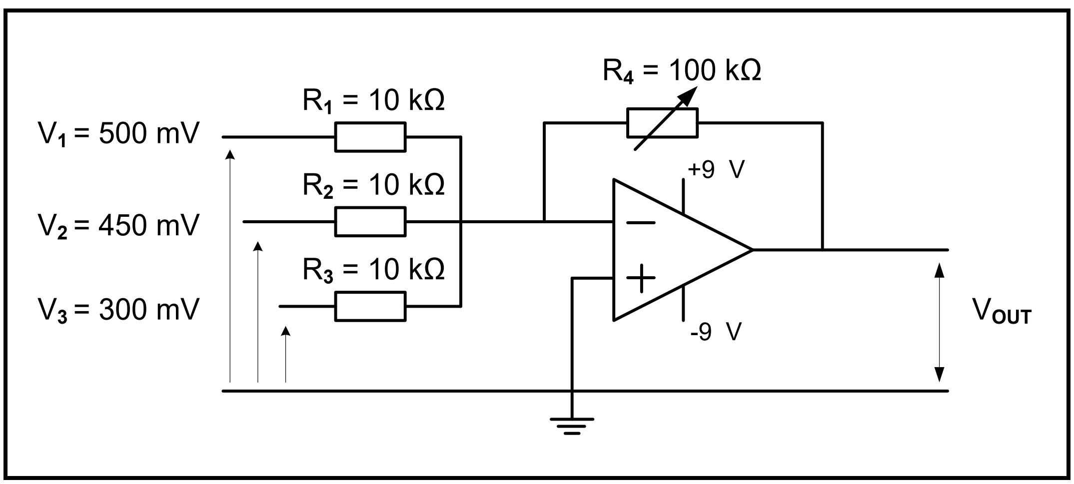

FIGURE 5.8 SUMMING AMPLIFIER

Given:

$R_1 = R_2 = R_3 = 10\ k\Omega$
R_4 = 100 kΩ (variable)
V_1 = 500 mV
V_2 = 450 mV
V_3 = 300 mV

5.8.1 Explain the purpose of variable resistor R_4 in the circuit. (2)

5.8.2 Calculate the output voltage if R_4 is set to 72 kΩ (3)

5.8.3 State why the output voltage can be calculated by the formula $V_{OUT} = -(V_1 + V_2 + V_3)$ when R_4 is set to 10 kΩ. (1)

5.8.4 Explain the effect on the circuit and its output if the value of R_4 is increased beyond 72 kΩ. (2)

5.9 FIGURE 5.9 below shows the input and output waveforms for a short time constant in a passive RC differentiator circuit. Answer the questions that follow.

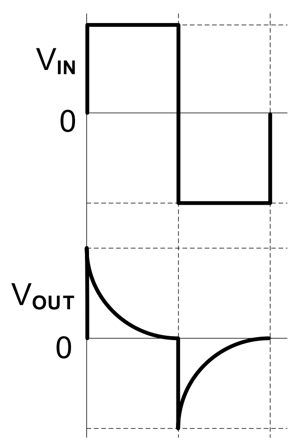

FIGURE 5.9: PASSIVE RC DIFFERENTIATOR WAVEFORMS

5.9.1 Explain the primary function of a passive differentiator circuit. (2)

5.9.2 Draw, on the ANSWER SHEET for QUESTION 5.9.2, the output waveform for a long time constant of the circuit for ONE full cycle. (3)

5.10 Differentiate between an *op amp differentiator* and an *op amp integrator* with reference to circuit configuration. (2)
[50]

QUESTION 6: AMPLIFIERS

6.1 Describe the term *attenuation* with reference to amplifiers. (2)

6.2 FIGURE 6.2 below shows a transistor amplifier biased with resistor R_C = 800 Ω and a supply voltage V_{CC} = 12 V. Answer the questions that follow.

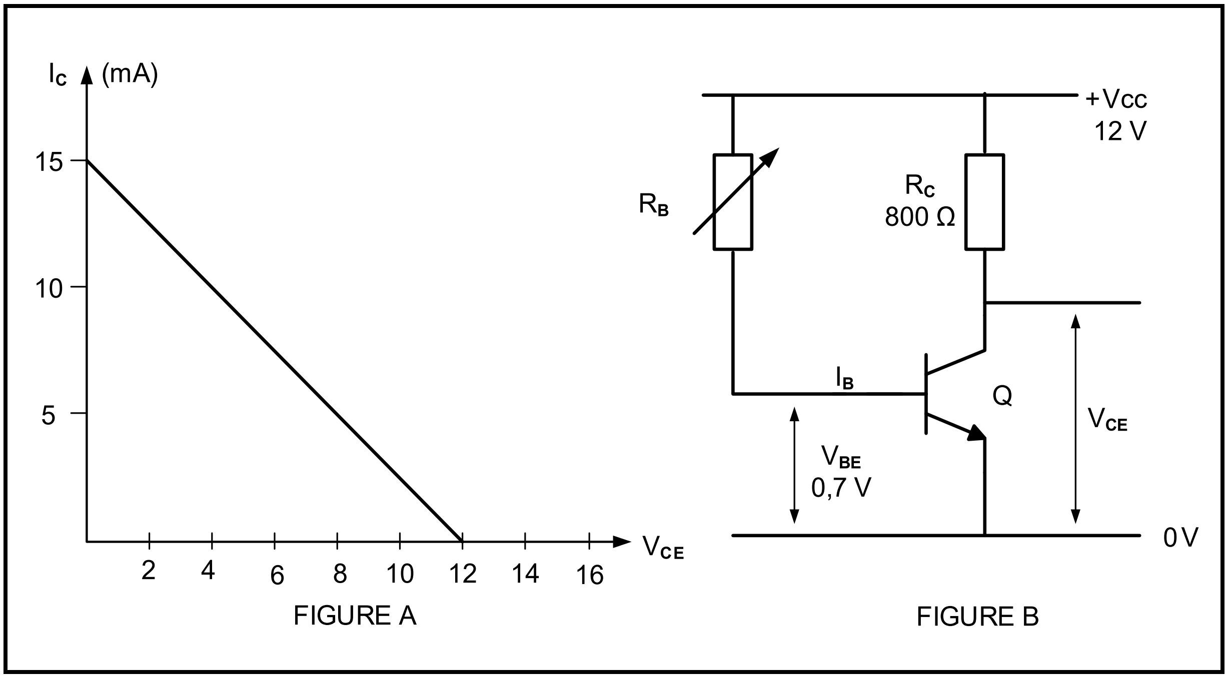

FIGURE 6.2: DC LOAD LINE AND TRANSISTOR BIASING

6.2.1 Briefly explain the purpose of the DC load line, as drawn in FIGURE A above. (1)

6.2.2 Determine the value of V_{CE} when the base current (I_B) is equal to zero. (1)

6.2.3 Determine the quiescent point voltage for a class A amplification. Give a reason for your answer. (2)

6.2.4 Indicate the quiescent point of QUESTION 6.2.3 on the ANSWER SHEET for QUESTION 6.2.4. (2)

6.3 Refer to FIGURE 6.3 below and answer the questions that follow.

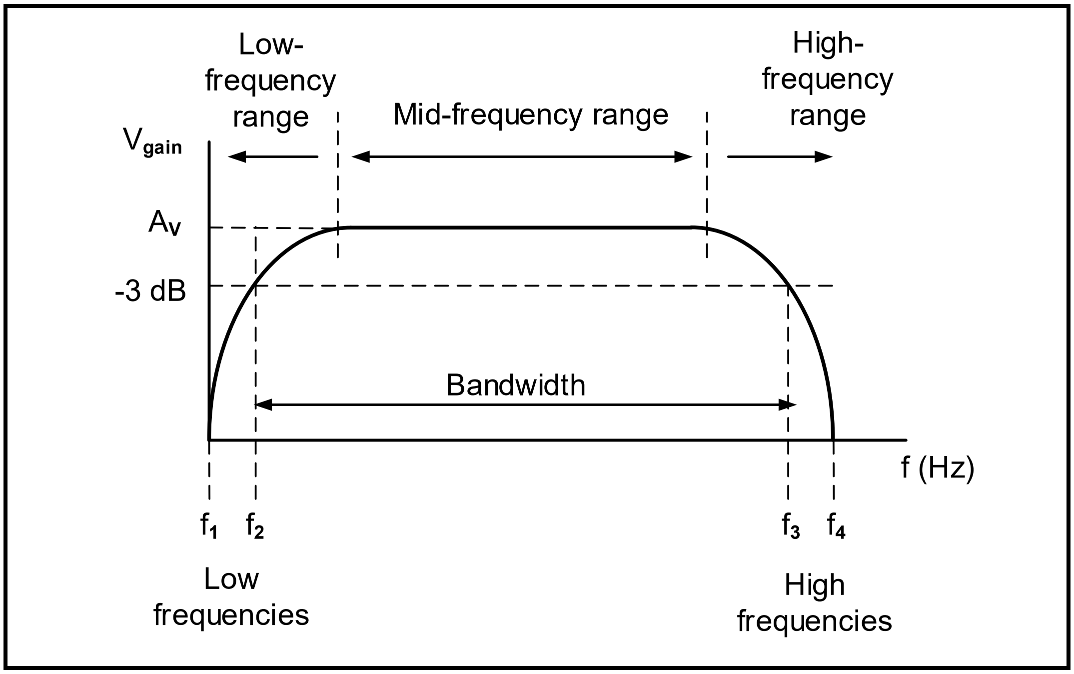

FIGURE 6.3: FREQUENCY RESPONSE CURVE

6.3.1 Identify the amplifier circuit from which the frequency response curve in FIGURE 6.3 is derived. (1)

6.3.2 Explain the term *roll-off* at the high-frequency range of an amplifier. (1)

6.3.3 With reference to the frequency response curve above, explain why the gain falls at:

(a) High frequencies (2)

(b) Low frequencies (2)

6.4 FIGURE 6.4 below shows an amplifier circuit diagram. Answer the questions that follow.

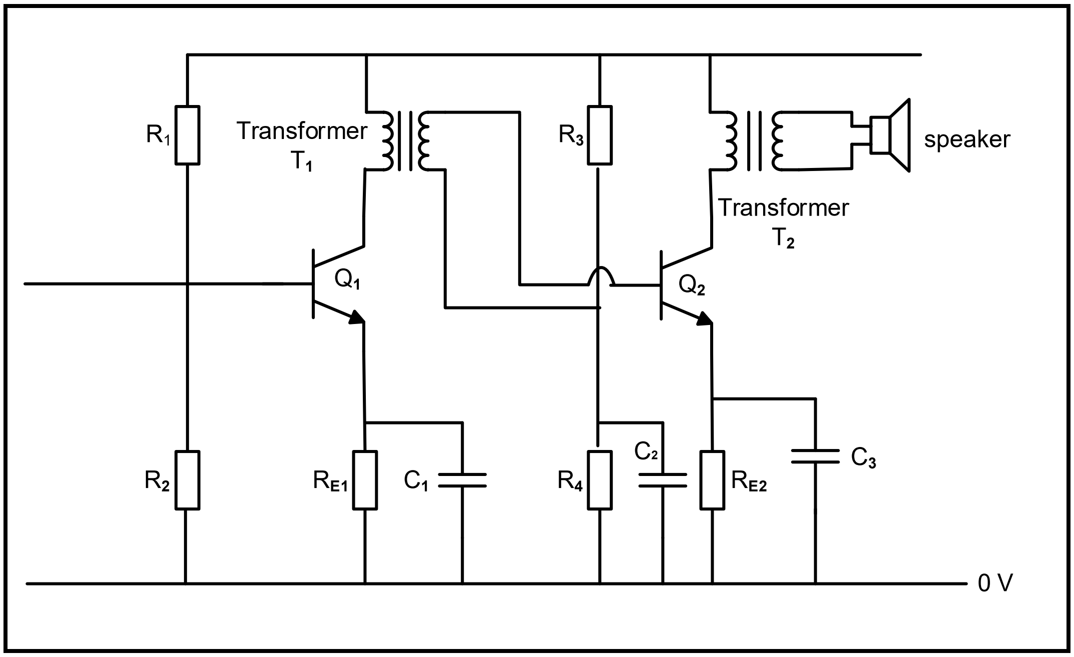

FIGURE 6.4: AMPLIFIER CIRCUIT DIAGRAM

6.4.1 Identify the amplifier in FIGURE 6.4 above. (1)

6.4.2 Name TWO devices that might be connected to the secondary terminals of transformer T_2, apart from the loudspeaker. (2)

6.4.3 State the function of transformer T_1 in the circuit. (1)

6.4.4 Describe what would happen if a 16 Ω, 10 W loudspeaker is connected to the output of a 8 Ω, 10 W transformer (T_2) in FIGURE 6.4 above. (3)

6.5 FIGURE 6.5 below shows a push-pull amplifier connected to a speaker. Answer the questions that follow.

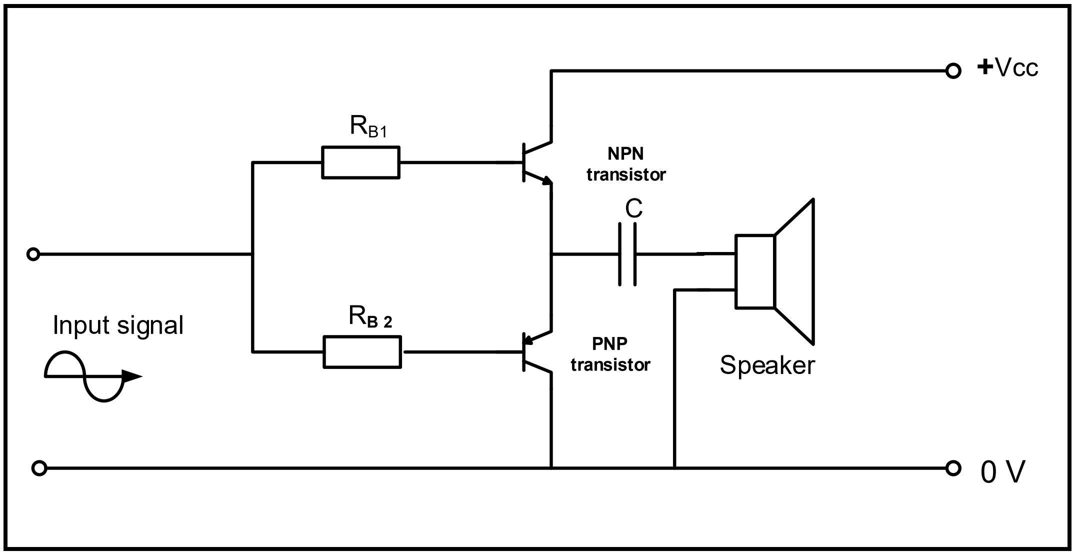

FIGURE 6.5: PUSH-PULL AMPLIFIER

6.5.1 Identify the type of the push-pull amplifier circuit in FIGURE 6.5 above. (1)

6.5.2 Explain the function of capacitor C in the circuit. (2)

6.5.3 Draw, on the ANSWER SHEET for QUESTION 6.5.3, the output waveform that would appear across the PNP transistor. (3)

6.6 Refer to FIGURE 6.6 below and answer the questions that follow.

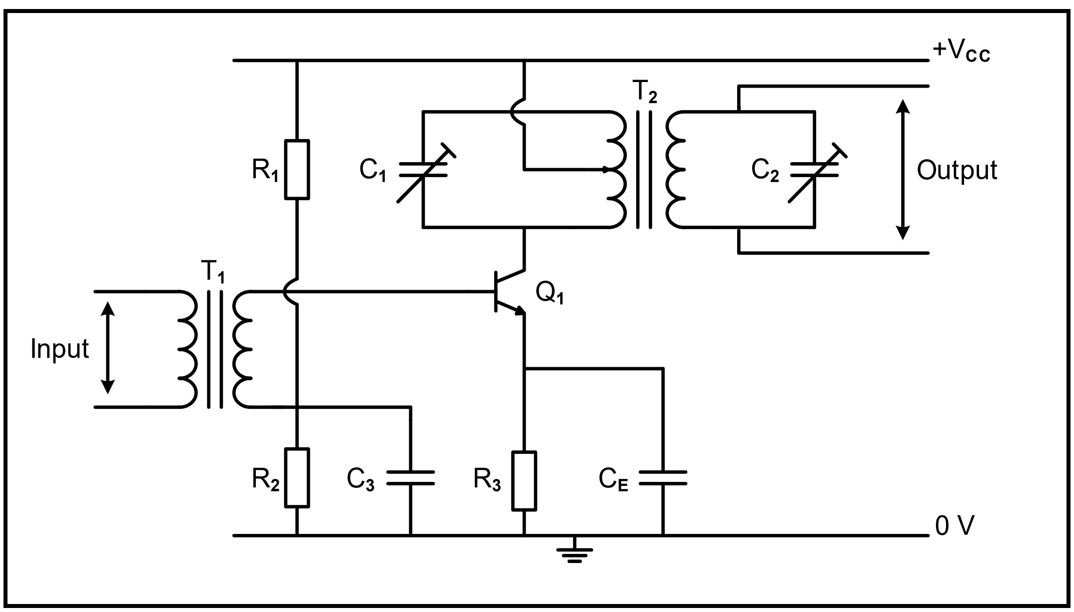

FIGURE 6.6: RADIO-FREQUENCY AMPLIFIER

6.6.1 State the purpose of transistor Q_1 in FIGURE 6.6. (1)

6.6.2 Describe how the radio-frequency amplifier circuit can be tuned to amplify different frequencies. (2)

6.6.3 Draw a fully labelled frequency response curve of the radio-frequency amplifier on the ANSWER SHEET for QUESTION 6.6.3. (4)

6.7 Refer to FIGURE 6.7 below and answer the questions that follow.

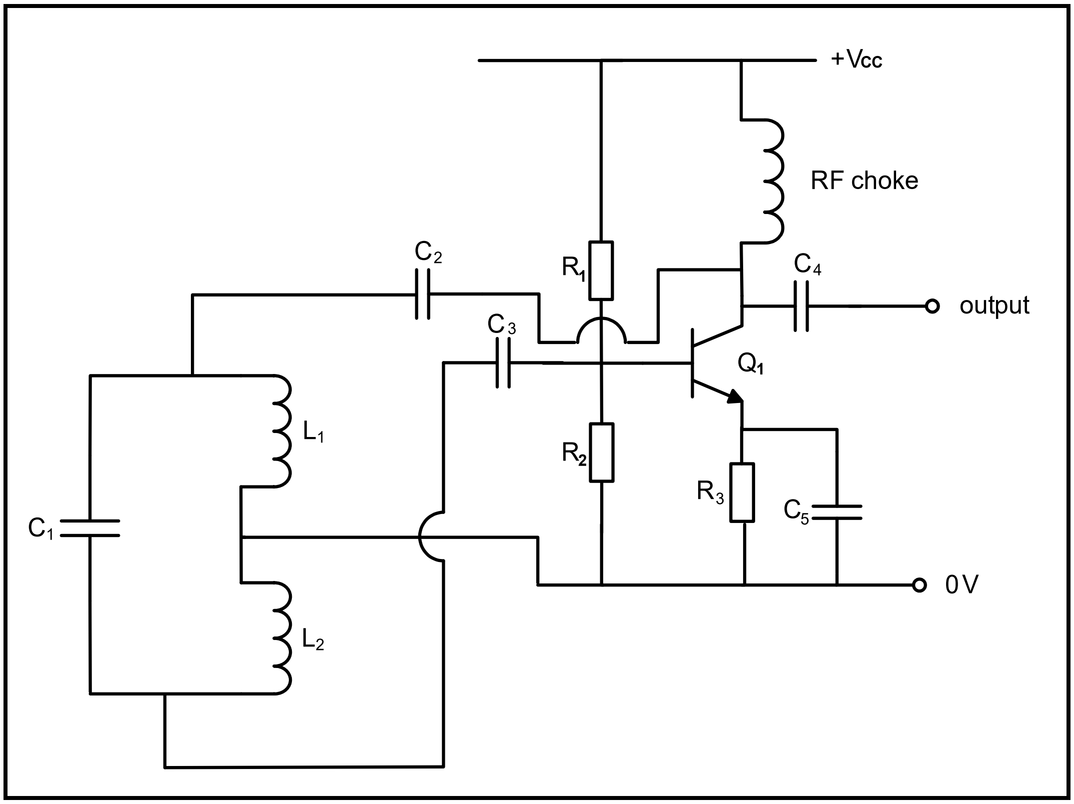

FIGURE 6.7: HARTLEY OSCILLATOR

6.7.1 Briefly discuss the *freewheeling effect* of the tank circuit. (3)

6.7.2 State ONE function of the coupling capacitors C_2 and C_3 in FIGURE 6.7 above. (2)

6.8 Refer to FIGURE 6.8 below and answer the questions that follow.

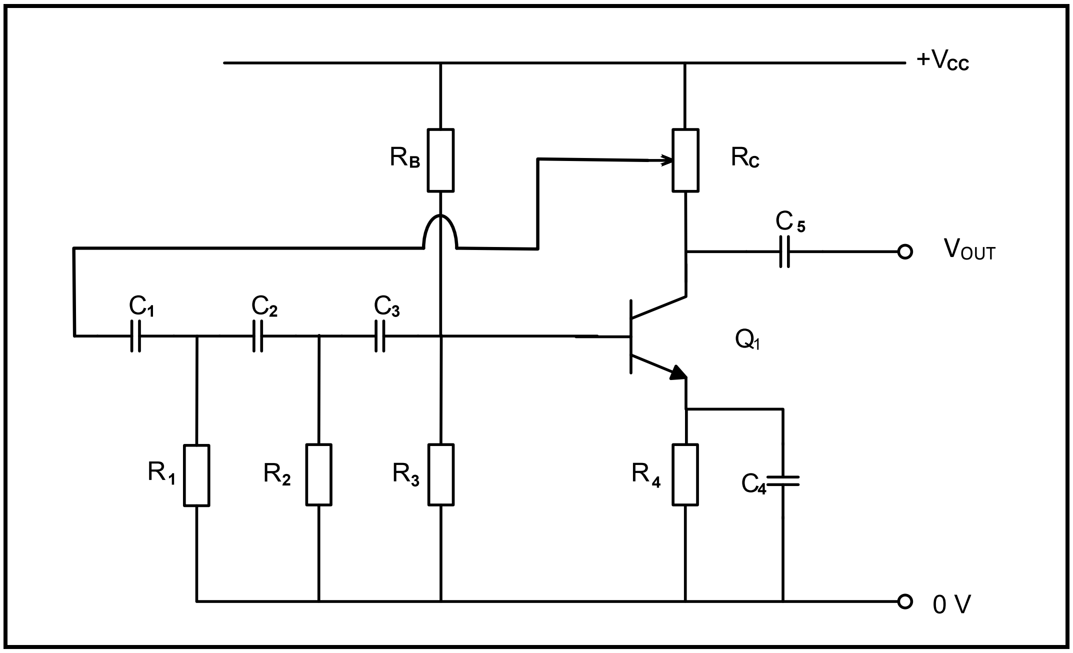

FIGURE 6.8: RC PHASE-SHIFT OSCILLATOR

6.8.1 Describe how the values of the capacitors (C_1, C_2, C_3) and resistors (R_1, R_2, R_3) in the feedback network are selected for the phase-shift oscillator. (2)

6.8.2 State the similarity between an *RC phase-shift oscillator* and a *radio-frequency amplifier circuit* with reference to their operating frequencies. (2)

6.9 Differentiate between an *RC phase-shift oscillator* and an *LC oscillator circuit* with reference to their feedback circuits. (2)
[45]

TOTAL: 200

FORMULA SHEET

RLC CIRCUITS

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

$X_L = 2\pi fL$

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

SERIES

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

$V_L = I X_L$

$V_C = I X_C$

$V_T = I Z$

$Q = \frac{X_L}{Z} = \frac{X_C}{Z} = \frac{V_L}{V_T} = \frac{V_C}{V_T} = \frac{1}{R}\sqrt{\frac{L}{C}}$

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

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

$\text{Cos}\,\theta = \frac{R}{Z}$

$\text{Cos}\,\theta = \frac{V_R}{V_T}$

PARALLEL

$\text{Cos}\,\theta = \frac{I_R}{I_T}$

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

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

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

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

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

$BW = \frac{f_r}{Q}$

SEMICONDUCTOR DEVICES

$\text{Gain } A_V = \frac{V_{OUT}}{V_{IN}} = -\left(\frac{R_F}{R_{IN}}\right)$

$V_{OUT} = V_{IN} \times \left(-\frac{R_F}{R_{IN}}\right)$

$V_{OUT} = V_{IN} \times \left(1 + \frac{R_F}{R_{IN}}\right)$

SWITCHING CIRCUITS

$V_{OUT} = -\left(V_1\frac{R_F}{R_1} + V_1\frac{R_F}{R_2} + V_1\frac{R_F}{R_3}\right)$

$V_{OUT} = -(V_1 + V_2 + V_3 + \ldots V_N)$

$V_{FB} = V_{SAT} \times \frac{R_2}{R_1 + R_2}$

$T = 1{,}1 \times R_1C_1$

$f = \frac{1}{T}$

$V_{TRIG} = V_{OUT} \times \frac{R_2}{R_1 + R_2}$

AMPLIFIERS

$I_C = \frac{V_C}{R_C}$ **AND** $V_{CC} = V_{CE} + I_C R_C$

$A_i = 20\log\frac{I_o}{I_i}$

$A_V = 20\log\frac{V_o}{V_i}$

$P_O = I^2 \times Z_O$

$A_P = 10\log\frac{P_o}{P_i}$

$A_{v(dB)} = 20\log A_V$

$\text{Gain } A_V = \frac{V_{OUT}}{V_{IN}} = -\left(\frac{R_F}{R_{IN}}\right)$

$f_O = \frac{1}{2\pi\sqrt{LC_T}}$ $f_O = \frac{1}{2\pi\sqrt{L_T C}}$

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

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 5: SWITCHING CIRCUITS

5.4.4

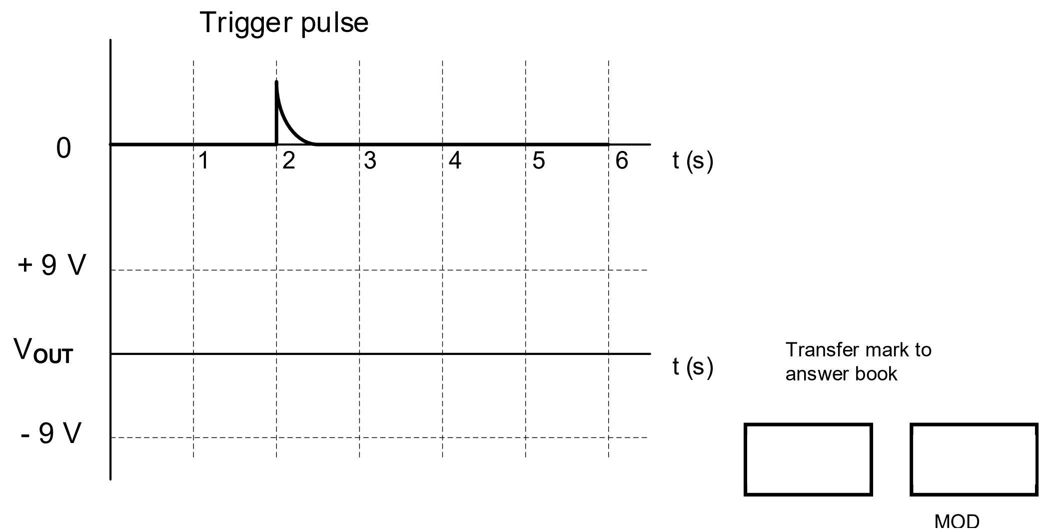

FIGURE 5.4.4 (4)

5.5.1

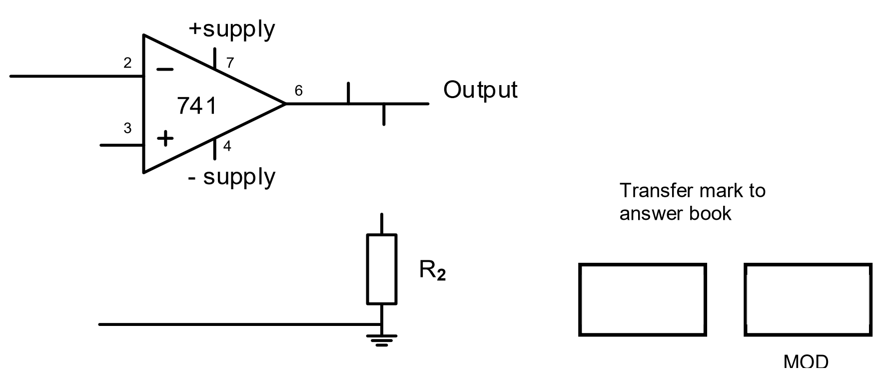

FIGURE 5.5.1 (4)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.9.2

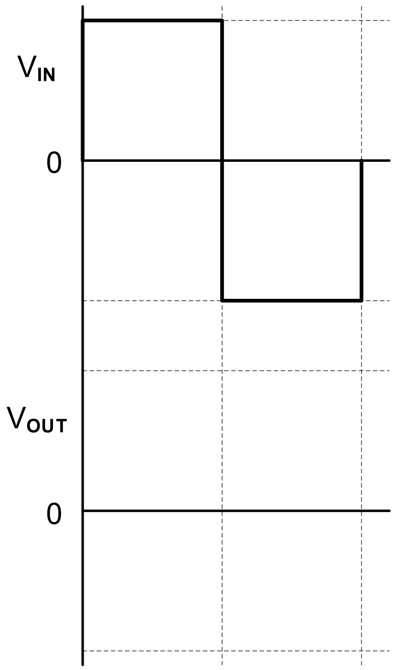

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FIGURE 5.9.2 (3)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 6: AMPLIFIERS

6.2.4

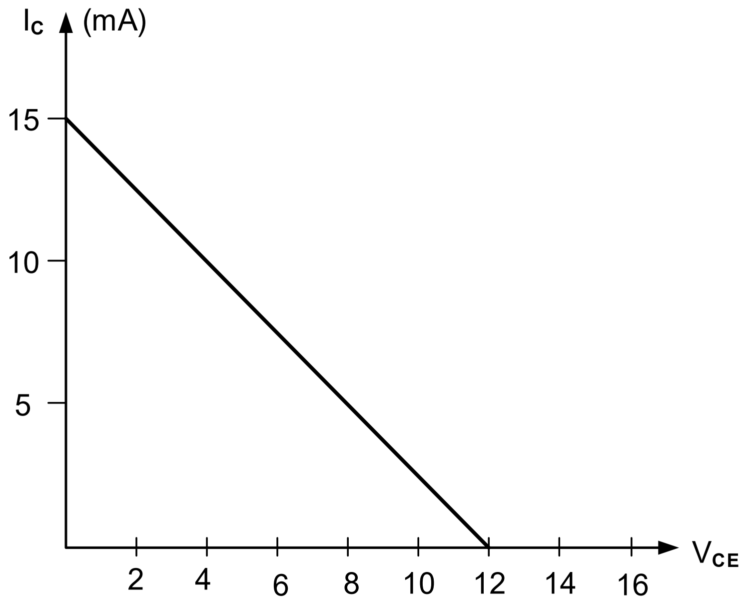

FIGURE A

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FIGURE 6.2.4 (2)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

6.5.3

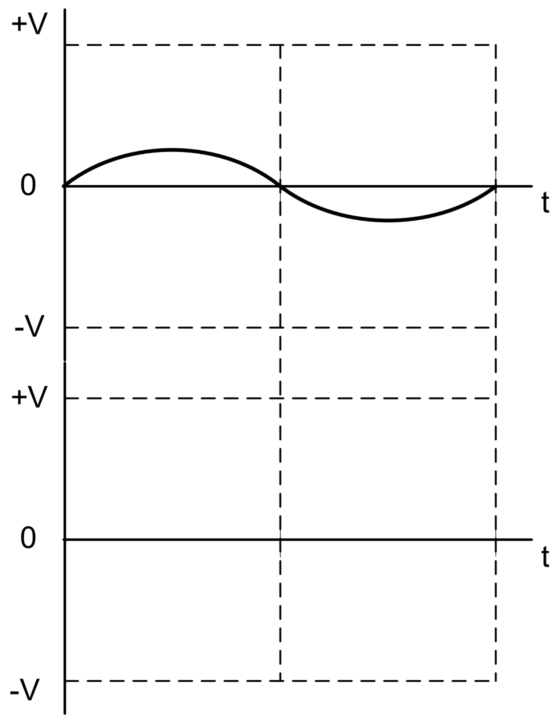

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FIGURE 6.5.3 (3)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

6.6.3

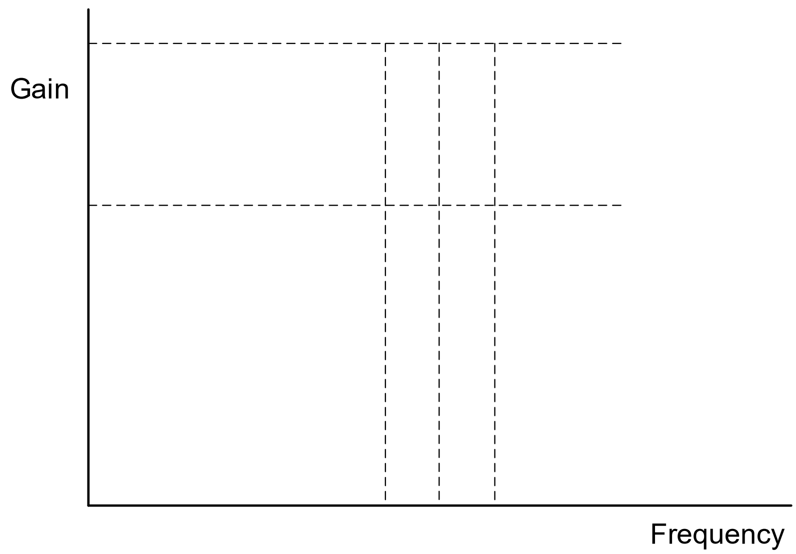

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FIGURE 6.6.3 (4)