basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: DIGITAL ELECTRONICS

NOVEMBER 2022

MARKS: 200

TIME: 3 hours

This question paper consists of 18 pages, a 1-page formula sheet and a 9-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 3.2.4 and 3.3.4
   QUESTION 4.2.3
   QUESTIONS 5.2, 5.3.2, 5.4, 5.5.2, 5.7.1 and 5.8
   QUESTION 6.8

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/An … is an occurrence when a serious or unexpected dangerous situation occurs that requires immediate attention.

A evacuation procedure
B non-critical incident
C critical incident
D unsafe condition (1)

1.2 A ... is used to eliminate switch bounce in electronics circuits.

A monostable multivibrator
B audio amplifier
C astable multivibrator
D oscillator (1)

1.3 A circuit used in an audio mixer to individually amplify or attenuate each input signal is the ...

A comparator
B Schmitt trigger
C summing amplifier
D inverting op amp (1)

1.4 A basic op-amp comparator circuit uses ...

A feedback.
B positive feedback.
C negative feedback.
D no feedback. (1)

1.5 A ... produces an output which is directly proportional to the rate of change of the input signal

A passive RC integrator
B comparator
C passive RC differentiator
D non-inverting amplifier (1)

1.6 An op-amp circuit without any feedback has ... gain.

A closed-loop
B forward-loop
C reverse-loop
D open-loop (1)

1.7 The pin that sets the voltage at which the 555 will trigger is known as ...

A output.
B discharge.
C threshold.
D reset. (1)

1.8 A J-K flip-flop output is in a 'no change' condition when ...

A J = 1, K = 1.
B J = 1, K = 0.
C J = 0, K = 1.
D J = 0, K = 0. (1)

1.9 Choose the correct number of flip-flops that are required to construct a decade counter:

A 10
B 8
C 5
D 4 (1)

1.10 Counters that are not triggered at the same time are called ...

A asynchronous counters.
B modulus counters.
C propagation counters.
D synchronous counters. (1)

1.11 … is the type of register that would shift a complete binary number in one bit at a time and shift all the stored bits out one bit at a time.

A Parallel-in: parallel-out
B Series-in: series-out
C Parallel-in: series-out
D Series-in: parallel-out (1)

1.12 The term RAM means … with reference to microcontrollers.

A read all memory
B random allocation memory
C read and memorise memory
D random access memory (1)

1.13 The communication protocol that only requires two signal lines is called the ...

A Inter-integrated bus
B Serial communication interface
C Serial peripheral interface
D Serial dual interface (1)

1.14 The RS-485 communication protocol has a maximum cable length of ...

A 400 m.
B 800 m.
C 1 200 m.
D 200 m. (1)

1.15 A sequence of instructions that instructs a computer how to do a task is called a/an ...

A algorithm.
B program.
C flow chart.
D convention. (1)
[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 State TWO human rights in the workplace that ensure that the dignity of the employer is not infringed. (2)

2.2 State TWO evacuation steps to be followed when an emergency alarm is sounded in a workshop. (2)

2.3 Explain why the misuse of equipment in a workshop could cause a health or safety threat. (2)

2.4 Refer to victimisation and state TWO actions by the employer that are forbidden. (2)

2.5 State TWO types of risk analysis reports done by the health and safety representative. (2)
[10]

QUESTION 3: SWITCHING CIRCUITS

3.1 State the difference between a *monostable multivibrator* and an *astable multivibrator* with reference to their output states. (2)

3.2 FIGURE 3.2 shows a bistable multivibrator using a 555 IC. Answer the questions that follow.

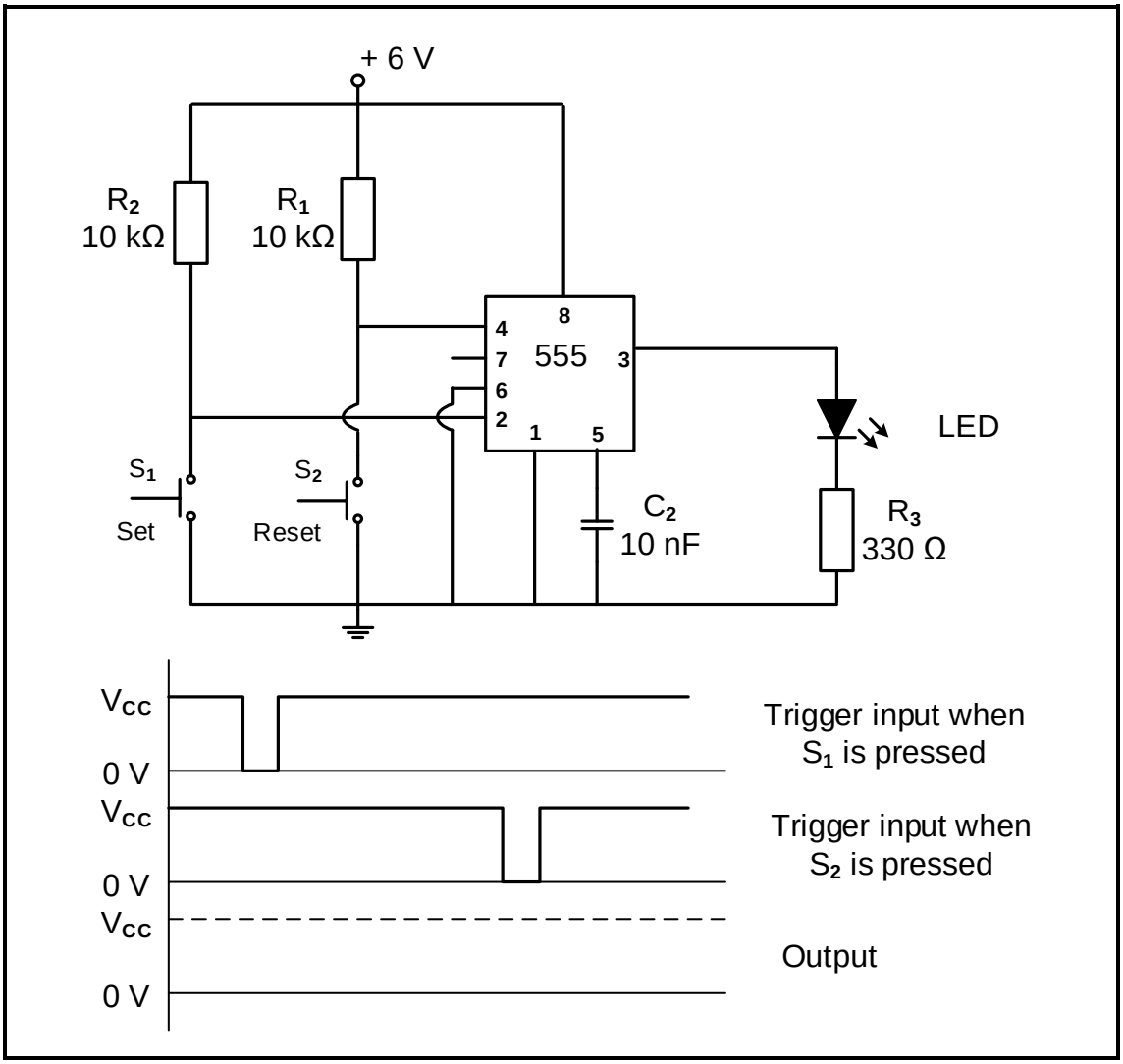


FIGURE 3.2: BISTABLE MULTIVIBRATOR

3.2.1 State ONE application of a bistable multivibrator. (1)

3.2.2 Explain why threshold pin 6 is connected directly to ground. (3)

3.2.3 Explain what will happen to the input voltage on pin 2 if resistor R_2 is disconnected from the supply leaving it as an open circuit. (2)

3.2.4 Draw the output waveform on the ANSWER SHEET for QUESTION 3.2.4. (3)

3.3 FIGURE 3.3 shows a 741 monostable multivibrator circuit in its natural resting condition. Answer the questions that follow.

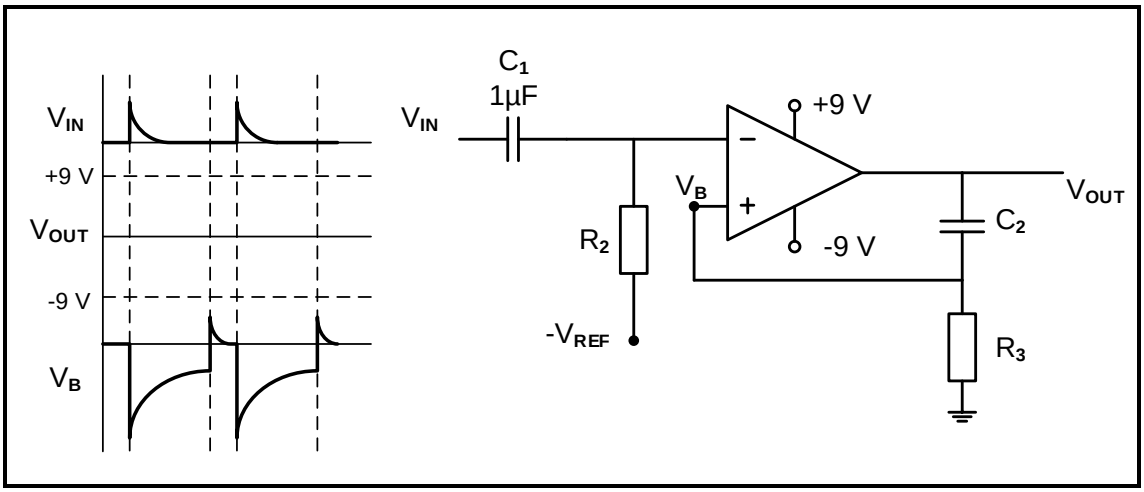


FIGURE 3.3: 741 IC MONOSTABLE MULTIVIBRATOR

3.3.1 State the purpose of C_2 and R_3. (2)

3.3.2 Determine the voltage at the non-inverting input (V_B) when capacitor C_2 is fully charged to the saturation voltage of 9 V and no current flows through R_3. (1)

3.3.3 Explain what happens to the output voltage the moment a positive input pulse is applied to the inverting input. (3)

3.3.4 Draw the output waveform on the ANSWER SHEET for QUESTION 3.3.4. (4)

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

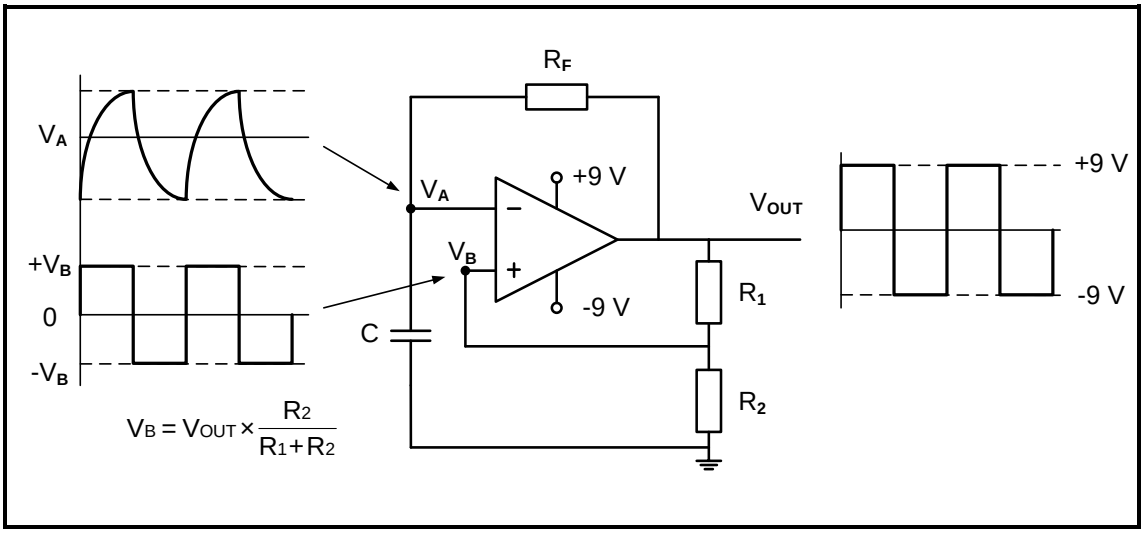


FIGURE 3.4: 741 IC ASTABLE MULTIVIBRATOR

3.4.1 Determine the polarity of V_B when the output is positive. (1)

3.4.2 Refer to V_A and V_B and state when the output changes from +9 V to –9 V. (1)

3.4.3 Describe how an increase in the value of R_F affects the operation of the circuit. (3)

3.5 Refer to FIGURE 3.5 and answer the questions that follow.

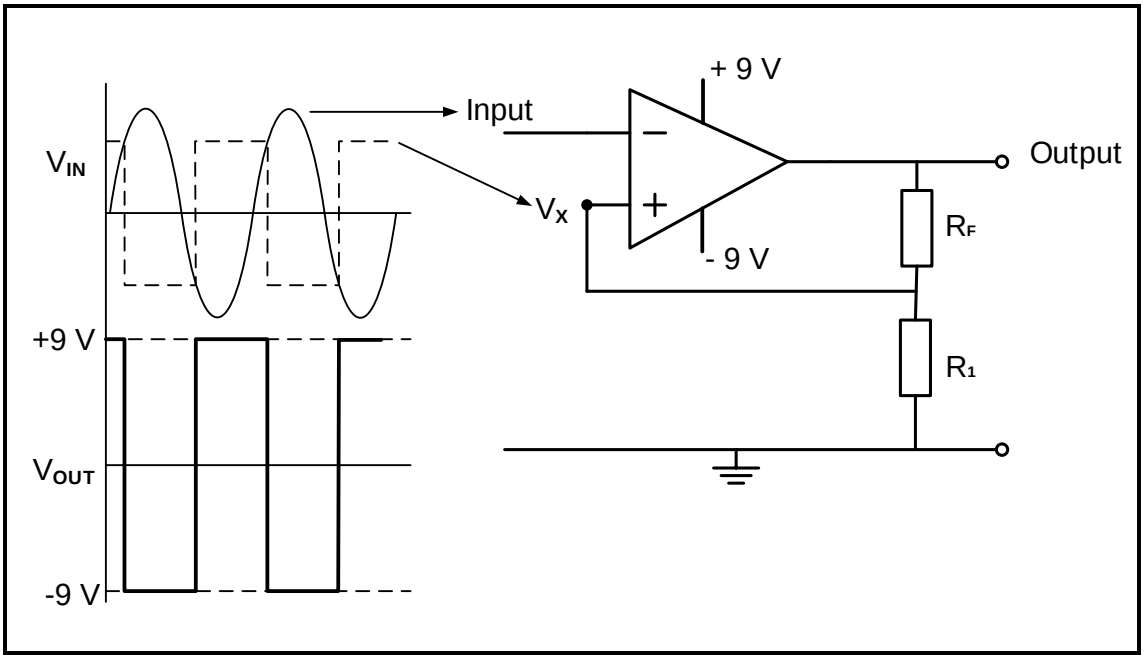


FIGURE 3.5: SCHMITT TRIGGER

3.5.1 Determine the saturation voltages of the Schmitt trigger. (1)

3.5.2 Explain the purpose of R_F and R_1 in the circuit. (2)

3.5.3 State when the output changes from high to low. (2)

3.6 Explain the operation of the circuit in FIGURE 3.6.

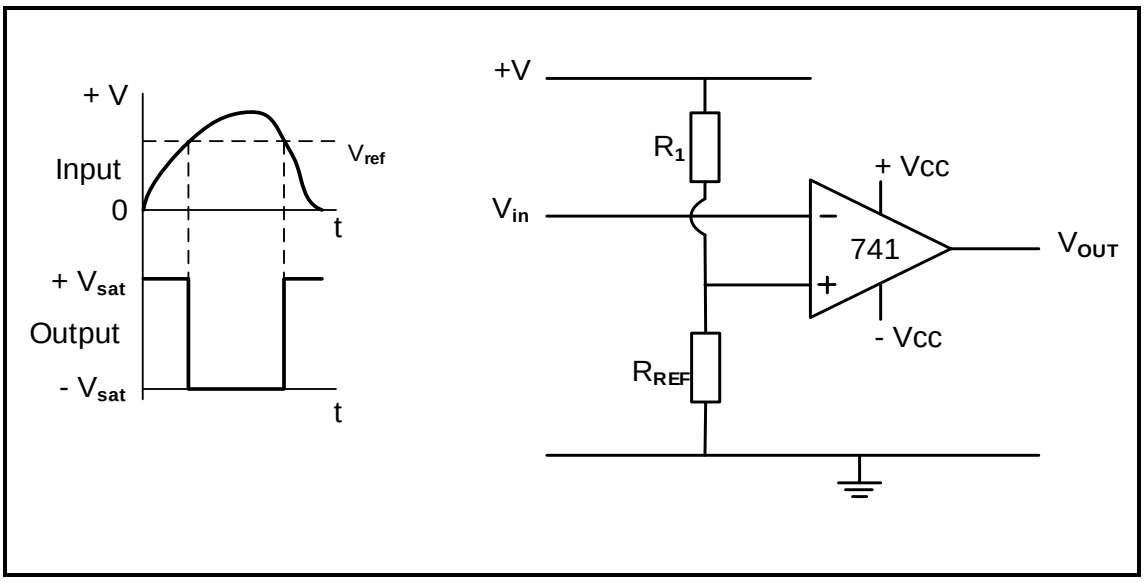


FIGURE 3.6: OP-AMP COMPARATOR (3)

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

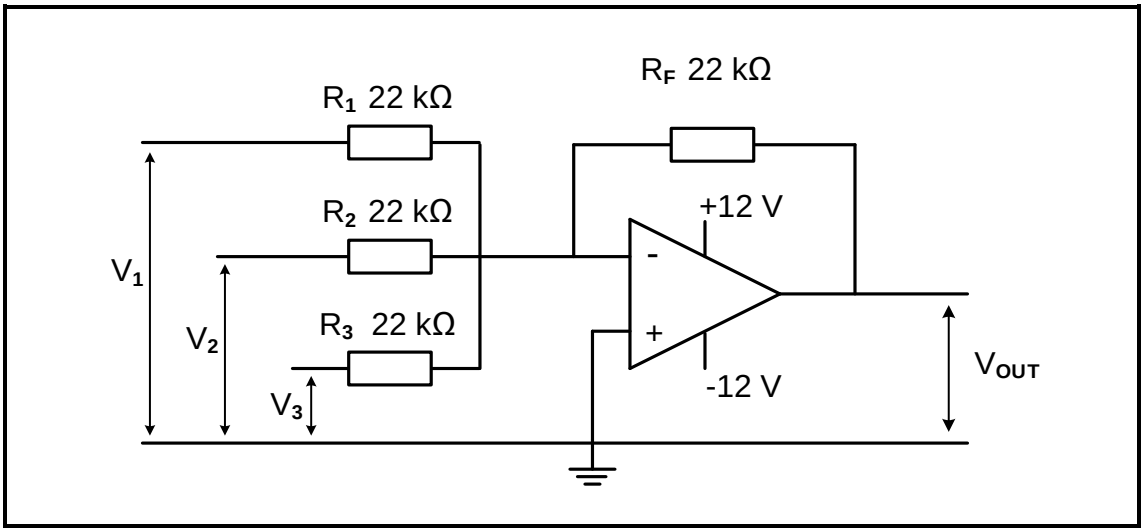


FIGURE 3.7: OP-AMP CIRCUIT

Given:

$R_1 = R_2 = R_3 = R_F$ = 22 kΩ
V_s = +12 V/-12 V
V_1 = 0,9 V
V_2 = 1,2 V
V_3 = 2,1 V

3.7.1 Identify the op-amp circuit in FIGURE 3.7. (1)

3.7.2 Determine the gain of the amplifier. Motivate your answer. (2)

3.7.3 Calculate the output voltage. (3)

3.7.4 Explain the effects of increasing the value of the feedback resistor. (2)

3.8 Refer to FIGURE 3.8 and answer the questions that follow.

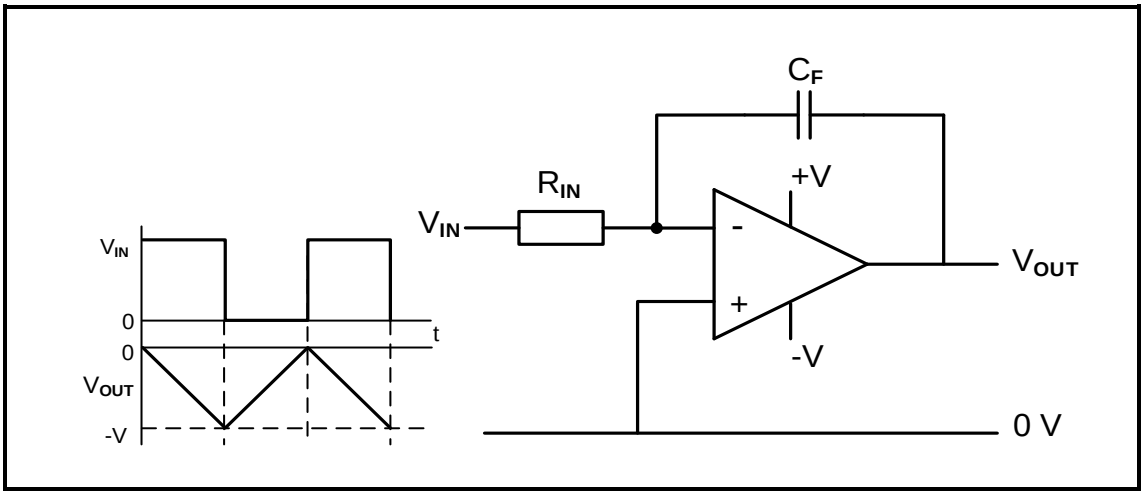


FIGURE 3.8: OP-AMP INTEGRATOR

3.8.1 State TWO factors that determine the output voltage of the circuit at any time. (2)

3.8.2 Explain why capacitor C_F charges at a fixed linear rate towards –V when a positive square wave is fed to the input. (4)

3.8.3 Explain the effect of a long RC time constant on the output. (2)
[50]

QUESTION 4: SEMICONDUCTOR DEVICES

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

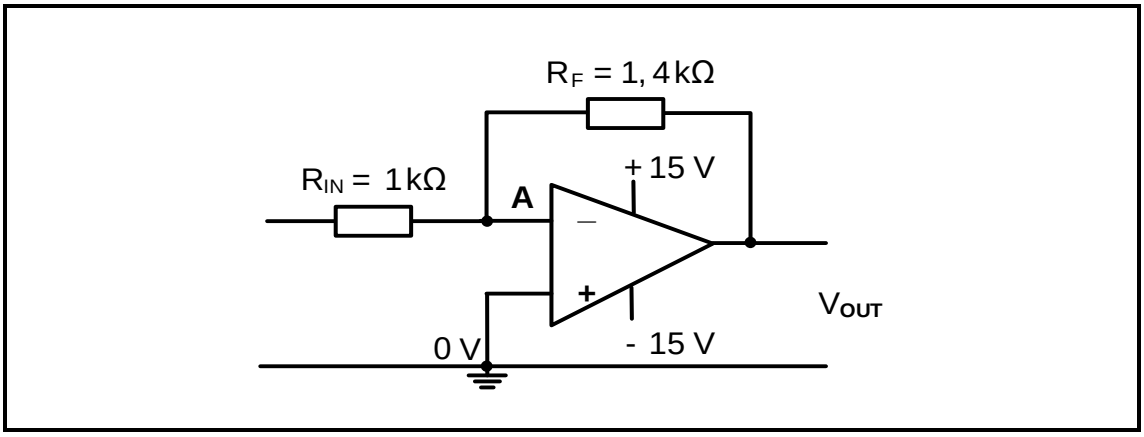


FIGURE 4.1: INVERTING OPERATIONAL AMPLIFIER

4.1.1 State the voltage at point **A**. (1)

4.1.2 Calculate the gain of the op amp. (3)

4.1.3 State the phase relationship between the input and the output signal when an AC signal is applied to the input. (1)

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

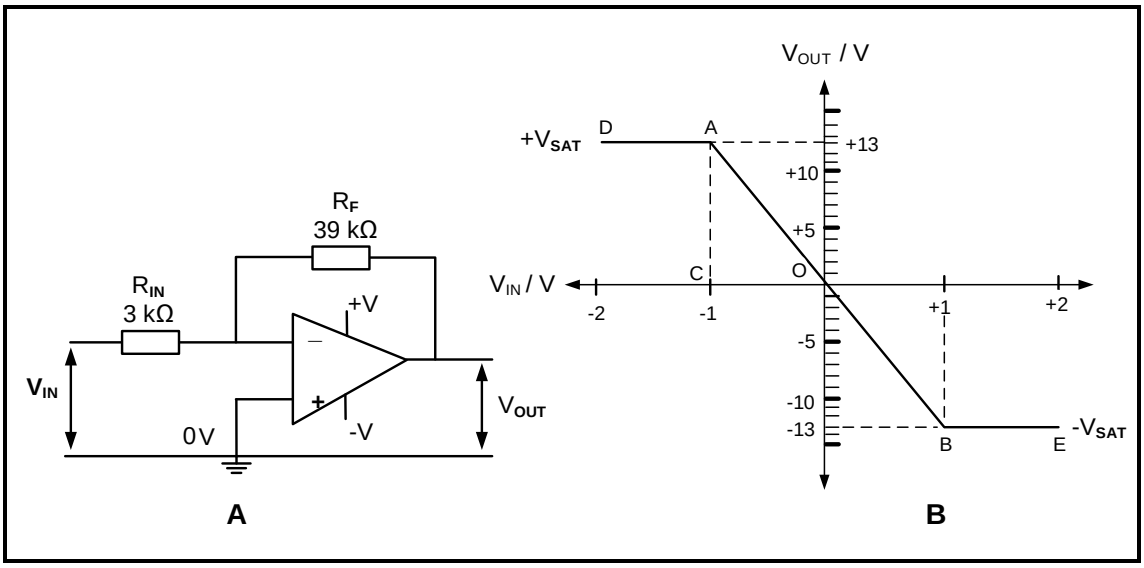


FIGURE 4.2: INVERTING OPERATIONAL AMPLIFIER

4.2.1 Identify the saturation regions in FIGURE 4.2 **B**. (2)

4.2.2 Calculate the gain by using the voltage values on FIGURE 4.2 **B**. (3)

4.2.3 Draw the output waveform on the ANSWER SHEET for QUESTION 4.2.3 when the op amp is saturated.

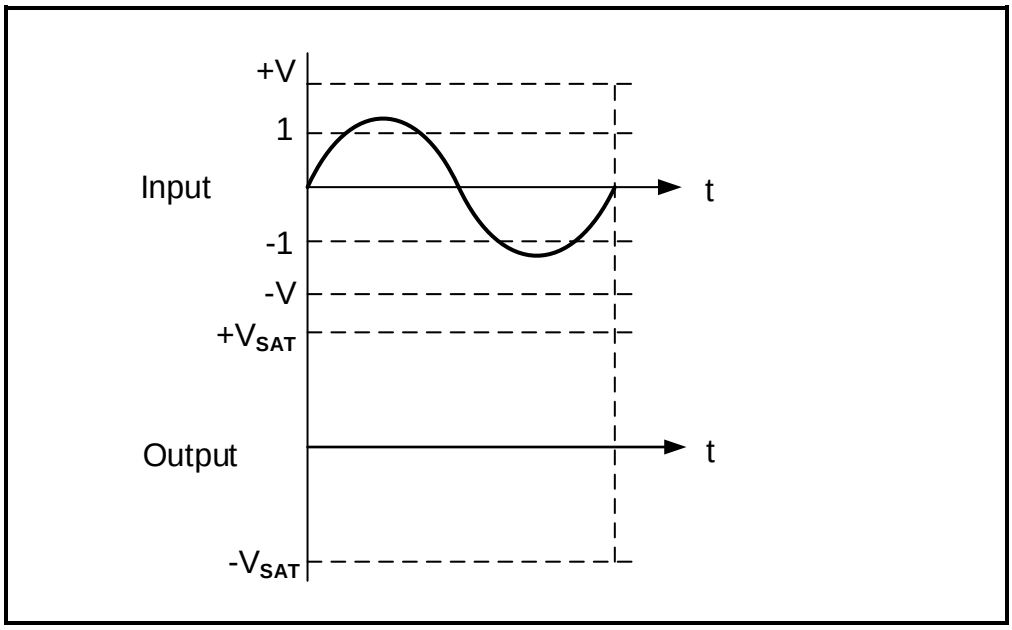


FIGURE 4.2.3 (3)

4.2.4 State TWO advantages of increasing the value of R_F. (2)

4.3 Refer to FIGURE 4.3 and answer the questions that follow

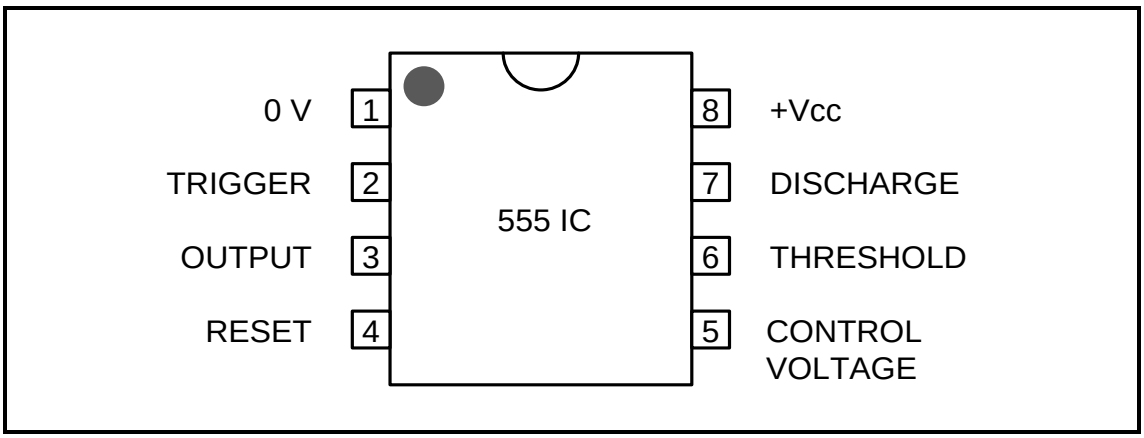


FIGURE 4.3: 555 IC PIN LAYOUT

4.3.1 State the function of pin 7. (1)

4.3.2 Describe how the 555 IC is triggered with reference to pin 2. (4)

[20]

QUESTION 5: DIGITAL AND SEQUENTIAL DEVICES

5.1 Refer to FIGURE 5.1 of a seven-segment display driver and answer the questions that follow.

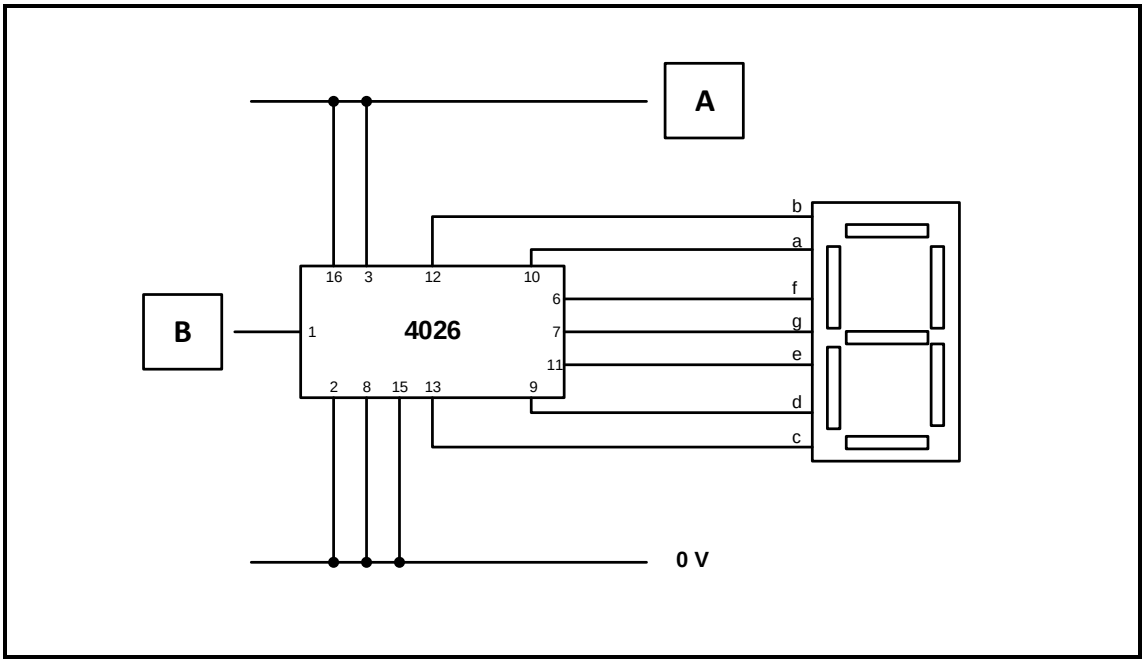


FIGURE 5.1: SEVEN-SEGMENT DISPLAY DRIVER

5.1.1 Label blocks **A** and **B**. (2)

5.1.2 Explain the main purpose of the seven-segment display driver. (2)

5.2 TABLE 5.2 shows the truth table of a two-digit binary-input to four-digit decimal-output decoder. Complete the equivalent logic circuit of this decoder on the ANSWER SHEET for QUESTION 5.2.

INPUTS		OUTPUTS			
A	**B**	**0**	**1**	**2**	**3**
0	0	1	0	0	0
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	0	0	1

TABLE 5.2 (5)

5.3 Refer to FIGURE 5.3 of a half-adder and answer the questions that follow.

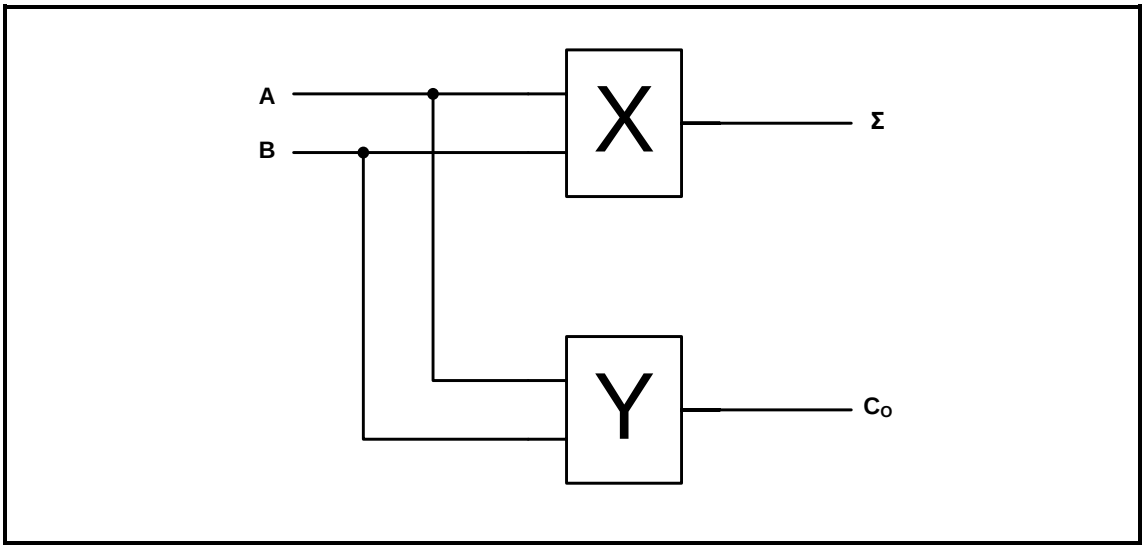


FIGURE 5.3: HALF-ADDER

5.3.1 Name the gates represented by **X** and **Y** respectively. (2)

5.3.2 Complete the truth table of the half-adder on the ANSWER SHEET for QUESTION 5.3.2.

A	B	Σ	C_{out}
0	0	0	0
0	1		
1	0		
1	1		

TABLE 5.3.2 (6)

5.4 Refer to FIGURE 5.4 and complete the timing diagrams on ANSWER SHEET 5.4. Assume that Q starts LOW.

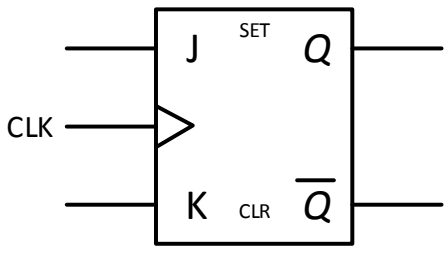


FIGURE 5.4: CLOCKED J-K FLIP-FLOP (6)

5.5 Refer to FIGURE 5.5 and answer the questions that follow.

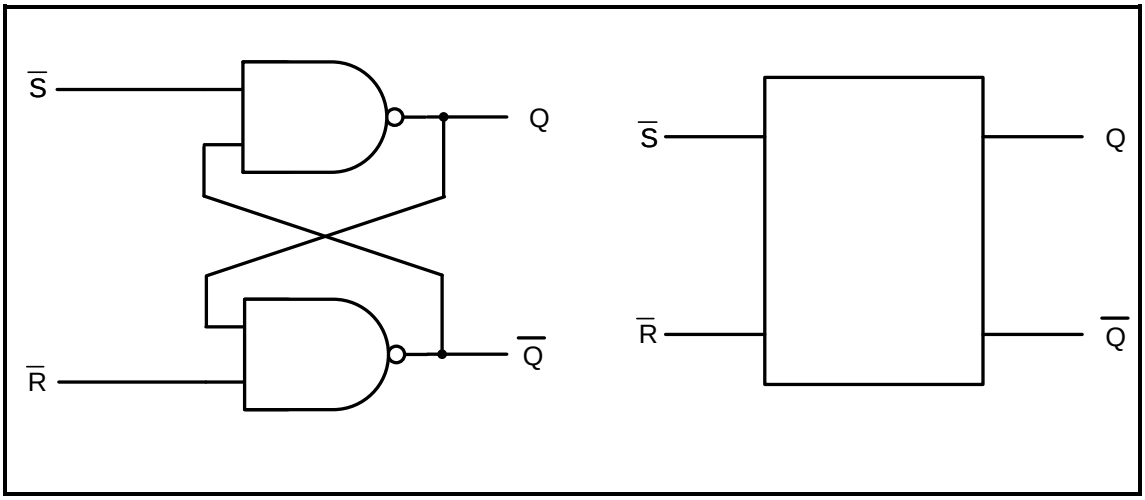


FIGURE 5.5

5.5.1 Identify the circuit in FIGURE 5.5. (1)

5.5.2 Complete the truth table on the ANSWER SHEET for QUESTION 5.5.2.

INPUTS		OUTPUTS	
$\overline{S}$	$\overline{R}$	Q	$\overline{Q}$
0	0		
0	1	1	
1	0		
1	1		

TABLE 5.5.2 (6)

5.6 Refer to counters and explain the following terms:

5.6.1 Up counter (2)

5.6.2 Up/Down counter (2)

5.6.3 Ripple counter (2)

5.7 Refer to FIGURE 5.7 of a synchronous down counter and answer the questions that follow.

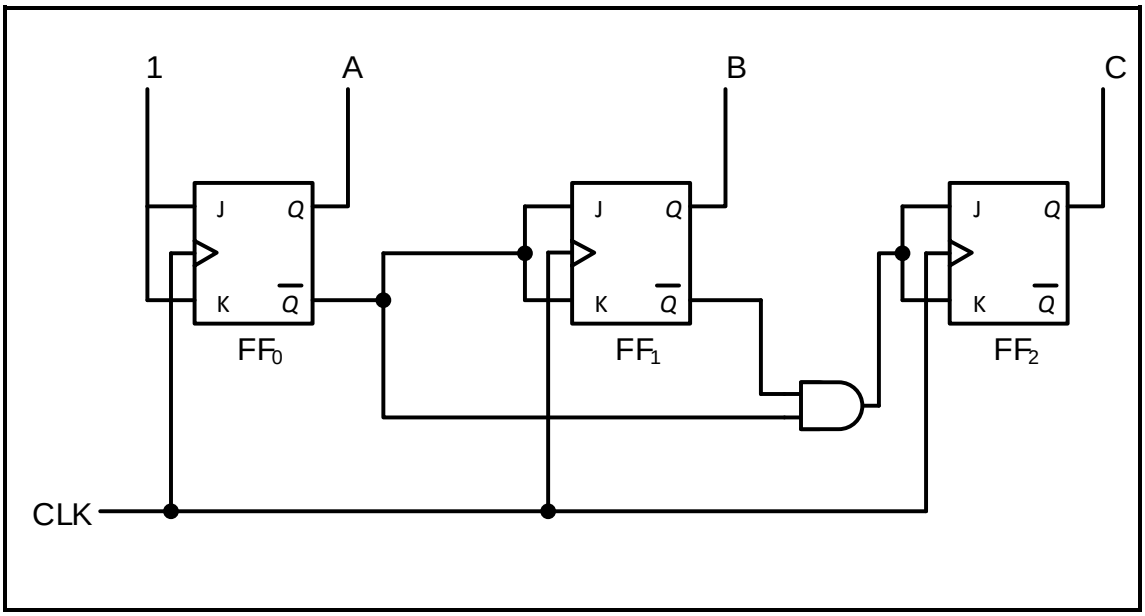


FIGURE 5.7: SYNCHRONOUS DOWN COUNTER

5.7.1 Complete the timing diagrams for this counter on the ANSWER SHEET for QUESTION 5.7.1. (8)

5.7.2 Explain why the down counter operates faster than an up/down counter. (2)

5.8 Refer to shift registers as digital and sequential devices. Complete the sketch of a 4-bit PARALLEL-IN: SERIAL-OUT shift register using D-type flip-flops on the ANSWER SHEET for QUESTION 5.8 AND show ALL the inputs and outputs. (9)
[55]

QUESTION 6: MICROCONTROLLERS

6.1 Draw the block diagram of a microcontroller. (5)

6.2 Refer to microcontrollers and explain how the control unit achieves its function. (5)

6.3 Refer to the input/output pins of a microcontroller and answer the following questions:

6.3.1 Explain the function of the TRIS (tristate) register. (2)

6.3.2 Explain how the TRIS (tristate) register achieves its function. (2)

6.4 Discuss the need for analogue-to-digital converters in microcontroller circuits. (3)

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

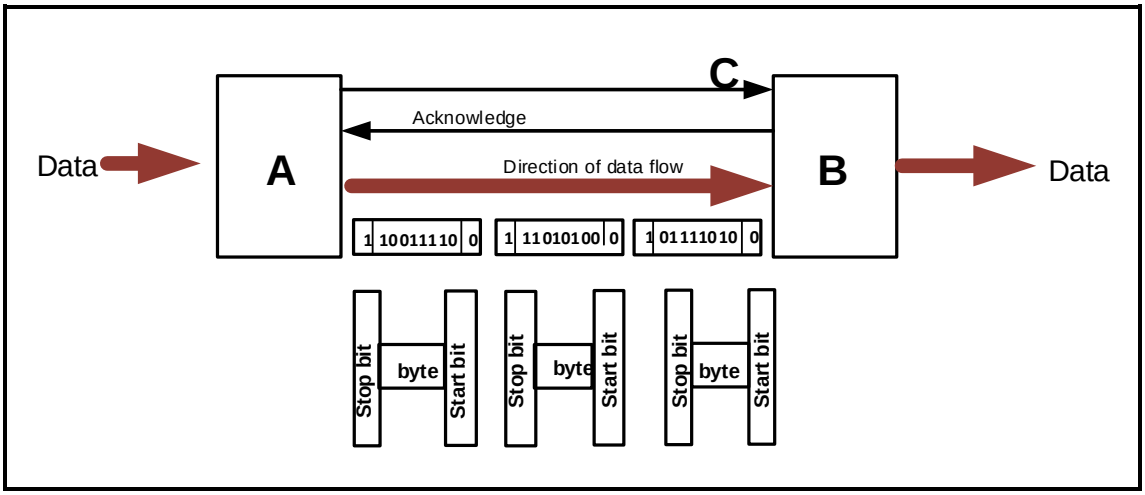


FIGURE 6.5: ASYNCHRONOUS COMMUNICATION

6.5.1 Label **A**, **B** and **C**. (3)

6.5.2 Describe how data is transferred from **A** to **B**. (6)

6.5.3 State TWO advantages of this method of communication. (2)

6.6 Refer to serial communication interface and answer the following questions:

6.6.1 Write out the abbreviation *SPI* in full. (1)

6.6.2 State the mode of communication of the SPI. (1)

6.6.3 Explain the operation of the SPI. (4)

6.6.4 State TWO advantages of the SPI. (2)

6.7 Refer to the software of microcontrollers and define the following terms:

6.7.1 Looping (2)

6.7.2 Condition (IF statement) (3)

6.8 FIGURE 6.8 on the ANSWER SHEET shows an incomplete flow chart of a PICAXE car park assistance system with nine parking bays.

- This system will be set up at the entrance of the car park. It will consist of a red light and a green light.
- The green light informs the driver entering the car park that a parking space is available.
- The system will use two digital sensors.
- Sensor 1 will increase the count when cars enter the parking bay.
- Sensor 2 will decrease the count when cars exit the parking bay.
- Sensor 1 will increase the count to nine parking bays and the program will toggle to the red light.
- This will indicate a full car park.
- Sensor 2 will reduce the count. The green light switches on if the count is less than nine; therefore, indicating that a parking bay is available.

Complete and label the flow chart of this device on the ANSWER SHEET for QUESTION 6.8. (9)
[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

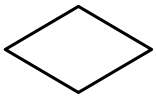
$$V_{OUT} = -\left(V_1 \frac{R_F}{R_1} + V_2 \frac{R_F}{R_2} + \ldots V_N \frac{R_F}{R_N}\right)$$

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

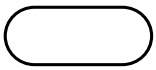
$$V_{OUT} = -(V_1 + V_2 + \ldots V_N)$$

FLOW CHART SYMBOLS USED IN PICAXE

Process



Decision



Terminator

Data

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 3: SWITCHING CIRCUITS

3.2.4

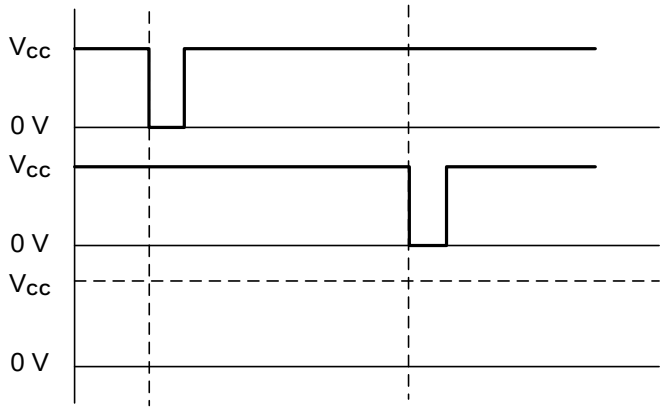


FIGURE 3.2.4

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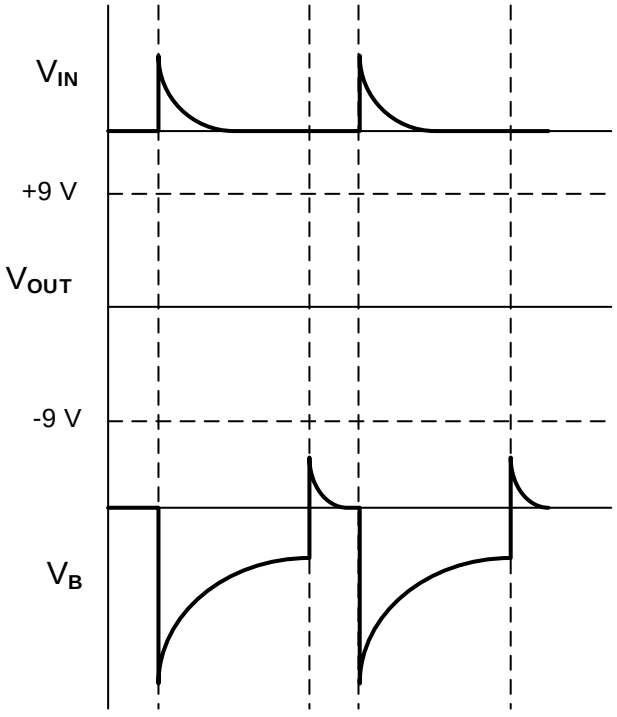
MOD (3)

3.3.4



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MOD (4)

FIGURE 3.3.4

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

4.2.3

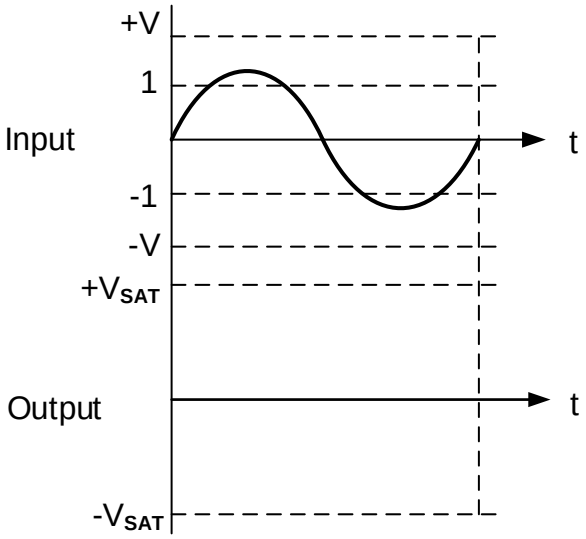

FIGURE 4.2.3

Transfer mark to answer book

MOD (3)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 5: DIGITAL AND SEQUENTIAL DEVICES

5.2

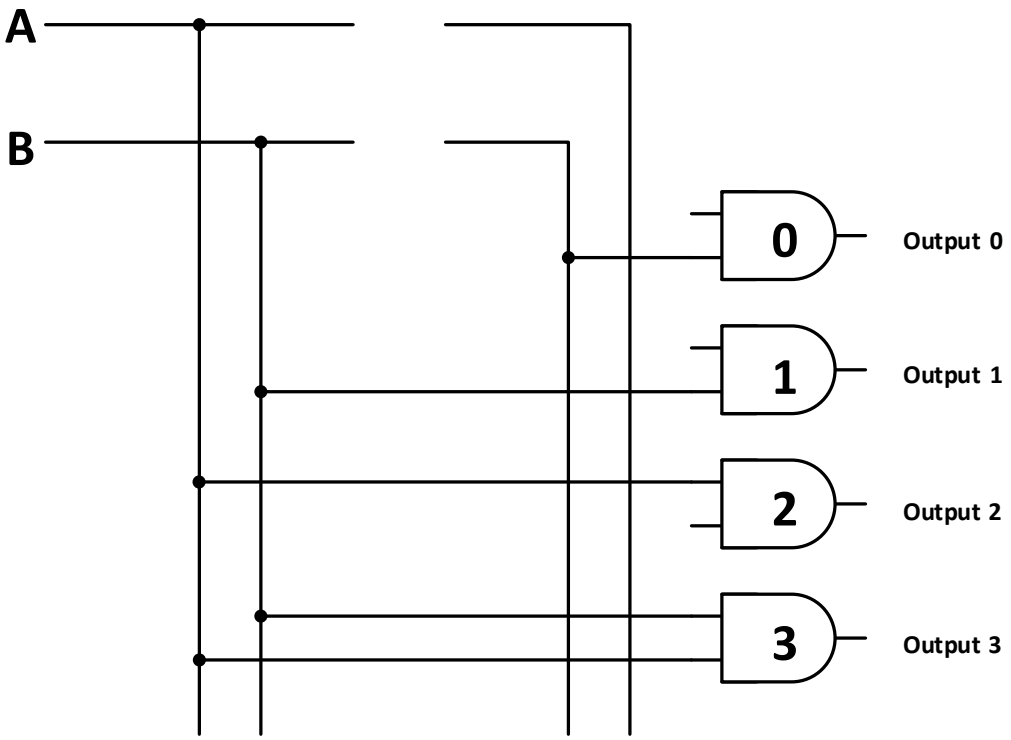

FIGURE 5.2

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MOD (5)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.3.2

A	B	Σ	C_{out}
0	0	0	0
0	1		
1	0		
1	1		

TABLE 5.3.2

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MOD (6)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.4

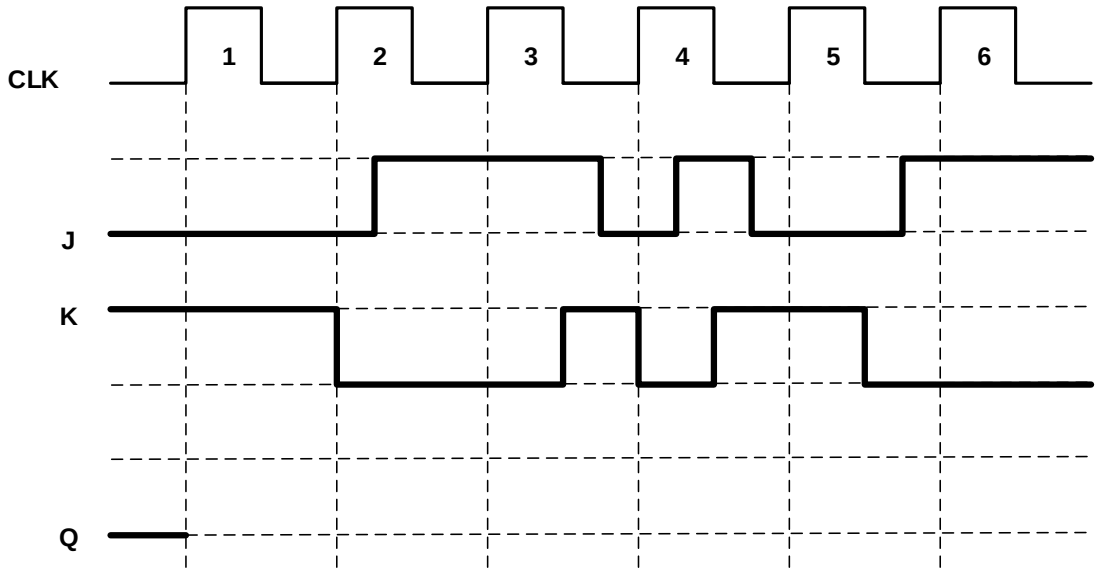

FIGURE 5.4

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MOD (6)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.5.2

INPUTS		OUTPUTS	
$\overline{S}$	$\overline{R}$	Q	$\overline{Q}$
0	0		
0	1	1	
1	0		
1	1		

TABLE 5.5.2

Transfer mark to answer book

MOD (6)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.7.1

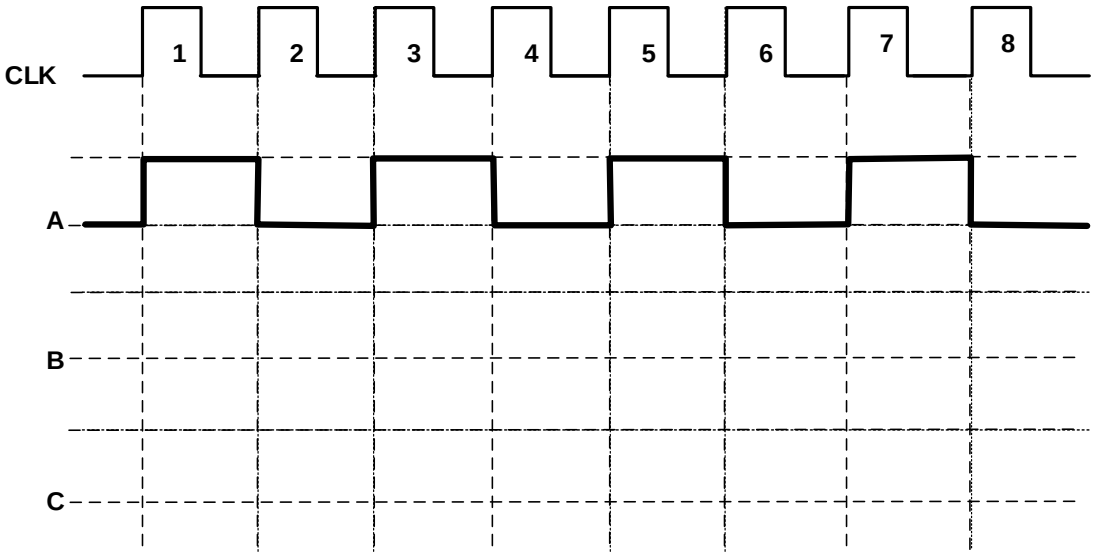

FIGURE 5.7

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MOD (8)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.8

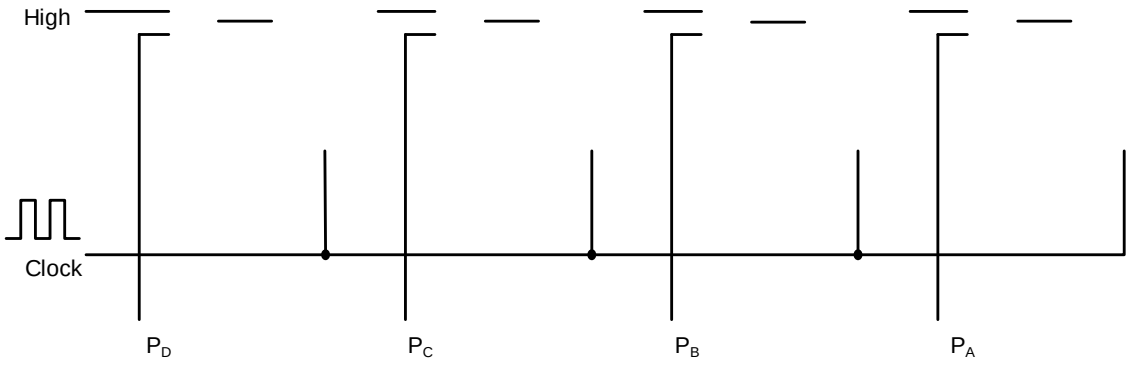

FIGURE 5.8

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MOD (9)

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 6: MICROCONTROLLERS

6.8

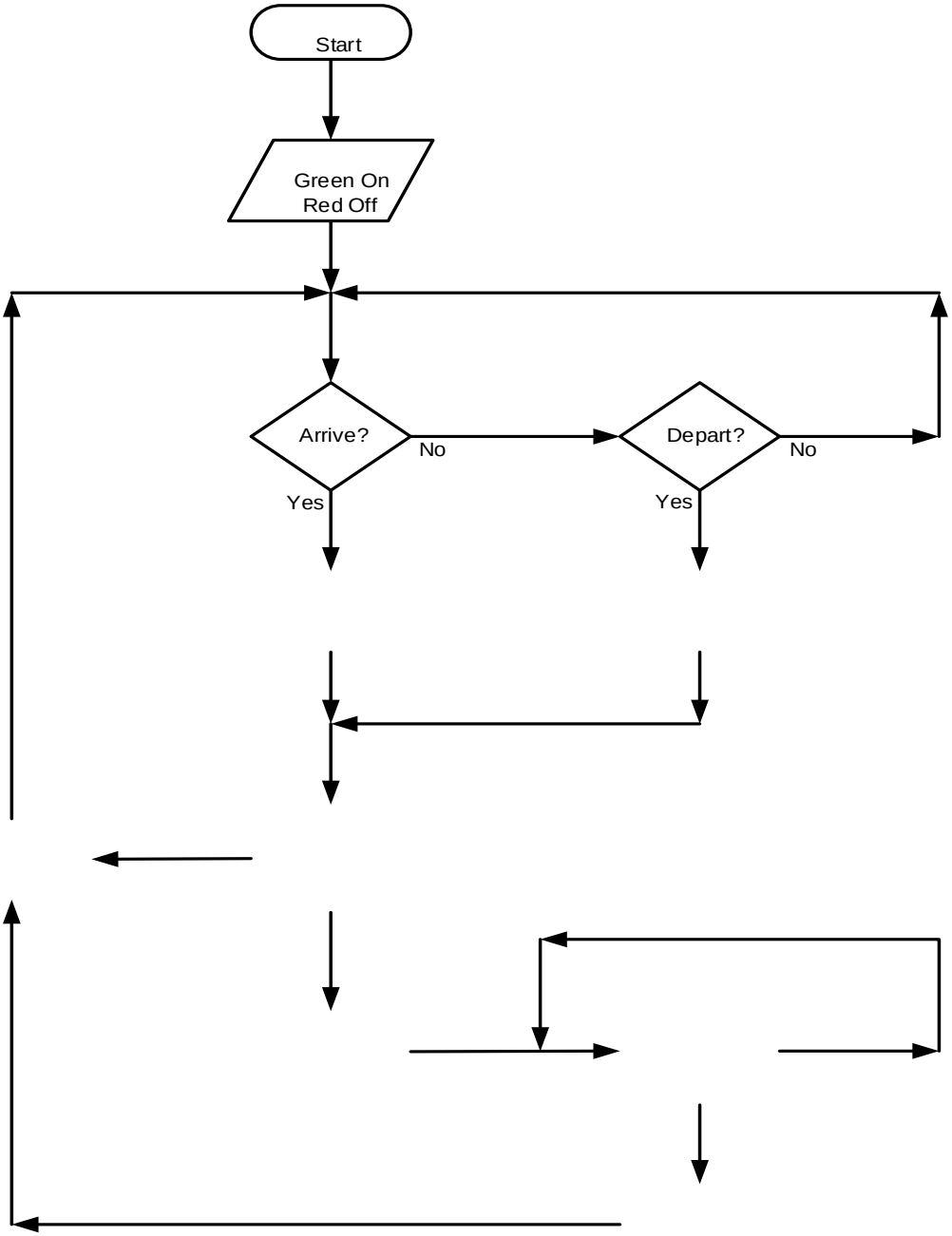

FIGURE 6.8

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MOD (9)