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|-------------------------|--------------------------------------------------|
| Department              | : Physics                                        |
| Level                   | : 05                                             |
| Name of the Examination | : Final Examination                              |
| Course Code and Title   | : PHU5303-Data Acquisition and Signal Processing |
| Academic Year           | : 2025/ 2026                                     |
| Date                    | : <b>04<sup>th</sup> January 2026</b>            |
| Time                    | : <b>1.30 pm - 03.30 pm</b>                      |
| Duration                | : <b>2 hours</b>                                 |

### General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **06** questions in **07** pages. (Page No 2- 7)
3. Answer any **04** questions only. All questions carry equal marks.
4. Answer for each question should commence from a **new page**.
5. Draw fully labelled diagrams where necessary
6. Having any unauthorized documents/ mobile phones in your possession is a punishable offense
7. Use blue or black ink to answer the questions.
8. Circle the number of the questions you answered in the front cover of your answer script.
9. Clearly state your **index number** in your answer script

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Boltzmann constant ( $k$ ) =  $1.38 \times 10^{-23} \text{ JK}^{-1}$

Charge of an electron =  $1.602 \times 10^{-19} \text{ C}$

A.

- (i) Describe two methods of classifying transducers and provide one example for each classification. (04 Marks)

- (ii) Figure 1 illustrates the wavefront of a charged particle moving with velocity  $v$  in a medium of refractive index  $n$ , where the velocity of light in vacuum is  $c$ . Cherenkov detectors identify charged particles by measuring the Cherenkov angle  $\theta$ ,

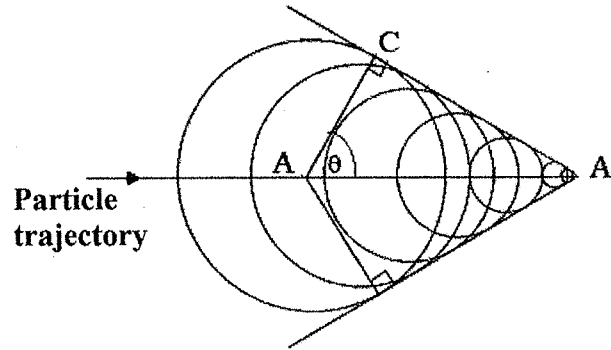


Figure 1

- (iii) Show that  $\cos\theta = 1/\beta n$ , where  $n$  is the medium's refractive index and  $\beta = v/c$ . (05 Marks)

- (iv) A charged particle travels through a medium with refractive index  $n = 1.33$  at a speed  $v = 0.8c$ , where  $c$  is the speed of light in vacuum. Calculate the Cherenkov angle  $\theta$  using the formula and determine whether Cherenkov radiation is emitted (06 Marks)

B.

Figure 2 shows basic elements of a proportional chamber.

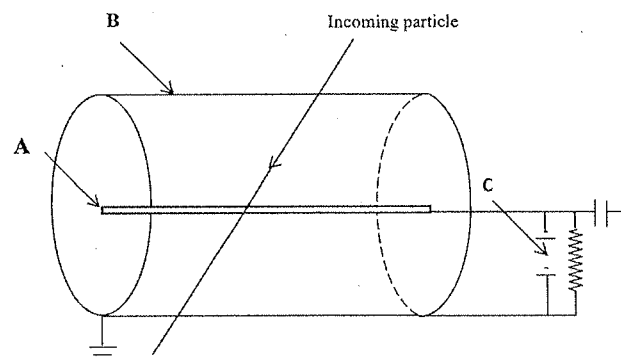


Figure 2

- (i) Identify components A, B, and C and explain their purpose. (03 Marks)
- (ii) Explain what would happen when a charged particle like an electron passes through the chamber. (04 Marks)
- (iii) Briefly explain secondary ionization process. (03 Marks)

**A**

- (i) State two (02) experimental techniques based on signal averaging used to detect signals buried in noise. (04 Marks)

- (ii) A photodiode generates a  $5 \mu\text{A}$  signal current which is fed into a pre-amplifier with an input impedance of  $2.2 \text{ M}\Omega$ . The system operates at an ambient temperature of  $27^\circ\text{C}$ .

Calculate the Signal-to-Noise Ratio (SNR) in dB at the amplifier's input for a bandwidth of  $500\text{kHz}$ . (Use standard formulas: Shot noise current,  $I_s = \sqrt{2eI\Delta f}$ , and Johnson noise voltage,  $V_J = \sqrt{4kTR\Delta f}$  where symbols have their usual meaning). (06 Marks)

**B**

- (i) Briefly describe a high pass filter with a proper circuit diagram and obtain the transfer function of the filter circuit (06 Marks)

- (ii) State the function of clipping and clamping circuits (04 Marks)

- (iii) Draw the output waveform ( $V_o$ ) of the following basic clipping circuits (05 Marks)

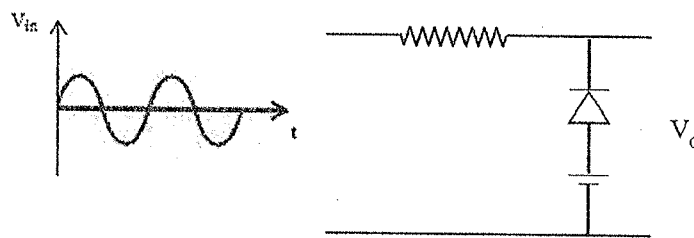


Figure 3

A

- (i) State the golden rules for an ideal operational amplifier. (03 Marks)
- (ii) A comparator circuit is given below. Draw the output ( $V_{out}$ ) if a sinusoidal signal is apply to the input terminals. (02 Marks)

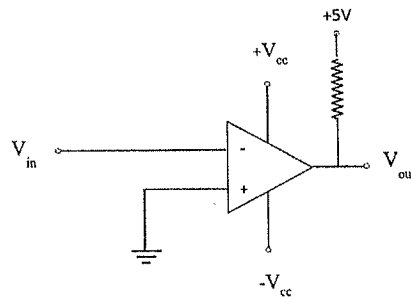


Figure 4

- (iii) Figure 4 shows the variation of an input signal voltage with respect to time, including noise fluctuations around a threshold level.

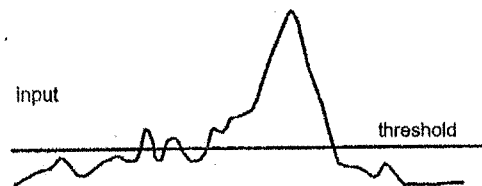


Figure 5

Draw the output responses of a simple comparator and a Schmitt trigger for the given noisy input signal. (10 Marks)

B.

- (i) Show that the output of the following summing amplifier is,  $V_{out} = -(V_1 + V_2 + V_3 + V_4)$  (05 Marks)

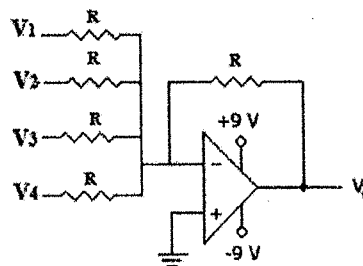


Figure 6

- (ii) An arrangement of a summing amplifier is given in figure 7. Find the  $V_{out}$  for the given input voltages of the summing amplifier assuming that supply voltages are +9 V and -9 V. (05 Marks)

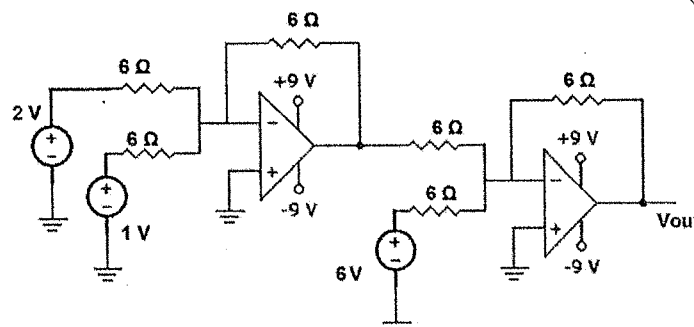


Figure 7

**A.**

A continuous time signal  $x(t) = \sin(2000\pi t) + \sin(4000\pi t)$  is sampled to convert it into a discrete time signal.

- (i) Determine the minimum sampling frequency ( $f_s$ ) required to avoid aliasing according to the sampling theorem. (03 Marks)
- (ii) Calculate the corresponding sampling interval ( $T_s$ ) in milliseconds. (03 Marks)
- (iii) What is aliasing? (02 Marks)

**B.**

An electrical signal  $f(t)$  is a continuous periodic signal with a period  $T$  and shown below,

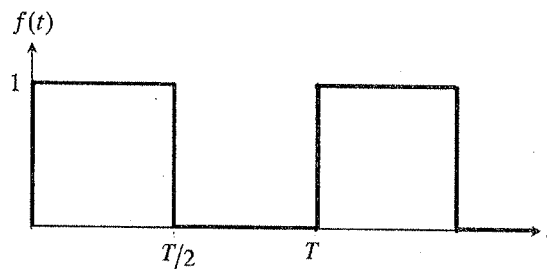


Figure 8

- (i) Write down the Fourier expansion of a function  $f(t)$  of period  $T$  and the expressions for the coefficients  $A_n$  and  $B_n$  in the Fourier series. (05 Marks)
- (ii) Find the coefficients  $A_n$  and  $B_n$  for the waveform given. (05 Marks)
- (iii) Show that the Fourier series for the function  $f(t)$  given above in the interval  $0 < t < T$  is (05 Marks)

$$f(t) = \frac{1}{2} + \frac{2}{\pi} \sin 2\pi f_0 t + \frac{2}{3\pi} \sin 2\pi 3f_0 t + \dots$$

- (iv) Sketch the power spectrum of the waveform. (02 Marks)

A.

A block diagram of analogue to digital converter (ADC) circuit is shown in figure 9.

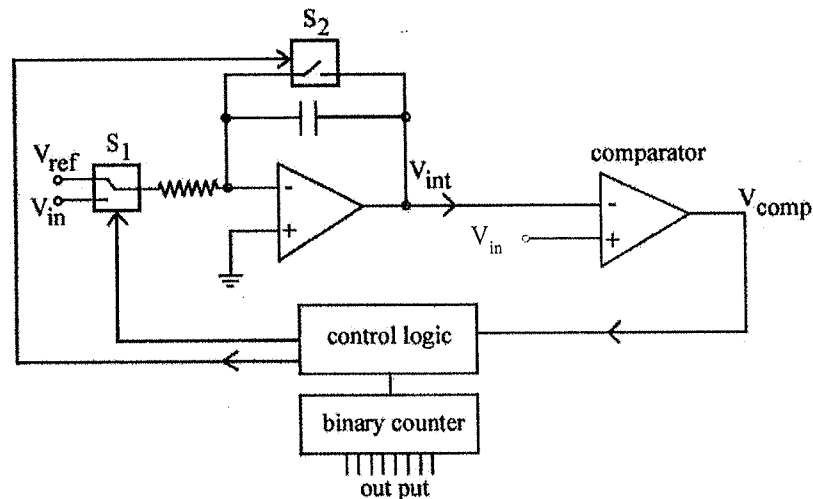


Figure 9

- (i) Explain the advantages and disadvantages of dual slope integration compared with single slope integration method. (05 Marks)
- (ii) Describe the operation sequence of the dual slope integration circuit given in figure 05 when converting an analogue signal to a digital signal. (05 Marks)

B.

An analog signal ranges from 0 to 5 volts and is to be converted to a digital signal using a 4-bit Successive Approximation Register (SAR) analog to digital converter (ADC) with a reference voltage of 5 V.

- (i) Determine the Range, Resolution, Conversion time of above ADC. (06 Marks)
- (ii) Show the step-by-step conversion process for an input of 2.3 V using the SAR method. (05 Marks)
- (iii) What will be the final digital output and the quantization error? (04 Marks)

A.

- (i) What advantages does using hexadecimal notation offer in programming compared to the binary notion which computers internally use? (03 Marks)
- (ii) Name and explain the purpose of the three primary buses in a microprocessor system (03 Marks)
- (iii) Write down the general operation sequence of a processor when running a program stored in the memory. (03 Marks)
- (iv) Explain the meaning of each mnemonic in the following assembly program written for a microprocessor (06 Marks)

```

MOV A, 05
MOV B, 03
ADD A, B
DEC A
CMP A, 02
JE 08
NOP

```

B.

D2716 is an UVEPROM chip and it has pins labeled  $V_{cc}$ ,  $\overline{CE}$  and  $\overline{OE}$  in addition to the address and data pins, You can construct an external memory using 2716 chip as in figure 10.

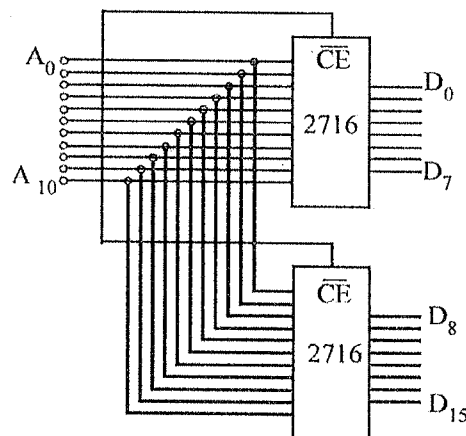


Figure 10

- (i) What are the functions of the pins,  $\overline{OE}$  and  $\overline{CE}$ ? (03 Marks)
- (ii) What should be the size of the address bus and the data bus in the above construction? (02 Marks)
- (iii) Determine the size of the memory in the above construction. (02 Marks)
- (iv) Write down the addresses of the top and bottom registers of the memory in hexadecimal (03 Marks)

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