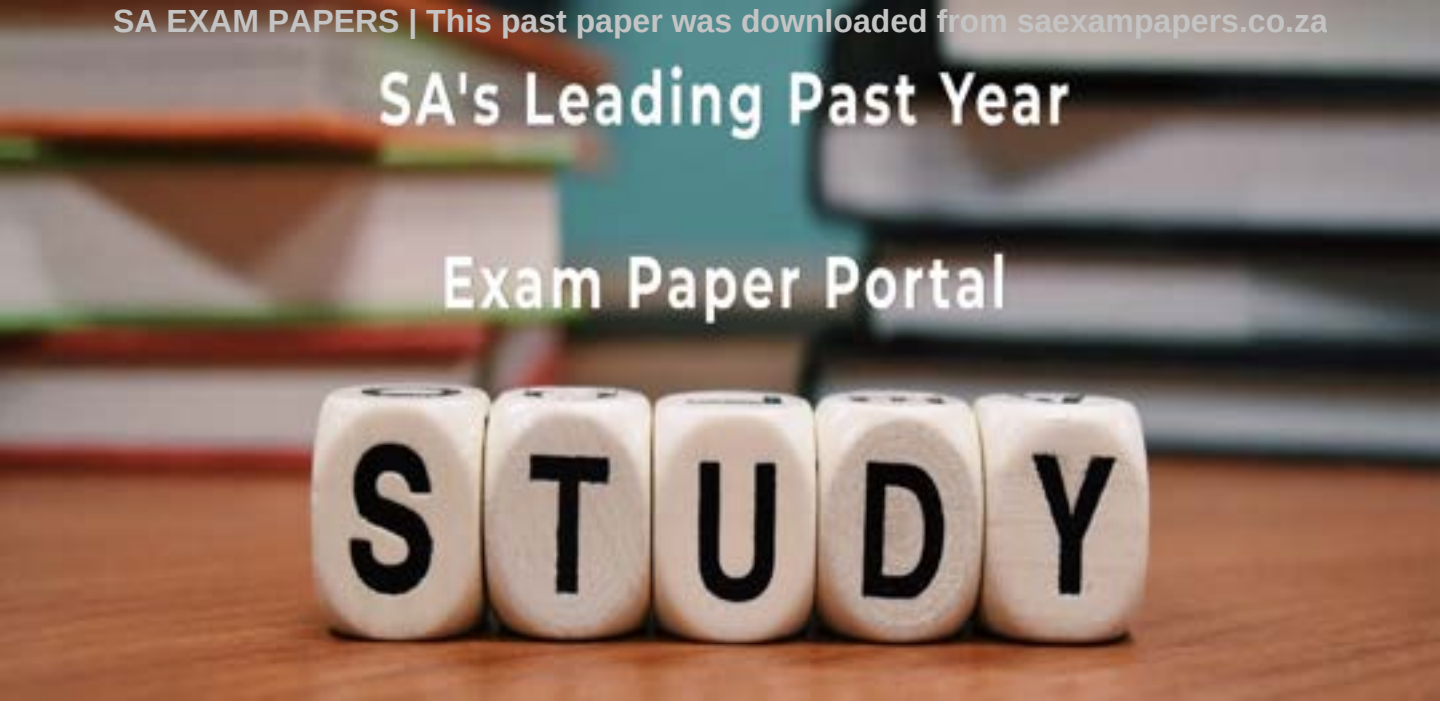


basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: DIGITAL ELECTRONICS

NOVEMBER 2024

MARKS: 200

TIME: 3 hours

This question paper consists of 16 pages, a 1-page formula sheet and a 7-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 3.4.4, 3.5.1 and 3.9.2
   QUESTIONS 5.2.1, 5.2.2, 5.3, 5.4.1, 5.4.2 and 5.5
   QUESTION 6.9

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 the following:

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

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

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

A remains stable until the 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)

1.4 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)

1.5 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)

1.6 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)

1.7 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)

1.8 A combinational logic circuit that combines an AND gate with an exclusive OR gate is known as a … adder.

A parallel
B full
C half
D serial (1)

1.9 A … output has the transistor emitter connected to the anode of the LED.

A sourcing
B draining
C distributing
D sinking (1)

1.10 A clocked RS flip-flop is in a set condition when …

A S = 1, R = 1.
B S = 1, R = 0.
C S = 0, R = 1.
D S = 0, R = 0. (1)

1.11 A counter that is modified to stop its count before reaching its maximum count is known as a/an … counter.

A down
B up/down
C truncated
D None of the above-mentioned (1)

1.12 A communication peripheral that converts data from the host processor into a serial data stream is known as a/an …

A SPI.
B UART.
C SCI.
D I^2C. (1)

1.13 The term SPI stands for …

A serial peripheral interface.
B standard peripheral interface.
C sequential peripheral interface.
D successive peripheral interface. (1)

1.14 A form of communication where the flow of data and information travels in one direction only is known as … communication.

A simplex
B fundamental
C duplex
D rudimentary (1)

1.15 The start-up instructions of a microcontroller are stored in the …

A CPU.
B RAM.
C ROM.
D I/O unit. (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: SWITCHING CIRCUITS

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

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

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

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

3.2.3 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)

3.3 FIGURE 3.3 below shows the circuit diagram of a 555 IC used as a bistable multivibrator. Answer the questions that follow.

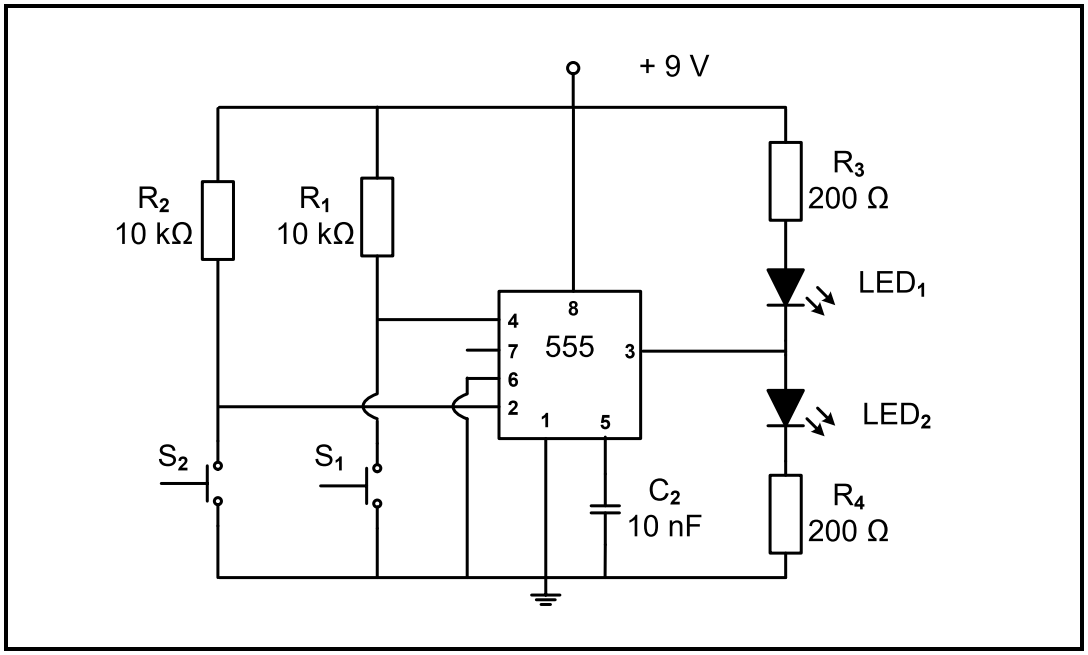


FIGURE 3.3: 555 BISTABLE MULTIVIBRATOR

3.3.1 State the purpose of resistor R_2. (1)

3.3.2 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)

3.3.3 Explain how the circuit is reset. (2)

3.4 FIGURE 3.4 below shows a monostable multivibrator circuit using a 741 op amp. Answer the questions that follow.

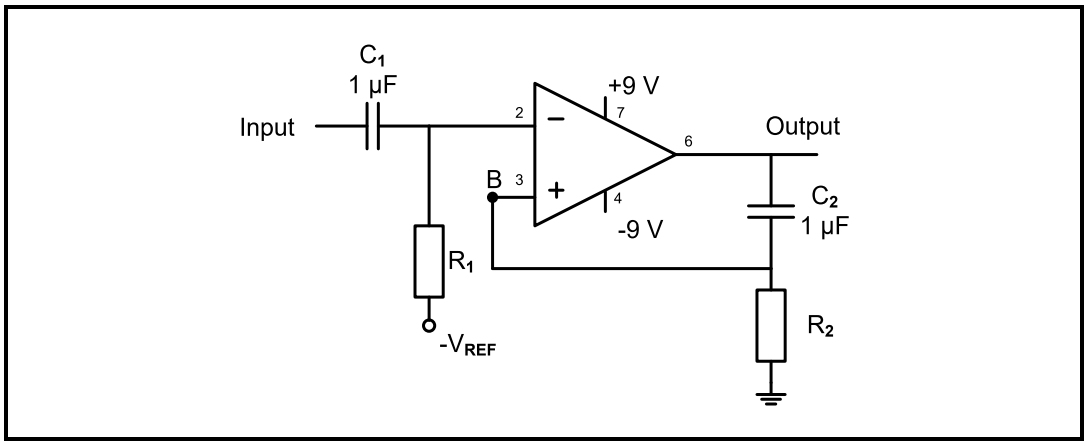


FIGURE 3.4: MONOSTABLE MULTIVIBRATOR

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

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

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

3.4.4 Draw the output for the circuit on the ANSWER SHEET for QUESTION 3.4.4 if R_2 and C_2 are chosen to create a changed (unstable) state for 3 seconds. (4)

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

3.5.1 Complete the circuit diagram in FIGURE 3.5.1 on the ANSWER SHEET for QUESTION 3.5.1 to make an astable multivibrator.

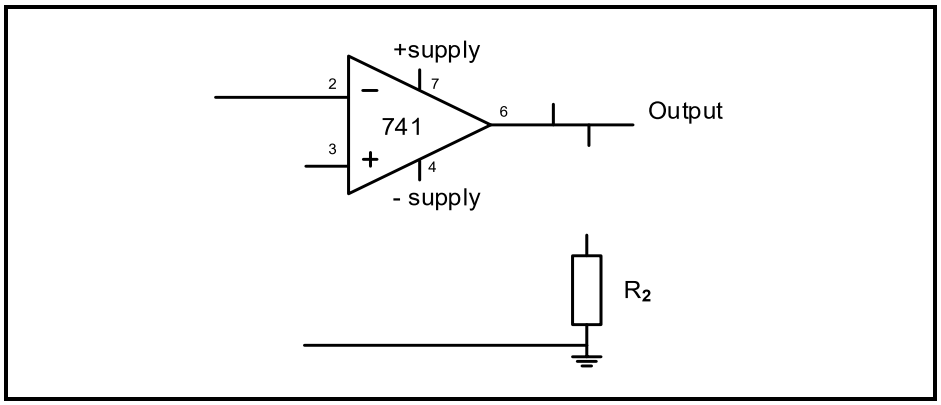


FIGURE 3.5.1: INCOMPLETE CIRCUIT DIAGRAM OF AN ASTABLE MULTIVIBRATOR (4)

3.5.2 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)

3.6 FIGURE 3.6 below shows a 741 op amp comparator circuit. Answer the questions that follow.

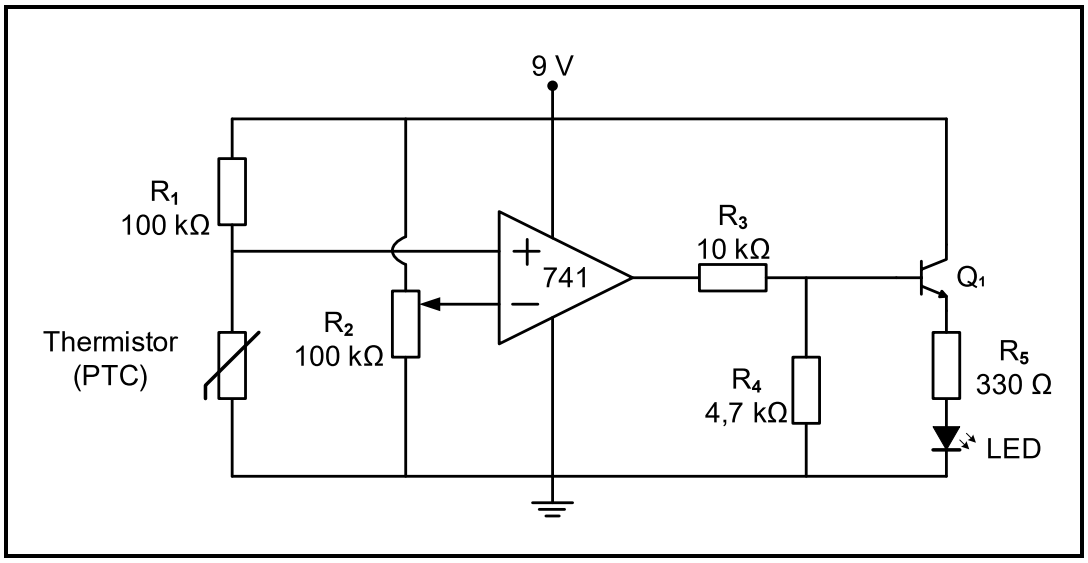


FIGURE 3.6: COMPARATOR AS A TEMPERATURE SENSOR

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

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

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

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

3.8 FIGURE 3.8 below shows the circuit diagram of an inverting summing amplifier. Answer the questions that follow.

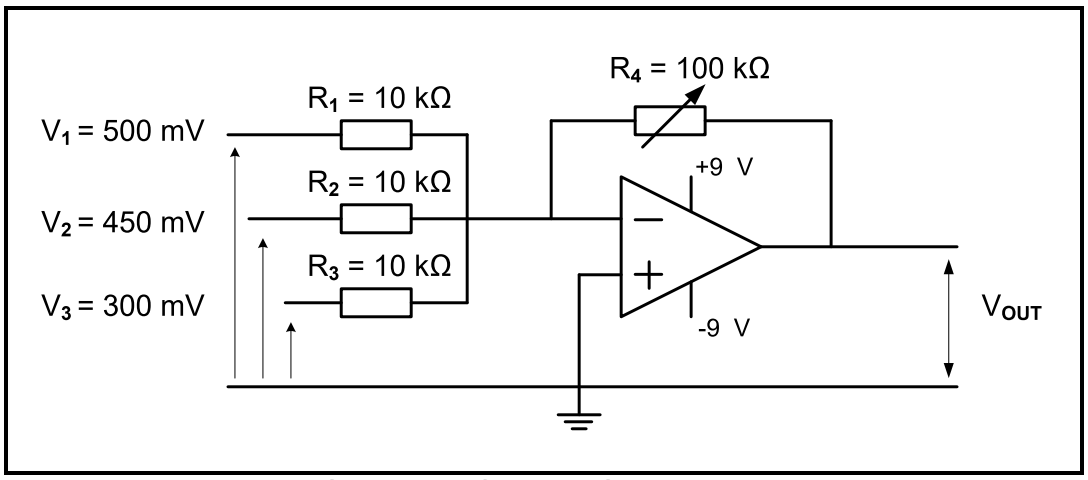


FIGURE 3.8: SUMMING AMPLIFIER

Given:

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

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

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

3.8.3 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)

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

3.9 FIGURE 3.9 below shows the input and output waveforms for a short time constant in a passive RC differentiator circuit. Answer the questions that follow.

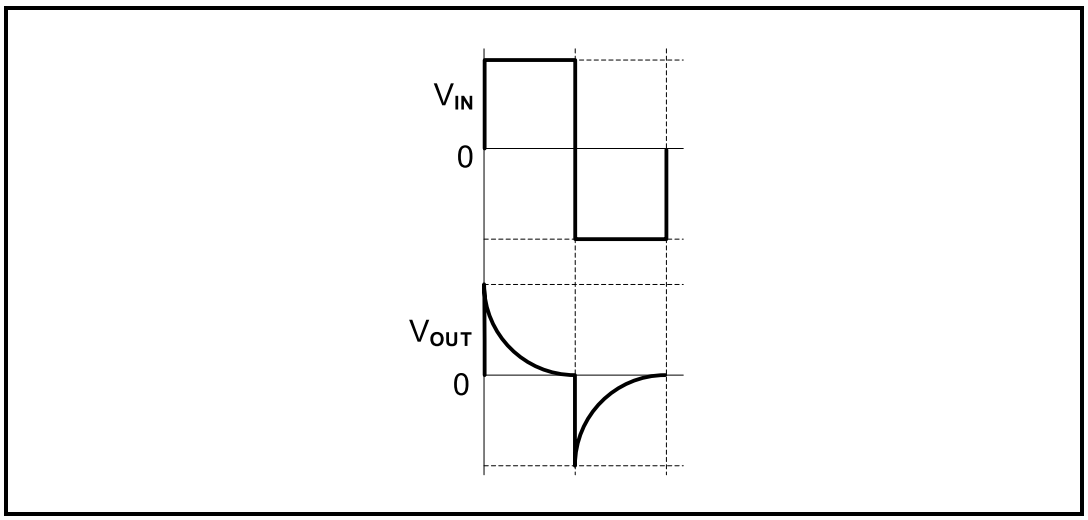


FIGURE 3.9: PASSIVE RC DIFFERENTIATOR WAVEFORMS

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

3.9.2 Draw, on the ANSWER SHEET for QUESTION 3.9.2, the output waveform for a long time constant of the circuit for ONE full cycle. (3)

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

QUESTION 4: SEMICONDUCTOR DEVICES

4.1 Refer to FIGURE 4.1 below and answer the questions that follow.

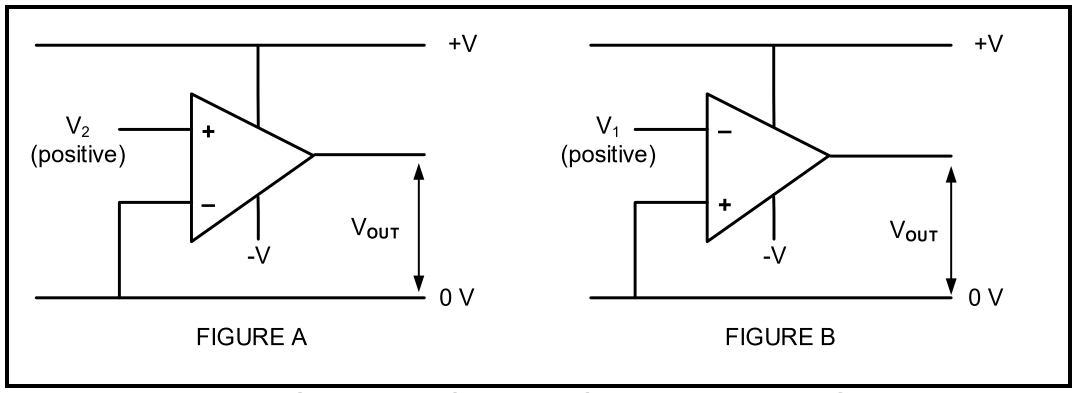


FIGURE 4.1: OPERATIONAL AMPLIFIERS

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

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

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

4.2 FIGURE 4.2 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.

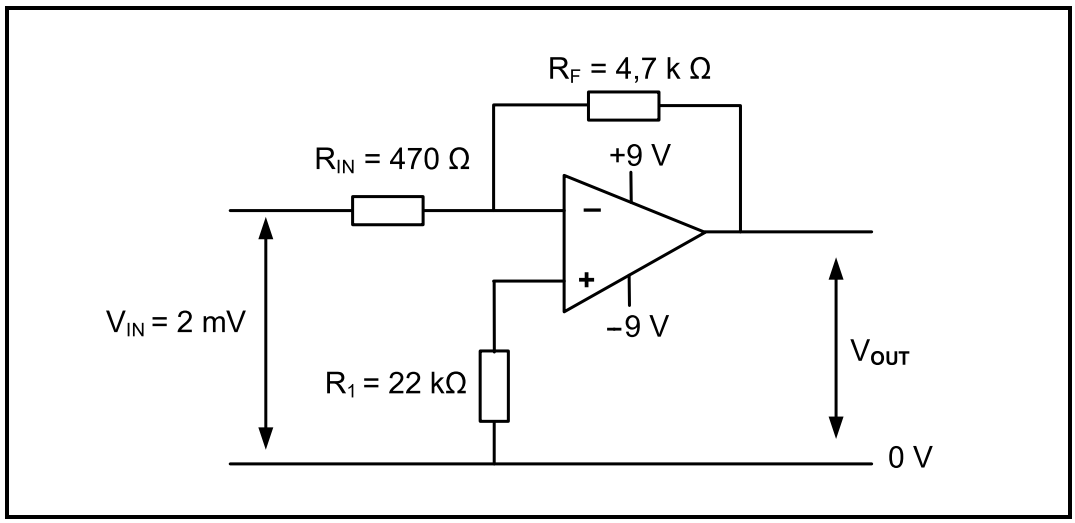


FIGURE 4.2: OPERATIONAL AMPLIFIER

Given:

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

4.2.1 Name the type of feedback used in FIGURE 4.2. (1)

4.2.2 Calculate the gain. (3)

4.2.3 Calculate the output voltage. (3)

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

4.3 FIGURE 4.3 below shows the internal circuit diagram of a 555 IC. Answer the questions that follow.

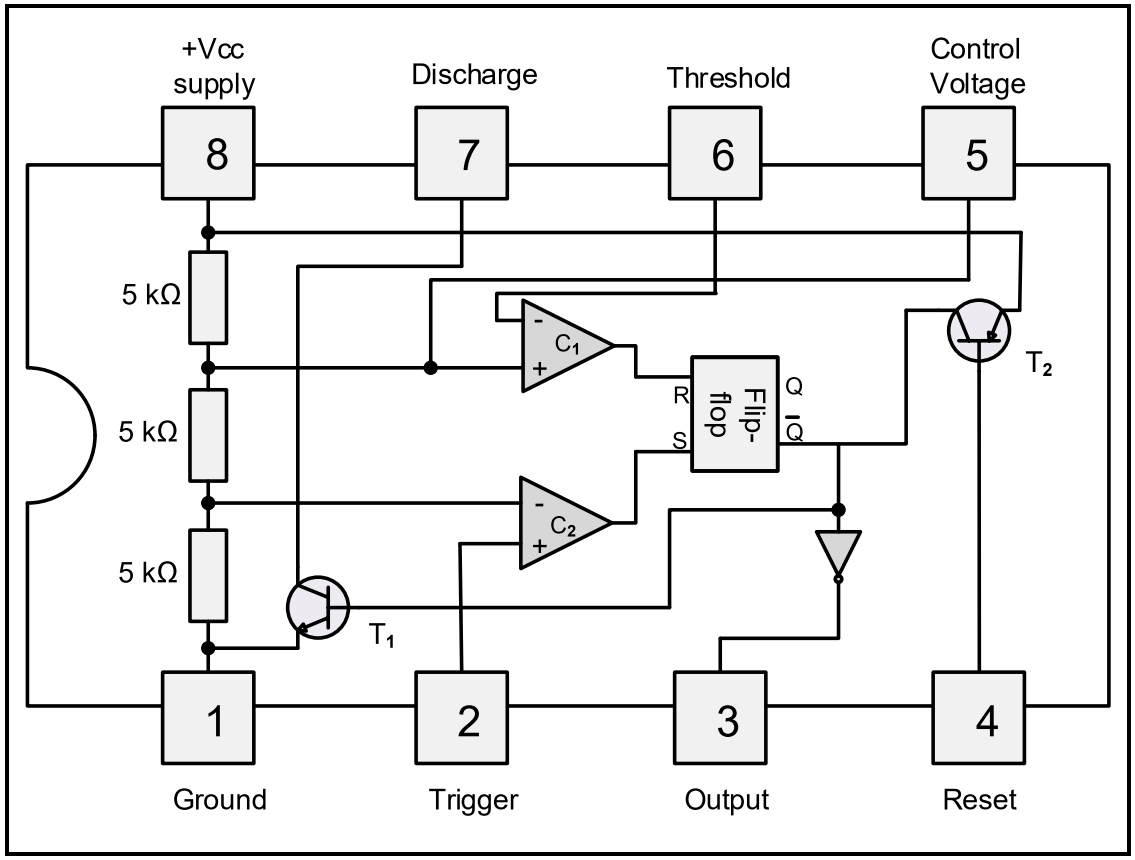


FIGURE 4.3: INTERNAL LAYOUT OF A 555 IC

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

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

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

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

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

[20]

QUESTION 5: DIGITAL AND SEQUENTIAL DEVICES

5.1 Refer to FIGURE 5.1 below of the liquid crystal display (LCD) and answer the questions that follow.

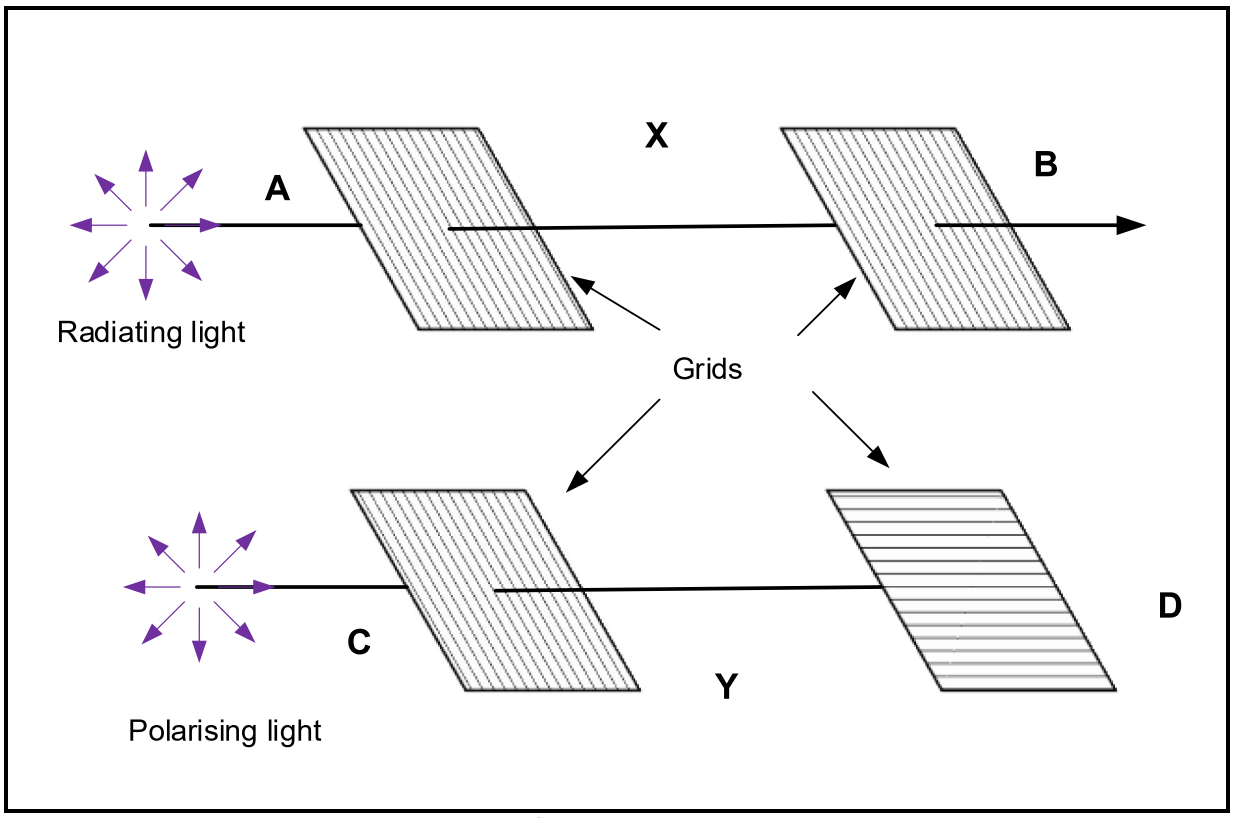


FIGURE 5.1

5.1.1 Explain why light waves will pass from point A to point B, but NOT from point C to point D. (4)

5.1.2 Describe how pixels are used to create a picture in an LCD screen. (3)

5.2 FIGURE 5.2 below represents the block diagram of a binary-to-decimal decoder.

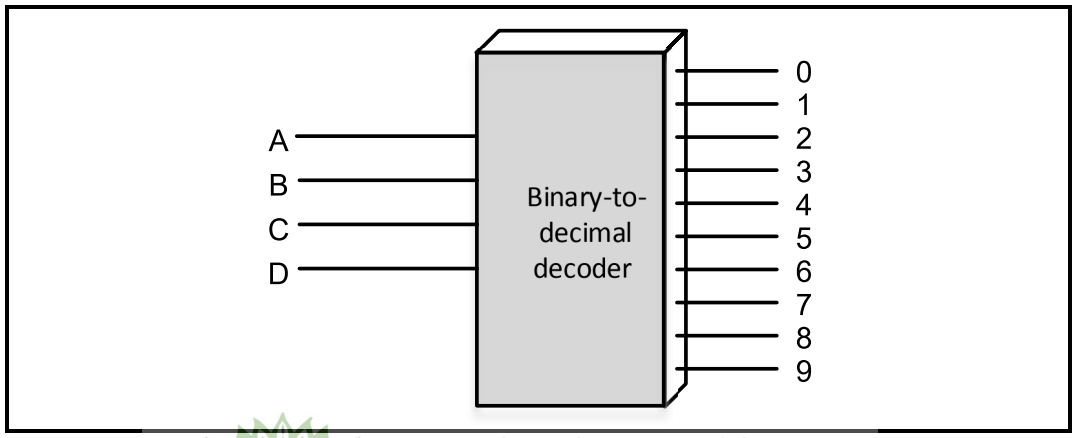


FIGURE 5.2: BINARY-TO-DECIMAL DECODER

5.2.1 On the ANSWER SHEET for QUESTION 5.2.1, complete the logic circuit of the binary-to-decimal decoder using AND gates and NOT gates. (6)

5.2.2 Complete the truth table of FIGURE 5.2 on the ANSWER SHEET for QUESTION 5.2.2 by indicating only the HIGH output states of W, X, Y and Z. (4)

5.3 Refer to FIGURE 5.3 below, which is a block diagram of a full adder, and complete the logic circuit of a full adder using AND gates, exclusive OR gates and an OR gate on the ANSWER SHEET for QUESTION 5.3

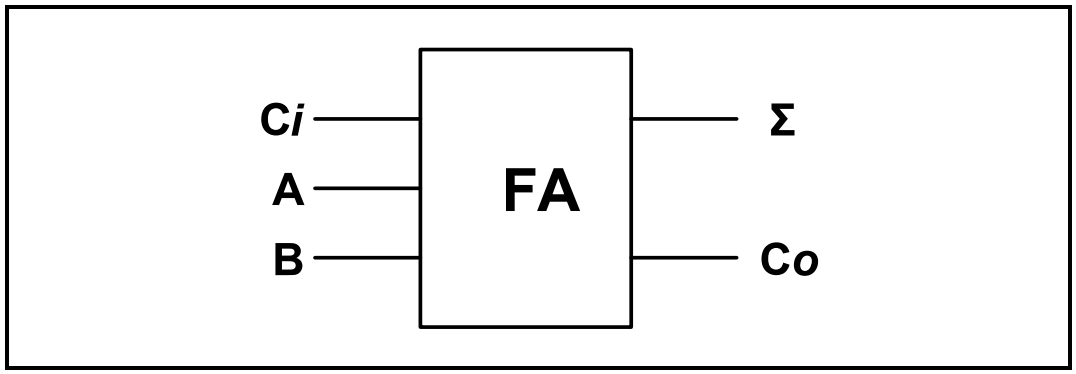


FIGURE 5.3: BLOCK DIAGRAM OF A FULL ADDER (5)

5.4 Refer to FIGURE 5.4 below of a clocked D-type flip-flop and answer the questions that follow.

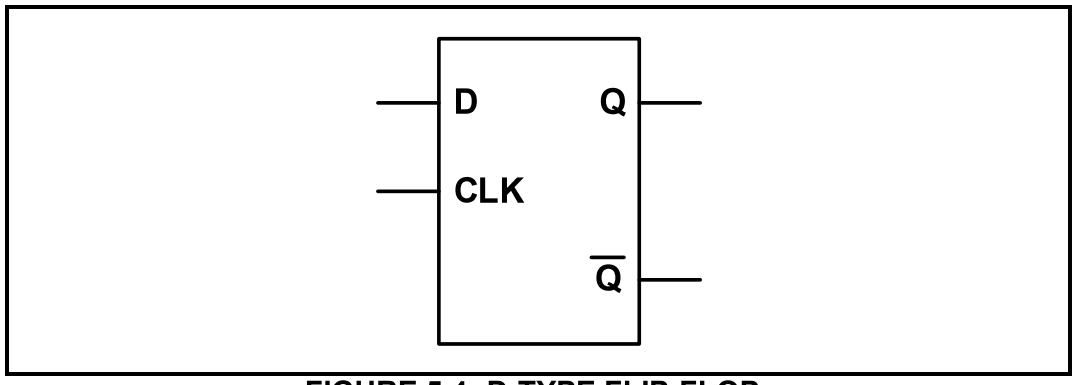


FIGURE 5.4: D-TYPE FLIP-FLOP

5.4.1 Complete the logic circuit of this flip-flop on the ANSWER SHEET for QUESTION 5.4.1. (6)

5.4.2 Complete the truth table of this flip-flop on the ANSWER SHEET for QUESTION 5.4.2. (4)

5.5 Refer to FIGURE 5.5 of a binary counter below and complete the timing diagrams of this counter on the ANSWER SHEET for QUESTION 5.5

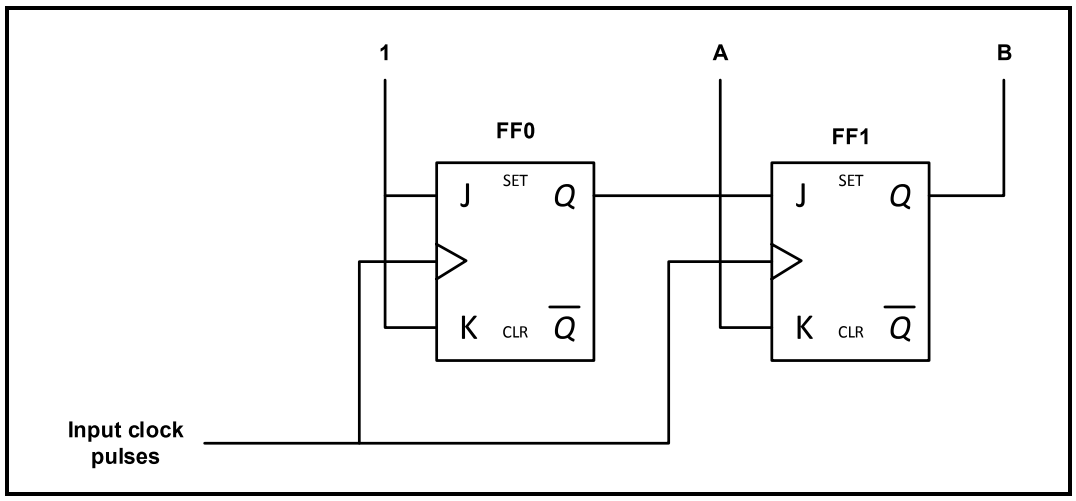


FIGURE 5.5 (6)

5.6 Explain the difference between *pulse-triggered* and *edge-triggered* flip flops. (4)

5.7 Briefly describe the following counters:

5.7.1 Frequency divider (2)

5.7.2 Decade counter (2)

5.8 Refer to FIGURE 5.8 below and answer the questions that follow.

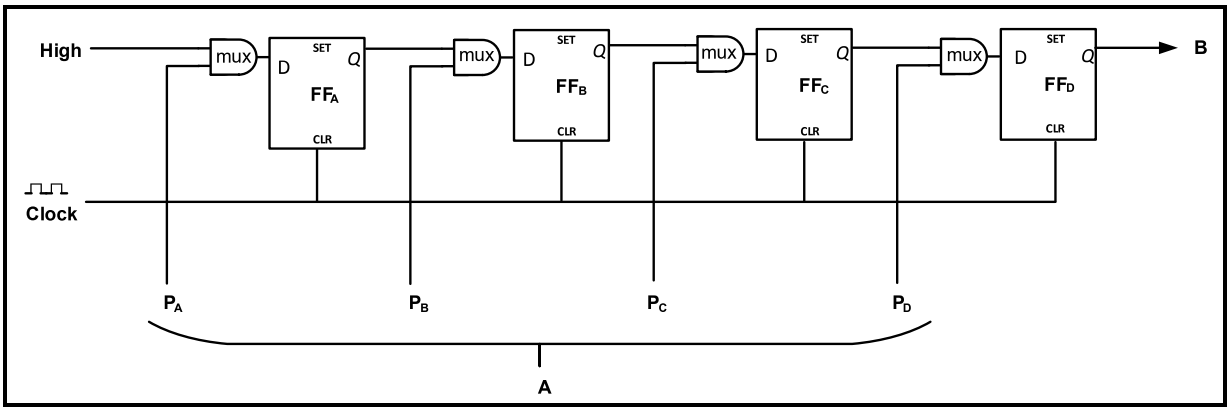


FIGURE 5.8

5.8.1 Identify the register in FIGURE 5.8. (1)

5.8.2 Label **A** and **B**. (2)

5.8.3 Explain the operation of this register. (3)

5.8.4 How many clock pulses are needed to unload the data from the register? (1)

5.8.5 State TWO uses of this register. (2)

[55]

QUESTION 6: MICROCONTROLLERS

6.1 Define the term *microcontroller.* (3)

6.2 Refer to the block diagram in FIGURE 6.2 below and answer the questions that follow.

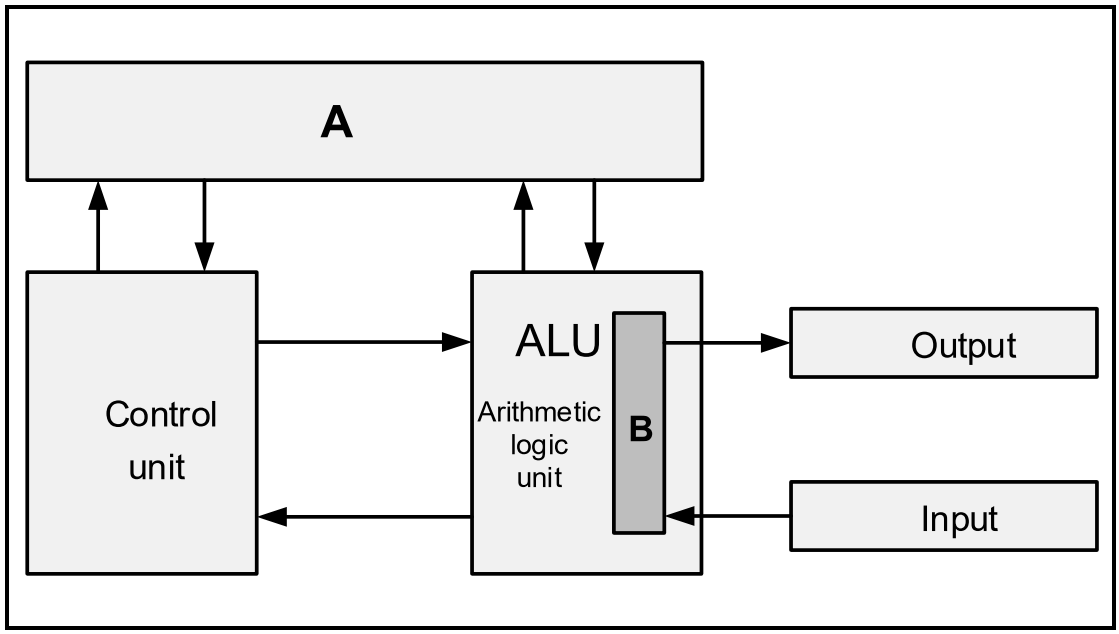


FIGURE 6.2: MICROCONTROLLER'S STRUCTURE

6.2.1 Label **A** and **B**. (2)

6.2.2 Explain the function of the control unit. (4)

6.2.3 State the function of the ALU. (2)

6.3 Refer to the hardware of a microcontroller and explain the difference between *discrete logic* and *integrated logic*. (2)

6.4 Describe the accumulator as a general-purpose register. (2)

6.5 Refer to communication in a microcontroller and answer the questions that follow.

6.5.1 Explain the function of the system bus. (4)

6.5.2 State TWO advantages of synchronous communication when it is compared to asynchronous communication. (2)

6.5.3 State TWO disadvantages of parallel communication when it is compared to serial communication. (2)

6.6 Refer to communication protocols in a microcontroller and explain the difference between *half-duplex communication* and *full-duplex communication*. (4)

6.7 FIGURE 6.7 below is the block diagram of the I^2C bus system. Answer the questions that follow.

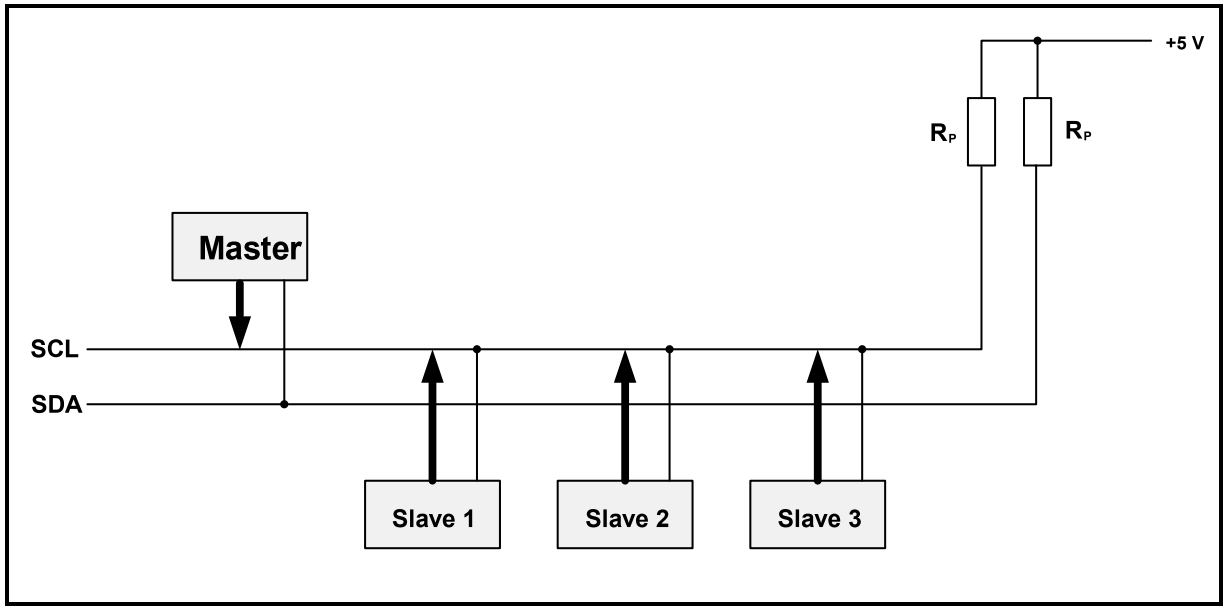


FIGURE 6.7

6.7.1 Write out the abbreviation SDA in full. (1)

6.7.2 Explain the function of the pull-up resistors. (2)

6.7.3 State TWO disadvantages of the I^2C bus. (2)

6.7.4 Explain the master-slave operation of the I^2C bus. (6)

6.8 Refer to microcontrollers and define the following terms:

6.8.1 Program (2)

6.8.2 Flow diagram (2)

6.9 FIGURE 6.9 on the ANSWER SHEET shows an incomplete flow chart of a PICAXE factory security system.

Design a flow diagram of a factory security system that has TWO sensors on different parts of the premises.

- This system consists of TWO sensors.
- The first sensor is set up at the main entrance of the factory.
- The second sensor is set up on the beam that protects the rear entrance of the factory.
- If any of the sensors is activated, the alarm will be activated.
- The alarm must include a reset function.
- No timing function is required.

Complete and label the flow chart of this device on the ANSWER SHEET for QUESTION 6.9. (8)

[50]

TOTAL: 200

FORMULA SHEET

SEMICONDUCTOR DEVICES

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

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

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

SWITCHING CIRCUITS

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

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

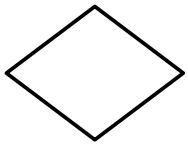
$$V_{OUT} = -(V_1 + V_2 + \ldots V_N)$$

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

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

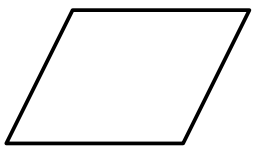
FLOW CHART SYMBOLS

Process



Decision

Terminator



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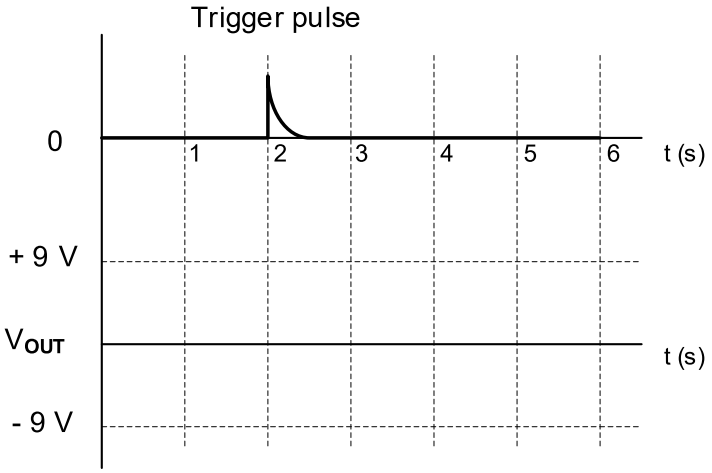
ANSWER SHEET

QUESTION 3: SWITCHING CIRCUITS

3.4.4



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MOD

FIGURE 3.4.4 (4)

3.5.1

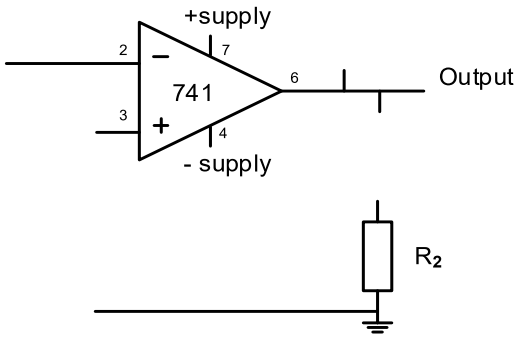

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FIGURE 3.5.1 (4)

CENTRE NUMBER:							

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ANSWER SHEET

3.9.2

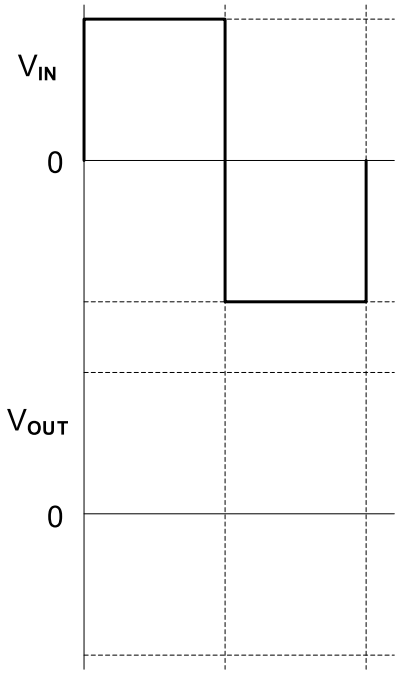

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FIGURE 3.9.2 (3)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 5: DIGITAL AND SEQUENTIAL DEVICES

5.2.1

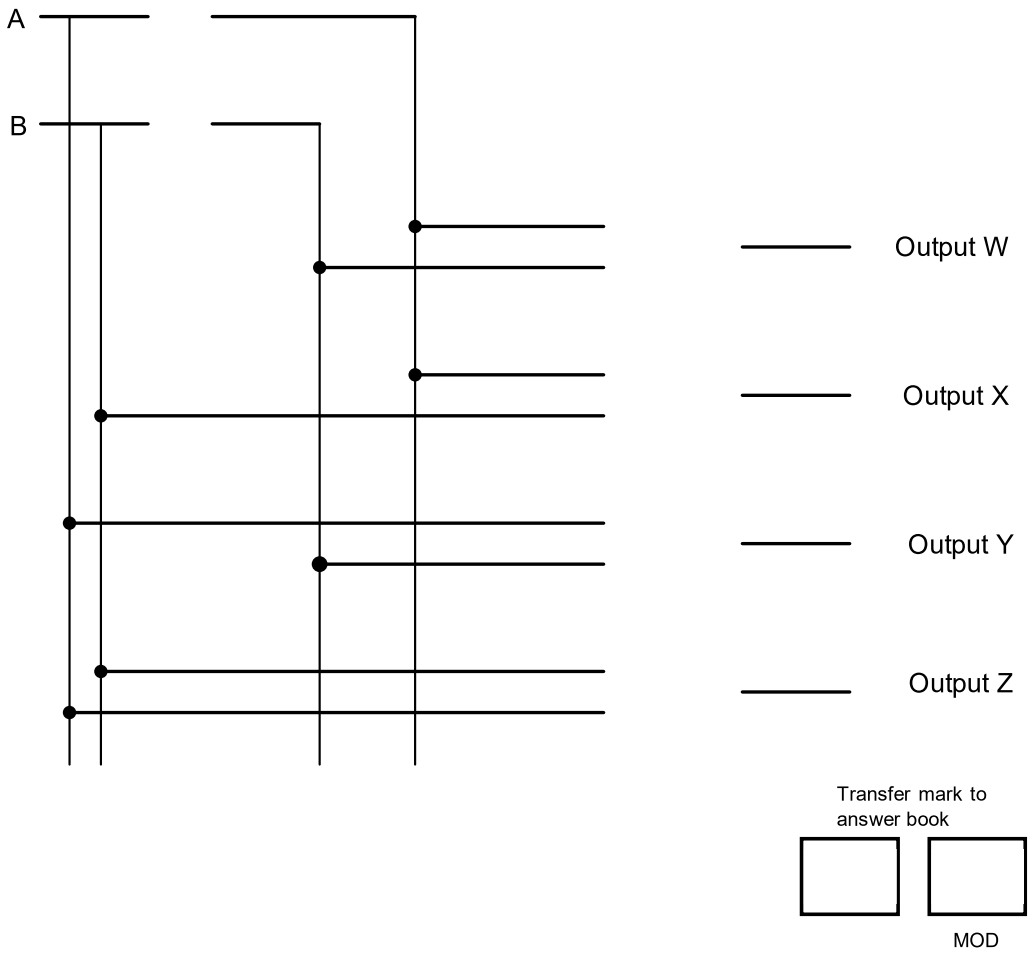

FIGURE 5.2.1 (6)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.2.2

Inputs		Outputs			
A	**B**	**W**	**X**	**Y**	**Z**
1	0				
1	1				
0	0				
0	1				

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FIGURE 5.2.2 (4)

5.3

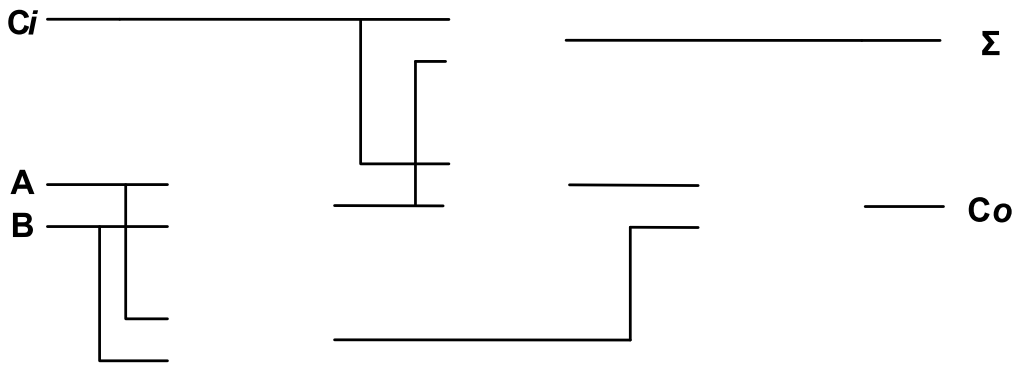

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FIGURE 5.3 (5)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.4.1

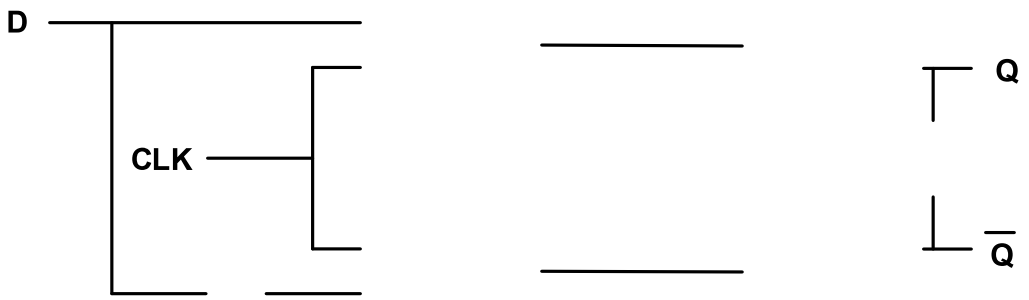

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FIGURE 5.4.1 (6)

5.4.2

CLK	D	Q	$\overline{Q}$
0	0	Latch	Latch
0	1	Latch	Latch
1	0		
1	1		

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FIGURE 5.4.2 (4)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.5

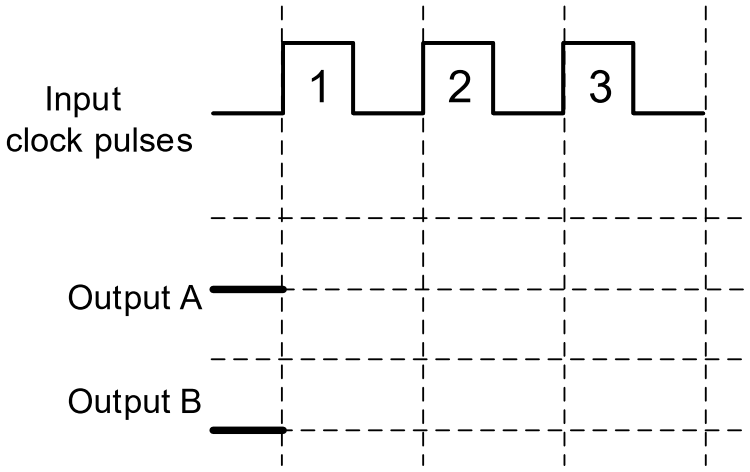

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FIGURE 5.5 (6)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 6: MICROCONTROLLERS

6.9

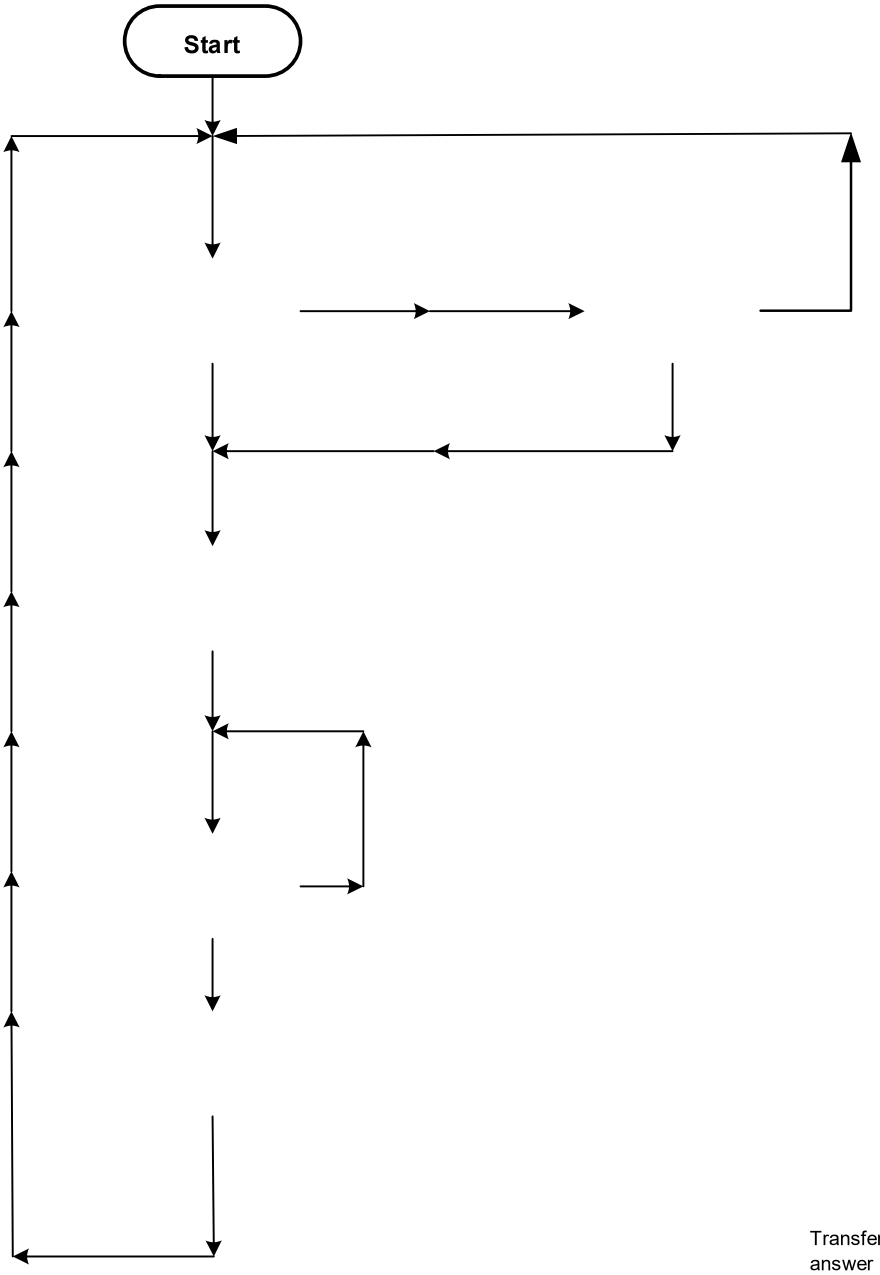

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FIGURE 6.9 (8)