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Department:
Basic Education
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SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: DIGITAL ELECTRONICS

MAY/JUNE 2024

MARKS: 200

TIME: 3 hours

**This question paper consists of 22 pages, a 1-page formula sheet
and an 8-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 3.3.3, 3.5.3 and 3.7.1
QUESTIONS 5.3, 5.4, 5.6, 5.7.1, 5.7.2, 5.8.1 and 5.10
QUESTIONS 6.9.2
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 In an op-amp bistable multivibrator circuit the op amp operates as a/an ...
A comparator.
B summing amplifier.
C differentiator.
D integrator. (1)
- 1.3 A/An ... changes its output state when a trigger pulse is received. It remains in that state for a time determined by the RC time constant. Thereafter it returns to its original state.
A astable multivibrator
B bistable multivibrator
C monostable multivibrator
D relaxation oscillator (1)
- 1.4 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)
- 1.5 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)
- 1.6 The 555 IC functions as a ... in an astable mode operation.
A voltage regulator
B frequency divider
C free running oscillator
D None of the above-mentioned (1)

- 1.7 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)
- 1.8 A ... output connects the transistor collector to the LED cathode.
- A sourcing
 - B draining
 - C absorbing
 - D sinking (1)
- 1.9 ONE method of displaying information in digital systems is through the use of a ...
- A keypad.
 - B light-emitting diode.
 - C light-dependent resistor.
 - D photo diode. (1)
- 1.10 An up/down counter is used as an application in ...
- A frequency dividers.
 - B mine-winding gears.
 - C CNC machines.
 - D lifts. (1)
- 1.11 Choose the correct JK input combinations that will produce a '1' (high) on the output of the JK flip-flop:
- A $J = 0$ and $K = 0$
 - B $J = 1$ and $K = 0$
 - C $J = 0$ and $K = 1$
 - D $J = 1$ and $K = 1$ (1)
- 1.12 Microcontrollers can be programmed in various ways. One of the methods to program a microcontroller is to use a flow chart. A flow chart is defined as a ...
- A block diagram with instructions in the order of execution.
 - B block diagram of the operation of the microcontroller.
 - C block diagram of the construction of the microcontroller.
 - D range of data that shows the flow of data to the microcontroller. (1)

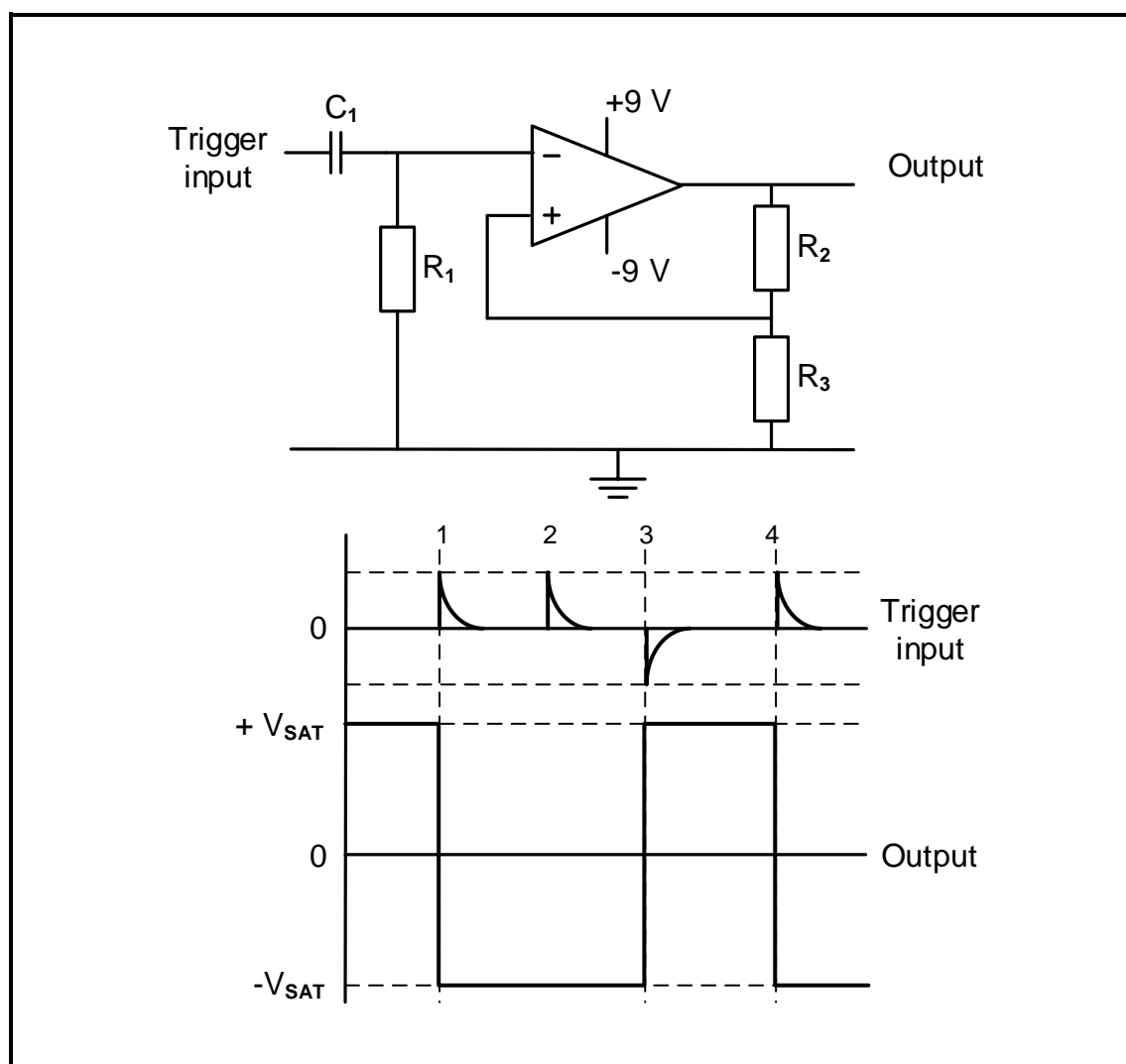
- 1.13 With reference to microcontrollers, the term ROM means ...
- A read-only memory.
 - B read-output memory.
 - C read-onset memory.
 - D random-only memory.
- (1)
- 1.14 A device that converts parallel data from the host processor into a serial data stream is known as a/an ...
- A universal asynchronous receiver transmitter (UART).
 - B central processing unit (CPU).
 - C serial peripheral interface (SPI).
 - D inter-integrated circuit (I²C).
- (1)
- 1.15 The process that allows a task to be repeated again and again is called
- A debugging.
 - B data flow lines.
 - C looping.
 - D a flow diagram
- (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: SWITCHING CIRCUITS

- 3.1 State ONE effect of switch bounce in electronic circuits. (1)
- 3.2 FIGURE 3.2 below shows the basic circuit diagram of an op-amp bistable multivibrator with its input and output waveforms. Answer the questions that follow.

**FIGURE 3.2: BISTABLE MULTIVIBRATOR**

- 3.2.1 Explain feedback with reference to the circuit. (2)
- 3.2.2 Explain how the capacitor reacts when a positive trigger pulse is applied to the input of the circuit. (2)
- 3.2.3 Describe the operation of the circuit when a negative trigger pulse is applied to the input. (3)
- 3.2.4 Explain why the output does not change when trigger pulse 2 is applied. (3)

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

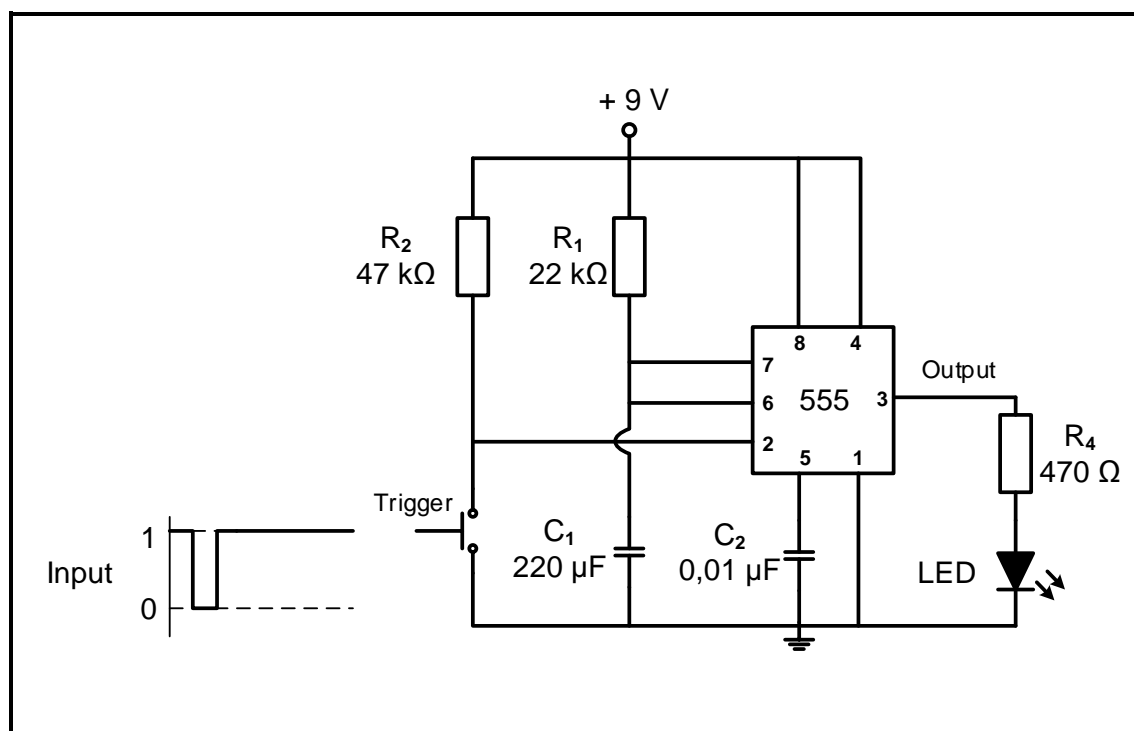


FIGURE 3.3: MULTIVIBRATOR CIRCUIT

- 3.3.1 Identify the multivibrator circuit in FIGURE 3.3. (1)
- 3.3.2 State the function of resistor R_2 in this circuit. (2)
- 3.3.3 Draw the output of the circuit for the given input on the ANSWER SHEET for QUESTION 3.3.3. (3)
- 3.3.4 Determine the voltage at which the circuit will reset to its resting state. Give a reason for the answer. (2)

3.4 Refer to FIGURE 3.4 below and answer the questions that follow.

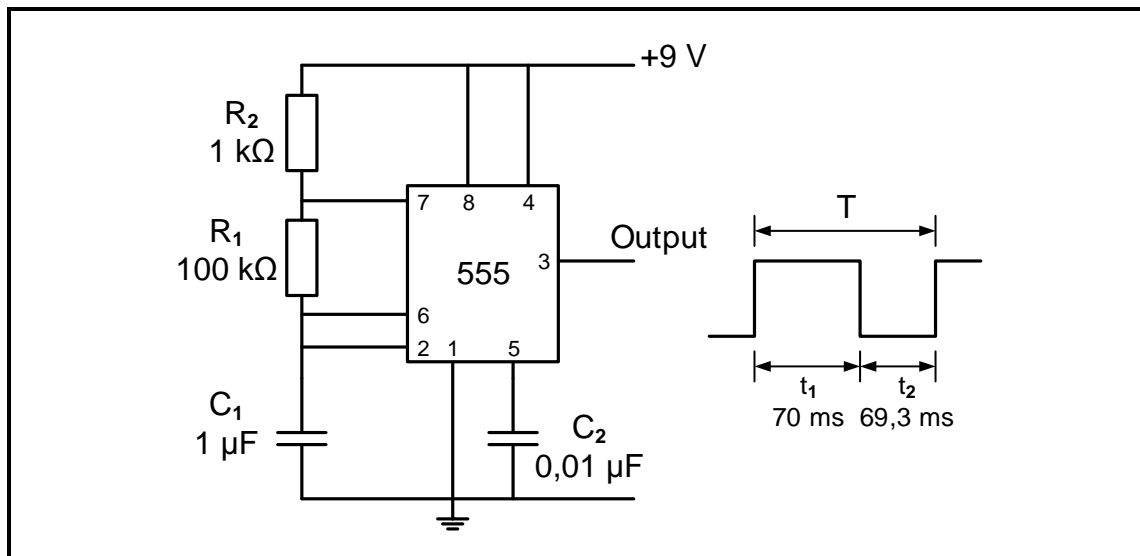


FIGURE 3.4: ASTABLE MULTIVIBRATOR

- 3.4.1 Explain why the output of the circuit changes state continually. (4)
- 3.4.2 Explain why t_1 and t_2 are not equal. (2)
- 3.4.3 Calculate the frequency of the output. (3)

3.5 FIGURE 3.5 below shows an op-amp as comparator. Answer the questions that follow.

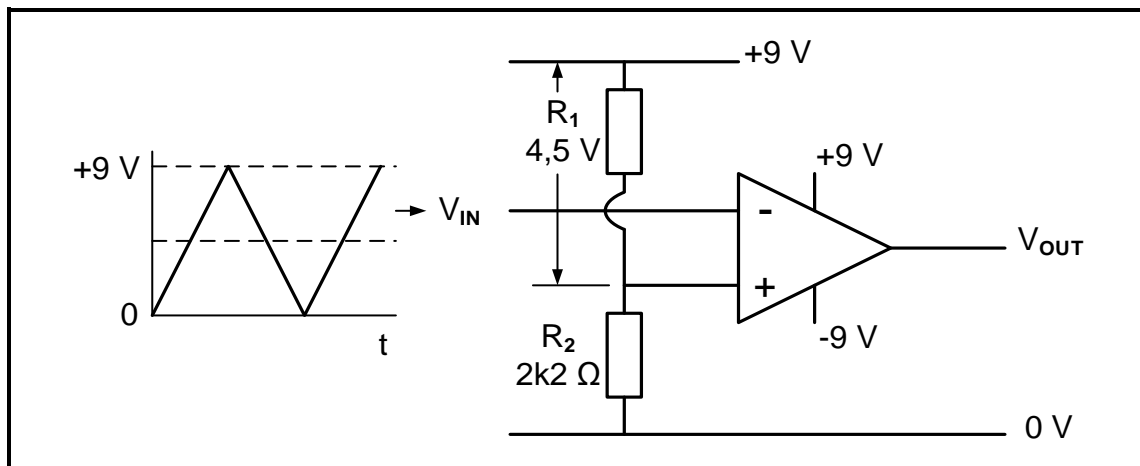


FIGURE 3.5: OP-AMP AS COMPARATOR

- 3.5.1 Determine the value of the reference voltage. (1)
- 3.5.2 Determine the resistance of R_1 . Motivate your answer. (2)
- 3.5.3 Draw the output voltage for the given input on the ANSWER SHEET for QUESTION 3.5.3. (3)
- 3.5.4 Explain how an increase in the value of R_1 will affect the voltage across R_2 . (2)

3.6 FIGURE 3.6 below shows the circuit diagram of an inverting summing amplifier.

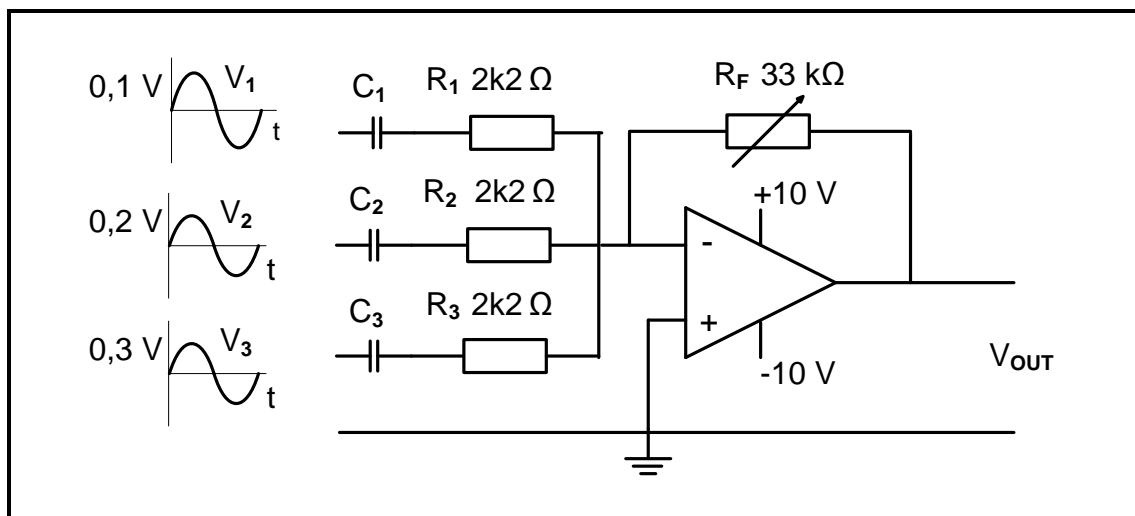


FIGURE 3.6: SUMMING AMPLIFIER

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

3.6.2 Given:

$$\begin{aligned}
 R_1 = R_2 = R_3 &= 2,2 \text{ k}\Omega \\
 R_F &= 33 \text{ k}\Omega \\
 V_{CC} &= \pm 10 \text{ V} \\
 V_1 &= 0,1 \text{ V} \\
 V_2 &= 0,2 \text{ V} \\
 V_3 &= 0,3 \text{ V}
 \end{aligned}$$

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

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

3.7 Refer to FIGURE 3.7 below and answer the questions that follow.

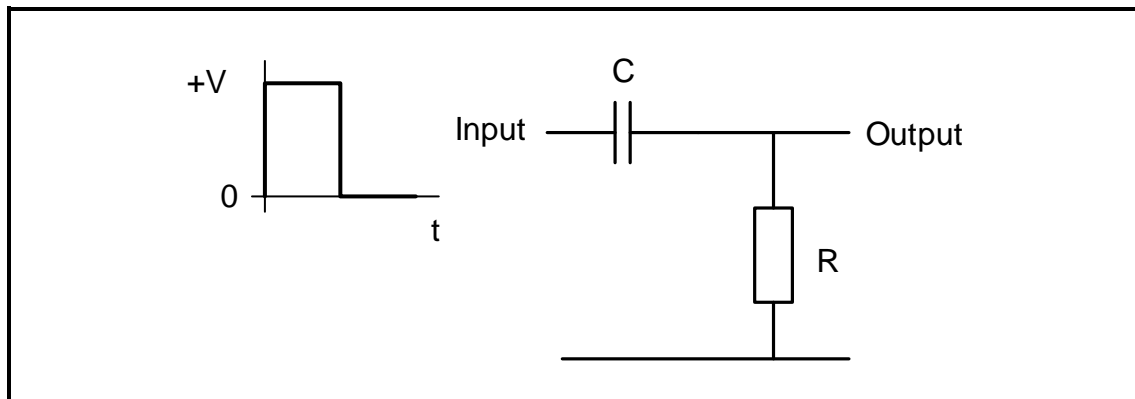
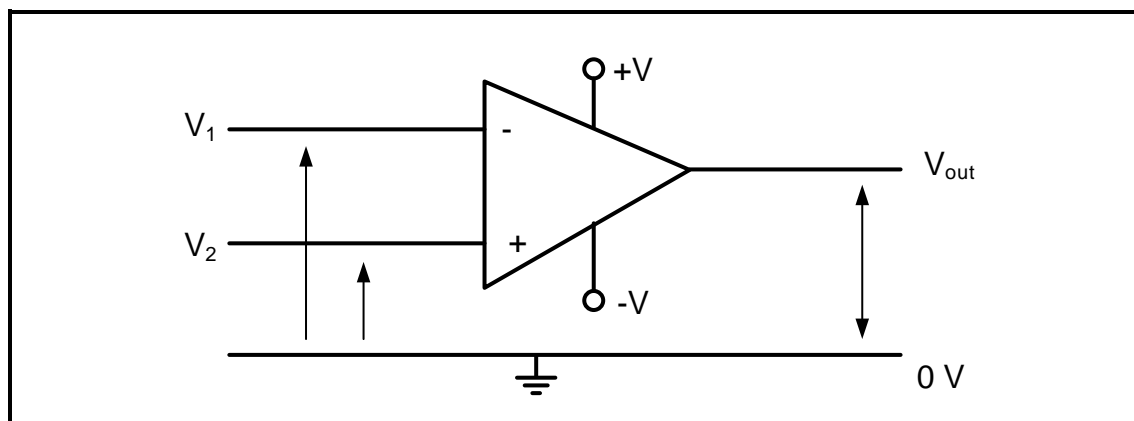


FIGURE 3.7: PASSIVE RC DIFFERENTIATOR

- 3.7.1 Draw the output of the circuit for the given input on the ANSWER SHEET for QUESTION 3.7.1. (2)
- 3.7.2 Explain the operation of the circuit during the first positive square wave. (3)
- 3.7.3 Illustrate, by means of a basic circuit diagram, how the circuit above can be changed to a passive integrator. (2)
- [50]**

QUESTION 4: SEMICONDUCTOR DEVICES

- 4.1 Determine the output state of the op amp in FIGURE 4.1 below for the conditions in TABLE 4.1 when V_1 and V_2 are in phase.

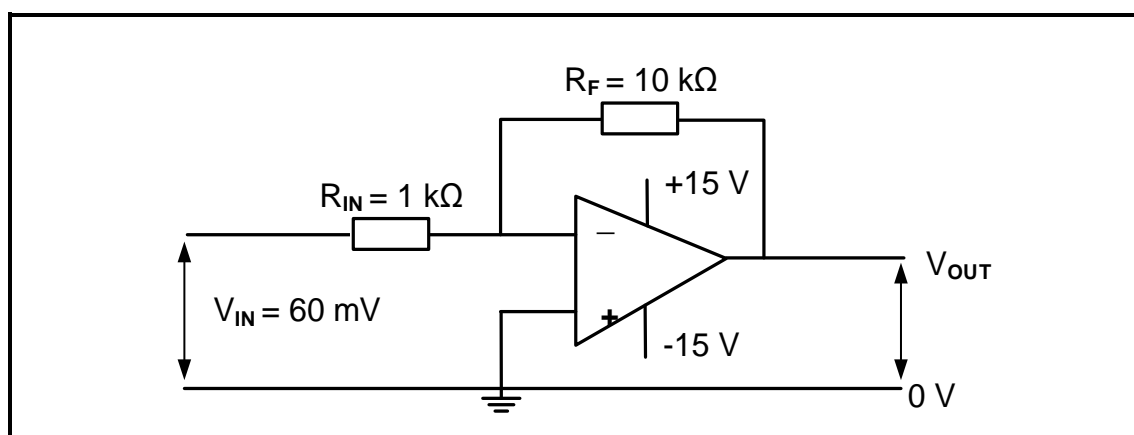
**FIGURE 4.1: OPERATIONAL AMPLIFIER**

	V_{IN}	V_{OUT}
4.1.1	If $V_1 < V_2$	V_{OUT} will be ...
4.1.2	If $V_1 = V_2$	V_{OUT} will be ...

TABLE 4.1

(2)

- 4.2 Study FIGURE 4.2 below and answer the questions that follow.

**FIGURE 4.2: INVERTING OPERATIONAL AMPLIFIER**

- 4.2.1 Explain why op amps are not frequently used in open-loop mode. (2)
- 4.2.2 Explain the term *bandwidth* as one of the characteristics of operational amplifiers. (2)
- 4.2.3 Calculate the output voltage. (3)

- 4.3 Refer to FIGURE 4.3 below and calculate the feedback resistance (R_F) that is needed if the input resistance is $2\text{ k}\Omega$ when the op amp is supplied with an input voltage of $0,5\text{ V}$ and produces an output voltage of 4 V .

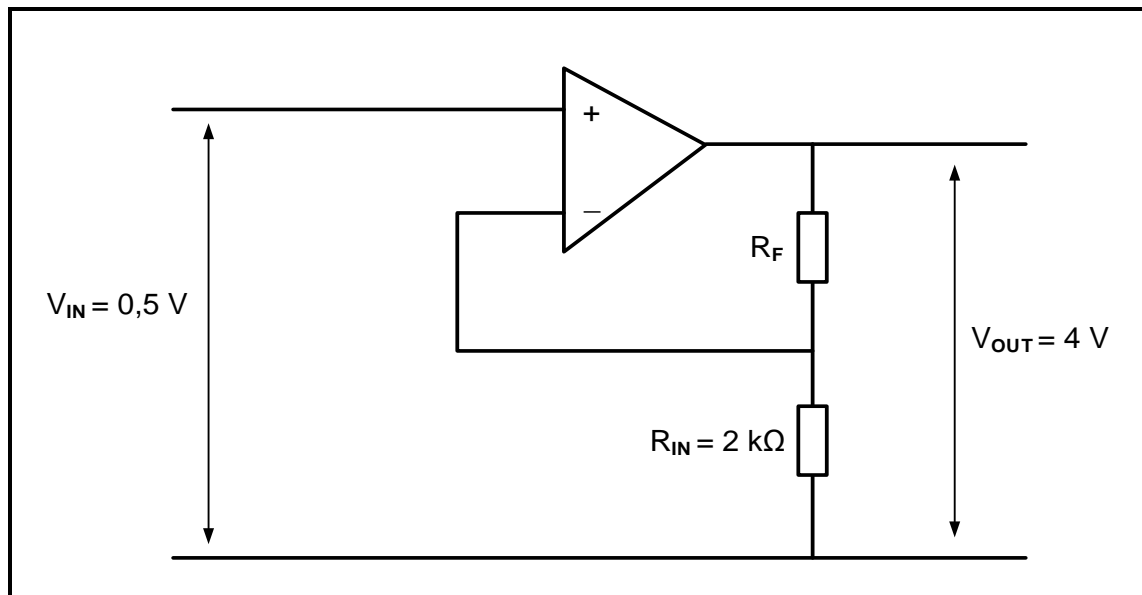


FIGURE 4.3: OPERATIONAL AMPLIFIER

Given:

$$V_{IN} = 0,5\text{ V}$$

$$V_{OUT} = 4\text{ V}$$

$$R_{IN} = 2\text{ k}\Omega$$

(3)

4.4 Refer to FIGURE 4.4 below and answer the questions that follow.

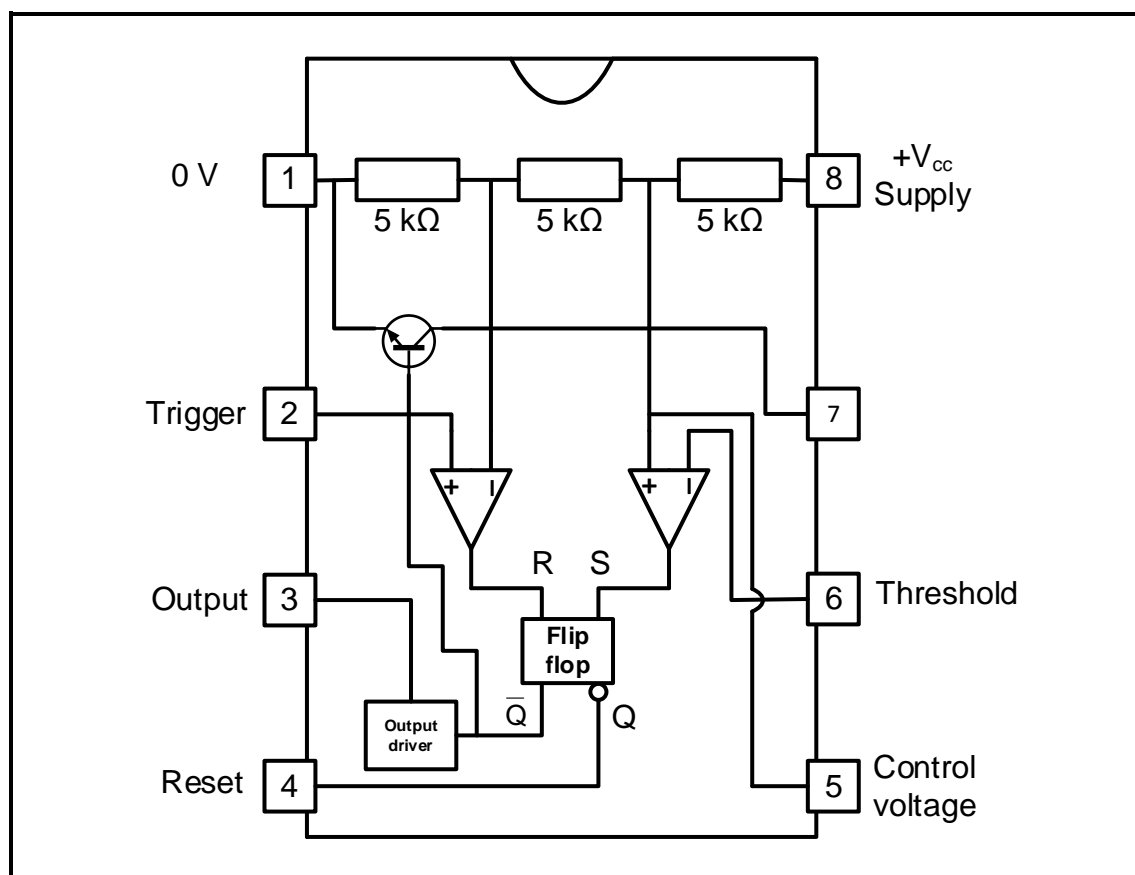
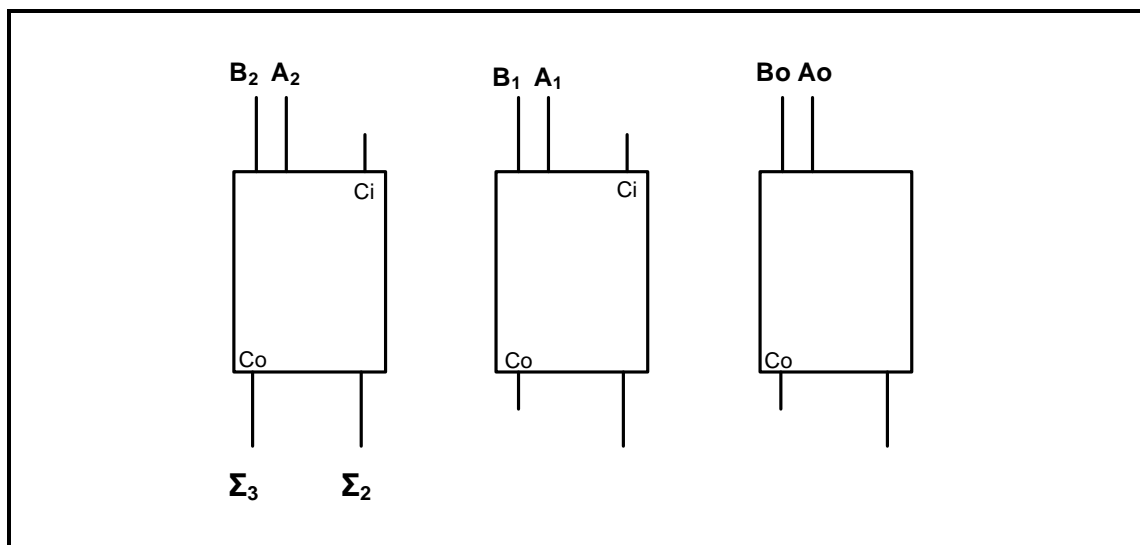


FIGURE 4.4: 555 IC

- 4.4.1 Label pin 7. (1)
- 4.4.2 Name ONE application of a 555 IC when used in monostable mode. (1)
- 4.4.3 Briefly describe the function of pin 4. (2)
- 4.4.4 Name TWO modes of operation for the 555 IC. (2)
- 4.4.5 Explain the function of the threshold input on a 555 IC. (2)
- [20]**

QUESTION 5: DIGITAL AND SEQUENTIAL DEVICES

- 5.1 Explain *polarisation* when used in the operation of a liquid crystal display (LCD.) (3)
- 5.2 Explain the difference between *common anode* and *common cathode* in a LED seven-segment display. (4)
- 5.3 FIGURE 5.3 below represents an incomplete block diagram of a three-bit parallel adder. Complete and label the diagram of this adder on the ANSWER SHEET for QUESTION 5.3.

**FIGURE 5.3**

(7)

- 5.4 Refer to FIGURE 5.4 below and determine the binary code at the output when switch 7 is pressed. Write the answers on ANSWER SHEET 5.4.1.

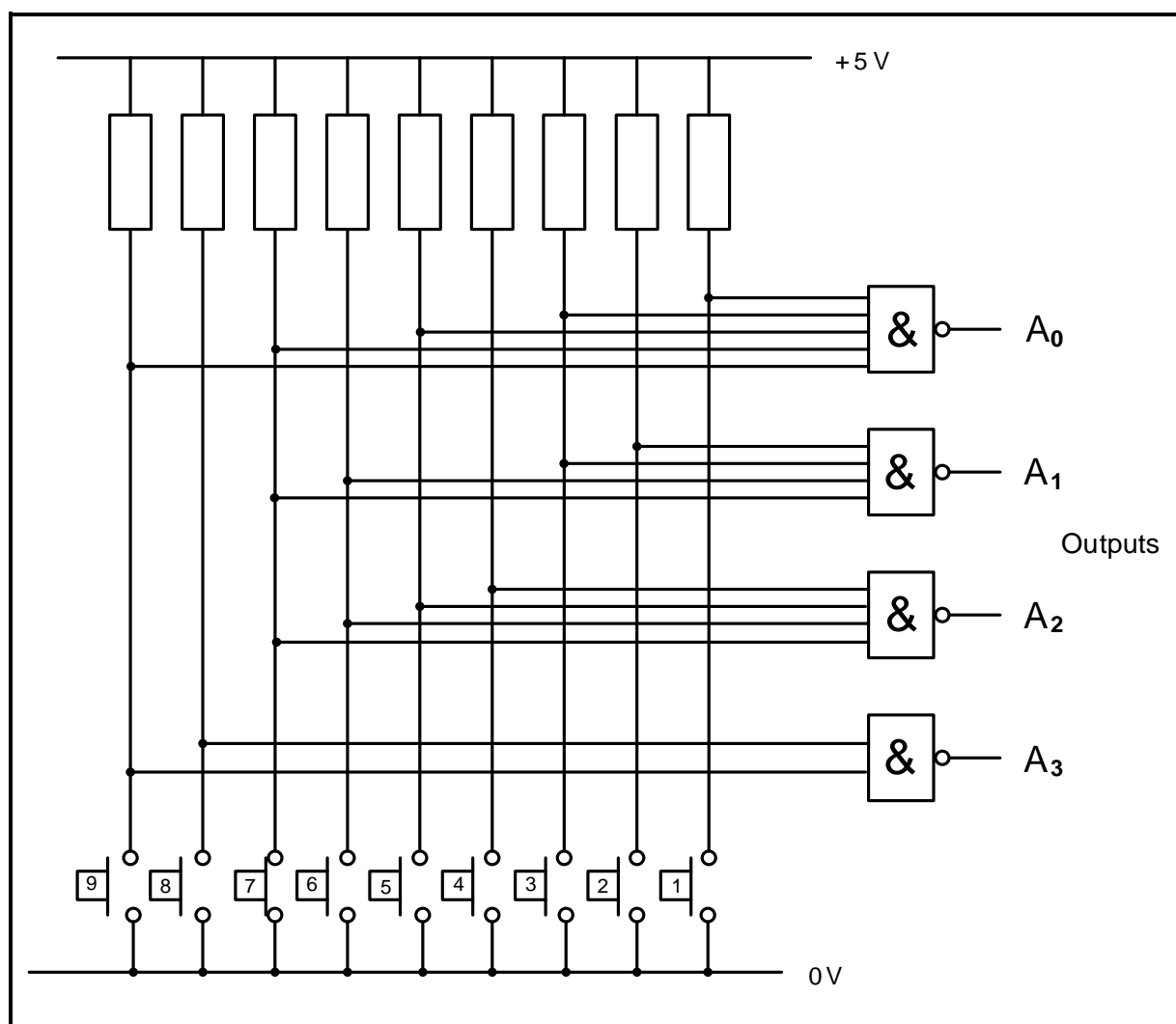


FIGURE 5.4

(4)

- 5.5 Explain the term *pulse triggering* as used in flip-flops.

(2)

- 5.6 Refer to FIGURE 5.6 below of a full adder and complete the logic circuit on ANSWER SHEET 5.6 using two half adders and an OR gate.

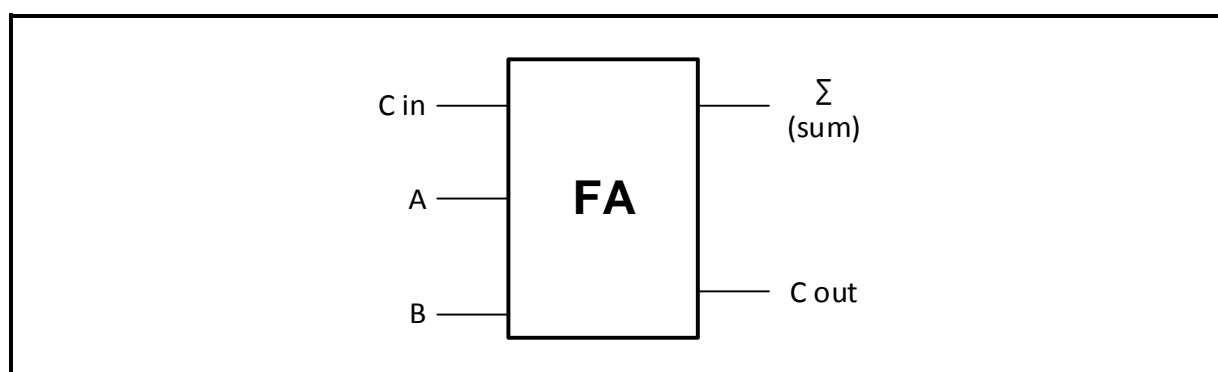


FIGURE 5.6: FULL ADDER

(6)

- 5.7 Refer to FIGURE 5.7 of a clocked JK-type flip-flop below and answer the questions that follow.

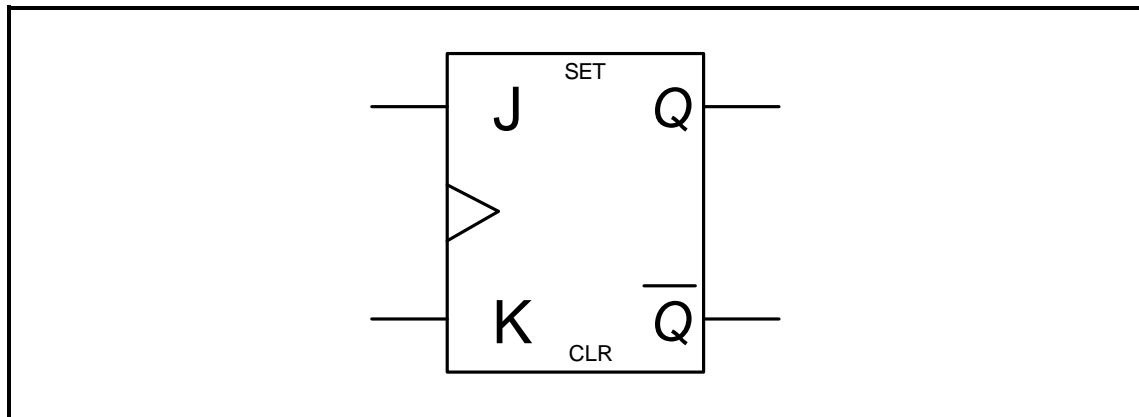


FIGURE 5.7: JK-TYPE FLIP-FLOP

- 5.7.1 Complete the logic circuit of this flip-flop on ANSWER SHEET 5.7.1.

(6)

- 5.7.2 Complete the output waveforms of this flip-flop on ANSWER SHEET 5.7.2. Assume that Q starts LOW.

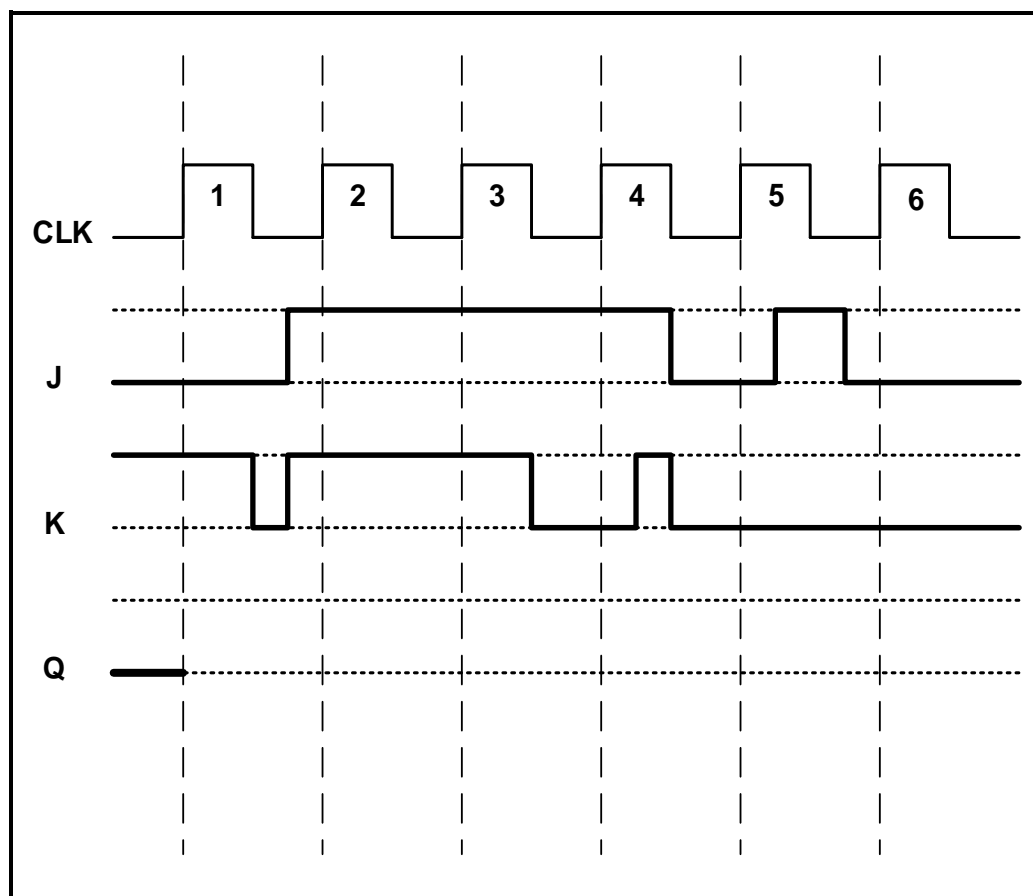


FIGURE 5.7.2

(6)

- 5.8 FIGURE 5.8 below shows a three-stage ripple counter and answer the questions that follow.

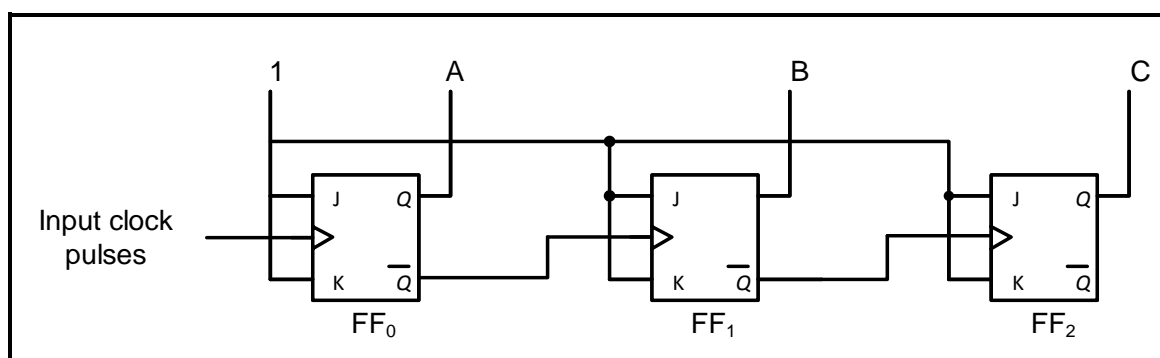


FIGURE 5.8 THREE-STAGE RIPPLE COUNTER

- 5.8.1 Complete the timing diagrams for this counter on ANSWER SHEET 5.8.1.

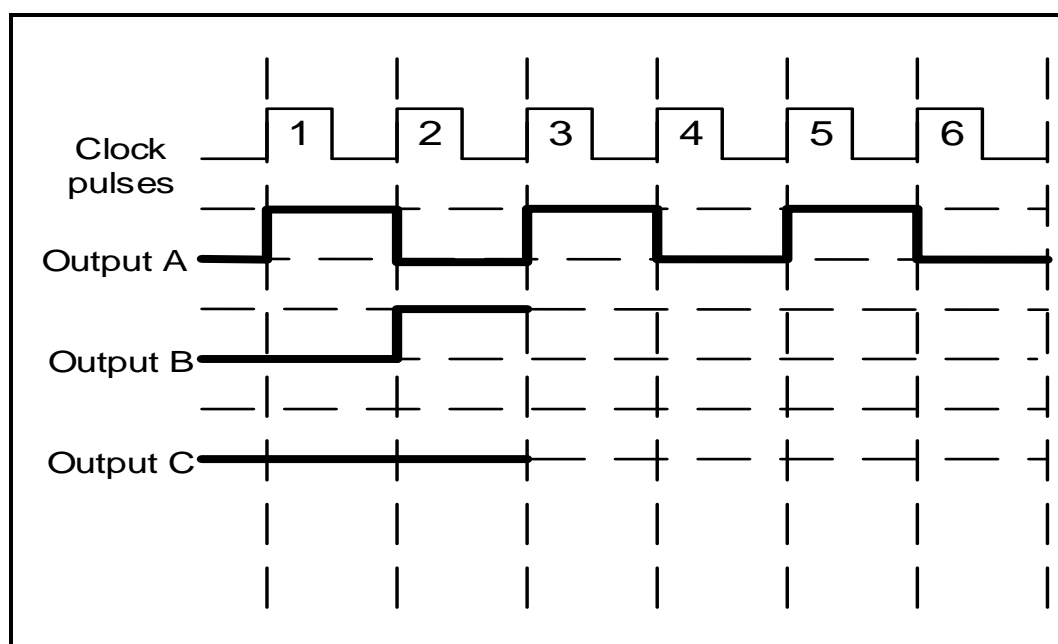


FIGURE 5.8.1

(8)

- 5.8.2 State whether the circuit in FIGURE 5.8 is synchronous or asynchronous. (1)

- 5.9 State a disadvantage of the up/down counter. (1)

- 5.10 Refer to shift registers and complete the sketch of a four-bit serial-in: parallel-out shift register using flip-flops on the ANSWER SHEET for QUESTION 5.10 and show ALL the inputs and outputs.

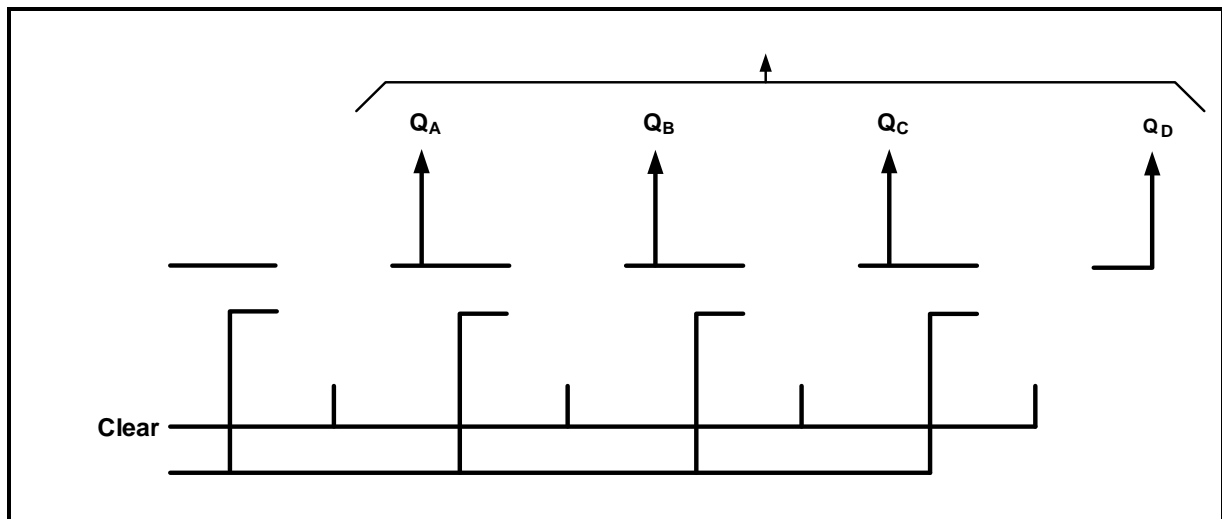
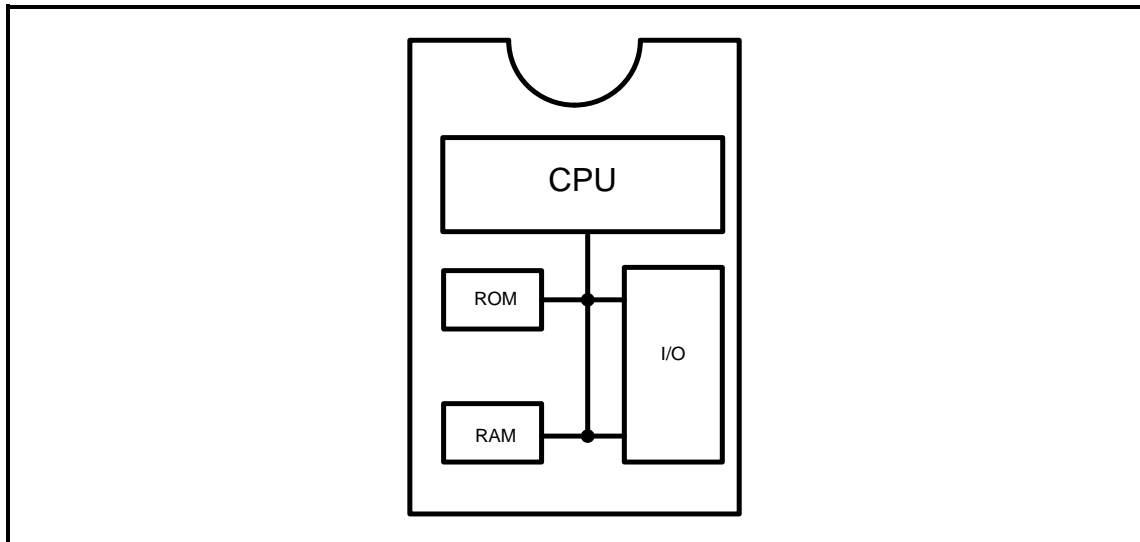


FIGURE 5.10

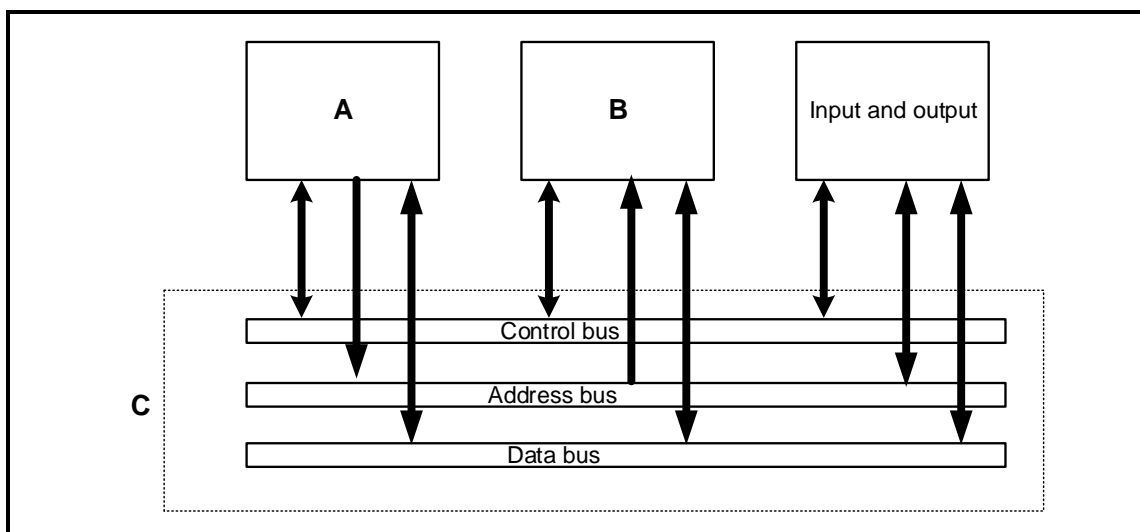
(7)
[55]

QUESTION 6: MICROCONTROLLERS

- 6.1 State TWO uses of a microcontroller as used in commercial devices. (2)
- 6.2 Refer to the block diagram in FIGURE 6.2 below and answer the questions that follow.

**FIGURE 6.2**

- 6.2.1 Identify the block diagram in FIGURE 6.2 above. (1)
- 6.2.2 State the basic function that the random access memory (RAM) performs. (2)
- 6.2.3 Write out the abbreviation CPU in full. (1)
- 6.3 Refer to FIGURE 6.3 below and answer the questions that follow.

**FIGURE 6.3**

- 6.3.1 Label **A**, **B** and **C**. (3)

6.3.2 State the function of the following:

(a) Control bus (2)

(b) Data bus (3)

6.3.3 Define the term *interface*. (2)

6.4 Refer to the block diagram in FIGURE 6.4 below of a CPU with registers and answer the questions that follow.

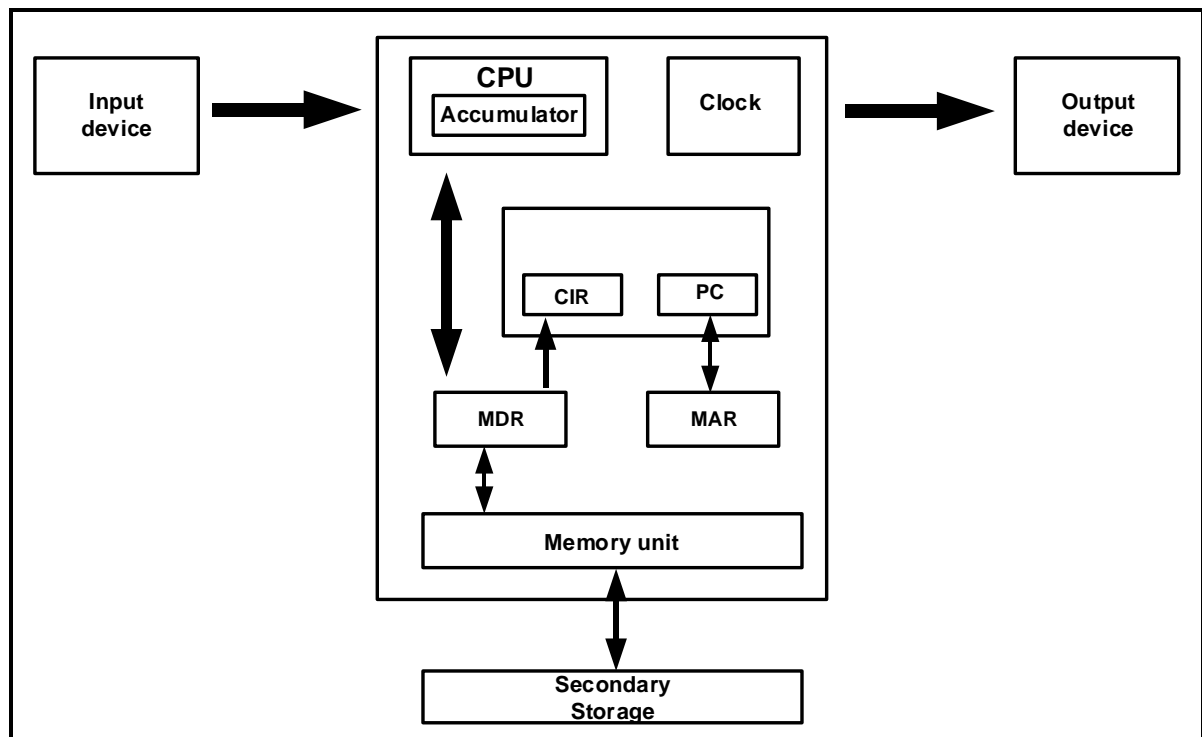


FIGURE 6.4

6.4.1 Explain how the data is processed once it enters the current instruction register (CIR) from the MDR. (3)

6.4.2 Describe the function of the accumulator. (2)

6.4.3 State the TWO types of registers that are used within the CPU. (2)

- 6.5 Refer to communication protocols and answer the questions that follow.
- 6.5.1 Define *communication protocols*. (2)
- 6.5.2 Explain the differences between *simplex communication* and *half-duplex communication*. (4)
- 6.6 Refer to serial communication interface and answer the questions that follow.
- 6.6.1 Explain the mode of operation of the serial peripheral interface (SPI). (3)
- 6.6.2 State TWO disadvantages of SPI. (2)
- 6.7 Refer to the RS-485 communication protocol and answer the following questions.
- 6.7.1 State the maximum cable length. (1)
- 6.7.2 State the mode of operation. (1)
- 6.7.3 Name TWO devices that can be used with the RS-485 interface. (2)
- 6.8 Refer to software of microcontrollers and describe an instruction cycle. (3)

- 6.9 Refer to the incomplete flow chart below of a monostable device which has only one stable state. It changes state when it is triggered by an input, and stays in that state for 5 seconds and then returns to its original state.

Draw a complete flow chart for this device on the ANSWER SHEET for QUESTION 6.9.

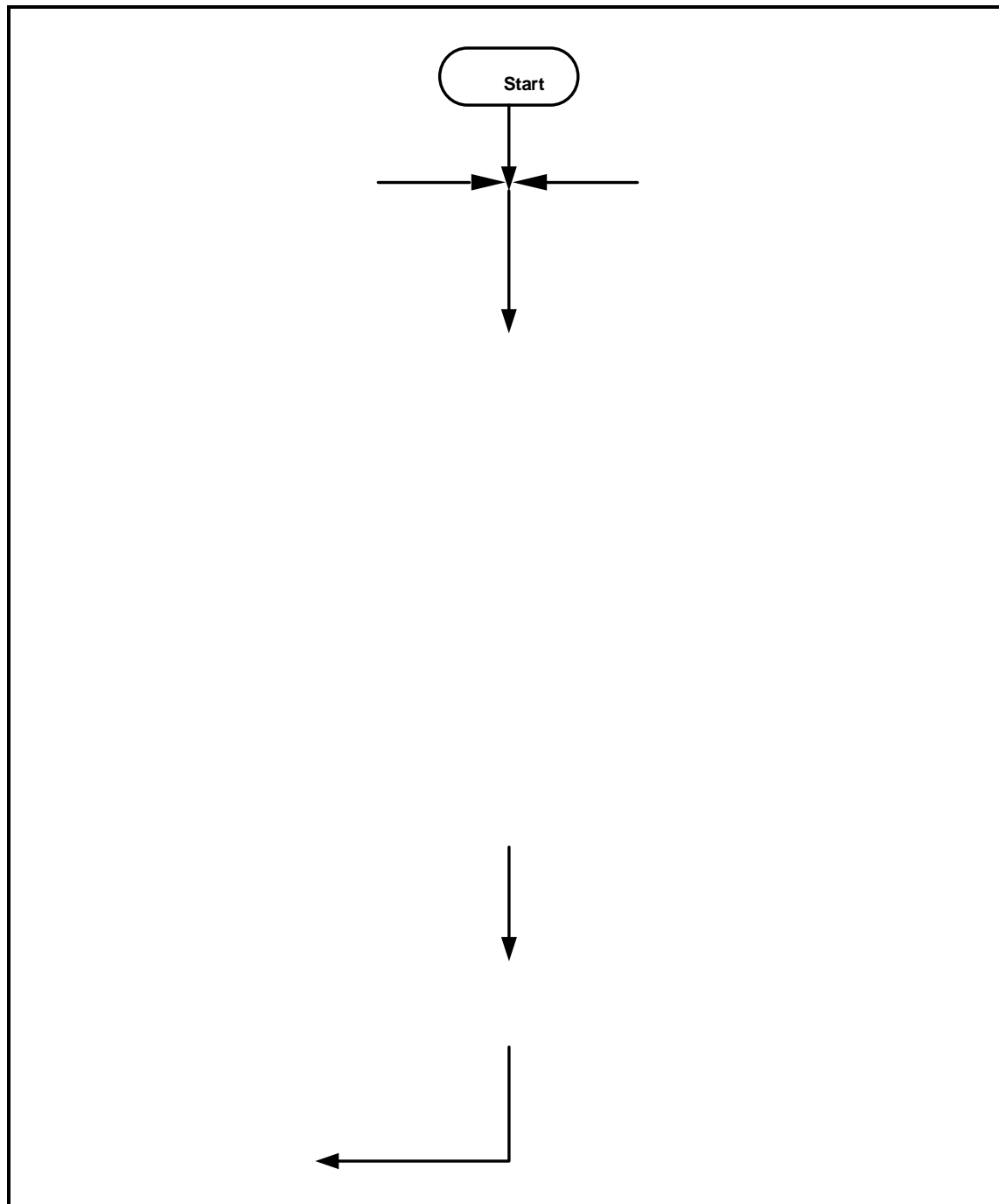


FIGURE 6.9

(9)
[50]

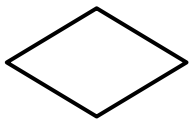
TOTAL: 200

FORMULA SHEET**SEMICONDUCTOR DEVICES**

$$\text{Gain } A_V = \frac{V_{\text{OUT}}}{V_{\text{IN}}} = - \left(\frac{R_F}{R_{\text{IN}}} \right) \quad \text{OR} \quad A_V = 1 + \frac{R_F}{R_{\text{IN}}}$$

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

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

FLOW CHART SYMBOLS IN PICAXE**Process****Decision****Terminator****Data****SWITCHING CIRCUITS**

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

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

$$V_{\text{OUT}} = -(V_1 + V_2 + \dots V_N)$$

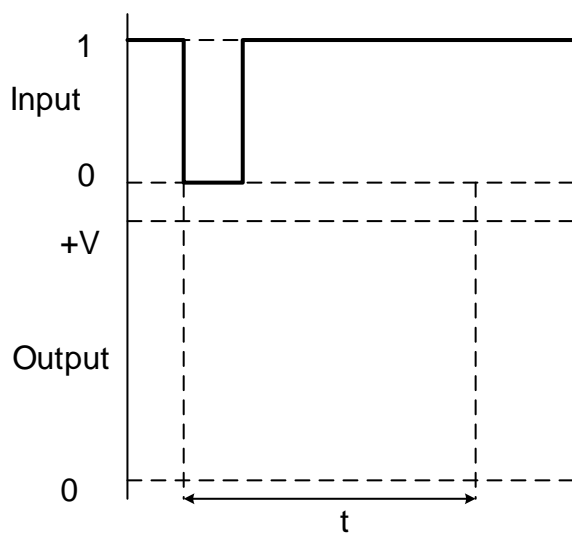
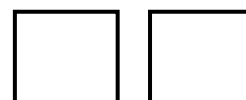
$$F = \frac{1}{T}$$

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ANSWER SHEET**QUESTION 3: SWITCHING CIRCUITS**

3.3.3

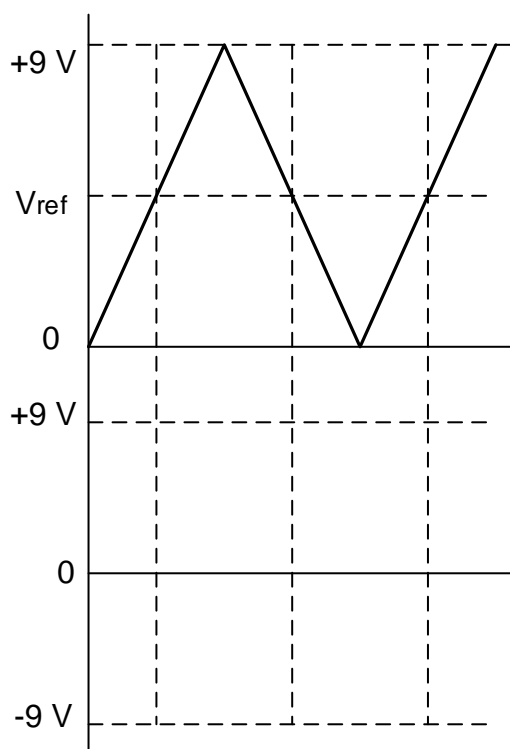
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FIGURE 3.3.3

(3)

3.5.3

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FIGURE 3.5.3

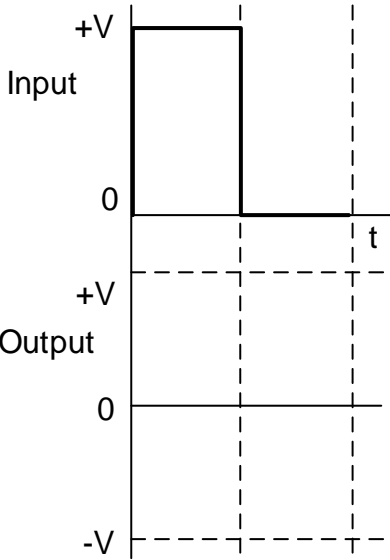
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ANSWER SHEET

3.7.1



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FIGURE 3.7.1

(2)

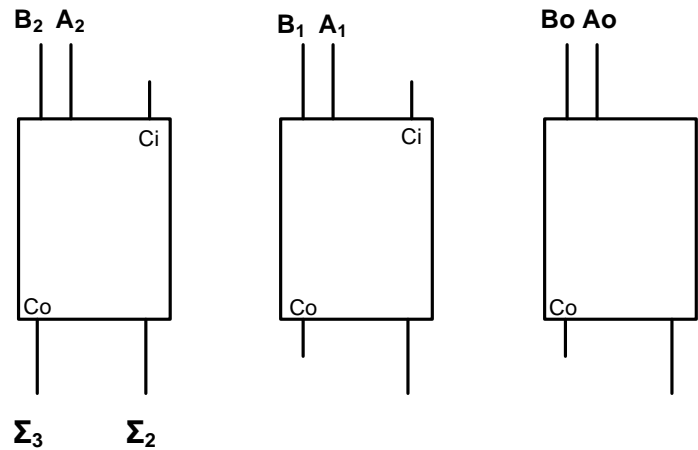
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ANSWER SHEET

QUESTION 5: DIGITAL AND SEQUENTIAL DEVICES

5.3



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FIGURE 5.3

(7)

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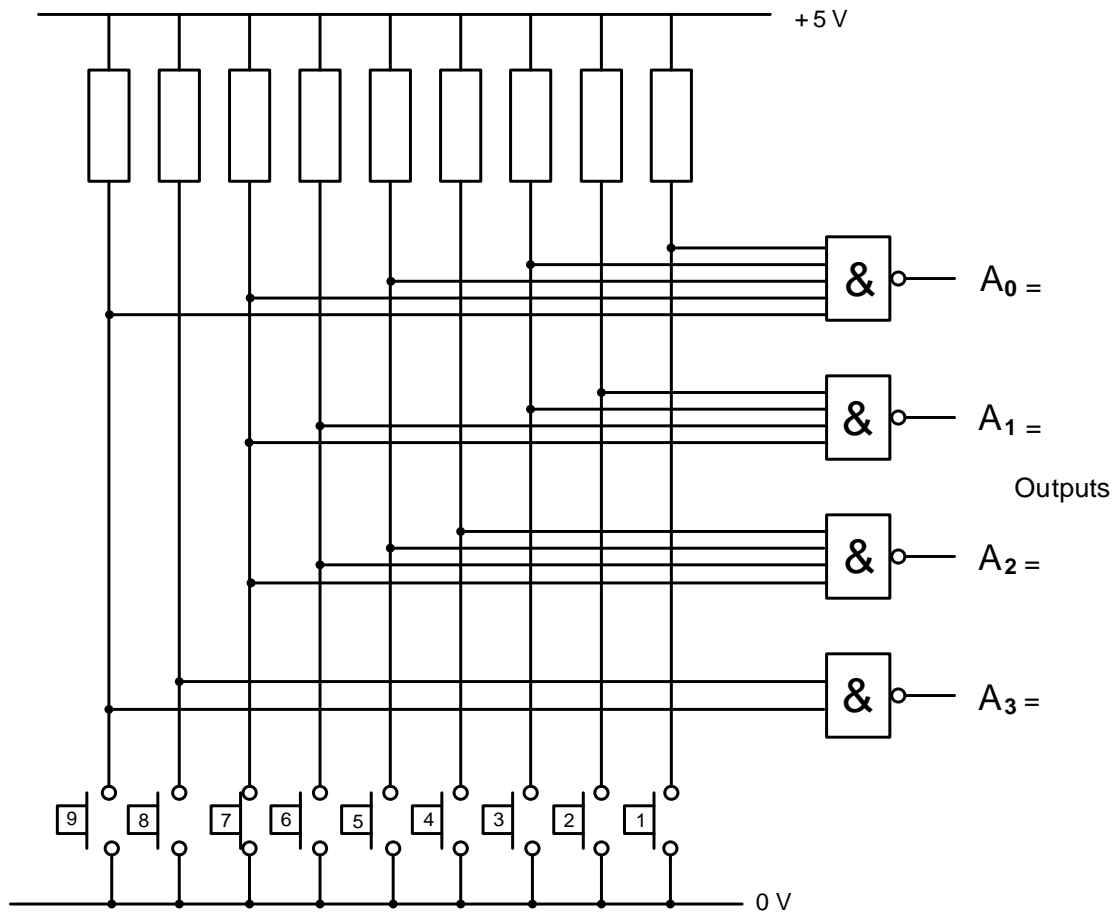
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ANSWER SHEET

5.4

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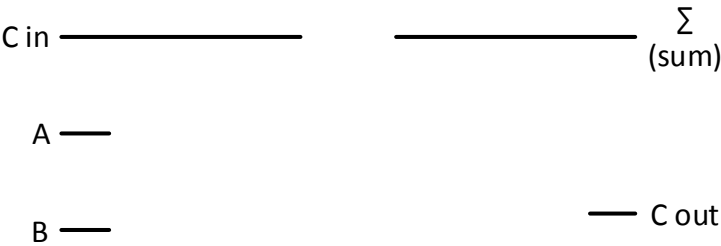
FIGURE 5.4**(4)**

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ANSWER SHEET

5.6



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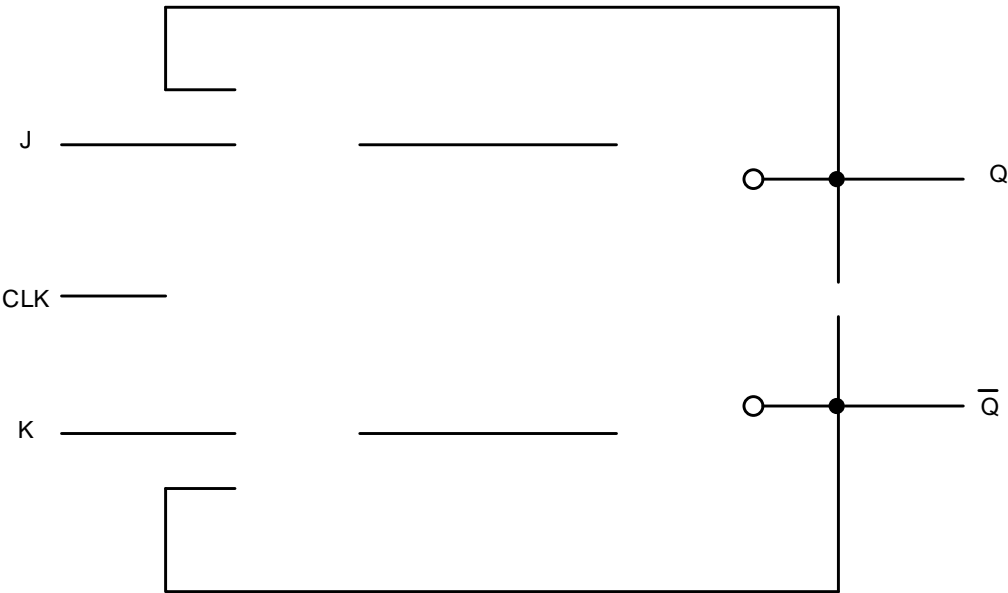
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MOD

FIGURE 5.6

(6)

5.7.1



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FIGURE 5.7.1

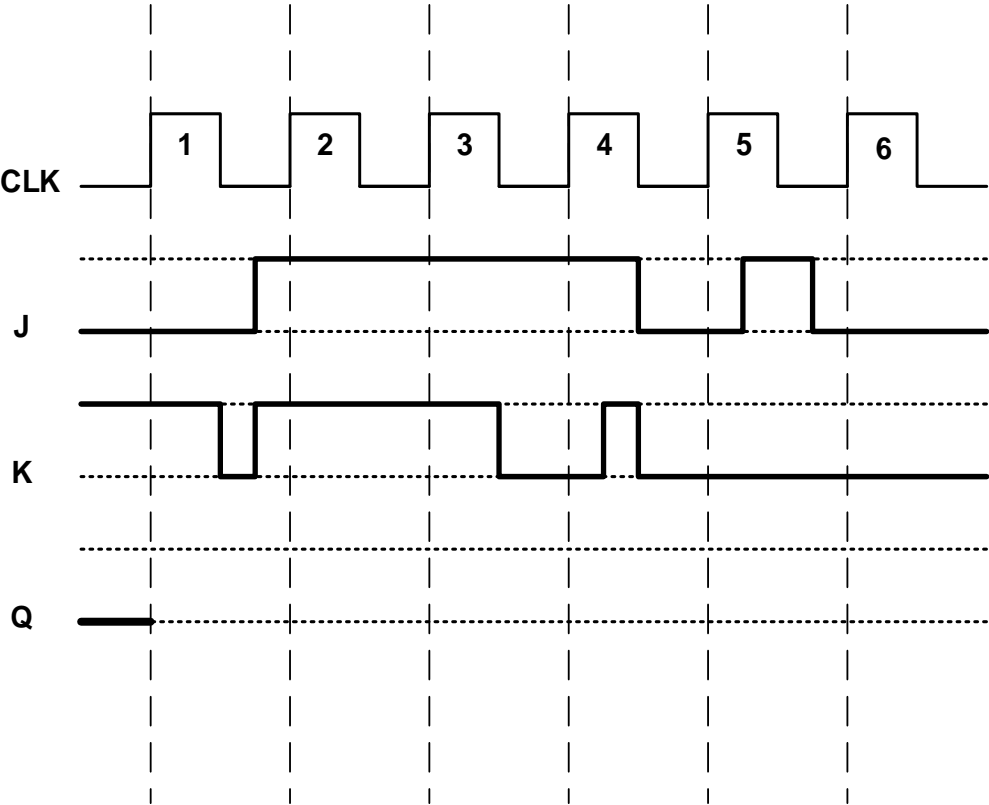
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ANSWER SHEET

5.7.2



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MOD

FIGURE 5.7.2

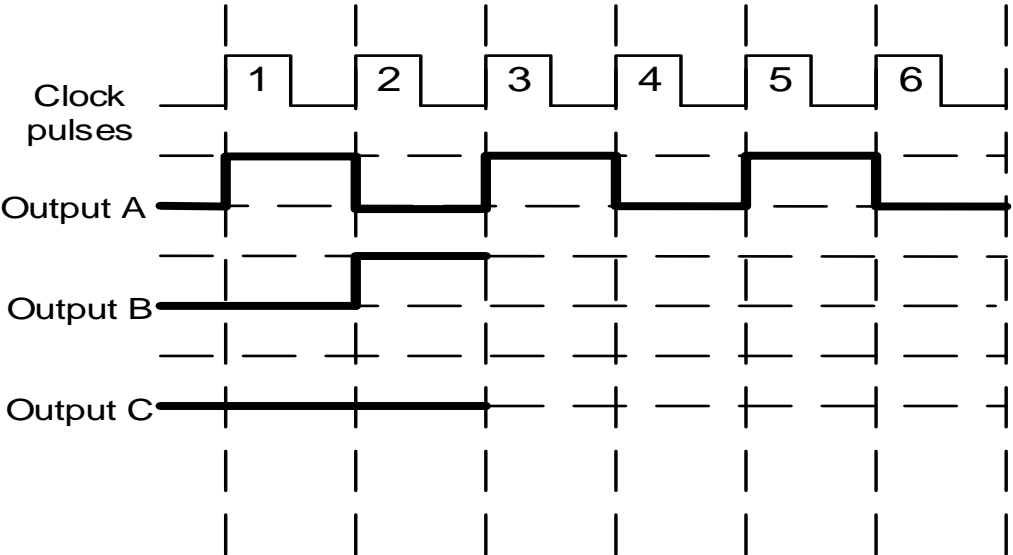
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CENTRE NUMBER:

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ANSWER SHEET

5.8.1



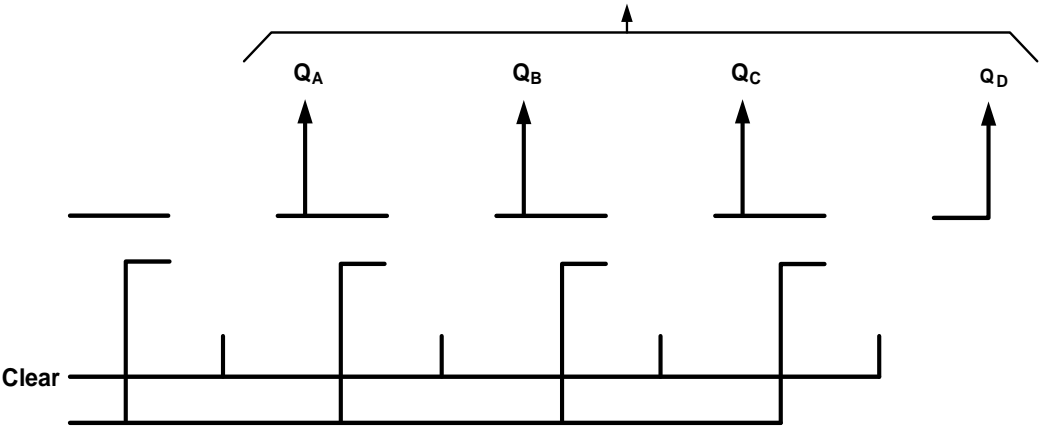
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FIGURE 5.8.1

(8)

5.10



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FIGURE 5.10

(7)

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QUESTION 6: MICROCONTROLLERS

6.9.2

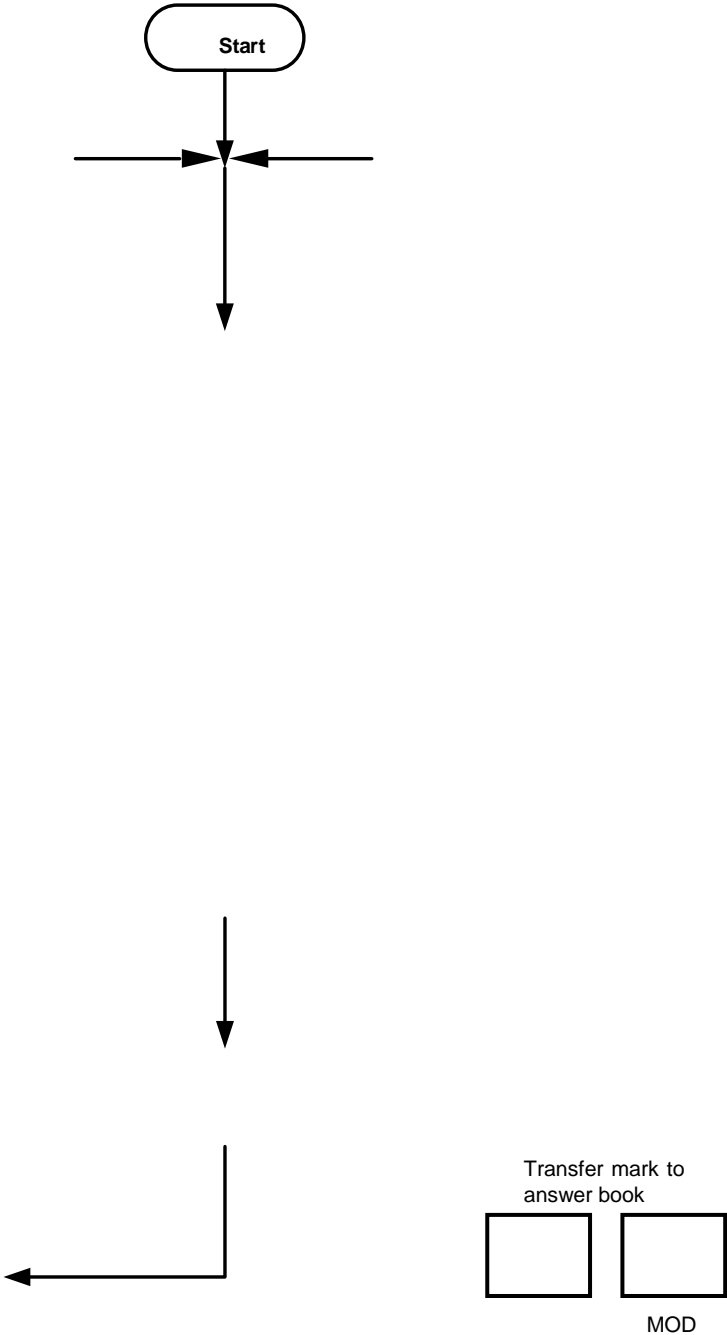


FIGURE 6.9