# The Open University of Sri Lanka
## Faculty of Natural Sciences
## B.Sc. Degree Programme

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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 | : 2023/ 2024 |
| Date | : **09th December 2024** |
| Time | : **9.30 am- 11.30 am** |
| Duration | : **2 hours** |

**General Instructions**

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **06** questions in **06** 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) = $1.38 \times 10^{-23}$ $JK^{-1}$ Charge of an electron = $1.602 \times 10^{-19}$ C

**Question No: 01**

**A.**

Read the passage below and answer the subsequent questions

A scintillation counter is an instrument for detecting and measuring ionizing radiation by using the excitation effect of incident high energy radiation on a scintillating material and detecting the resultant light pulses. The excitation effect is exhibited by many organic and inorganic materials. It consists of a scintillator which generates photons in response to incident radiation and a sensitive photodetector, usually a photomultiplier tube (PMT). Scintillation counters are widely used in radiation protection, assay of radioactive materials and physics research because they can be made inexpensively yet with good quantum efficiency and can measure both the intensity and the energy of incident radiation. Figure 1 shows a Schematic diagram of a scintillation counter.

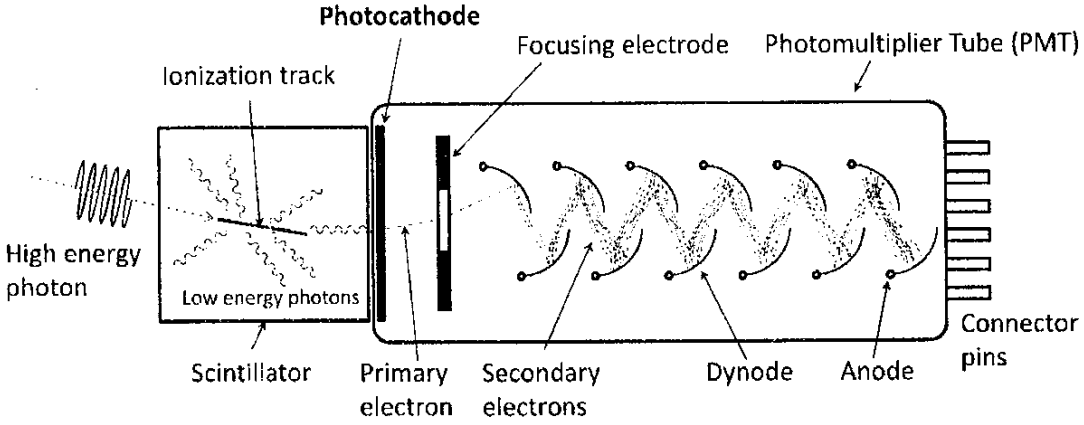


Figure 1

(i) Write down the purpose of using a scintillation counter. (02 Marks)

(ii). Give some examples for high energy radiation. (02 Marks)

(iii). What do you mean by excitation effect? (02 Marks)

(iv). Explain, how the excitation occurs in organic and inorganic materials. (02 Marks)

(v). Write down the main three (03) parts of the scintillation counter and explain their functions. (02 Marks)

(vi). Describe, why the scintillation counters are widely used in nuclear research. (02 Marks)

B. Current through a forward biased pn junction diode is given by the expression

$$\mathbf{I} = I_S \left[ exp\left(\frac{eV}{2kT}\right) - 1 \right]$$

(i) Name the symbols in this expression. (05 Marks)

(ii) Derive an expression for V using the above expression. (08 Marks)

**Question No: 02**

**A**

(i) What are the noise associated with electrical signals? (04 Marks)

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

(iii) A 1 μA current of a signal produced by a transducer is fed into an amplifier of input impedance of 1 MΩ at room temperature (30 $^0$C). Calculate the shot noises associated with the signal of the amplifier within the band width of 1 MHz. (05 Marks)

**B**

(i) Explain the importance of Filter circuits in signal processing. (02 Marks)

(ii) Briefly describe a law pass filter with a proper circuit diagram. (02 Marks)

(iii). A demodulator of an AM (amplitude modulated) radio receiver is shown in figure 2. The diode is used for rectification of the radio frequency carrier signal (550 kHz). The RC low pass filter is used to extract the audio signal by removing the carrier wave. Calculate a suitable capacitor value of the demodulator, if R is given as 1 MΩ. (Assume that the cut of frequency is 100 kHz) (08 Marks)

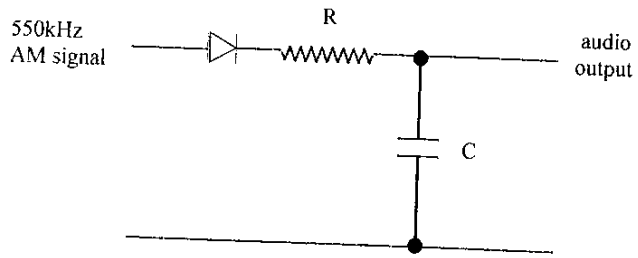


Figure 2

**Question No: 03**

A

i. State the golden rules for an ideal operational amplifier. (03 Marks)

ii. A differential amplifier is shown below in figure 3.

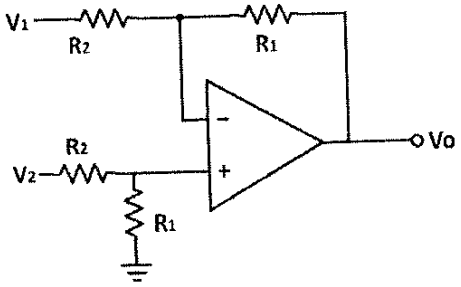


Figure 3

Show that the output of the above circuit is given by the following expression (07 Marks)

$$V_0 = \frac{R_1}{R_2}(V_2 - V_1)$$

ii. An arrangement of a differential amplifier is given in figure 4. Find $V_o$ for the given input voltages of the differential amplifier assuming that supply voltages are + 9 V and − 9 V.

(05 Marks)

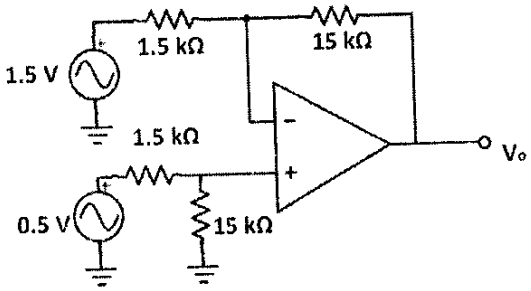


Figure 4

B.

Write short notes about any **two of the** following topics. (10 Marks)

(i) Voltage Follower

(ii) Integrating Amplifier

(iii) Comparator

(iv) Summing Amplifier

**Question No: 04**

**A.**

(i) Explain the significance of the Sampling Theorem in preventing signal aliasing.

(03 Marks)

(ii) A biomedical engineer is designing a system to digitize electrocardiogram (ECG) signals. The system uses a sampling rate of 1 kHz. What is the maximum frequency component of the ECG signal that can be digitized without causing aliasing?

(02 Marks)

B.

An electrical signal f (t) is given by

$$f(t) = \begin{cases} 1, & if \quad if\ 0 < t < \frac{T}{2} \\ -1, & if \quad if\ \frac{T}{2} < t < T \end{cases}$$

(i) Sketch a waveform of the signal in the interval $0 < t < T$ . (02 Marks)

(ii) Write down the Fourier expansion of a function f(t) of period $T_0$ and the expressions for the coefficients $A_n$ and $B_n$ in the Fourier series. (05 Marks)

(iii) Find the coefficients $A_n$ and $B_n$ for the waveform given above. (05 Marks)

(iv) Show that the Fourier series for the function f(t) given above in the interval $0 < t < T$ is

(05 Marks)

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

(v) Sketch the power spectrum of the waveform. (03 Marks)

**Question No: 05**

A.

(i) State the methods used to convert an analogue signal to a digital signal comparing their conversion speeds in the ascending order of conversion time. (03 Marks)

(ii) A block diagram of a Single slope ADC is shown in figure 5. Describe its operation sequence when converting an analogue signal to a digital signal. (05 Marks)

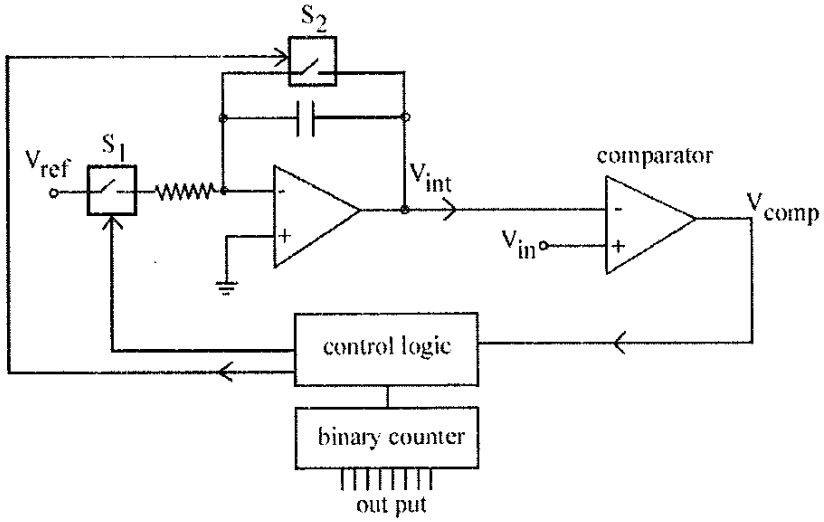


Figure 5

(iii) Explain the advantage of dual slope ADC comparing with single slope ADC. (04 Marks)

(iv) Explain the principle of the single slope ADC given in figure 05. (04 Marks)

B.

(i) Briefly describe about Range, Resolution, Conversion time of an ADC. (03 Marks)

(ii) An analog signal ranges from 0 to 5 volts and is to be converted to a digital signal using an 8-bit Successive Approximation Register (SAR) analog to digital converter (ADC) with the counter operating at 500 Hz,

a) Calculate the resolution of the ADC. (02 Marks)

b) What will be the maximum conversion time of the ADC. (02 Marks)

c) How do you modify the counter ADC to a Successive Approximation Register (SAR) ADC? (02 Marks)

**Question No: 06**

A.

(i) Write down the general operation sequence of a processor when running a program stored in the memory. (06 Marks)

(ii) Explain the concepts of mnemonics, assembly language, and machine language in the context of computer programming. (03 Marks)

(iii) Write down the meaning of each mnemonic in the following simple assembly programme written for a microprocessor. (07 Marks)

```
MOVE A, 00
MOVE B, O3
ADD A, B
DEC B
CMP B, 00
JG 14
NOP
```

B.

D2716 is an UVEPROM chip and it has pins labeled Vcc, $\overline{WE}$, $\overline{CE}$ and $\overline{OE}$ in addition to the address and data pins, You can construct an external memory using 2716 chip as in figure 6.

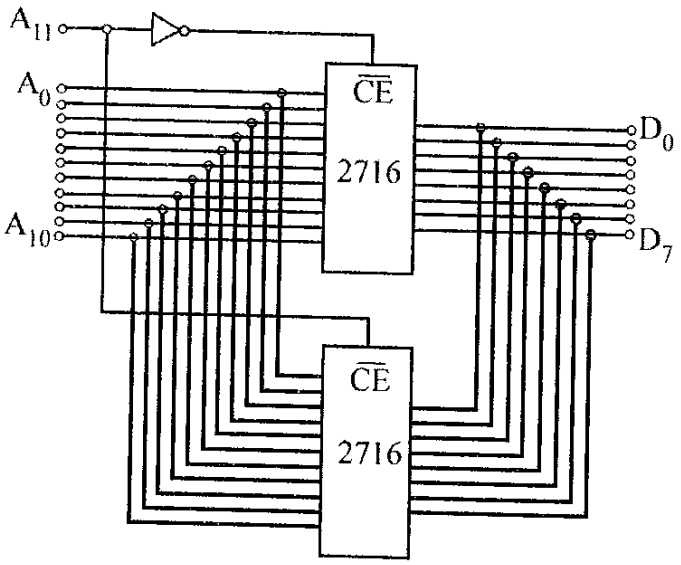


Figure 6

(i) What are the functions of the pins $\overline{WE}$ and $\overline{CE}$ ? (03 Marks)

(ii) What should be the size of the address bus and the data bus in the above construction? (03 Marks)

(iii) Determine the size of the memory in the above construction. (03 Marks)

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