

## EXAMINATION INTERNAL VERIFICATION FORM (2017-2018)

|                                                |                                           |                                            |         |
|------------------------------------------------|-------------------------------------------|--------------------------------------------|---------|
| <b>MODULE :</b>                                | PSDE4004 Electronics 1                    | <b>LEVEL:</b>                              | 4       |
| <b>PROGRAMME :</b>                             | HNC Electrical and Electronic Engineering | <b>TERM OF EXAM:</b><br>(SPRING OR SUMMER) | Summer  |
| <b>LEARNING OUTCOME(S)<br/>BEING ASSESSED:</b> | MILO 1, MILO 2                            | <b>EXAM<br/>PAPER:</b>                     | Main    |
|                                                |                                           | <b>EXAMINATION<br/>AUTHOR :</b>            | M. Hall |

| VERSION: | DATE SUBMITTED<br>FOR VERIFICATION: | INTERNAL VERIFIER COMMENTS (Approval or detail of amendments required):                                                          | DATE:    |
|----------|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|----------|
| 1.       | 24-01-18                            | <i>Conforms to the assessment pattern described in the module syllabus and tests the module learning outcomes appropriately.</i> | 12-03-18 |
| 2.       |                                     |                                                                                                                                  |          |

| INTERNAL VERIFIER PLEASE TICK TO INDICATE THAT THE EXAMINATION: |                                                                     |
|-----------------------------------------------------------------|---------------------------------------------------------------------|
| <input checked="" type="checkbox"/>                             | Conforms to the assessment pattern described in the module syllabus |
| <input checked="" type="checkbox"/>                             | Tests the module learning outcome(s) appropriately                  |

| SIGNATURES OF FINAL APPROVAL:                                                                                                                                         | SIGNATURE        | DATE     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------|
| <b>INTERNAL VERIFIER:</b> I confirm that this version of the exam paper is ready to be sent to the external examiner                                                  | <i>R. Davies</i> | 12-03-18 |
| <b>EXAM AUTHOR:</b> I confirm that internal verifier and external examiner approval have been received and that this version of the exam paper is ready for printing. |                  |          |

**LOCATION: COLEG SIR GAR**

**LLEOLIAD: COLEG SIR GAR**

**LEVEL 4**

**LEFEL 4**

**EXAMINATION PERIOD  
MAY 2018**

**CYFNOD ARHOLIADAU  
MAI 2018**

**MODULE CODE: PSDE 4004**

## **Electronics I**

**TIME: 2 HOURS**

**THIS PAPER IS IN 2 PARTS:**

**ANSWER ALL QUESTIONS IN PART A**

**ANSWER TWO QUESTIONS OUT OF THREE IN PART B**

*Equipment or materials required – Calculator*

*Adnoddau neu ddefnyddiau sydd eu hangen - Cyfrifiannell*

# **Main**

## Formulae

$$R_s = \frac{V_s - V_D}{I_F}$$

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

$$\alpha = \frac{I_C}{I_E}$$

$$\beta = \frac{I_C}{I_B}$$

$$I_E = I_C + I_B$$

$$h_{fe} = \frac{I_C}{I_B}$$

$$A_f = \frac{A}{1 + \beta A}$$

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{R_F}{R_S}$$

$$A_v = \frac{R_F + R_S}{R_S}$$

$$f_2 = \frac{f_{unity}}{A_{CL}}$$

$$f_{max} = \frac{Slew\ Rate}{2\pi \times V_{pk}}$$

$$Integrator\ f_c = \frac{1}{2\pi R_f C}$$

**PART A – Answer ALL 10 questions.**

A1. Draw a diagram of an unbiased PN junction and explain how a depletion layer is formed.  
(4 marks)

A2. Explain the principle of operation of the Zener diode.  
(3 marks)

A3. An LED is connected in series with a 2k resistor. Calculate the current through the LED if the voltage drop across the LED is 2.2V and the supply voltage is 9V.  
(3 marks)

A4. Describe with the aid of a graph the “Input Characteristic” of the common emitter amplifier configuration.  
(3 marks)

A5. Show how an op-amp can be connected to behave as a comparator and as an integrator  
(3 marks)

A6. Explain with the aid of diagrams, the 3 configurations that a bipolar transistor may be connected in.  
(6 marks)

A7. Simplify the following Boolean expression using a Karnaugh Map:

$$F = A\bar{B}.D + \bar{A}C + ABC\bar{D} + \bar{B}C.D + A\bar{B}.\bar{C} + BCD$$

(4 marks)

A8. Complete the following table by carrying out the required conversions:

| Binary                | Octal           | Decimal           | Hex             |
|-----------------------|-----------------|-------------------|-----------------|
| 11001101 <sub>2</sub> |                 |                   |                 |
|                       | 25 <sub>8</sub> |                   |                 |
|                       |                 | 238 <sub>10</sub> |                 |
|                       |                 |                   | B7 <sub>H</sub> |

(6 marks)

A9. Explain the basic operation of a 8-to-3 line encoder.  
(4 marks)

A10. Explain the operation of a JK flip-flop using a truth table to illustrate your answer.  
(4 marks)

**Total Marks for Part A = 40**

## PART B – Only answer 2 of the following 3 questions (B1, B2, B3)

*\*If you answer all 3, only B1 and B2 will be marked\**

### Question B1 – Transistor Amplifiers

- a. Figure B1.1 shows a common emitter transistor amplifier. Given the following criteria, calculate the required values for the biasing components;  $R_L$ ,  $R_E$ ,  $R_1$ ,  $R_2$ . You must state any assumptions made.

$$V_{CC} = 9V, I_Q = 1.1mA, h_{FE} = 75$$

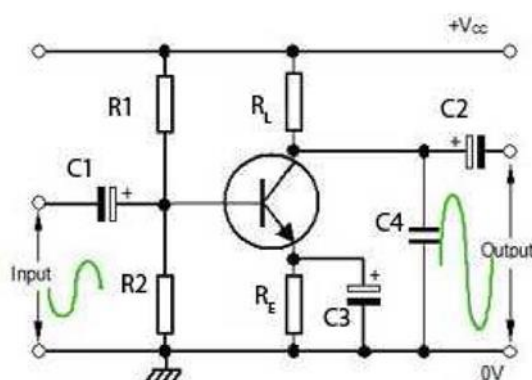


Figure B1.1

(8 marks)

- b. Calculate  $I_E$  in a transistor for which  $\beta = 80$  and  $I_B = 15\mu A$ .  
(3 marks)
- c. Describe with the aid of suitable diagrams and graphs the 3 classes of transistor amplifier: Class A, Class B and Class C.  
(6 marks)
- d. Explain how the input impedance of an amplifier can be found using standard test equipment.  
(6 marks)
- e. With reference to the 4 impedances of an amplifier; source, load, input and output, draw an equivalent diagram and describe the requirements for an ideal current amplifier.  
(7 marks)

**Total Marks for Question B1 = 30**

## Question B2 – Op-amps

- Describe the 5 characteristics of an ideal op-amp. (5 marks)
- Calculate the gain of a non-inverting op-amp amplifier if the feedback resistor is 200k and the series resistor is 18k. (3 marks)
- Draw 2 diagrams showing how an op-amp can be connected to behave as a comparator and as a differentiator. (4 marks)
- An OP-amp has a gain-bandwidth product of 30MHz. Determine the bandwidth of the OP-amp when the  $A_{CL} = 800$ . (3 marks)
- Determine the maximum operating frequency for the circuit shown in Figure B2.1 if the slew rate is  $1.2\text{V}/\mu\text{s}$ . What would the maximum frequency be if the maximum output voltage was  $200\text{mV}_{\text{pk}}$ .

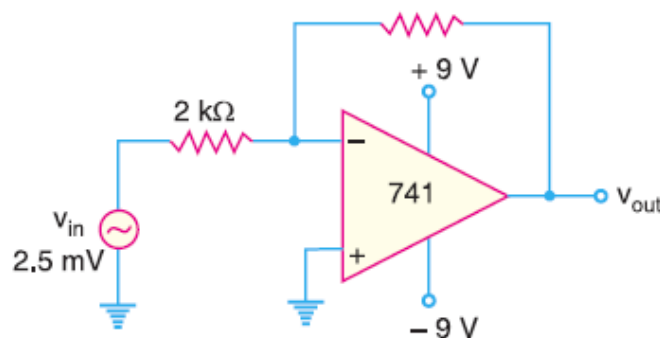


Figure B2.1

(5 marks)

- Calculate the output voltage from the circuit shown in Figure B2.2 for an input of  $150\mu\text{V}$  and a  $180\text{k}\Omega$  feedback resistor.

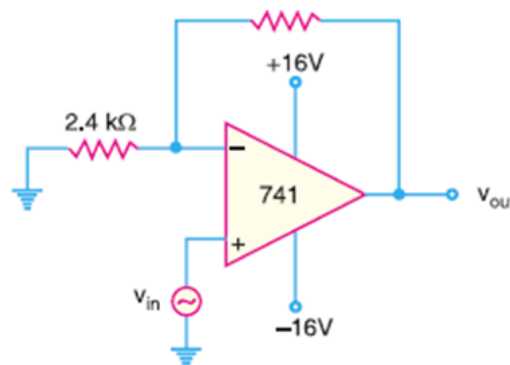


Figure B2.2

(4 marks)

g. Find the closed-loop gain for the circuit in Figure B2.3 if:

- i.  $R_{\text{source}} = 1\Omega$
- ii.  $R_{\text{source}} = 8k\Omega$

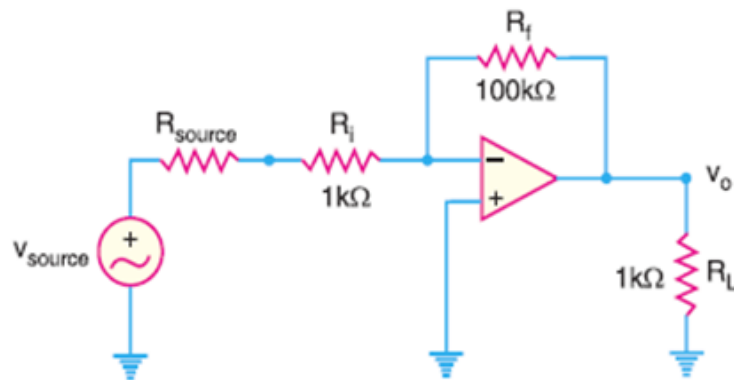


Figure B2.3

(3 marks)

- h. Determine the critical frequency for an op-amp integrator circuit if the feedback capacitor is  $33nF$  and the feedback resistor is  $100k\Omega$ .

(3 marks)

**Total Marks for Question B2 = 30**

### Question B3 – Digital Logic Design

a. Show how the following gates can be implemented using NOR gates only:

- i. NOT
- ii. AND
- iii. OR
- iv. NAND

(4 marks)

b. Use DeMorgan's Theorem and a Karnaugh map to simplify:

i.  $F = \overline{A + \overline{B} + \overline{BC} + \overline{A(B + C)}}$

ii.  $G = \overline{A + \overline{B} + \overline{ABC} + \overline{A + \overline{BC}}}$

(6 marks)

c. Using a finite state machine, produce the Boolean equations required to build a circuit that will repeatedly count from 2 to 11. Show and explain all of the stages of the design process.

(20 marks)

**Total Marks for Question B3 = 30**

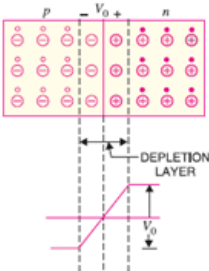
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**EXAMINATION SOLUTIONS**  
(to accompany the examination paper sent to the external examiner  
but NOT to be seen by students)

May 2018

|                   |                                                       |               |                    |
|-------------------|-------------------------------------------------------|---------------|--------------------|
| <b>Programme:</b> | <b>HNC in Electrical &amp; Electronic Engineering</b> | <b>Level:</b> | <b>4</b>           |
| <b>Module:</b>    | <b>PSDE4004 Electronics I</b>                         |               |                    |
| <b>Author:</b>    | <b>M Hall</b>                                         | <b>Page:</b>  | <b>Page 1 of 9</b> |

| Part A    | Question                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Marks                                                        |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| <b>A1</b> |  <p>At the junction of the N and P type materials, the free electrons near the junction in the N region begin to diffuse across the junction into the P region where they combine with holes near the junction. The result is that the N region loses free electrons as they diffuse into the junction. This creates a layer of positive charges near the junction. As the electrons move across the junction, the P region loses holes as the electrons and holes combine. The result is that there is a layer of negative charges (trivalent ions) near the junction. These two layers of positive and negative charges form the depletion layer.</p> | <b>1</b><br><br><br><br><br><br><br><br><br><br><br><b>3</b> |
| <b>A2</b> | <p>A Zener diode is a special type of diode that is designed to operate in the reverse breakdown region. A zener diode is heavily doped to reduce the reverse breakdown voltage. This causes a very thin depletion layer. As a result, a zener diode has a sharp reverse breakdown voltage <math>V_Z</math>. Two things happen when <math>V_Z</math> is reached: the diode current increases rapidly and the reverse voltage <math>V_Z</math> across the diode remains almost constant. In other words, the zener diode operated in this region will have a relatively constant voltage across it, regardless of the value of current through the device. This permits the zener diode to be used as a voltage regulator.</p>             | <b>3</b>                                                     |

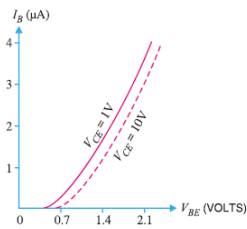
A3

$$I_F = \frac{V_S - V_D}{R_S}$$

$$= (9 - 2.2) / 2k = 3.4mA$$

3

A4



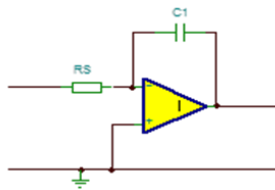
1

The input characteristics of a CE connection can be determined graphically by keeping  $V_{CE}$  constant (say at 10 V) and plotting a graph of base current for various values of  $V_{BE}$ . The characteristic resembles that of a forward biased diode curve. This is expected since the base-emitter section of transistor is a diode and it is forward biased.

2

A5

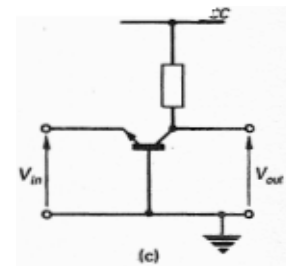
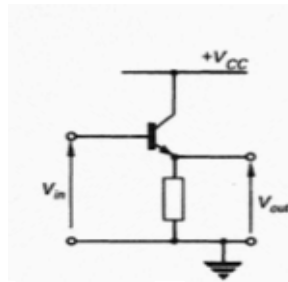
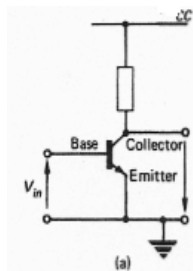
Integrator



3

A6

The various ways in which a bipolar transistor may be connected to provide gain are shown below. These are: Common Emitter, Common Collector and Common Base



6

A7

| CD \ AB | 00 | 01 | 11 | 10 |
|---------|----|----|----|----|
| 00      |    |    | 1  | 1  |
| 01      |    |    | 1  | 1  |
| 11      | 1  | 1  | 1  |    |
| 10      | 1  | 1  | 1  |    |

1

$$F = \bar{A}C + AD + A\bar{C} \quad \text{or} \quad F = \bar{A}C + CD + A\bar{C}$$

3

**A8**

| Binary                | Octal           | Decimal           | Hex             |
|-----------------------|-----------------|-------------------|-----------------|
| 11001101 <sub>2</sub> | 315             | 205               | CD              |
| 10101                 | 25 <sub>8</sub> | 21                | 15              |
| 11101110              | 356             | 238 <sub>10</sub> | EE              |
| 10110111              | 267             | 183               | B7 <sub>H</sub> |

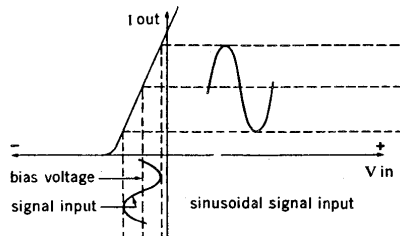
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each****A9**

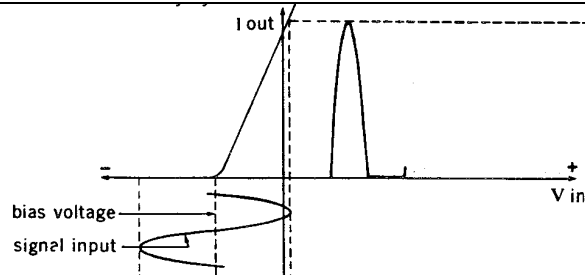
A code converter that converts from octal, decimal or hexadecimal into binary is usually known as an encoder. Unlike the multiplexer, it has more than one input line, does not have any control lines and data is not routed through it. The number of input lines must correspond to the base of the input number i.e. if converting from octal to binary, then 8 input and 3 output lines would be required. Only one of its inputs is active at a time and this input produces a specified output data word.

**4****A10**

| J | K | Q | Q <sup>+</sup> | Comments  |
|---|---|---|----------------|-----------|
| 0 | 0 | 0 | 0              | no change |
| 0 | 0 | 1 | 1              |           |
| 1 | 0 | 0 | 1              | set       |
| 1 | 0 | 1 | 1              |           |
| 0 | 1 | 0 | 0              | reset     |
| 0 | 1 | 1 | 0              |           |
| 1 | 1 | 0 | 1              | toggle    |
| 1 | 1 | 1 | 0              |           |

**4**

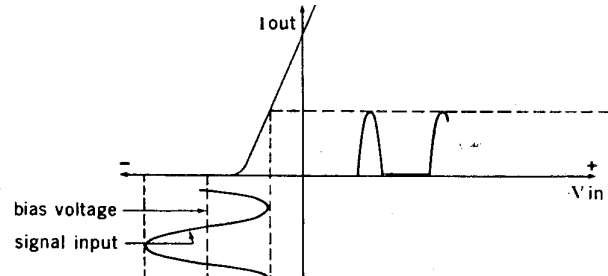
| Q. B1 | Question                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Marks                                                                   |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| a.    | <p><math>V_{CC} = 9V</math><br/> <math>I_Q = 1.1mA</math></p> <p><math>V_C = \frac{1}{2} V_{CC} = 4.5V</math><br/> <math>R_L = (V_{CC} - V_C)/I_Q = 4.5/1.1m = 4.09k\Omega</math></p> <p><math>I_E \approx I_C = 1.1mA</math><br/> <math>V_E = 10\% \text{ of } V_{CC} = 0.9V</math></p> <p><math>R_E = V_E/I_E = 0.9/1.1m = 818\Omega</math></p> <p><math>I_B = I_C/h_{FE} = 1.1m/75 = 14.67\mu A</math></p> <p><math>V_B = V_E + 0.7 = 1.6V</math></p> <p><math>I_{R1} = I_{R2} = I_B \times 10 = 147\mu A</math></p> <p><math>R_1 = (V_{CC} - V_B) / I_{R1} = (9 - 1.6)/147\mu = 50.3k\Omega</math></p> <p><math>R_2 = V_B/I_{R1} = 1.6/147\mu = 10.9k\Omega</math></p>     | <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> |
| b.    | <p><math>\beta = \frac{I_C}{I_B}</math></p> <p><math>\beta = \frac{I_C}{I_B}</math></p> <p><math>I_C = 80 \times 15u = 1.2mA</math></p> <p><math>I_E = I_C + I_B = 1.2m + 15u = 1.215mA</math></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <p>2</p> <p>1</p>                                                       |
| c.    | <p><u>Class A</u></p> <p>This is the most widely used class as it gives an output signal which is an exact replica of the input i.e. it introduces very little distortion. The disadvantage with this class is that it has a low efficiency of around 20%, this means that for every 5 watts of DC power from the supply, only 1 watt is actually used, the rest is dissipated mainly as heat.</p>  <p><u>Class B</u></p> <p>For this class, current flows through the output for 50% of the input cycle, the efficiency of this class is 50%, but 50% distortion has been introduced.</p> | <p>2</p>                                                                |



2

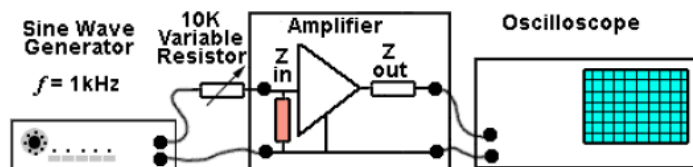
### Class C

For this class, current flows through the output for less than 50% of the input cycle, this is illustrated below. The efficiency of this class is around 80%, but a high degree of distortion has been introduced.



2

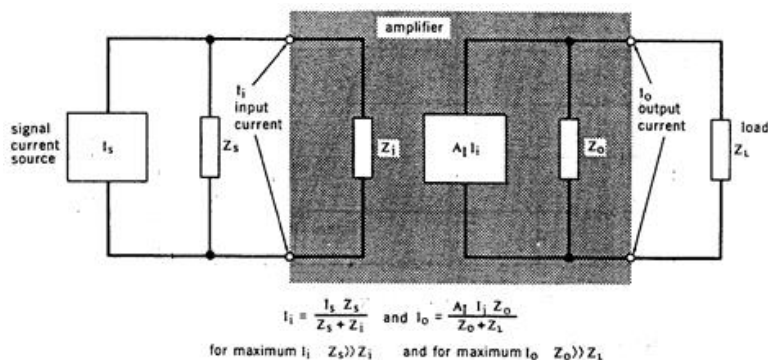
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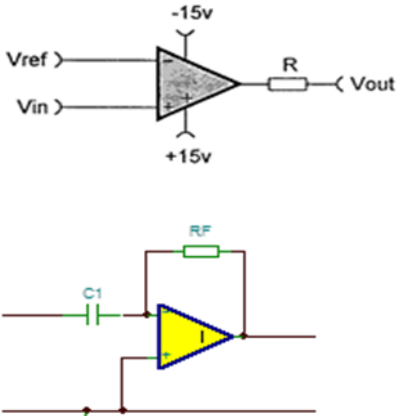
To find the value of  $Z_{in}$  (at 1kHz) a variable resistor of about 10K ohms is connected between the generator and the amplifier input. Initially the variable resistor is set to zero ohms and the generator is adjusted to give a large undistorted display on the oscilloscope. The variable resistor is now adjusted until the peak-to-peak of the output wave is exactly half its original value. As the variable resistor and the input impedance must both be the same value to give 50% of the amplitude across each, the resistance value of the variable resistor is therefore the same value as  $Z_{in}$ .

6

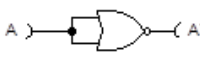
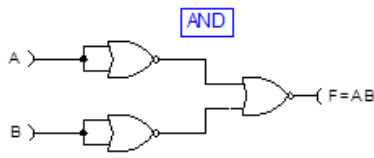
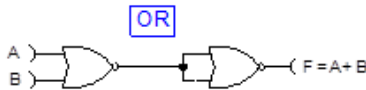
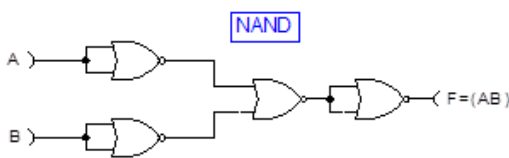
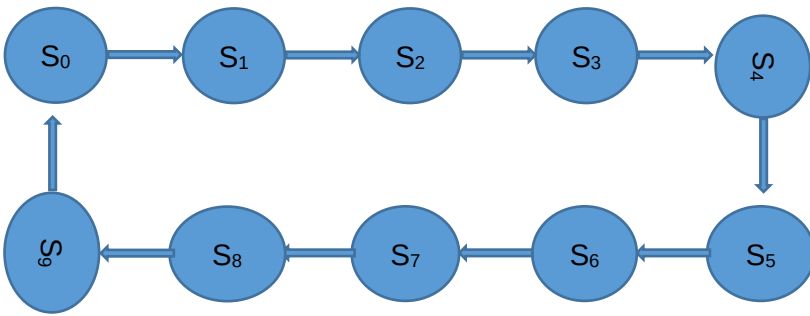
e.



7

| Q.B2 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Marks                                        |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| a.   | <p><u>Infinite Voltage Gain</u></p> <p>This means that the open loop gain <math>A_v</math> (i.e. without the feedback network) should be infinite, commercially available devices have open loop gains exceeding one million.</p> <p><u>Infinite Bandwidth</u></p> <p>This would mean equal amplification for all signals from DC to infinity and is not achievable in practice. Integrated circuit operational amplifiers are invariably direct coupled (no capacitors) and some will operate at frequencies up to a few megahertz under small signal conditions with a closed loop gain of about 100.</p> <p><u>Infinite Input Resistance</u></p> <p>Ideally, the input resistance <math>R_{IN}</math> should be infinite; in practice all integrated circuit types have a very high input impedance and their loading effect on the signal source is negligible. Some FET types of integrated operational amplifier have an input impedance as high as <math>100G\Omega</math></p> <p><u>Zero Output Impedance</u></p> <p>The output impedance of operational amplifiers is extremely low and they can cope with changes in load impedance by supplying more (or less) current without any significant change in the output voltage.</p> <p><u>Zero Offset</u></p> <p>This means that the output should be zero when the input is zero and is difficult to achieve in production devices. However, the effect can be cancelled out by supplying a small offset voltage to zero the output - often by a simple potentiometer adjustment external to the integrated circuit.</p> | <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> |
| b.   | $A_v = \frac{R_F + R_S}{R_S}$ $= (200k + 18k) / 18k = 12.1$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 3                                            |
| c.   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <p>2</p> <p>2</p>                            |
| d.   | $f_2 = \frac{f_{unity}}{A_{CL}}$ $= 30M / 800 = 37.5KHz$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3                                            |

|    |                                                                                                                                                                                                                            |   |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| e. | $f_{max} = \frac{Slew\ Rate}{2\pi \times V_{pk}}$ $= 1.200M / (2\pi \times 7) \quad \text{Note: } V_{out_{pk}} = V_{cc} - 2$ $= 27.28KHz$ <p>If Vout is limited to 200mV then</p> $= 1200k / (2\pi \times 0.2)$ $= 955KHz$ | 3 |
| f. | $A_{CL} = 1 + \frac{R_f}{R_i}$ $= 1 + (180k / 2.4k) = 76$ $v_{out} = A_{CL} \times v_{in}$ $= 76 \times 150u = 11.4mV$                                                                                                     | 2 |
| g. | <p>When <math>R_{source} = 1\Omega</math>, <math>A_{CL} = -100k / (1k + 1) = -99.9</math></p> <p>When <math>R_{source} = 8k\Omega</math>, <math>A_{CL} = -100k / (1k + 8k) = -11.1</math></p>                              | 2 |
| h. | $f_c = \frac{1}{2\pi R_f C}$ $= 1 / (2\pi \times 100k \times 33n)$ $= 48Hz$                                                                                                                                                | 1 |

| Q. B3          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Marks                                               |                |                |                |                             |                             |                             |                             |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|----------------|----------------|----------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|--|--|----------------|----------------|----------------|----------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|----------------|----------------|---|---|---|---|---|---|---|---|----------------|----------------|---|---|---|---|---|---|---|---|----------------|----------------|---|---|---|---|---|---|---|---|----------------|----------------|---|---|---|---|---|---|---|---|----------------|----------------|---|---|---|---|---|---|---|---|----------------|----------------|---|---|---|---|---|---|---|---|----------------|----------------|---|---|---|---|---|---|---|---|----------------|----------------|---|---|---|---|---|---|---|---|----------------|----------------|---|---|---|---|---|---|---|---|----------------|-----------------|---|---|---|---|---|---|---|---|----------------------------------------|
| a.             | <div><div>NOT</div></div> <div><div>AND</div></div> <div><div>OR</div></div> <div><div>NAND</div></div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <div>1</div> <div>1</div> <div>1</div> <div>1</div> |                |                |                |                             |                             |                             |                             |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| b.i            | $F = \overline{A}\overline{C} + \overline{A}B + B\overline{C}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3                                                   |                |                |                |                             |                             |                             |                             |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| ii             | $G = \overline{A}B$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3                                                   |                |                |                |                             |                             |                             |                             |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| c.             | <p><u>Allocate states and draw state diagram</u></p> <p><math>S_0 = \text{count } 2, S_1 = \text{count } 3, S_2 = \text{count } 4, S_3 = \text{count } 5, S_4 = \text{count } 6, S_5 = \text{count } 7, S_6 = \text{count } 8, S_7 = \text{count } 9, S_8 = \text{count } 10, S_9 = \text{count } 11</math></p>  <p><u>Draw State table</u></p> <table><thead><tr><th rowspan="2">Current</th><th rowspan="2">Next</th><th colspan="4">Current</th><th colspan="4">Next</th></tr><tr><th>Q<sub>A</sub></th><th>Q<sub>B</sub></th><th>Q<sub>C</sub></th><th>Q<sub>D</sub></th><th>Q<sub>A</sub><sup>+</sup></th><th>Q<sub>B</sub><sup>+</sup></th><th>Q<sub>C</sub><sup>+</sup></th><th>Q<sub>D</sub><sup>+</sup></th></tr></thead><tbody><tr><td>S<sub>0</sub></td><td>S<sub>1</sub></td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>S<sub>1</sub></td><td>S<sub>2</sub></td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td>S<sub>2</sub></td><td>S<sub>3</sub></td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td></tr><tr><td>S<sub>3</sub></td><td>S<sub>4</sub></td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>S<sub>4</sub></td><td>S<sub>5</sub></td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td></tr><tr><td>S<sub>5</sub></td><td>S<sub>6</sub></td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>S<sub>6</sub></td><td>S<sub>7</sub></td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td></tr><tr><td>S<sub>7</sub></td><td>S<sub>8</sub></td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>S<sub>8</sub></td><td>S<sub>9</sub></td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>S<sub>9</sub></td><td>S<sub>10</sub></td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td></tr></tbody></table> | Current                                             | Next           | Current        |                |                             |                             | Next                        |                             |  |  | Q <sub>A</sub> | Q <sub>B</sub> | Q <sub>C</sub> | Q <sub>D</sub> | Q <sub>A</sub> <sup>+</sup> | Q <sub>B</sub> <sup>+</sup> | Q <sub>C</sub> <sup>+</sup> | Q <sub>D</sub> <sup>+</sup> | S <sub>0</sub> | S <sub>1</sub> | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | S <sub>1</sub> | S <sub>2</sub> | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | S <sub>2</sub> | S <sub>3</sub> | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | S <sub>3</sub> | S <sub>4</sub> | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | S <sub>4</sub> | S <sub>5</sub> | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | S <sub>5</sub> | S <sub>6</sub> | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | S <sub>6</sub> | S <sub>7</sub> | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | S <sub>7</sub> | S <sub>8</sub> | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | S <sub>8</sub> | S <sub>9</sub> | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | S <sub>9</sub> | S <sub>10</sub> | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | <div>1</div> <div>2</div> <div>5</div> |
| Current        | Next                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                     |                | Current        |                |                             |                             | Next                        |                             |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
|                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Q <sub>A</sub>                                      | Q <sub>B</sub> | Q <sub>C</sub> | Q <sub>D</sub> | Q <sub>A</sub> <sup>+</sup> | Q <sub>B</sub> <sup>+</sup> | Q <sub>C</sub> <sup>+</sup> | Q <sub>D</sub> <sup>+</sup> |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>0</sub> | S <sub>1</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0                                                   | 0              | 0              | 0              | 0                           | 0                           | 0                           | 1                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>1</sub> | S <sub>2</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0                                                   | 0              | 0              | 1              | 0                           | 0                           | 1                           | 0                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>2</sub> | S <sub>3</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0                                                   | 0              | 1              | 0              | 0                           | 0                           | 1                           | 1                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>3</sub> | S <sub>4</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0                                                   | 0              | 1              | 1              | 0                           | 1                           | 0                           | 0                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>4</sub> | S <sub>5</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0                                                   | 1              | 0              | 0              | 0                           | 1                           | 0                           | 1                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>5</sub> | S <sub>6</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0                                                   | 1              | 0              | 1              | 0                           | 1                           | 1                           | 0                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>6</sub> | S <sub>7</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0                                                   | 1              | 1              | 0              | 0                           | 1                           | 1                           | 1                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>7</sub> | S <sub>8</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 0                                                   | 1              | 1              | 1              | 1                           | 0                           | 0                           | 0                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>8</sub> | S <sub>9</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                                   | 0              | 0              | 0              | 1                           | 0                           | 0                           | 1                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |
| S <sub>9</sub> | S <sub>10</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                   | 0              | 0              | 1              | 1                           | 0                           | 1                           | 0                           |  |  |                |                |                |                |                             |                             |                             |                             |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                |   |   |   |   |   |   |   |   |                |                 |   |   |   |   |   |   |   |   |                                        |

Draw Karnaugh Maps

$Q_A^+$

| CD<br>AB | 00 | 01 | 11 | 10 |
|----------|----|----|----|----|
| 00       | 0  | 0  | 0  | 0  |
| 01       | 0  | 0  | 1  | 0  |
| 11       | x  | x  | x  | x  |
| 10       | 1  | 0  | x  | x  |

$Q_B^+$

| CD<br>AB | 00 | 01 | 11 | 10 |
|----------|----|----|----|----|
| 00       | 0  | 0  | 1  | 0  |
| 01       | 1  | 1  | 0  | 1  |
| 11       | x  | x  | x  | x  |
| 10       | 0  | 0  | x  | x  |

$Q_C^+$

| CD<br>AB | 00 | 01 | 11 | 10 |
|----------|----|----|----|----|
| 00       | 0  | 1  | 0  | 1  |
| 01       | 0  | 1  | 0  | 1  |
| 11       | x  | x  | x  | x  |
| 10       | 0  | 0  | x  | x  |

$Q_D^+$

| CD<br>AB | 00 | 01 | 11 | 10 |
|----------|----|----|----|----|
| 00       | 1  | 0  | 0  | 1  |
| 01       | 1  | 0  | 0  | 1  |
| 11       | x  | x  | x  | x  |
| 10       | 1  | 0  | x  | x  |

Derive Boolean Expressions

$$Q_A^+ = A\bar{C} + BCD$$

$$Q_B^+ = B\bar{C} + B\bar{D} + \bar{B}CD$$

$$Q_C^+ = C\bar{D} + \bar{A}\bar{C}D$$

$$Q_D^+ = \bar{D}$$

4

2

2

2

2