Confidential

basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: ELECTRONICS

MAY/JUNE 2024

MARKS: 200

TIME: 3 hours

This question paper consists of 25 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:

   QUESTION 4.5.3
   QUESTIONS 5.3.3, 5.5.3 and 5.7.1
   QUESTIONS 6.3.3 and 6.4.4

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 burn must be treated by …

- A covering the burnt area with butter.
- B putting ice on the burn wound.
- C puncturing the blisters.
- D running cold water over the burnt area until the pain reduces. (1)

1.2 The power in an inductor is …

- A apparent power.
- B active power.
- C reactive power.
- D true power. (1)

1.3 A parallel RLC circuit is more capacitive when …

- A $X_C > X_L$
- B $R = Z$
- C $I_C > I_L$
- D $V_C > V_L$ (1)

1.4 An increase in resistance of a parallel resonant circuit will cause the total current to …

- A double.
- B decrease.
- C increase.
- D be zero. (1)

1.5 A UJT will go into a permanent ON state when it reaches the … region.

- A cut-off
- B saturation
- C valley
- D negative resistance (1)

1.6 The characteristics of a Darlington transistor amplifier are …

- A lower input impedance and higher current gain.
- B higher input impedance and lower current gain.
- C higher input impedance and higher current gain.
- D lower input impedance and low current gain. (1)

1.7 The 555 IC functions as a … in an astable mode of operation.

A voltage regulator
B frequency divider
C free-running oscillator
D None of the above-mentioned (1)

1.8 The main characteristics of operational amplifiers are …

A very high output impedance, low input impedance, high voltage gain and wide bandwidth.
B low voltage gain, low current gain, low output impedance and narrow bandwidth.
C very high voltage gain, high current gain, low output impedance and high input impedance.
D very high voltage gain, high input impedance, low output impedance and wide bandwidth. (1)

1.9 In an op-amp bistable multivibrator circuit the op amp operates as a/an …

A comparator.
B summing amplifier.
C differentiator.
D integrator. (1)

1.10 A/An … changes its output state when a trigger pulse is received, remains in that state for a time determined by the RC time constant after which it returns to its original state.

A astable multivibrator
B bistable multivibrator
C monostable multivibrator
D relaxation oscillator (1)

1.11 A circuit used to change a sine wave into a square wave with the same frequency is a …

A comparator.
B Schmitt trigger.
C monostable multivibrator.
D op-amp differentiator. (1)

1.12 When a positive square wave is applied to the inverting input of an op-amp integrator and the non-inverting input is connected to ground, the capacitor will …

A charge exponentially to the supply voltage.
B discharge exponentially to 0 V.
C charge at a constant fixed rate to the negative saturation voltage.
D discharge at a constant fixed rate to 0 V. (1)

1.13 … is the process of transferring signal energy between circuits.

A Isolation
B Coupling
C Saturation
D Stabilisation (1)

1.14 … occurs when the peak of a sine waveform is amplified into saturation.

A Frequency distortion
B Phase distortion
C Amplitude distortion
D Cross-over distortion (1)

1.15 The … amplifier has the highest efficiency.

A class AB
B class A
C class B
D class C (1)
[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 State TWO unsafe acts that would be regarded as dangerous practices by a user when operating machinery. (2)

2.2 With reference to the Occupational Health and Safety Act, 1993 (Act 85 of 1993), give TWO examples that are considered to be offences when reporting to the safety inspector. (2)

2.3 Discuss the general duties that manufacturers perform when designing or manufacturing articles used at work. (2)

2.4 Define a *non-critical incident*. (2)

2.5 Describe a dangerous effect that a current of 200 mA has on the human body. (2)
[10]

QUESTION 3: RLC CIRCUITS

3.1 Explain the term *reactance* with reference to an alternating current circuit. (2)

3.2 FIGURE 3.2 below shows the circuit diagram, waveforms and a partial phasor diagram of the voltages in an RLC circuit that is connected to an AC supply. Study the diagrams below and answer the questions that follow.

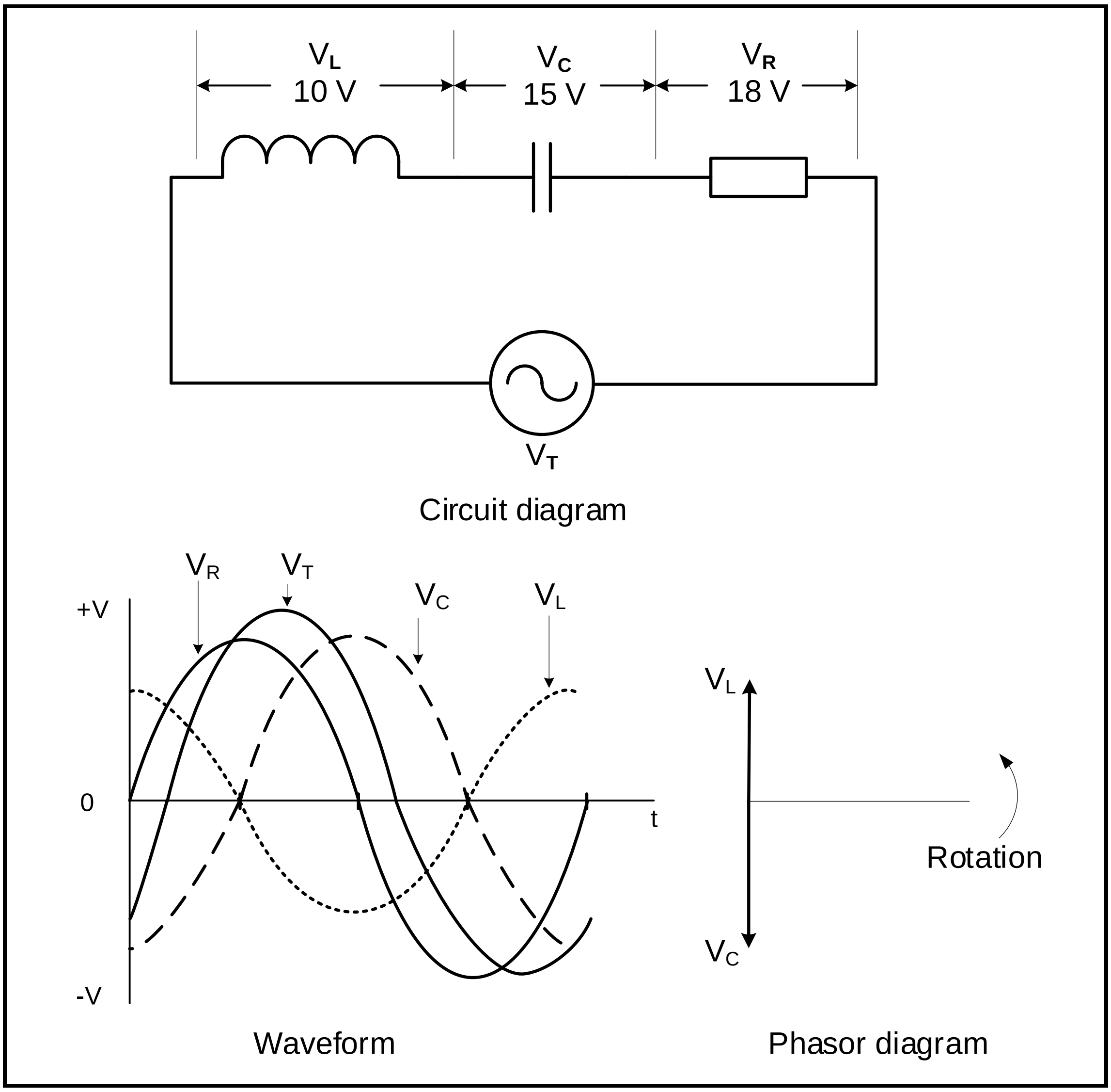


FIGURE 3.2: RLC CIRCUIT, WAVEFORM AND PHASOR

Given:

V_R = 18 V
V_L = 10 V
V_C = 15 V

3.2.1 State whether the circuit is predominantly inductive or capacitive. Motivate your answer. (2)

3.2.2 Calculate the supply voltage. (3)

3.2.3 Calculate the phase angle. (3)

3.2.4 Redraw and complete the phasor diagram in the ANSWER BOOK. (3)

3.2.5 Explain why it could be assumed that the supply current is leading the supply voltage. (2)

3.3 Refer to FIGURE 3.3 below and answer the questions that follow.

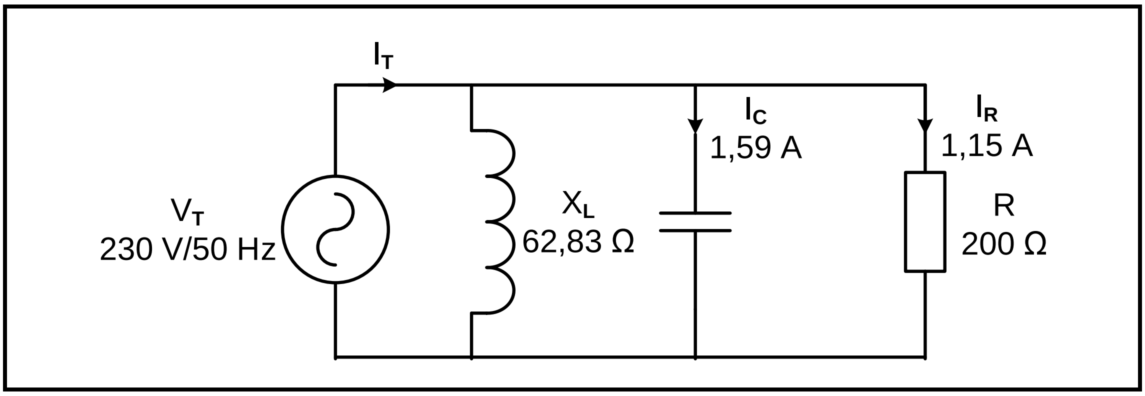


FIGURE 3.3: RLC PARALLEL CIRCUIT

Given:

X_L = 62,83 Ω
R = 200 Ω
I_R = 1,15 A
I_C = 1,59 A
V_T = 230 V
f = 50 Hz

Calculate the:

3.3.1 Current flow through the inductor (3)

3.3.2 Total current flow (3)

3.3.3 Power factor (3)

3.3.4 Value of capacitance that would cause resonance when the frequency and inductor remain constant (4)

3.4 FIGURE 3.4 below shows the current vs frequency response curves of a series resonant circuit with a variable resistor. The inductive reactance of the circuit is 2 000 Ω at resonance and each response curve is for a different resistance value.

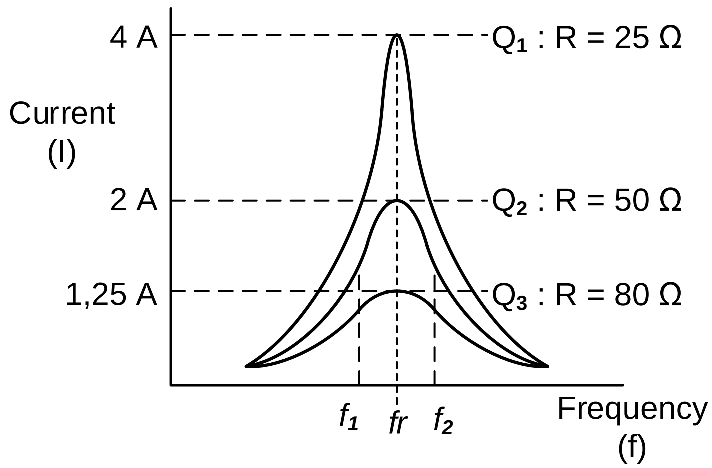


FIGURE 3.4: FREQUENCY RESPONSE

Given:

X_L = 2 000 Ω

3.4.1 State how a decrease in resistance affects the Q-factor of the circuit. (1)

3.4.2 Calculate the Q factor when R = 50 Ω. (3)

3.4.3 Calculate the resonant frequency when f_1 = 1 200 Hz and f_2 = 2 100 Hz. (3)

[35]

QUESTION 4: SEMICONDUCTOR DEVICES

4.1 Name the semiconductor that is represented by the symbol in FIGURE 4.1.

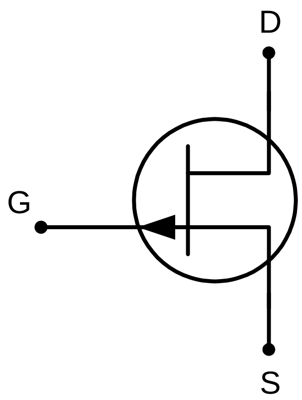


FIGURE 4.1: SEMICONDUCTOR CIRCUIT SYMBOL (2)

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

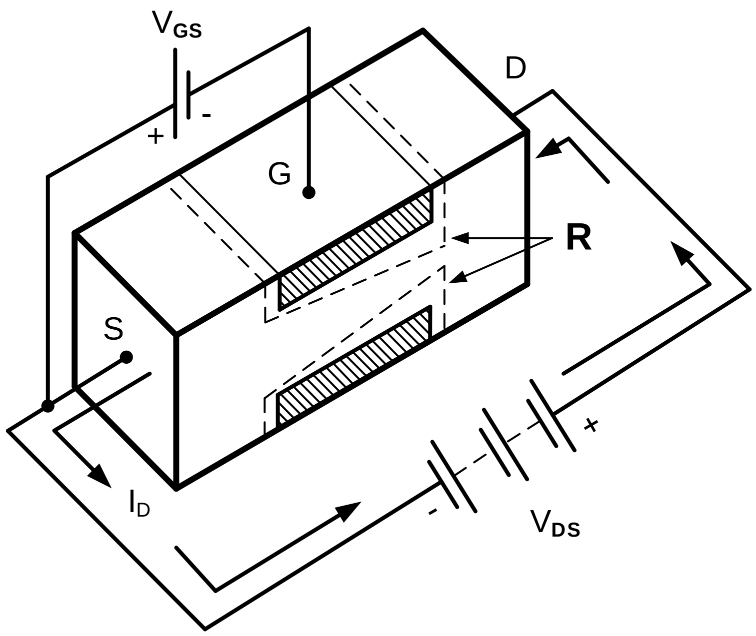


FIGURE 4.2: CONSTRUCTION OF A JFET

4.2.1 Identify the sections labelled **R** in FIGURE 4.2 above. (1)

4.2.2 Briefly describe how an increase in V_{GS} affects current flow in the conducting channel of the field-effect transistor. (3)

4.2.3 Explain why JFETs are sometimes referred to as depletion-mode transistors. (2)

4.2.4 Describe why the JFET is referred to as a unipolar device. (2)

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

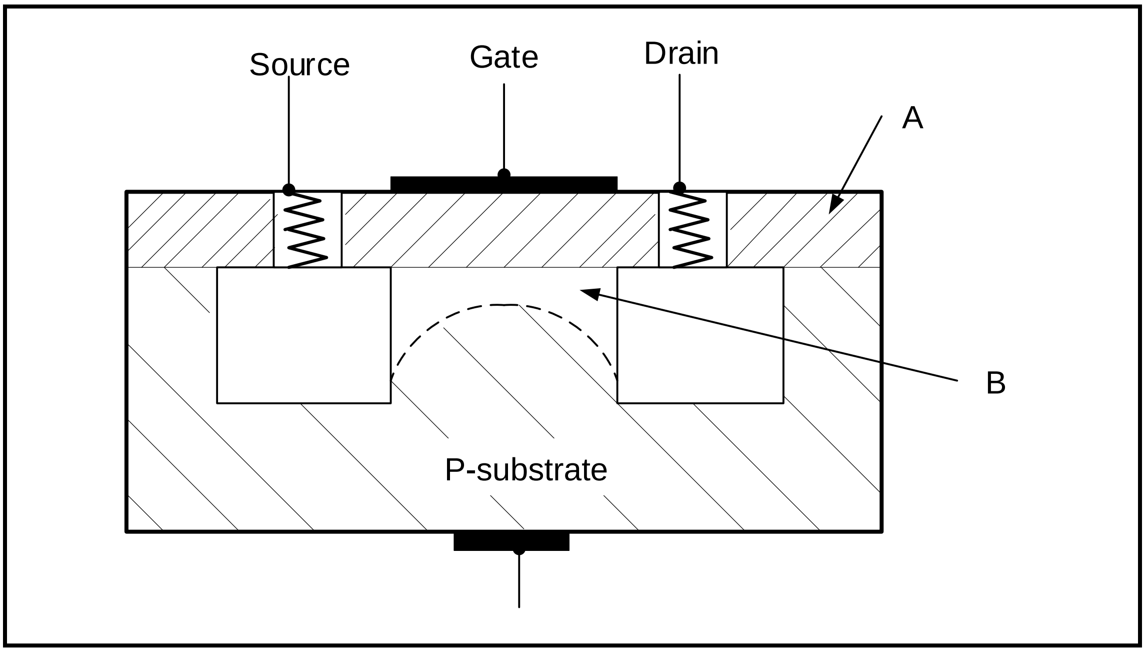


FIGURE 4.3: CONSTRUCTION OF A MOSFET

4.3.1 Identify the MOSFET mode represented in FIGURE 4.3 above. (1)

4.3.2 Identify sections A and B. (2)

4.3.3 Briefly explain the operation of the MOSFET when a positive voltage is applied on the gate. (3)

4.4 State the main difference between the respective modes of operation of a JFET and a MOSFET. (3)

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

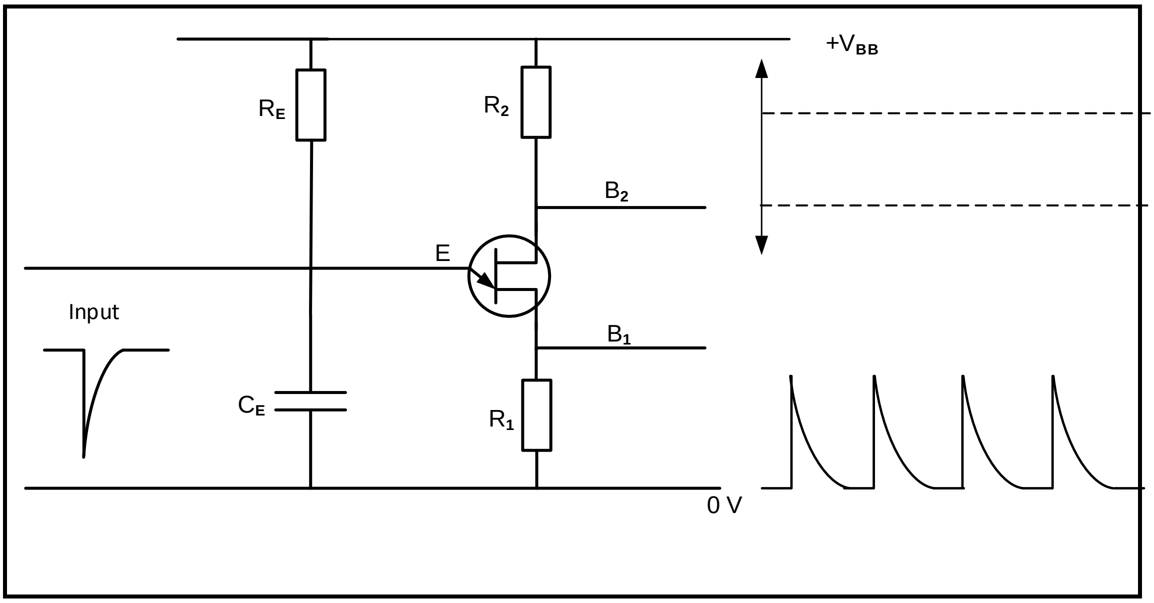


FIGURE 4.5: UJT AS A SAWTOOTH GENERATOR

4.5.1 State the function of R_1 in FIGURE 4.5 above. (1)

4.5.2 Briefly describe the operation of the UJT when a negative pulse is applied to the emitter. (2)

4.5.3 Draw the output waveform that would develop across B_2 of the UJT on the ANSWER SHEET for QUESTION 4.5.3. (3)

4.6 Determine the output state of the op amp in FIGURE 4.6 below for the conditions in TABLE 4.6 below when V_1 and V_2 are in phase.

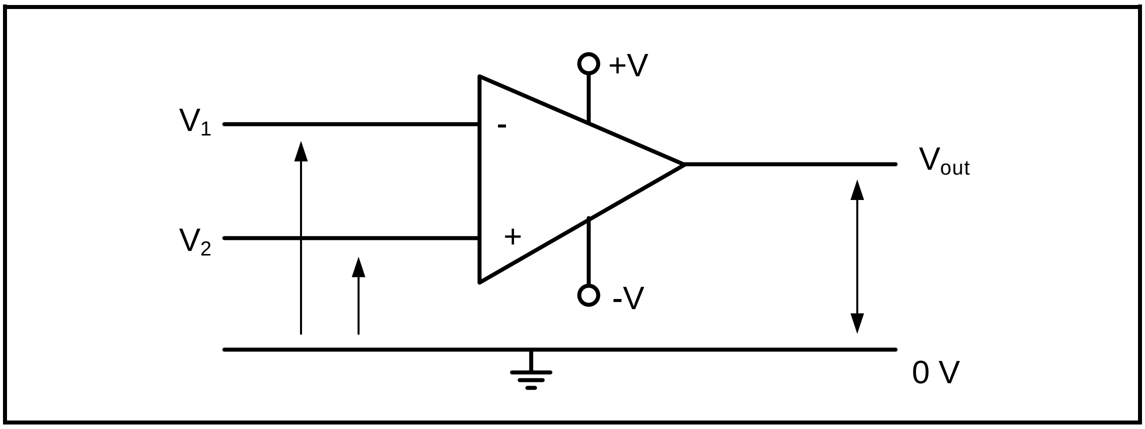


FIGURE 4.6: OPERATIONAL AMPLIFIER

	V_{IN}	V_{OUT}
4.6.1	If $V_1 < V_2$	V_{OUT} will be …
4.6.2	If $V_1 = V_2$	V_{OUT} will be …

TABLE 4.6 (2)

4.7 Study FIGURE 4.7 below and answer the questions that follow.

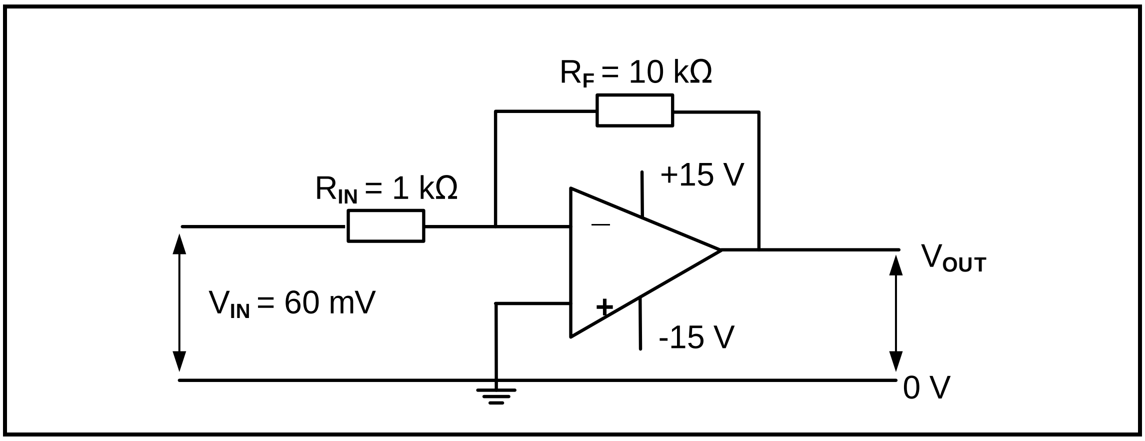


FIGURE 4.7: INVERTING OPERATIONAL AMPLIFIER

4.7.1 Explain why op amps are not used frequently in open-loop mode. (2)

4.7.2 Explain the term *bandwidth* as one of the characteristics of operational amplifiers. (2)

4.7.3 Calculate the output voltage. (3)

4.8 Refer to FIGURE 4.8 below and calculate the feedback resistance (R_F) that is needed if the input resistance is 2 kΩ when the op amp is supplied with an input voltage of 0,5 V and produces an output voltage of 4 V.

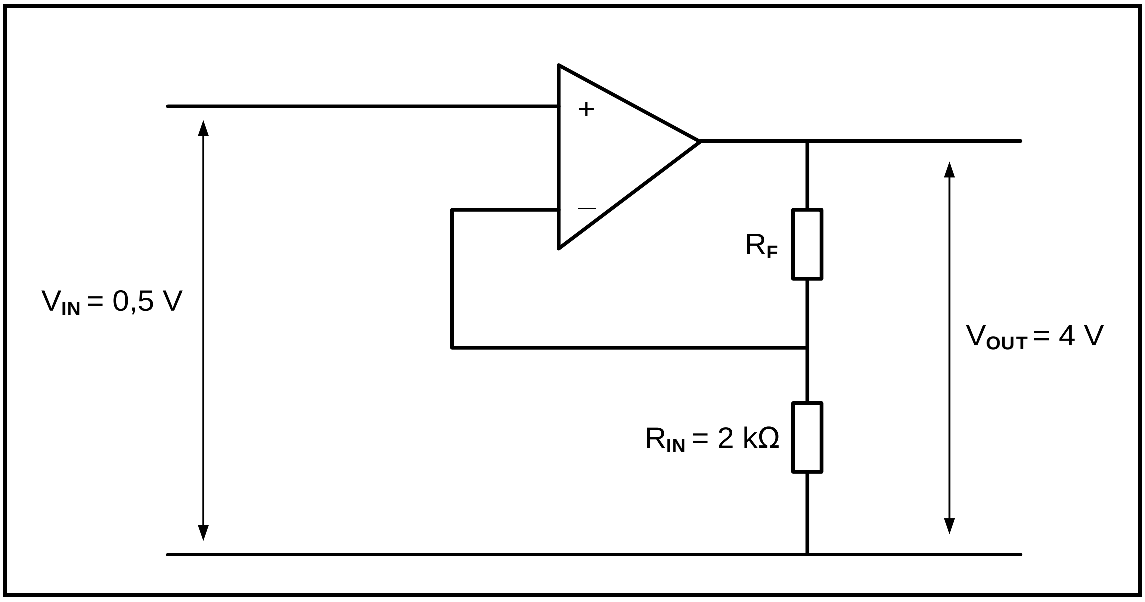


FIGURE 4.8: OPERATIONAL AMPLIFIER

Given:

V_{IN} = 0,5 V
V_{OUT} = 4 V
R_{IN} = 2 kΩ (3)

4.9 Refer to FIGURE 4.9 below and answer the questions that follow.

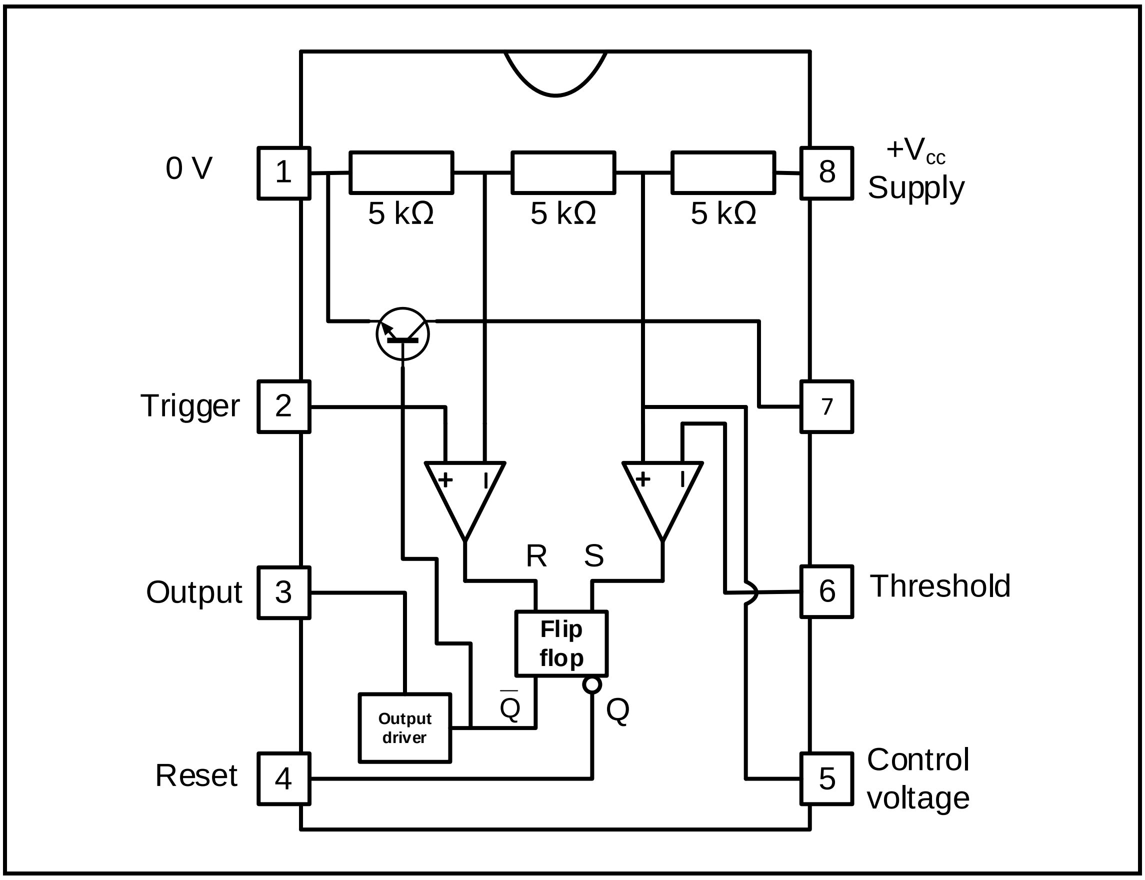


FIGURE 4.9: 555 IC

4.9.1	Label pin 7.	(1)
4.9.2	Name ONE application of a 555 IC when used in monostable mode.	(1)
4.9.3	Briefly discuss the function of pin 4.	(2)
4.9.4	Name TWO modes of operation for the 555 IC.	(2)
4.9.5	Explain the function of the threshold input on a 555 IC.	(2)
		[45]

QUESTION 5: SWITCHING CIRCUITS

5.1 State ONE effect of switch bounce in electronic circuits. (1)

5.2 FIGURE 5.2 below shows the basic circuit diagram of an op-amp bistable multivibrator with its input and output waveforms. Answer the questions that follow.

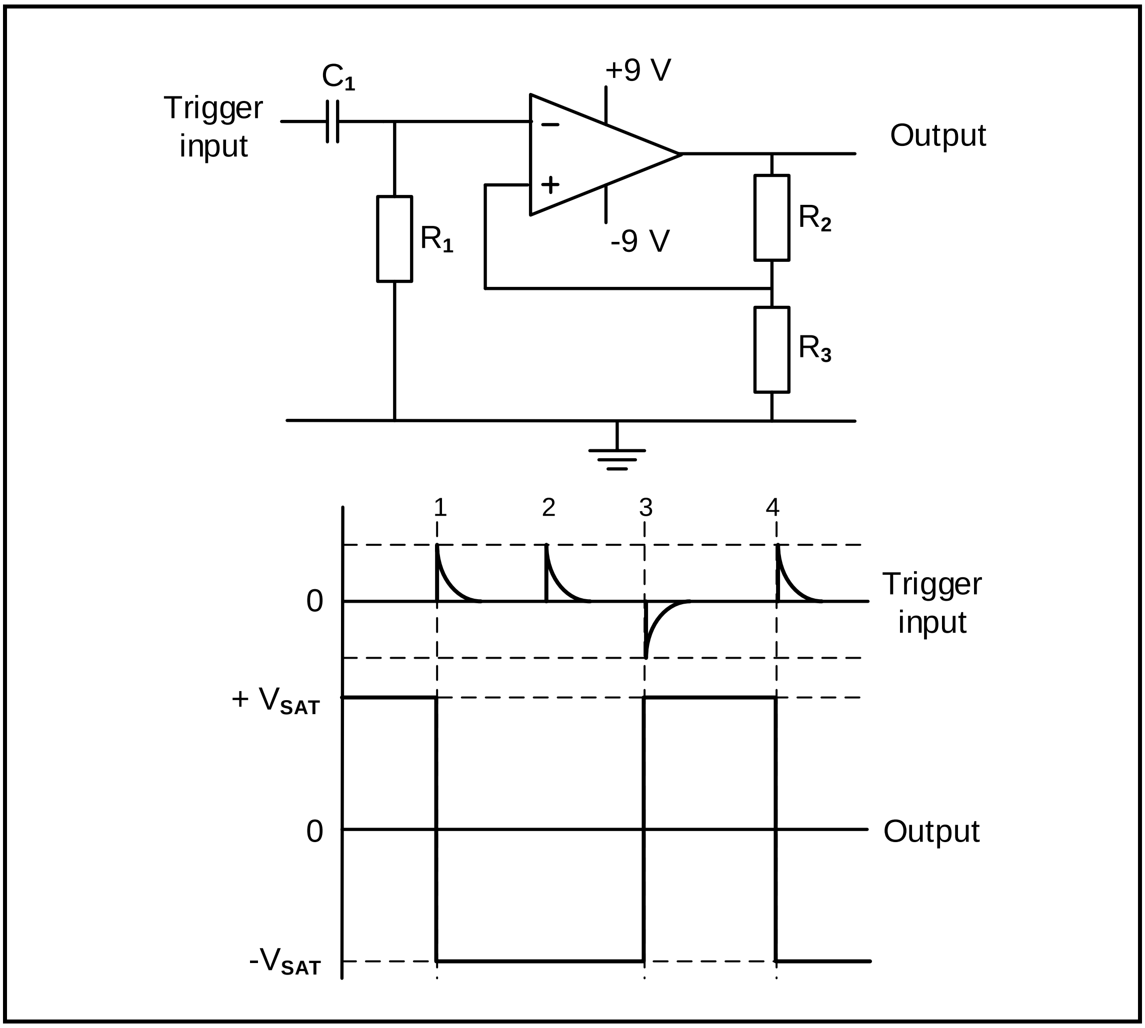


FIGURE 5.2 BISTABLE MULTIVIBRATOR

5.2.1 Explain feedback with reference to the circuit. (2)

5.2.2 Explain how the capacitor reacts when a positive trigger pulse is applied to the input of the circuit. (2)

5.2.3 Describe the operation of the circuit when a negative trigger pulse is applied to the input. (3)

5.2.4 Explain why the output does not change when trigger pulse 2 is applied. (3)

5.3 Refer to FIGURE 5.3 below and answer the questions that follow.

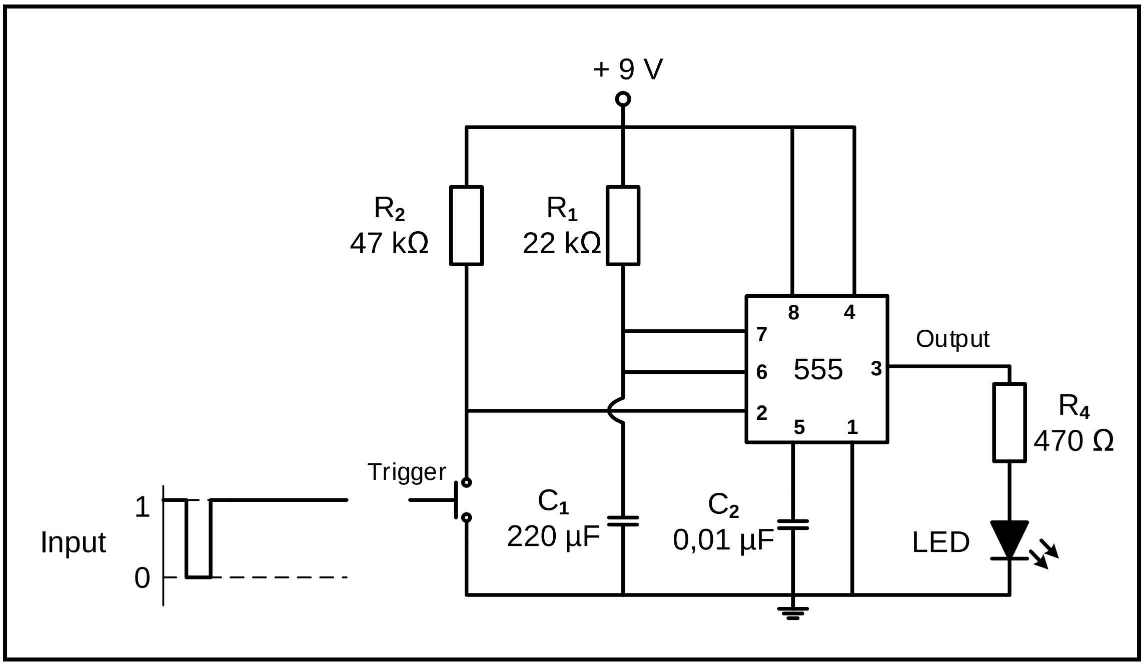


FIGURE 5.3: MULTIVIBRATOR CIRCUIT

5.3.1 Identify the multivibrator circuit in FIGURE 5.3. (1)

5.3.2 State the function of resistor R_2 in this circuit. (2)

5.3.3 Draw the output of the circuit for the given input on the ANSWER SHEET for QUESTION 5.3.3. (3)

5.3.4 Determine the voltage at which the circuit will reset to its resting state. Give a reason for the answer. (2)

5.4 Refer to FIGURE 5.4 below and answer the questions that follow.

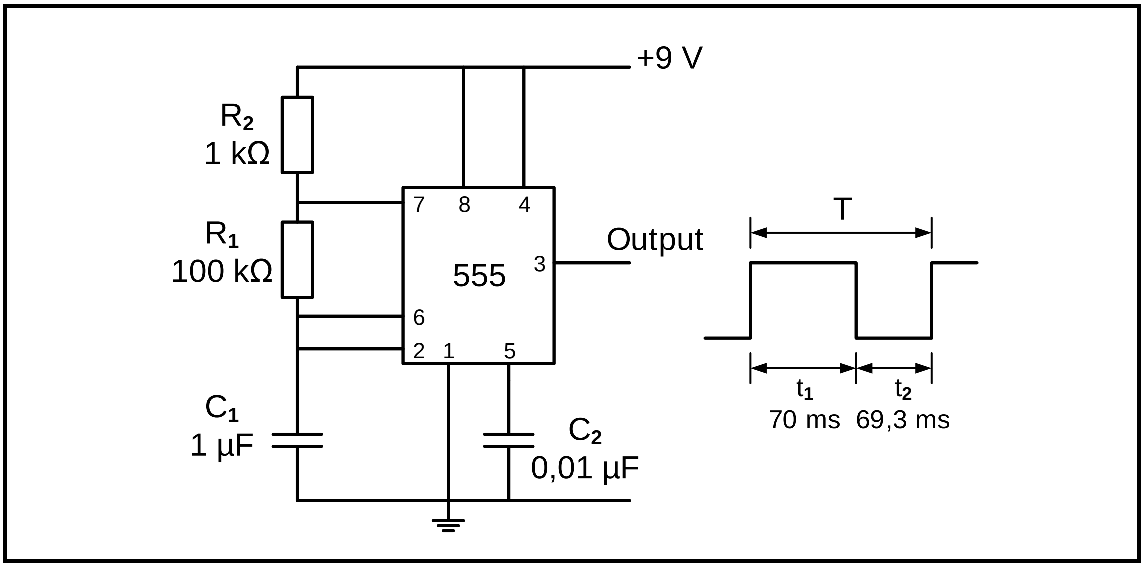


FIGURE 5.4: ASTABLE MULTIVIBRATOR

5.4.1 Explain why the output of the circuit changes state continually. (4)

5.4.2 Explain why t_1 and t_2 are not equal. (2)

5.4.3 Calculate the frequency of the output. (3)

5.5 FIGURE 5.5 below shows an op amp as comparator. Answer the questions that follow.

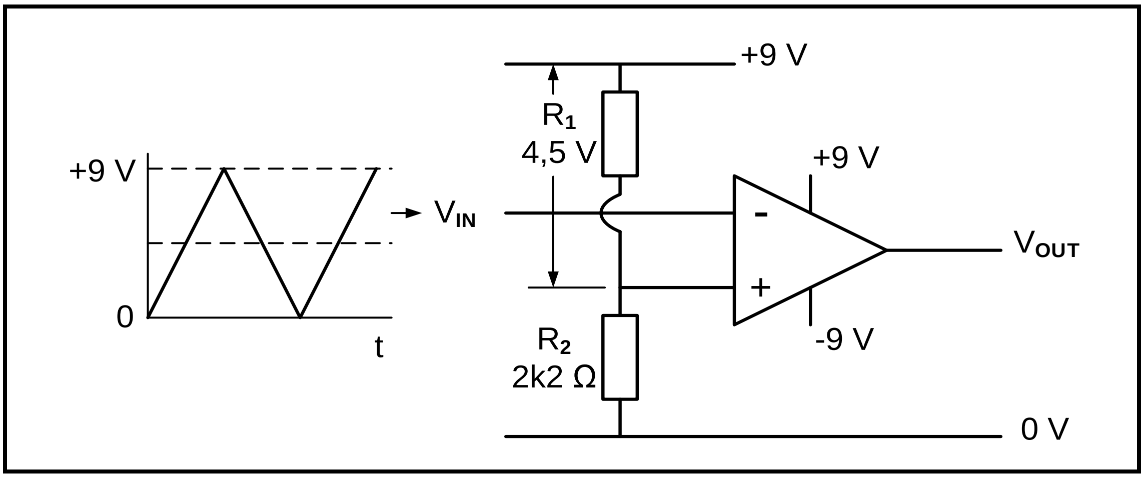


FIGURE 5.5: OP AMP AS COMPARATOR

5.5.1 Determine the value of the reference voltage. (1)

5.5.2 Determine the resistance of R_1. Motivate your answer. (2)

5.5.3 Draw the output voltage for the given input on the ANSWER SHEET for QUESTION 5.5.3. (3)

5.5.4 Explain how an increase in the value of R_1 will affect the voltage across R_2. (2)

5.6 FIGURE 5.6 below shows the circuit diagram of an inverting summing amplifier.

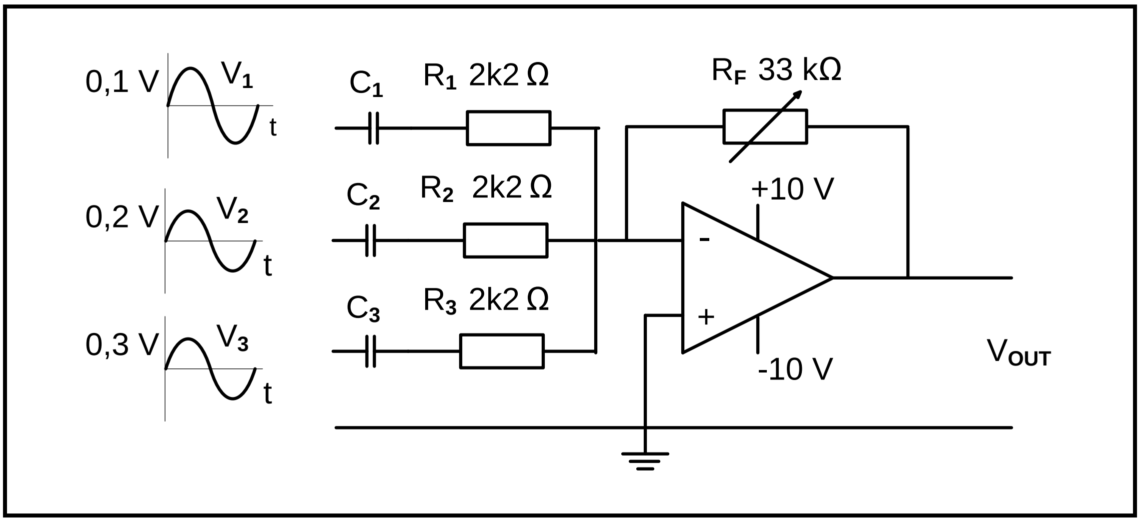


FIGURE 5.6: SUMMING AMPLIFIER

5.6.1 Explain the purpose of a summing amplifier. (3)

5.6.2 Given:

$R_1 = R_2 = R_3 = 2{,}2\ k\Omega$
$R_F = 33\ k\Omega$
$V_{CC} = +/- 10\ V$
$V_1 = 0{,}1\ V$
$V_2 = 0{,}2\ V$
$V_3 = 0{,}3\ V$

Calculate the output voltage if R_F is set to 33 kΩ. (3)

5.6.3 State why the output falls to 0,6 V when R_F is set to 2 200 Ω. (1)

5.7 Refer to FIGURE 5.7 below and answer the questions that follow.

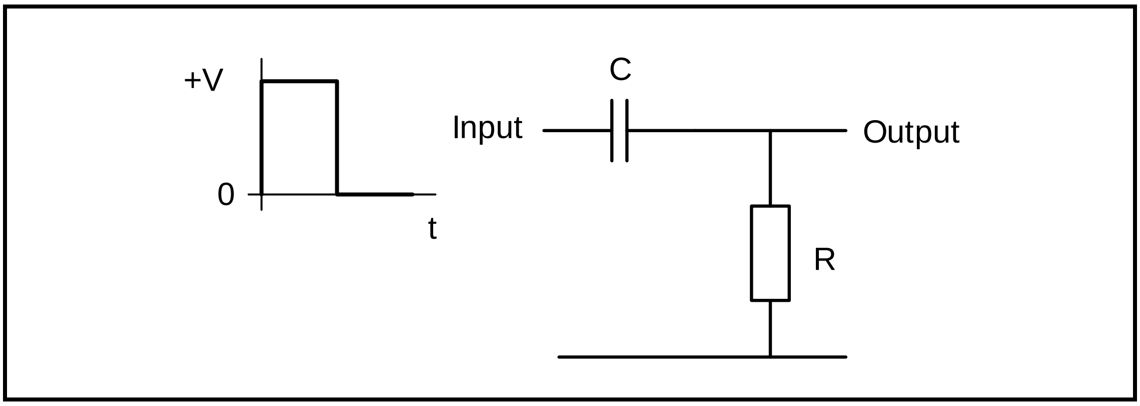


FIGURE 5.7: PASSIVE RC DIFFERENTIATOR

5.7.1 Draw the output of the circuit for the given input on the ANSWER SHEET for QUESTION 5.7.1. (2)

5.7.2 Explain the operation of the circuit during the first positive square wave. (3)

5.7.3 Illustrate, by means of a basic circuit diagram, how the circuit above can be changed into a passive integrator. (2)

[50]

QUESTION 6: AMPLIFIERS

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

6.2 State ONE advantage of class AB push-pull amplifiers. (1)

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

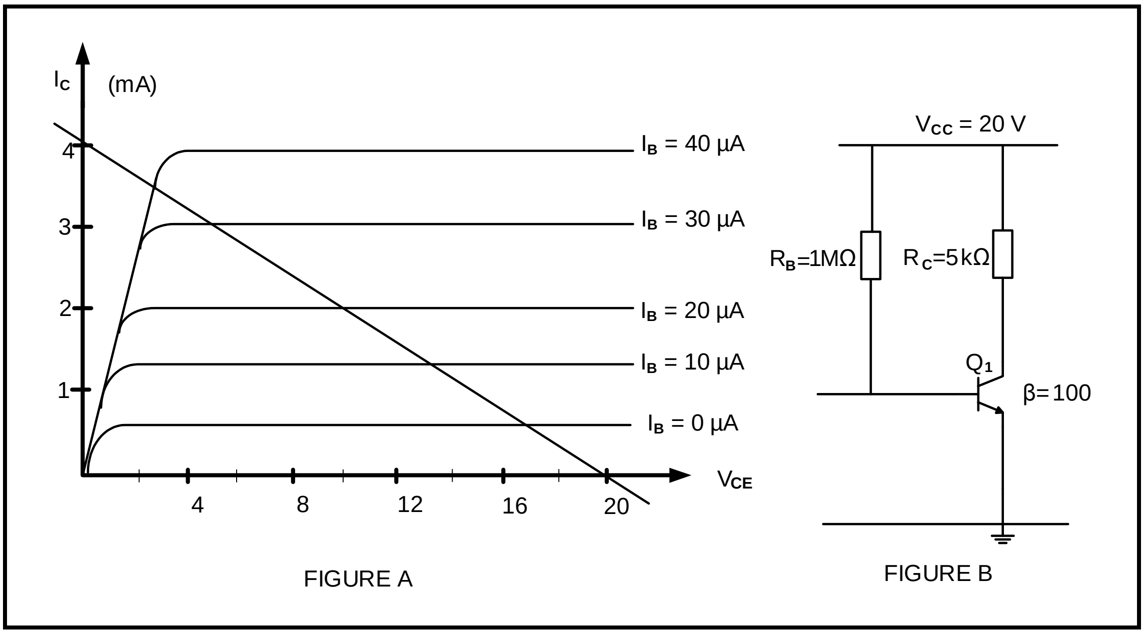


FIGURE 6.3: DC LOADLINE

6.3.1 Determine the quiescent collector current if the base current is 20 µA. (1)

6.3.2 Determine the quiescent voltage. (1)

6.3.3 Indicate the quiescent point for QUESTION 6.3.3 on the ANSWER SHEET. (1)

6.3.4 Name TWO undesirable effects of incorrect biasing of the transistor in FIGURE 6.3 above. (2)

6.4 Refer to FIGURE 6.4 below and answer the questions that follow.

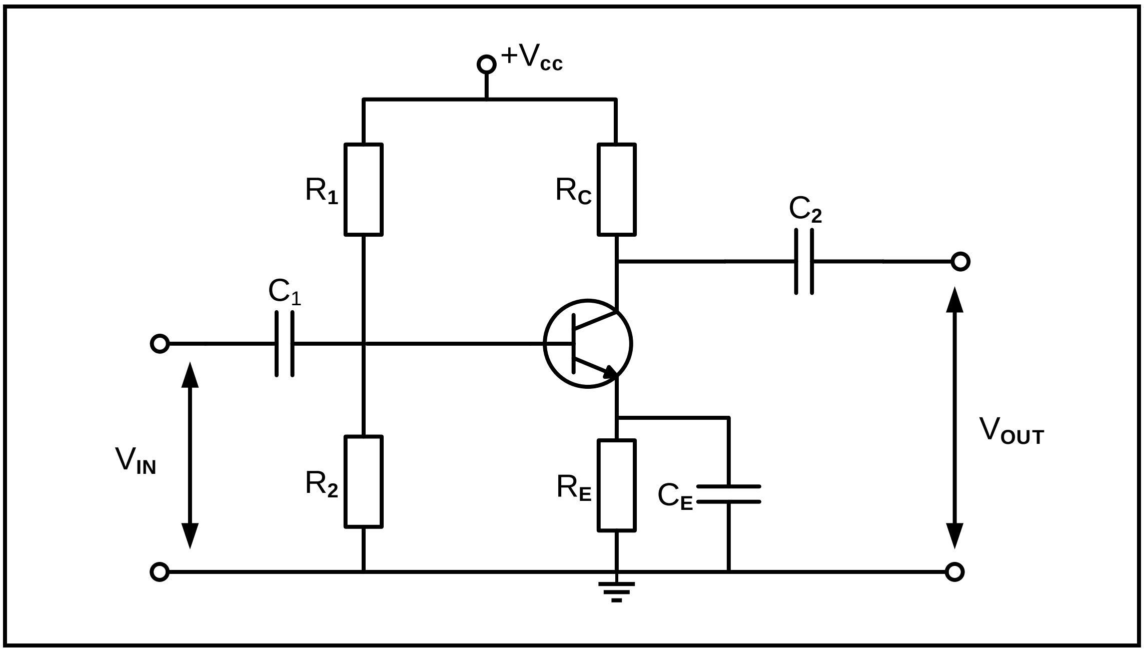


FIGURE 6.4: RC-COUPLED AMPLIFIER

6.4.1 Name ONE disadvantage of the RC-coupled amplifier. (1)

6.4.2 Briefly describe the effect when the temperature of a transistor increases beyond its normal operating value. (2)

6.4.3 Explain why the RC-coupled amplifier can be regarded as a low-frequency filter. (2)

6.4.4 Draw, on the ANSWER SHEET for QUESTION 6.4.4, a fully labelled frequency response curve of the RC-coupled amplifier in FIGURE 6.4 (4)

6.5 Refer to FIGURE 6.5 below and answer the questions that follow.

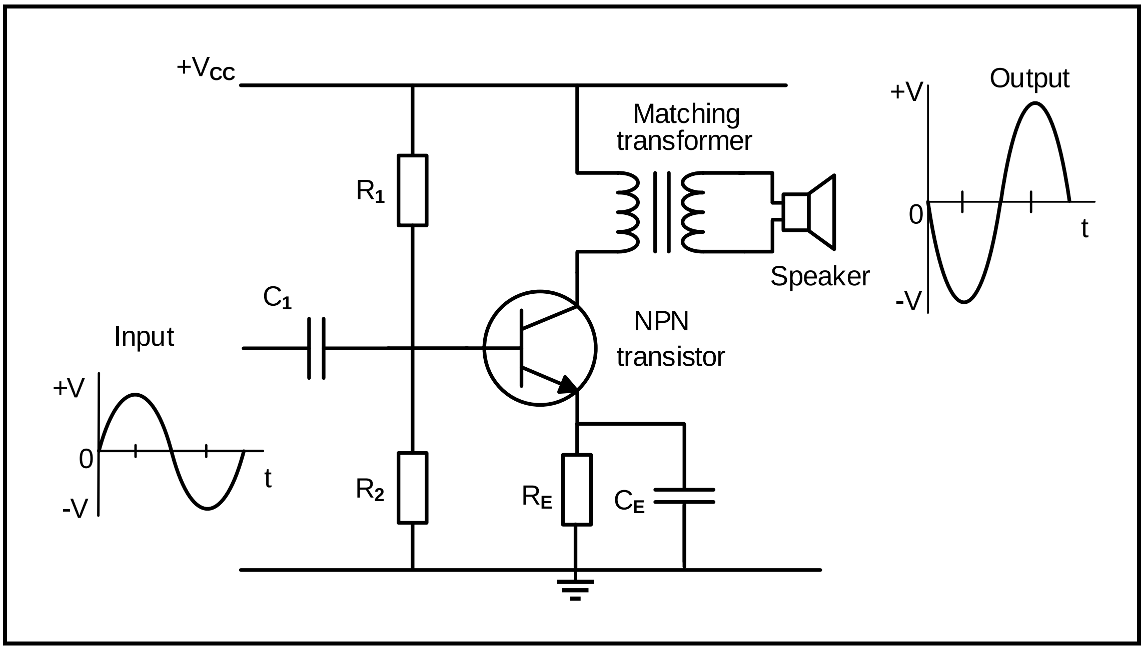


FIGURE 6.5: TRANSFORMER-COUPLED AMPLIFIER

6.5.1 State ONE disadvantage of the amplifier in FIGURE 6.5 above, besides the cost and the size of the transformer. (1)

6.5.2 State the importance of the impedance matching transformer in FIGURE 6.5 above. (1)

6.5.3 State the TWO functions of capacitor C_1. (2)

6.5.4 Explain why the output waveform in FIGURE 6.5 is inverted and amplified. (2)

6.6 FIGURE 6.6 below shows a push-pull amplifier using NPN and PNP transistors. Answer the questions that follow.

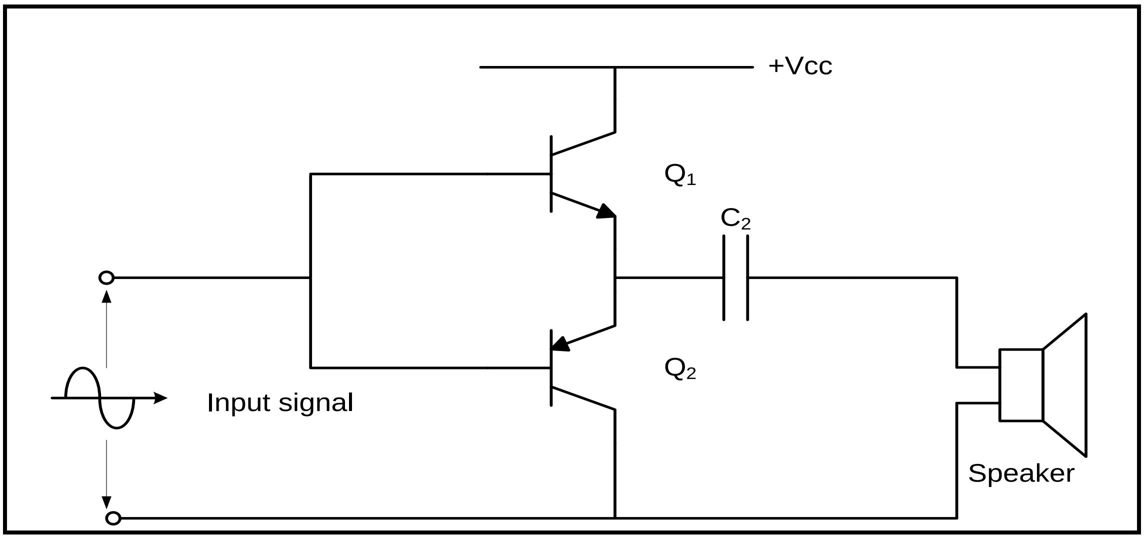


FIGURE 6.6: PUSH-PULL AMPLIFIER

6.6.1 Name ONE advantage of the amplifier in FIGURE 6.6 above. (1)

6.6.2 State how cross-over distortion can be eliminated during the operation of the circuit in FIGURE 6.6 above. (1)

6.6.3 Describe the operation of the circuit during the negative half cycle of the input signal. (3)

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

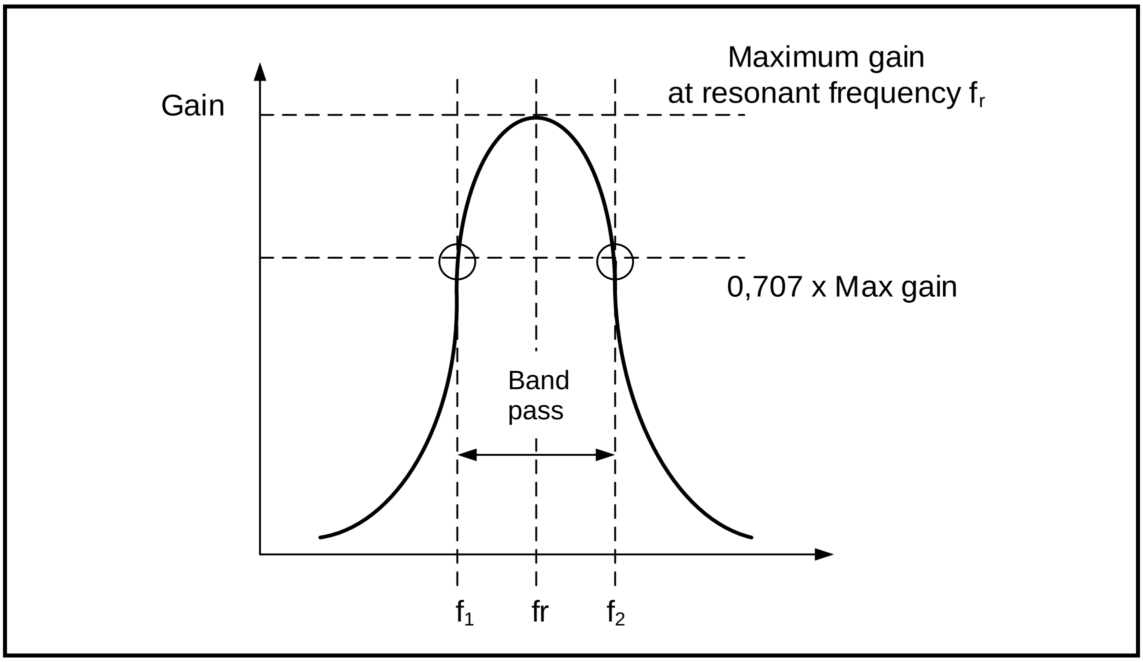


FIGURE 6.7: FREQUENCY RESPONSE CURVE

6.7.1 Identify the amplifier circuit from which the frequency response curve in FIGURE 6.7 above is derived. (1)

6.7.2 Explain the term *band-pass filter* with reference to the frequency response curve in FIGURE 6.7 above. (2)

6.7.3 Briefly describe how resonant frequency can be changed. (2)

6.8 Study FIGURE 6.8 below and answer the questions that follow.

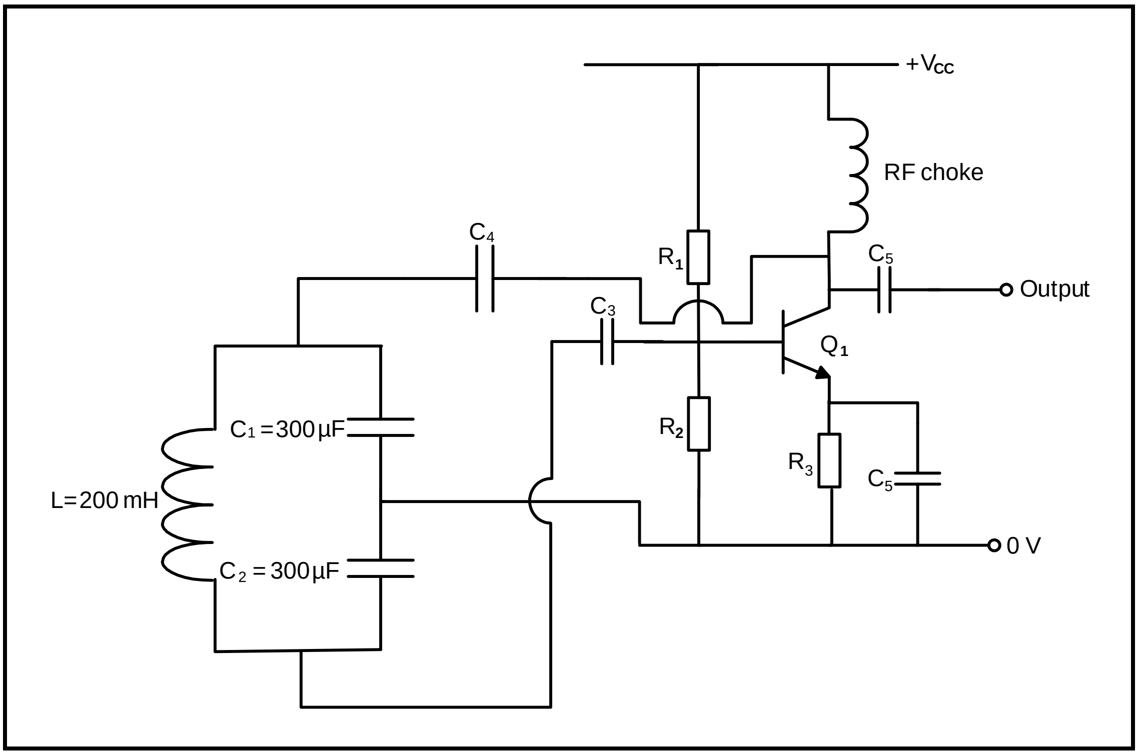


FIGURE 6.8: COLPITTS OSCILLATOR

6.8.1 Name ONE application of the Colpitts oscillator. (1)

6.8.2 State the purpose of the tank circuit in FIGURE 6.8 above. (1)

6.8.3 Given:

$L = 200\ mH$
$C_1 = C_2 = 300\ \mu F$
$C_T = 150\ \mu F$

Calculate the oscillating frequency of the circuit in FIGURE 6.8 above when the total capacitance of the tank circuit is 150 µf and the value of the inductor is 200 mH. (3)

6.9 Refer to FIGURE 6.9 below and answer the questions that follow.

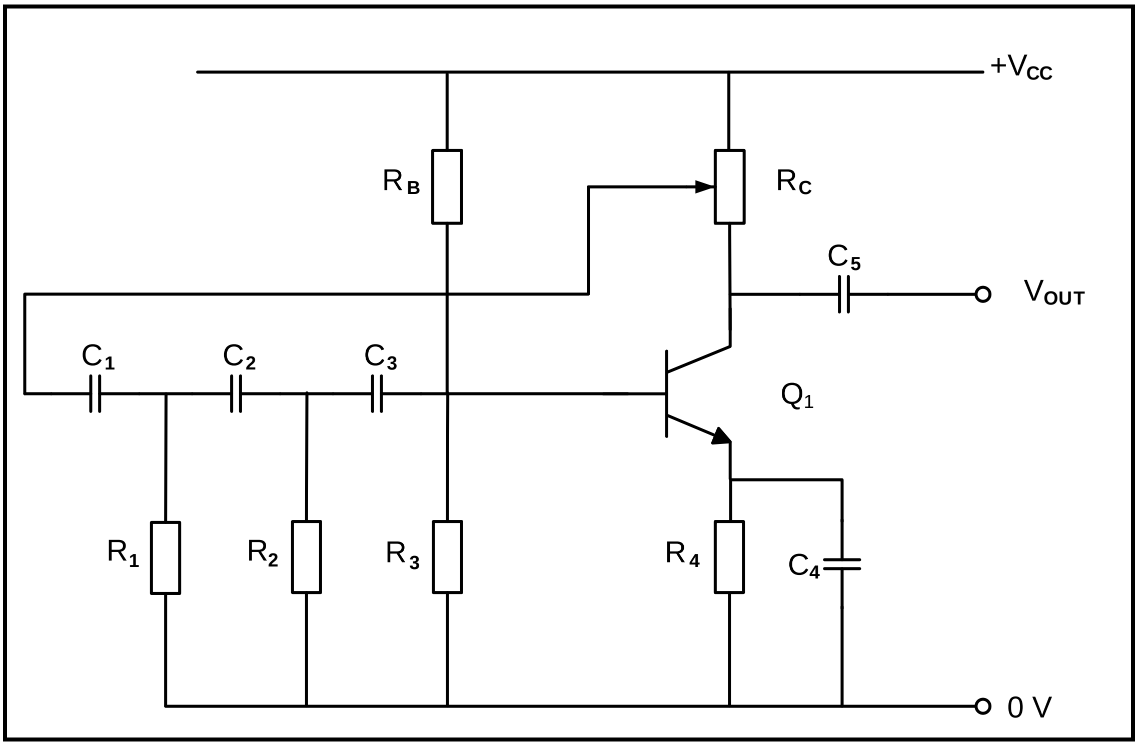


FIGURE 6.9: RC PHASE-SHIFT OSCILLATOR

6.9.1 State the type of feedback used in FIGURE 6.9 above. (1)

6.9.2 State the value of the phase shift each RC combination produces. (1)

6.9.3 Calculate the frequency of oscillation when $R_1 = R_2 = R_3 = 10\ k\Omega$ and $C_1 = C_2 = C_3 = 0{,}001\ \mu f$. (3)

6.9.4 Explain the term *attenuation*. (2)

[45]

TOTAL: 200

FORMULA SHEET

RLC CIRCUITS

$P = V \times I \times \cos\theta$

$X_L = 2\pi fL$

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

$f_r = \frac{1}{2\pi\sqrt{LC}}$ **OR** $f_r = \frac{f_2 + f_1}{2}$

$BW = \frac{f_r}{Q}$ **OR** $BW = f_2 - f_1$

SERIES

$V_R = IR$

$V_L = IX_L$

$V_C = IX_C$

$I_T = \frac{V_T}{Z}$ **OR** $I_T = I_R = I_C = I_L$

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

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

$\text{Cos}\,\theta = \frac{R}{Z}$ **OR** $\text{Cos}\,\theta = \frac{V_R}{V_T}$

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

PARALLEL

$V_T = V_R = V_L = V_C$

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

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

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

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

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

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

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

SEMICONDUCTOR DEVICES

$\text{Gain } A_V = \frac{V_{OUT}}{V_{IN}} = -\frac{R_F}{R_{IN}}$ $\quad A_V = 1 + \frac{R_F}{R_{IN}}$

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

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

SWITCHING CIRCUITS

$V_{OUT} = -\left(V_1\frac{R_F}{R_1} + V_2\frac{R_F}{R_2} + \ldots V_N\frac{R_F}{R_N}\right)$

$\text{Gain } A_V = \frac{V_{OUT}}{V_{IN}} = \frac{V_{OUT}}{(V_1 + V_2 + \ldots V_N)}$

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

AMPLIFIERS

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

$V_B = V_{BE} + V_{RE}$

$A_V = \frac{V_{OUT}}{V_{IN}}$

$A_I = \frac{I_{OUT}}{I_{IN}}$

$A_P = \frac{P_{OUT}}{P_{IN}}$ **OR** $A_P = A_V \times A_I$

$\beta_T = \beta_1 \times \beta_2$ **OR** $A_{VT} = A_{V1} \times A_{V2} \times A_{V3} \times \ldots A_{Vn}$

$P_{IN} = I^2 \times Z_{IN}$ **AND** $P_{OUT} = I^2 \times Z_{OUT}$

OSCILLATION FREQUENCY

$f_o = \frac{1}{2 \times \pi\sqrt{LC}}$ **OR** $f_o = \frac{1}{2 \times \pi\sqrt{6}RC}$

GAIN IN DECIBELS

$A_I = 20\log_{10}\frac{I_{OUT}}{I_{IN}}$

$A_V = 20\log_{10}\frac{V_{OUT}}{V_{IN}}$ **OR** $A_V = 20\log_{10}A_{VT}$

$A_P = 10\log_{10}\frac{P_{OUT}}{P_{IN}}$ **OR** $A_P = 10\log_{10}\frac{P_2}{P_1}$

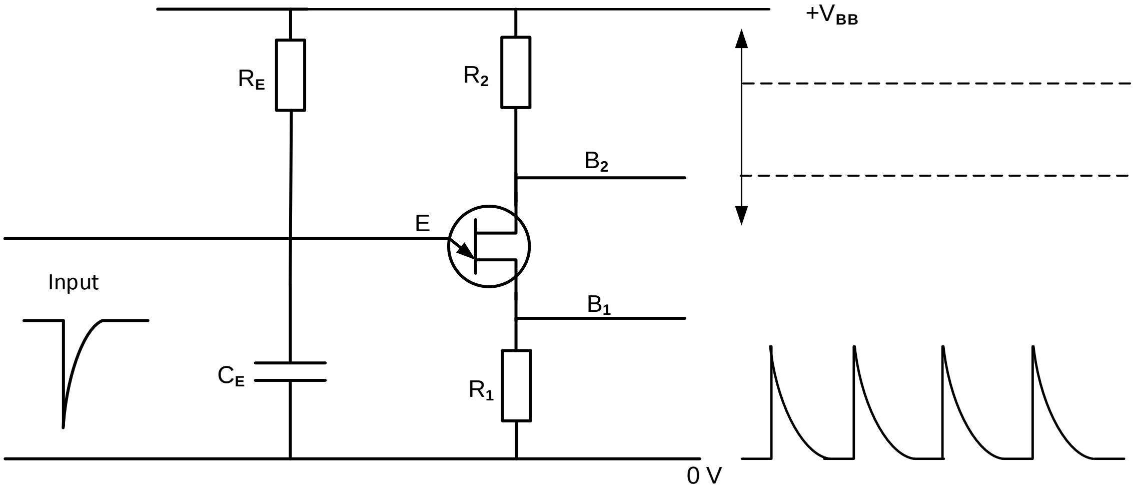
CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 4: SEMICONDUCTOR DEVICES

4.5.3



Transfer mark to
answer book

MOD

FIGURE 4.5.3 (3)

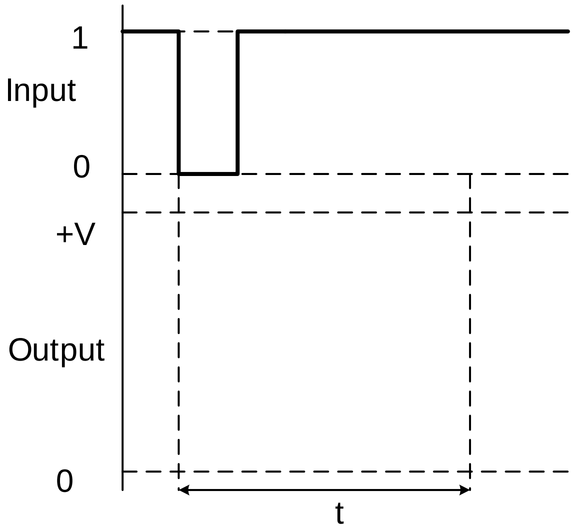
CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 5: SWITCHING CIRCUITS

5.3.3



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MOD

FIGURE 5.3.3 (3)

5.5.3

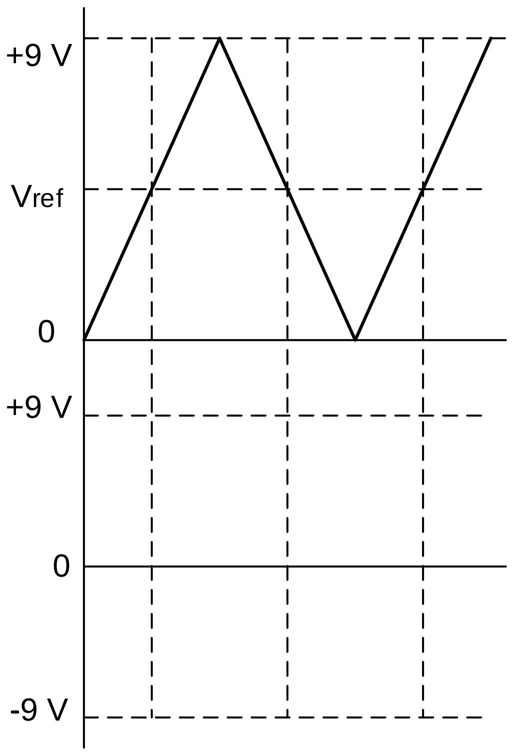

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FIGURE 5.5.3 (3)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.7.1

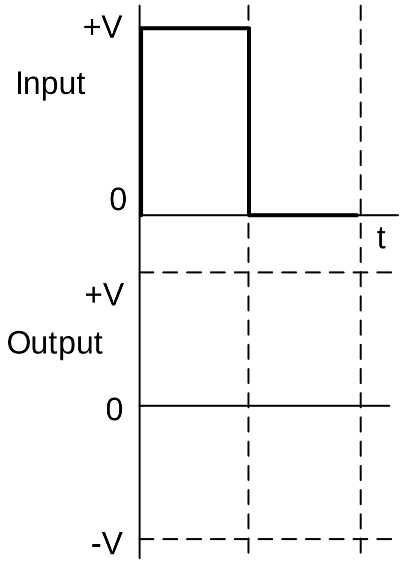

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FIGURE 5.7.1 (2)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

QUESTION 6: AMPLIFIERS

ANSWER SHEET

6.3.3

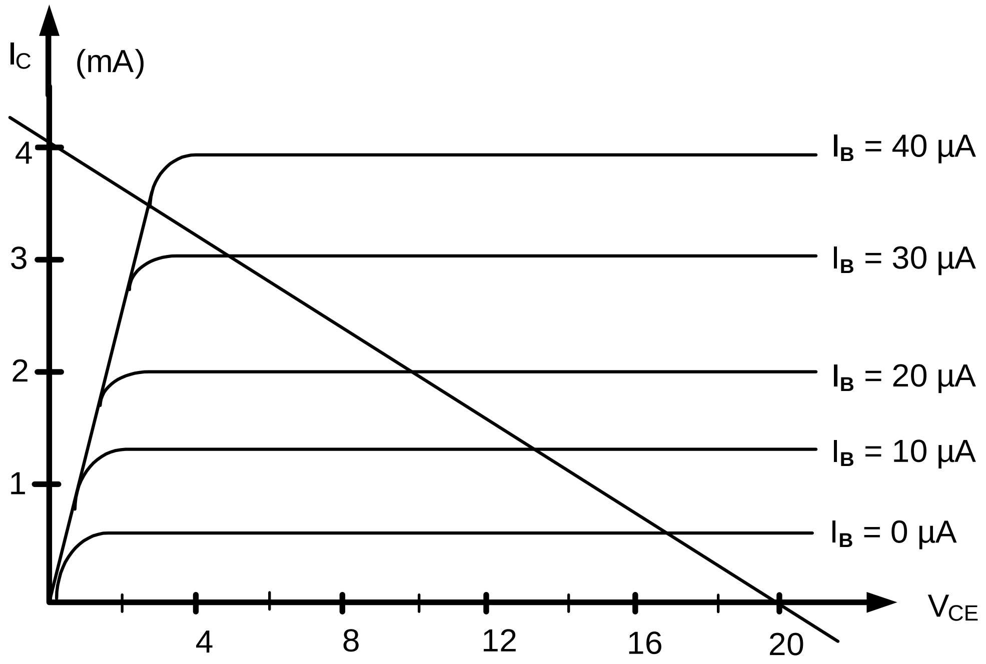

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FIGURE 6.3.3 (1)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

6.4.4

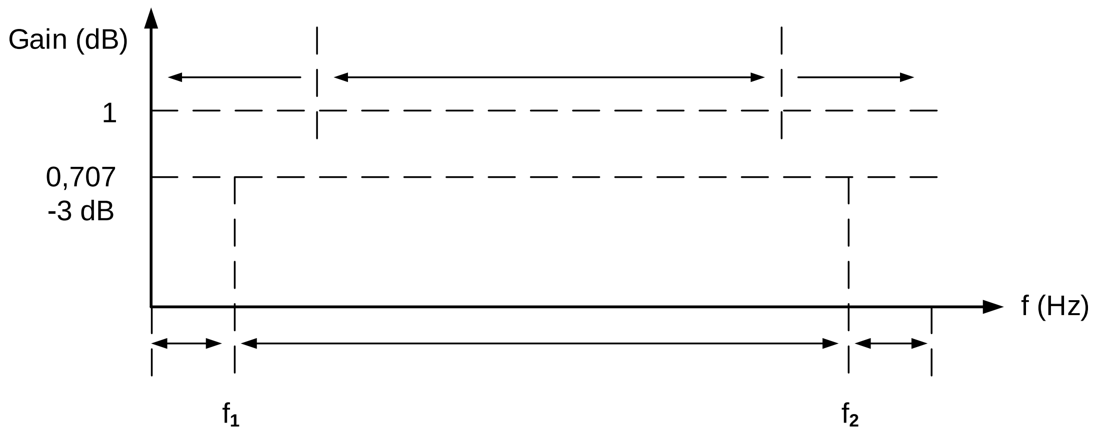

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FIGURE 6.4.4 (4)