TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2079 Baishakh

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II (*EX 602*)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. What are the basic features of MBI system? Compare open loop and closed loop microprocessor based system with suitable examples. [2+6]
2. 8255 is to be operated in mode O. Port A and port C upper are designed as output for LEDs and port B and port C lower as input ports for DIP switches. Address line A15 is connected with $\overline{cs}$ of 8255 through an inverter.
   a) Draw the complete mapping diagram. [2]
   b) Determine the port addresses. [2]
   c) Determine the control word. [1]
   d) Write a program to read the DIP switches and display the reading from port B at port A and C lower at port C upper. [3]
3. a) Show the interfacing circuit of TTL logic with RS 232, appropriate line drivers and line receivers. [3]
   b) Describe the enumeration process in USB 2.0 appropriate flow diagrams. Compare and contrast between USB device and host interface chips and list three examples of each type. [4+3]
4. Consider yourself as a fluid dynamic engineer, who has been assigned the task of designing a hardware circuit that keeps a gas chamber under standard temperature and pressure (STP) conditions. The circuit should be an MBI system, an 8255 PPI, two 10-bit ADCs and appropriate temperature and pressure sensors that constantly monitor the pressure and temperature inside the gas chamber. An alarm LED should be lighted to notify the operator when either the temperature exceeds zero degree Celsius or the pressure exceeds hundred Kilopascals. Calibrate your temperature and pressure sensors accordingly. Sketch your design, show the necessary control words, and draw an appropriate flowchart to show the logic of your software algorithm. [8]
5. Describe the Bluetooth network topologies. Explain the characteristics and application of data logger. [4+4]
6. Define grounding and shielding. Explain inductive and capacitive shielding mechanisms. [2+4]
7. Explain the different types of transmission line issues that should be considered while designing the high speed circuit. [6]
8. a) Discuss the general process of creating a PCB with appropriate figures. [3]
   b) Why is routing signal traces important during circuit layout? Explain the factors that need to be considered while creating a signal trace. [1+2]
9. a) What do you mean by embedded and real time software? Discuss the software model suitable for your academic project. [4]
   b) What are good programming practices? Discuss the nature of bugs and preventive steps to minimize it. [4]

10. Suppose, the CEO of the company where you performed your case study is impressed with your case study report, and decides to hire you as a consulting engineer to oversee their existing MBI system. You are assigned the task of revamping their existing MBI system with the blueprint that you have designed. Show a well labeled, clear and detailed sketch of your design that you will be presenting to the board of directors to convince them to implement your idea. Your block diagram and supporting documents should include a minimum of the following items: the hardware solution, the software requirements, the advantages and disadvantages of your own strategy, the gain in efficiency of the plant after employing your plan, and a cost breakdown of realizing your project. [12]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2078 Kartik

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX 602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
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- ✓ *Assume suitable data if necessary.*

1. a) What is the rationale behind using a microprocessor in instrumentation systems? Describe two situations where an open-loop MBI system performs better than a closed-loop MBI system, illustrating your answer with block diagrams. [1+3]

   b) Describe the DMA active and idle cycles with appropriate figures. Provide at least five disadvantages of using DMA controllers. [2+2]

2. Draw the circuit diagram to interface 8255A PPI with 8085 microprocessor at base address B0H. Write an assembly program that determines the addition of contents of port A and port B and display the result in port C. Use appropriate control word to initialize the 8255A. [3+5]

3. a) Define bit rate and baud rate, Determine a character transmission rate using asynchronous serial data transfer method at baud rate 9600. Suppose a character has 7 bits data, one bit start bit, two bits stop bit and none parity. Calculate the time required to send a word: Engineer. [5]

   b) Describe the problems occur when you try to connect RS-232 devices that both are configured as DTE. How this problem can be resolved? [5]

4. What are the parameters to characterize ADCs? Design a circuit to interface ADC0808 with 8085 microprocessor using 8255A PPI. [2+6]

5. a) Draw the block diagram of a digital transmission system that can be used to transmit analog as well as digital data. Compare and contrast analog and digital transmission techniques with at least five distinguishing characteristics. [2+2]

   b) Design a data logging and storage system that is capable of receiving and storing signals from optical fibers, satellites and Bluetooth devices. Provide the block diagram of the overall system, which should show how messages get transmitted over the three transmission schemes and how the logger receives them. [4]

6. How ground loop can be prevented? Explain the Electromagnetic coupling. [6]

7. Explain ground bounce, decoupling and crosstalk in the context of circuit design. [6]

8. What are the factors that need to be considered while routing the signal traces in circuit layout. How do you avoid crosstalk while making layout of the circuit? [2+4]

9. What are the different phases of bugs in software development? Explain the different types of techniques used for software testing. [3+5]

10. Draw the complete block diagram of industrial process control system involved in your case study. Explain why you want to implement your control system over existing one in terms of cost, manpower and plant automation? What problems you might face after implementing this control system? What are the benefits of new system over old one? [12]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2078 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX 602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
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1. Define instrumentation system. Compare status check I/O, Interrupt driven I/O and DMA. [2+6]
2. Design an interfacing circuit to set up bidirectional data communication in the master-slave format between two 8085A microcomputers. Use the 8255A as the interfacing between the master and the slave microcomputers. What will be the port addresses and control word. Write necessary program to transfer a block of data from the master to the slave along with its flowchart diagram. [9]
3. a) Explain simplex, half duplex and full duplex operation of RS-232 serial standard. [4]
   b) Describe different types of USB protocols along with the common USB packet fields. [6]
4. Explain the principle involved while interfacing an 8-bit ADC using interrupt; including suitable block diagram, process flow diagram and necessary ALP subroutine. [8]
5. List the major characteristics of Bluetooth. Draw the block diagram of data acquisition system and explain each block. [3+5]
6. Explain the principle of energy coupling. Describe about capacitive coupling with remedies. [6]
7. Discuss and differentiate between different types of fault tolerance schemes used in the purpose of circuit design. [6]
8. Explain ground, returns and shields in the context of circuit layout. [6]
9. a) Draw the complete block diagram for prototype model in software development process and explain its component in brief. [4]
   b) Write about White box testing and Black box testing. [3]
10. Draw the complete block diagram of industrial process control system involved in your case study. Explain why you want to implement this control system over existing one in terms of cost, manpower and plant automation. What problems you might face after implementing this control system. [12]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2076 Chaitra

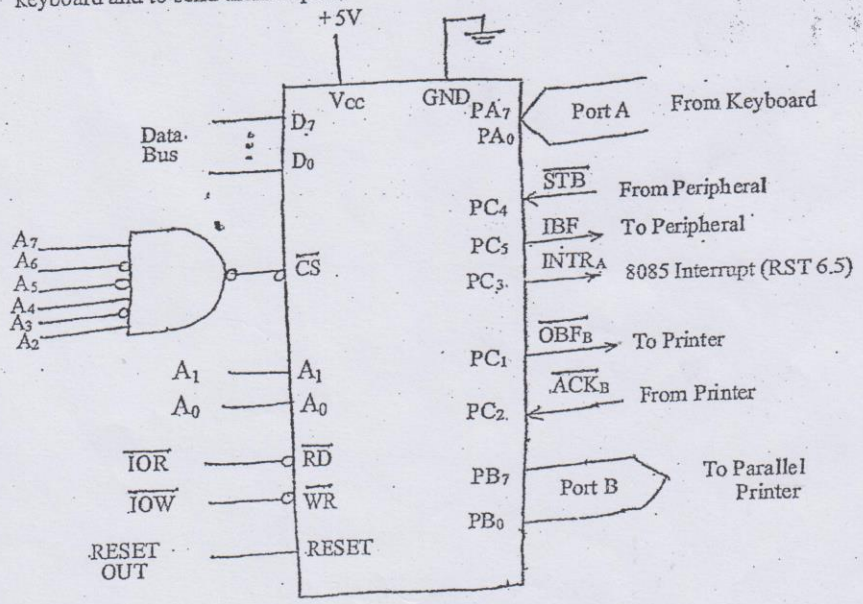
Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX 602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt <u>All</u> questions.*
- ✓ *The figures in the margin indicate <u>Full Marks</u>.*
- ✓ *Assume suitable data if necessary.*

1. a) Explain the basic modes of data transfer techniques available between microprocessor and peripheral devices. [5]
   b) Mention the features of Microprocessor Based Instrumentation system. [3]

2. Port A is to design as the input for a keyboard in interrupt driven I/O and Port B as the output for a printer in status check I/O using mode 1 of 8255 with 8085 microprocessor as shown below: [9]
   a) Find port addresses by analyzing decoding logic.
   b) Determine the control word to set up port A as input and port B as output.
   c) Determine the BSR word to enable $INTE_A$.
   d) Determine the masking byte to verify the OBF_B line.
   e) Write main program and a read and write subroutines to accept characters from keyboard and to send them to print.



3. a) Explain the Null modem with and without handshaking mechanism. [5]
   b) Explain Cyclic Redundancy Code with suitable example. [4]

4. Design the interfacing of 1408 DAC with an output port of address AF H for 0v to 10v range. Note that take appropriate values for resistors and capacitors. [8]

5. a) How can you design the communication system with satellite as an unguided transmission scheme? [4]
   b) Explain the Data Acquisition system with the help of compact data logger. [4]

6. Explain different types of filtering mechanisms used to reduce conductive noise coupling on the basis of frequency, mode and amplitude. [6]

7. Define ground bounce and crosstalk in circuit design. List their reduction ways. [6]

8. Describe the different terminologies used in routing signal traces for designing a commercial circuit layout. [6]

9. Explain spiral software development model with its advantages and disadvantages. Describe cohesion and coupling. [5+3]

10. Answer the following questions with regard to your case study. [12]
    a) Describe the existing work flow mechanism of the industrial instrumentation system.
    b) What are the critical factors affecting the production of existing system and what measures you can recommend for mitigating those factors?
    c) Design a proposed system using microprocessor/ microcontroller, input/ output devices, interfacing process, communication protocols, data converters and handshake signals with neatly labeled block diagram.
    d) List out the different advantages of the proposed plan in terms of technology, production rate, quality assurance, cost-benefit and return on investment (ROI).

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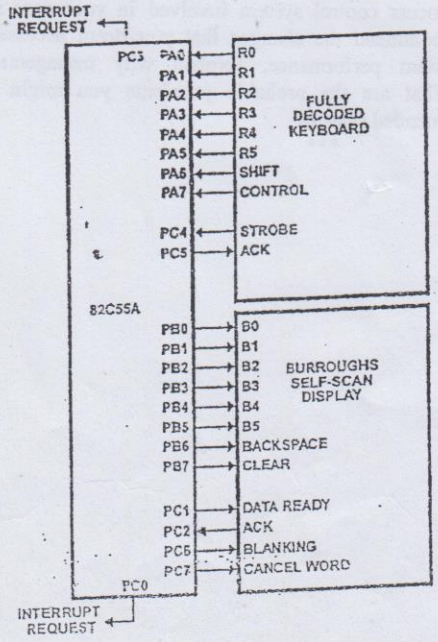
TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2076 Ashwin

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX 602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt All questions.*
- ✓ *The figures in the margin indicate Full Marks.*
- ✓ *Assume suitable data if necessary.*

1. a) Explain microprocessor based instrumentation system with its block diagram. [5]
   b) List out the factors to be consider while selecting a processor. [3]
2. An 8255A PPI card is connected to 8085 microprocessor has system as shown in figure below in which control word is stored in address of F3H. [1+3+2+2+2]
   a) What are the addresses captured by 8255A PPI card?
   b) Draw the minimum interfacing circuit.
   c) Write down the control word to initialize the 8255A PPI card.
   d) Write down the status word format for 8255A PPI card for the system.
   e) Write down BSR control word to initialize port A interrupt request.



3. a) What is the importance of RS 232-C in serial communication? Explain the RS 232-C working principle with its different types of signals. [1+4]

b) What is USB? Explain its common packet fields. [1+3]

4. a) Describe INL and DNL error of data converter with necessary illustrations. [4]

   b) With necessary diagram, Explain interfacing of 8 channel 8 bit ADC with 8085 microprocessor along with timing diagram. [5]

5. a) Discuss analog communication system and digital communication system with an appropriate block diagram. [4]

   b) Mention the characteristics of Bluetooth. Differentiate between piconet and scatternet network topology used in Bluetooth environment. [4]

6. a) What will happen to the electronic circuit connected in single point ground system when operated in frequency greater than 1 MHz? Explain with necessary illustration. [3]

   b) Explain how decoupling capacitor can be used to suppress the transient current. What effects do you observe when very large decoupling capacitor is connected in your circuit? [3+2]

7. a) What is reliability? List out the factor affecting reliability. [1+2]

   b) What are the factors that need to be considered while designing high speed circuit. [3]

8. How do you reduce crosstalk when routing signal traces on a PCB? [4]

9. Explain different types of software bugs that might exist in software. How these bugs can be identified while implementing different types of software testing. [6]

10. Explain existing industrial process control system involved in your case study with necessary block diagram. Recommend the changes that you deem necessary for the improvement of overall system performance. Explain why management should implement these changes. What are the probable problems you might face after implementation of your recommended system? [12]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2075 Chaitra

Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX 602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Define closed loop MBI system with suitable example. [2]
   b) Among full or partial address decoding, which method of address decoding do you choose while interfacing memory device? Give reasons with suitable example. [4]
2. Interface a parallel bus centronics printer with 8085 microprocessor using 8255A in mode 1 output configuration.
   a) Draw the necessary interfacing circuit required for this purpose using 8255 PPI in handshake mode. [3]
   b) Determine port address as per your chip select logic. [2]
   c) Determine the control word required for printing operation. [2]
   d) Draw the timing waveform for transferring data to the printer. [2]
   e) Write an ALP to print characters whose ASCII code is available in memory location from 9000H. [3]
3. a) Explain the transferring of serial data using asynchronous transfer. One character is formed with 7-bit ASCII code, 1-bit start, 2-bit stop and 1-bit parity. [4]
   b) Describe up to date USB standards. Differentiate different USB data transfer mechanisms with suitable example of each. [6]
4. a) Explain the interfacing technique of 12-bit DAC to 8-bit Data bus. [6]
   b) Explain different types of errors in ADC & DAC. [4]
5. Explain Bluetooth network topology in detail. Why optical fiber has high demand in the field of communication. [4+2]
6. Explain different types of Energy coupling mechanisms with suitable example of each. How can a circuit be protected from ESD? [6]
7. What do you mean by reliability in a circuit design? Discuss how the reliablity can be achieved by incorporating fault tolerance. [6]
8. a) What is PCB? Write down the advantages of PCB. [1+2]
   b) How do you reduce cross talk when routing signal traces on a PCB? [3]
9. Define roll back recovery with suitable example. Explain the spiral model software development cycle. [2+4]
10. Explain your industrial visit carried out on your case study in terms of existing system circumstances, problem identification and analysis, recommendation plan, requirement and feasibility analysis of the recommended plan and rollback plan if necessary. Also list out the different advantages of the proposed plan in terms of technology, production rate, quality assurance, cost-benefit and return on investment (ROI) for the particular industry. [12]

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13 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2075 Ashwin

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
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1. a) What do you mean by interfacing? A RAM chip of 512 bytes is given for interfacing with 8085 microprocessor system. Design an address decoding hardware for the same. [1+3]
   b) What is an interrupt driven data transfer? Explain the operation of interrupt driven data transfer with flowchart of interrupt subroutine and main programme sequence. [1+5]
2. A/D converter requires signal to start the conversion and indicates with the end of conversion signal. 8255A PPI is interfaced with 8085 microprocessors at 80H. Microprocessor reads 8-bits O/P data of the ADC at port A and display the same data to eight LED's connected at port B of 8255A. State any assumptions made.
   a) Identify the address captured by the card [1]
   b) Determine the necessary control words [2]
   c) Draw the schematic interfacing circuit [2]
   d) Write a program to perform the operation [3]
3. a) What is the importance of RS232-C in serial communication? Determine the time required to transmit a string: "Life is beautiful." using asynchronous serial data transfer method in baud rate of 4800 Baud. Suppose a character has 7 bits data, one bit start bit, one bit stop bit and one bit even parity bit. [2+4]
   b) Differentiate between USB 1.0 and USB 2.0. [1]
4. Interface a 10-bit DAC with 8255 PPI and 8085 CPU running at 2 MHz. Write an ALP to generate a triangular wave of frequency 500 Hz using the same interfacing circuit. The amplitude of the triangular wave should be +5V. [8]
5. a) 'In satellite communication the uplink frequency and downlink frequency are different.' Why? Explain the Bluetooth network topology. [1+3]
   b) Compare data archiving and data storage. With the block diagram describe the characteristics of data logger. [1+4]
6. Explain different types of filtering based on frequency, mode (common and differential) and amplitude (surge suppression). [6]
7. While selecting a processor for an embedded system product, you have to specify the performance, number of peripherals functions, memory and tool support to determine the appropriate processor for the product. As a system designer, provide a technical explanation for each of these factors required to achieve the proper functional design. [6]
8. What are general guidelines to avoid the crosstalk while routing signal traces on Printed Circuit Board? What are the problems due to impedance mismatch? [4+2]
9. What is software reliability? Compare waterfall and prototyping model. Describe Embedded and Real Time Software. [2+3+3]
10. Answer the following questions with regard to your case study.
    a) Design a proposed system using microprocessor/microcontroller input/output devices, interfacing process, communication protocols, data converters and handshake signals with neatly labeled block diagram. [6]
    b) Mention different types of problems that might occur after implementing the

13 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2074 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL,BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

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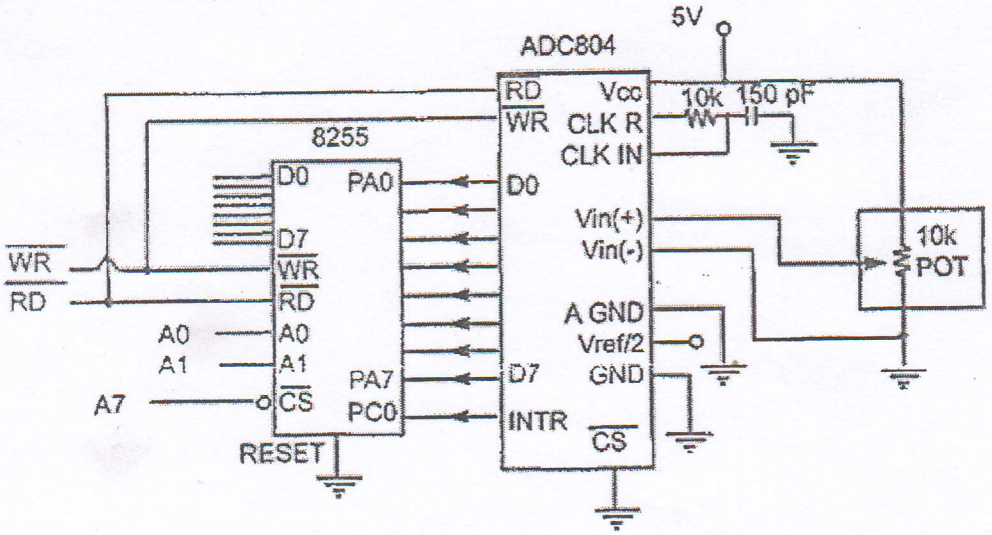
1. a) Describe various well-known techniques while interfacing an I/O device with a personnel computer system. [3]
   b) Differentiate I/O mapped I/O and memory mapped I/O with suitable examples. How can you generate I/O mapped and memory mapped signals using IO/M, RD and WR signals? [5]
2. Explain the different schemes of parallel data transfer with suitable timing diagram. Explain the functional block diagram of 8255A PPI with neat diagram. [4+4]
3. a) Describe the various error detection techniques used in serial data transmission. [3]
   b) Explain the functions of USB Host, USB Hub and USB Device. Discuss different packets used in USB protocol. [5]
4. What are the different types dynamic errors in ADC and DAC? What will be the control word for interfacing as shown figure below? Also write the subroutine program to read the digital data from ADC. [4+6]



5. Explain the advantages of optical fiber over copper wire? Explain each block of data logger. [2+6]
6. a) What are the different noise coupling mechanism? [3]
   b) How can you reduce the conductive noise coupling? Explain in detail. [3]
7. What are general approaches of establishing requirements for circuit design? What are the two factors that drive reliability of a product? [4+2]
8. Poor circuit layout and signal propagating principle may cause many problems in the circuit operation, manufacturing ease and probability of design errors. What factors will you consider while routing the signal traces on PCB. [6]
9. Explain Prototyping Model for software development in brief. Explain different phases of introduction of bugs in software. [3+5]
10. Describe the different processing plants that you have studied in case study. With neat and clean block diagram explain how the further improvement of these plants can

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INSTITUTE OF ENGINEERING
Examination Control Division
2074 Ashwin

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

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- ✓ *Attempt **All** questions.*
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(1) If the speeds of I/O devices do not match the speed of the microprocessor, what types of data transfer techniques are used? Describe them with necessary block diagrams and control signals. [6]

(2) A microprocessor kit has an onboard 8255. Interface to the 8255 eight single-pole-double-throw (SPDT) switches numbered S0 to S7 and a seven segment common anode LED display. Draw the complete circuit setup. Define clearly the functions of all ports, write a program to initialize 8255, detect a switch closure, and display the value of the switch number on the LED display. [8]

(3) (a) Explain the design of a USB to RS-232 adapter with the aid of a neat circuit diagram, appropriate voltage translation chips, and necessary handshake/control signals. [6]

(b) What is the time required for transmission of a character with one start bit, seven data bits, one parity bit, and one stop bit with 1200 baud? [2]

(4) The data converter that is being used in your project is suffering from differential nonlinearity and harmonic distortion. Instead of purchasing a new converter, you are required to use the defective converter. Discuss technical measures that can be implemented to mitigate the aforementioned errors. [6]

(5) Signals from three different transducers need to be recorded in a data logger. The analog signals supplied by the three transducers are dual polarity (– 50 mV to 50 mV) having frequencies of 5 KHz, 10 KHz and 15 KHz. Explain the design of the following stages of the data logger:

(a) Input scanner stage of the data logger such that it can appropriately sample the incoming signals [3]

(b) Signal conditioner stage if the 8-bit ADC used inside the data logger accepts only positive polarity signals ranging from 0 volts to 5 volts. [3]

(6) Explain the mechanism of filtering line noise with the aid of chokes. How does a choke differentiate between the signal that it needs to pass and the noise that it needs to suppress? Describe the circumstances where chokes are preferred over other noise filtering approaches. [8]

(7) During circuit design process, what are some general technical dilemmas faced by engineers? Explain how an engineer can arrive at an optimal solution given the requirements of a customer? [8]

(8) (a) In a multi-layer PCB, describe how grounding is performed and how coupling amongst the layers is minimized. [4]

(b) A faulty computer motherboard has severe clock jitter. The crystal producing the clock pulses is functioning properly, but clock signals arriving at various motherboard chips suffer from jitter. Discuss the source of the problem and provide some remedies. [4]

(9) (a) Discuss the shortcomings of existing software development models, and suggest measures to overcome them. [5]

(b) The testing time for software cannot be too long, yet software needs to be thoroughly tested before it can be commercialized. Explain how this paradox is overcome in a real-world software development environment. [5]

(10) Answer the following questions with regard to your case study:

(a) Discuss the main architectural differences between the existing system and the proposed system. [2]

(b) Does your proposed system use a microcontroller or a microprocessor? Justify your choice, and make a neatly labeled block diagram of your proposed system. [3]

(c) In your proposed system, explain in detail the interfacing process of peripheral devices with the microcontroller or microprocessor in terms of data format, data rate, data converters, communication protocols, timing diagrams, and handshaking signals. [5]

(d) List the technical drawbacks present in your proposed design. [2]

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24 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2073 Shrawan

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
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- ✓ *Assume suitable data if necessary.*

1. a) Explain the features of microprocessor based instrumentation system. [3]
   b) Differentiate between open loop and closed loop instrumentation system along with block diagrams. [5]
2. Assume that your group has decided to make microprocessor based instrumentation system for an Ice Cream Factory using an 8255 PPI card at base address 5000H in memory mapped I/O mode for controlling purpose. You need to measure pressure and temperature of a manufacturing plant. [1+1+2+2+4]
   i) List out the collected documents and components.
   ii) List out different signals you need to derive and or can be directly connected to your interfacing circuit.
   iii) Draw minimum mapping circuit for above system
   iv) What are the addresses captured by your card? Generate the control word for the system
   v) Write a program module for measuring temperature and control if the temperature is not in the range. Assume suitable data if necessary.
3. a) Explain why system that uses the RS 422A can transmit data over longer distance and at higher baud rate than Rs 232C and RS 423A. [4]
   b) The fundamental elements of communication on the USB data Bus is a packet. Discuss various types of packets used in USB protocol. [4]
4. a) Why analog signal needs to be converted to digital? What are the selection criteria for selecting ADC? [2+2]
   b) What are the characteristics of ADC and DAC? [4]
5. a) What is spread spectrum frequency hopping in Bluetooth? Write the application of Bluetooth. [1+2]
   b) What is data logger? Explain the operation of data logger along with its block diagram. [5]
6. How inductive noise is introduced in electronic system? Discuss the shielding mechanism for capacitive coupling. [3+3]
7. Establishing requirements is the most difficult part of circuit design. What could be the basic tips and thoughts for setting requirements towards selecting the appropriate technology which help you to achieve a new circuit design? [6]

8. Write about the factors we should consider while doing component placement. Explain the role of grounding and shielding to reduce noise in PCB. [3+3]

9. The essential components of software development interact in different ways in different process models which helps to plan the development of a project and estimate the effort for it. Describe different types of software models used in Software Development platform. Also mention the merits and demerits of each model. [8]

10. What changes do you recommend in the visited industry during your case study? Why do you think that the management should implement these changes? Assume that you have a senior reporting engineer closely looking at work from the system development level, apart from convincing the management team at the visited industry to implement new system, you also need to convince the senior engineer technically so that your recommendations will be implemented. How do you want to achieve this technically? Debate on your technical design to replace the current system and also relate probable problems you might face after system implementation. [12]

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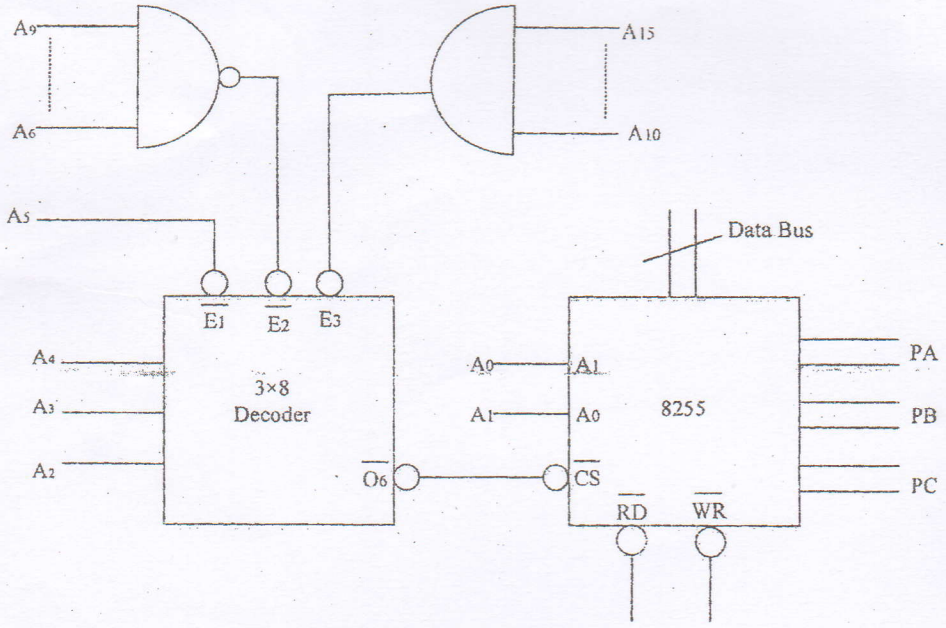
INSTITUTE OF ENGINEERING
Examination Control Division
2072 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) What do you understand by a closed loop MBI system? [1]
   b) Differentiate unique vs non unique address decoding. [4]
   c) Specify the addresses for the ports of 8255PPI shown in figure below. [3]



2. a) List out the technical benefits of using 8255 PPI in a MBI system. [2]
   b) With a neat timing diagram and an appropriate example, explain the operation of 8255 PPI in mode 2. You should clearly show the necessary control signals and an interfacing circuit to connect 8255PPI to 8085 microprocessor. Also write the necessary control words to configure the 8255 in this fashion. [3+3+2]
3. a) What are the errors associated with serial data transfer and their error checking mechanism? [4]
   b) What is USB on the Go? Write short note on USB packet types. [1+3]
4. a) With necessary illustrations, explain the cause behind the DNL and INL errors in A/D and D/A conversion. [2]
   b) Interface a suitable DAC using 8255 PPI to a 8085 microprocessor to generate a square wave oscillating between 0V and -5V having a frequency of 1 KHz. Show the interfacing circuit and the necessary program. [3+3]

5. A datalogger receives signals from Bluetooth Scatternet which consists of different Bluetooth devices. The data retrieved needs to be transmitted via option fiber links.

   a) What is frequency hopping? Relate it with the Bluetooth technology. [2]
   b) Write in brief about the typical characteristics of a datalogger. [3]
   c) Draw a neat and labelled block diagram of the complete system. [2]
   d) Compare and contrast the terms data archiving and data storage. [1]

6. a) Explain the remedial strategies for various energy coupling mechanisms. [4]

   b) An electronic circuit receives noise from a switching element. If voltage on the switching device swings from 4V to 6V within 100μs, during which current makes a transition from 10 μA to 25 μA in 10 ns, what might be the noise coupling mechanism? Identify it using suitable calculations. [2]

7. DOECE is looking for an expert engineer to work in the research projects of high frequency, high speed applications. What guidelines would you suggest as an engineer to design high speed and high frequency circuits? Explain in detail. [6]

8. Circuit boards combine electronic components and connectors in to a functional system through electrical connections and mechanical support. Explain the factors that need to be considered while creating traces to connect the electronic components. [6]

9. A software company is planning to make new software. Suggest good procedure to develop software. Explain different types of software models. [3+5]

10. Draw the complete block diagram of the industrial process control involved in your case study. What are the critical factors affecting the production you have noticed in the visited industry and what are the measures can you suggest for the same? Also mention advantages and disadvantages of suggested system. [12]

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23 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2072 Kartik

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt All questions.*
- ✓ *The figures in the margin indicate Full Marks.*
- ✓ *Assume suitable data if necessary.*

1. a) "Microprocessors are indispensible tools in modern industrial instrumentation systems". As an engineer, provide a technical explanation including block diagrams to this statement by relying on observations from your case-study. [4]

   b) What benefit are obtained from a memory-mapped I/O design? Design an interface arrangement for 8085 microprocessor to map output ports in address space 1000H to 2000H and input ports in address space 3000H to 4000H. [4]

2. a) Consider a double handshake scheme that allows data transfer from an input peripheral device to an 8085-microprocessor through an 8255-PPI. [5]

      i) List all control signals that get exchanged between the devices.
      ii) Draw a detailed timing diagram showing the exchange of control and data signals. Include the cause and effect arrows in your timing diagram.
      iii) With a neat sketch how the overall system diagram between the modules mentioned above
      iv) Generate an appropriate control word based upon your drawing and derive the address of the control register of the 8255-PPI used in your design.

   b) List the control signals used by the ISA bus. Provide convincing arguments to justify the replacement of the ISA bus by the PCI bus. Calculate the brandwidth of a 64 bit PCI bus operating at 66-MHz. [3]

3. a) What are the criteria should be involved during the design of RS-232A in Simplex, Half Duplex and Full Duplex modes. [4]

   b) Explain the USB signals and associated bus states. Also mention the signal levels to achieve these bus states. [4]

4. a) Why do we need to digitize a signal? What are the errors associated with A/D or D/A converters? [6]

   b) What are the selection criteria for A/D or D/A converter? [2]

   c) To convert an analog signal into digital form, 8-bit ADC is used. The ADC has eight input channels, and channel four is used to capture the incoming analog signal. The address of the desired channel is sent through pins PB0, PB1 and PB2. After at least 50-nanoseconds, this address must be latched. The latching signal is sent using PB4. After another 2.5-microseconds, PB3 is used to initiate the conversion process. The completion of the process is signaled via PC5. The output latch of the ADC can be enabled through PB6, and digital data can be read through port A of 8255-PPI. [8]

i) Draw a circuit showing the interfacing of the ADC module, 8255-PPI and 8085 microprocessor on the basis of the connections described above.

ii) Draw the timing waveforms of all the control and data signals involved in the process.

iii) Provide a flowchart that depicts the ADC process

iv) Derive port addresses from your circuit diagram and provide the control word

5. a) In high-speed circuits, "ground" is a meaningless concept, the important question is, "what path does return current follow?" Justify the above statement with proper reasons and examples. [4]

b) Discuss the importance of an interface unit. What factors need to be accounted for while designing input and output interface units? [4]

6. a) Define impedance matching. What is the impact of impedance discontinuities? [2]

b) How do you reduce crosstalk when routing signal traces on a PCB? [4]

7. What are the basic principles of signal propagation and circuit layout for Routing Signal Traces which are predominant of effective circuit layout? [6]

8. Programs are to be read by humans. For programs to be useful, reliable and maintainable, you must make them readable and understandable. Good design and programming practices can make programs more readable. Explain in brief how you can make programs more readable. [8]

9. Answer the following questions with respect to your case study: [12]

i) What is techno-commercial feasibility of a system? Provide examples from your case-study experience.

ii) List the major technical drawbacks present in the existing MBI system that you witnessed at the industrial site.

iii) Give at least three feasible technical solutions to overcome the drawbacks that you witnessed. Show how your solution will offer higher reliability and incorporate fault-tolerant design practices. Include block diagrams.

iv) If you had to present your design to the company's management team, what sort of question would you anticipate? Provide a list of at least five questions that would be asked from a management point of view. How would you cope with the questions, and how would you convince the team to accept your design?

v) Repeat part (d), but now you are trying to convince senior engineers. How will the question and answer session change compared to part (d)?

vi) Compare and contrast your design with the existing design in terms of the following metrics: cost/performance ratio, technical specifications (hardware and software) and design complexity (provide diagrams)

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24 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2071 Shawan

Exam.	[illegible]		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt All questions.*
- ✓ *The figures in the margin indicate Full Marks.*
- ✓ *Assume suitable data if necessary.*

1. Draw and explain the block diagram of microprocessor based instrumentation system. Also list out advantages of implementing an MBI system. Explain briefly the concept of DMA. [4+2+2]
2. Assume that your group has decided to make a PC based instrumentation control system for automatic concrete purifying factory using an 8255 PPI card at base address 4000H in memory mapped I/O mode for controlling purpose. [1+1+2+2+4]
   a) List out the collected documents and components.
   b) List out the different signals you need to derive and or can be connected directly to your interfacing circuit.
   c) Draw minimum mapping circuits for the above system.
   d) What are the addresses captured by your card? Generate the control word for the system.
   e) Write a program module to read ten set of raw data from port A and port B; add the data and store the result starting from address 4040H.
3. a) Describe the problem that occurs when you attempt to connect together two Rs.232 devices that are both configured as DTE. Draw a diagram which shows how this problem can be resolved. [5]
   b) Explain USB protocols which should be followed during the USB design. [5]
4. What are characteristics of A/D or D/A converters? With necessary diagram explain the interfacing of 10 bit DAC with 8085 along with timing diagram. [2+4]
5. a) What is data logger? Explain the characteristics for a data logger. [5]
   b) Write the advantages and disadvantages of optical fiber communication. [3]
6. Elucidate the principle of grounding? Mention how many configurations are available to provide the basic principle of grounding. [1+3]
7. a) What are the reasons for using low power design? [2]
   b) Write about ground bounce, cross talk, impedance matching and timing skew. [4]
8. Fault tolerance reduces possibility of dysfunction or damage from abnormal stresses and failure. It has three distinct areas: careful design, testable functions and redundant architecture. Explain how we can avoid many failures using these three approaches. [6]
9. IOE is planning to apply new software for its database management system. Suggest the best selection and purchase procedure? Explain in detail about good programming practice. [3+5]
10. What have you learned from case study? Draw the complete block diagram of the industrial process control involved in your case study. What are the critical factors affecting the production you have noticed in the visited industry and what measures can you suggest for the same? What problems you might face after implementing your suggested process control system. [12]

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23 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2071 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) How do you select a microprocessor or a microcontroller for your project? [3]
   b) Explain the block diagram of a microprocessor based instrumentation system. What are the basic features of a microprocessor based instrumentation system? [5]
2. a) Write a short note on PCI Bus. [2]
   b) Interface a keyboard and a printer in mode 1. Port A is designed as input for keyboard with interrupt I/O port B is designed as output for printer with status check I/O. Draw the mapping circuit and write the control word and address map. [6]
3. a) Design a cable that has a USB connector at one end and an RS-422 connector at the other end. Assume the USB is connected to a laptop and the RS-422 connector is attached to a printer. Your design should include the following: [6]
   i) Technical names of the pins and wires involved in the design.
   ii) Intermediate chips to maintain voltage uniformity between the two standards.
   iii) Neat and labeled sketch of the wiring between the two standards.
   b) What is a USB interface chip? Why are they required? Compare and contrast USB device interface chips and USB host interface chips. [4]
4. a) Calculate the values of the LSB, MSB, resolution and full-scale output for an 8-bit DAC for the 0 to 10V range. [2]
   b) How can you design a DAC with 12 bit resolution with the 8085 microprocessor having 8 bits data lines? Explain with suitable block diagram. [6]
5. a) What are the essential components of data acquisition system? Explain with the help of block diagram. [4]
   b) Explain Bluetooth network topology in brief. What are the advantages of Bluetooth applications? [4]
6. a) What are the characteristics of a safety ground? [2]
   b) Describe different types of noise coupling mechanism in brief. How do you check their predominance in the circuit? [4]

7. A data logger receives signals from a Bluetooth scatternet. The scatternet consists of three piconets and within each piconet there are four bluetooth devices. The piconets communicate within themselves and amongst each other using the master/slave protocol. [10]

   a) Describe an analog transmission mechanism to capture the blue tooth signals by the data logger. Draw a complete system block diagram.
   b) Describe the mater/slave protocol that is present in blue tooth piconets and scatternets
   c) Draw the scatternet topology depicting the scenario maintained in the question. Make sure you adhere to the rules of the masters/slave protocol.

8. a) While designing an electronic instrument you should group circuits according to their characteristics to maintain the correct operation of each circuit. What are the considerations during grouping components and circuits and what is the impact of such grouping? [4]

   b) What are the factors that derive reliability of an electronic system? [2]

9. Compare and contrast the three traditional models of software development with respect to their strengths and weaknesses. Propose a fourth software development model that outperforms the classical methods and justify your choice in terms of reliability, maintainability, flexibility, portability and reusability. [4]

10. Draw the complete block diagram of industrial process control system involved in your case study. Explain why you want to implement this control system over existing one in terms of cost, manpower and plant automation. What problems you might face after implementating this control system. [12]

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24 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2069 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. Explain briefly the concept of DMA. Draw circuit Diagram of an interfacing circuit containing 4 KB ROM and 8 KB RAM. Assuming Base address in 4000H. You also need to draw write and read cycle timing diagram. [2+6]
2. In a microprocessor based system, an 8255A PPI card is used to interface a keyboard and a printer to the processor. The 8255A PPI is interfaced with the 8085 microprocessor in the system such that the base address of 8255 A PPI is 4044 H.
   a) What are the addresses captured by the card? [1]
   b) Draw the complete interfacing circuit of 8255A PPI with 8085 microprocessor for the given system. [3]
   c) If the printer is interfaced to port A and the keyboard is interfaced to port B of the PPI generate the control word to initialize the 8255A PPI with proper explanations. Both printer and keyboard use 8-bit parallel data transfer with handshaking. [2]
   d) Derive the control word to enable interrupt request to the microprocessor by port A of 8255A PPI in above system, with proper explanations. [2]
3. a) Compare the USB standards: USB 1.1 and USB 2.0 [3]
   b) Describe simplex, half duplex and full duplex operation using RS-232 port. [7]
4. What are types of errors present in a A/D or D/A converters? With necessary diagram explain the interfacing a ADC using interrupt. [3+5]
5. a) Explain different network topologies of Bluetooth device with appropriate diagrams. [4]
   b) What is a data logger? Explain the desirable characteristics for a data logger. [1+3]
6. Explain different types of Noise coupling Mechanism with concept of Pseudo impedance. [6]
7. What are the reasons for using low power? Mention the guidelines to be considered for low power design. [2+4]
8. A careful circuit layout not only makes the production of circuit boards easier but also makes them less error prone. What rules does a designer have to follow while routing signal tracks in PCBs in order to avoid the effects of impedance mismatch and crosstalk? [3+3]
9. What is fault tolerance in software? What do you mean by roll-back recovery and roll-forward recovery? Explain different types of bugs in software. [2+2+4]
10. a) What are the types of Microprocessor based system used in instrumentation system? How it makes more benefits in industry? [3]
    b) Explain detail about different processing plant which you have studied in case study. Also draw the block diagram for further improvement of these all plant and overall system. [9]

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24 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2069 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II *(EX602)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

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   a) What are the addresses captured by the card? [1]
   b) Draw the complete interfacing circuit of 8255A PPI with 8085 microprocessor for the given system. [3]
   c) If the printer is interfaced to port A and the keyboard is interfaced to port B of the PPI generate the control word to initialize the 8255A PPI with proper explanations. Both printer and keyboard use 8-bit parallel data transfer with handshaking. [2]
   d) Derive the control word to enable interrupt request to the microprocessor by port A of 8255A PPI in above system, with proper explanations. [2]
3. a) Compare the USB standards: USB 1.1 and USB 2.0 [3]
   b) Describe simplex, half duplex and full duplex operation using RS-232 port. [7]
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   b) What is a data logger? Explain the desirable characteristics for a data logger. [1+3]
6. Explain different types of Noise coupling Mechanism with concept of Pseudo impedance. [6]
7. What are the reasons for using low power? Mention the guidelines to be considered for low power design. [2+4]
8. A careful circuit layout not only makes the production of circuit boards easier but also makes them less error prone. What rules does a designer have to follow while routing signal tracks in PCBs in order to avoid the effects of impedance mismatch and crosstalk? [3+3]
9. What is fault tolerance in software? What do you mean by roll-back recovery and roll-forward recovery? Explain different types of bugs in software. [2+2+4]
10. a) What are the types of Microprocessor based system used in instrumentation system? How it makes more benefits in industry? [3]
    b) Explain detail about different processing plant which you have studied in case study. Also draw the block diagram for further improvement of these all plant and overall system. [9]

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41R TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2068 Baishakh

Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Microprocessor Based Instrumentation

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. Interface two 8K RAM chips and two 4K EPROM chips with 8086 so as to form a completely working system configuration. We know that, after reset, 8086 starts from address FFFF0H. Select the starting address of EPROM such that this address (FFFF0H) lies in it. The RAM address must start at 00000H. [10]
2. a) If the speeds of I/O devices do not match the speed of the microprocessor, what types of data transfer techniques are used? Describe them briefly with necessary block diagrams and control signals. [8]
   b) An 8255A PPI connected to 8085 has a system base address of 80H. [5]
      i) What are the addresses assigned for Port A, Port B, Port C and control register?
      ii) Write down the control word to initialize this card as follows: Port A mode 0 output, Port B handshake input, Port C_{upper} output and reaming pin of Port C_{lower} input.
      iii) For above case, write down bit set/reset control word to initialize Port B interrupt request.
3. Differentiate between synchronous and asynchronous data transmission. What is the time required for transmission of a character with one start bit, 7 data bits, one parity bit and one stop bit with 1200 baud? [4+4]
4. What are the criteria for selection of Analog to Digital converter for your design? [4]
5. a) An arc welder on the end of the robotic arm generators noise interference in the local embedded controller. The welder produces 120A at 12V. What could be the coupling mechanism for noise interference? How this can be minimized? [4]
   b) How would you protect against electrostatic discharge? [4]
6. a) Define crosstalk. How can reduce crosstalk when routing signal traces on a PCB. [6]
   b) List out the factors which you need to consider for high speed design. [3]
7. Discuss the prototyping model of software development with its merits and demerits. [8]
8. a) Discuss the advantages of digital signal transmission over analog signal transmission. [4]
   b) Draw the clear block diagram of data logger showing all necessary components. [4]
9. Write short notes on: [6×2]
   a) Static and Dynamic errors in Digital to Analog Converters
   b) Software selection and purchase

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24 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2068 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL, BEX, BCT	Pass Marks	32
Year / Part	III / I	Time	3 hrs.

Subject: - Instrumentation II ***(EX 602)***

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) One thing embedded real time systems have in common is that they include some type of processor. They range any where from a serial-program input device to a full-fledged PC on a chip or board. At some point, an engineer decided on the type of processor to use. How did he pick it? Are there any rational reasons for picking one over another? Or are all processor selections based on personal bias? And what are the situational factors imposing selection of a microprocessor or microcontroller for a design. Discuss at length. [7]

   b) Give a short introduction of ISA bus. [3]

2. You have to interface ADC with 8085 using 8255A ports. Interface a fan and a heater using opto couplers to derive the I/O devices. If the temperature is less than 10°C, turn on the heater and if the temperature is higher than 35°C, turn on the fan. Use port A of 8255 for transferring digital data output of ADC to the CPU and part C for control signals. Assume that an analog input is present at second input of the multiplexer and a clock input of suitable frequency is available for ADC. Also write an appropriate flow chart and algorithm to facilitate your design. Draw the diagram of your design. [8]

3. a) What is disaster recovery in software? How could it be implemented at your organization? [3]

   b) In the software developments process, proper planning is essential in delivering the finished product to the client. Equally it is important that bugs have to be removed from the product. Discuss in details about the nature of bugs in software development process. What are the preventive steps you would take to minimize introduction of the bugs? [6]

4. How stub discontinuity cause impedance mismatch. Also point out the causes of crosstalk. Explain in your own words with relevant figure. [4+2]

5. "Establishing requirement is the most difficult part of circuit design". While designing the electronic circuit, specify and explain the procedure of converting the requirements into design. [6]

6. a) Differentiate between USB 1.1 and USB 2.0. State briefly how USB 2.0 identifies itself with the interfacing unit and establishes communication protocol. Draw the necessary diagrams. [6]

   b) Explain the functions the DSR, DTR, RTS, CTS, TXD and RXD signals. [2]

7. Signals from three different transducers (A, B and C) located 100 meters away from a control room in a factory are very important to control stepper motors to give final tune to the products. The strength of these signals ranges from 10mV to 20mV and separated at 4KHz. Transducer A, B and C generate 6KHz, 10KHz and 14KHz signals

a) How do you want to route these signals to the control room? [2]

b) If your A/D converter do not have S/H hold circuits, what specification of S/H chip you select for your design? Discuss also the errors associate with the converter. [6]

8. a) Why protecting against ESD should be considered in design? [2]

b) Describe different types of noise coupling mechanism in brief and how do you check their predominance in the circuit? [4]

9. a) What is Bluetooth device? How does it transmit data using pico and scatter net? [3]

b) Draw the block diagram of a data logger and explain its operation in details. [4]

10. Recommend the changes that you deem necessary in the visited industry during your case study? Explain the reasons why management should implement these changes? Assume that you have a senior reporting Computer/Electronics engineering closely looking at work from the system development level, apart from convincing the management team at the visited industry to implement new system, you also need to convince the senior engineer technically so that your recommendation will be implemented. How do you want to achieve this technically? Debate on your technical design to replace the current system and also relate probable problems you might face after system implementation. [12]

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