



SCHOOL OF COMPUTING AND ENGINEERING SCIENCES
BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING
END OF SEMESTER EXAMINATION
BEE 3203 ELECTRICAL MEASUREMENT AND INSTRUMENTATION
DATE: Monday, 16th March 2026. TIME: 08.30 - 10.30Hours

INSTRUCTIONS:

- i. This paper contains **FIVE** questions.
 - ii. You are required to answer **THREE** questions, that is, **QUESTION ONE** which is **COMPULSORY** and any other **TWO** questions.
 - iii. All questions carry equal marks i.e. **20 MARKS** each.
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QUESTION ONE (30 MARKS).

Analog Devices IoT and the Intelligence of Things

The Internet of Things (IoT) in the most basic sense is a way of connecting every day functions with the world. As IoT has transformed over time it can be broken down into five different and distinct sections: Sense, Measure, Interpret, Connect, and Power Management.

The entire process starts with Sensing something such as light, heat, vibration, etc. and then measures it to generate data. What does the data mean? Data by itself is not meaningful and needs to be interpreted. At this point the interpreted data can be connected to the world to be analyzed and learned. Lastly one needs to act or send commands based on what has been learned. Analog Devices has a large portfolio of Sensing, Measuring, Interpreting, Connecting, and Power Management parts ideally suited for today's IoT world. Check out the Temperature, Optical and MEMS Sensing products. For Measuring, there is wide range of Integrated Analog Front Ends (AFEs), Converters, Amplifiers, References, and Switches/Muxes.

To Analyze, ADI has Blackfin® low power DSPs, microcontrollers and processors that include the latest ARM® Cortex®-M3 technology which can do that heavy Interpretation of your data for you. To Connect your world to the Cloud, there is a large portfolio of radio/transceiver products for long range and/or high data rates from the narrow bands to the Sub-GHz ISM bands. Since many IoT applications are remote, mobile or wireless, efficient power management is a must. As energy harvesting is a viable option now and can be incorporated, it will extend battery applications so much farther. Check out the large portfolio of IoT-ready parts from Analog Devices.



SENSE



MEASURE



INTERPRET



CONNECT



**POWER MANAGEMENT
IN IOT**

- a) With reference to the above case, briefly discuss the author's statement. (4 marks)

- b) List and describe three types of sensors and actuators that can be used in the health sector according to the above case indicating their relation to instrumentation. (3 marks)
- c) Based on the above case and taking the three types of sensors, develop a proposal on an IoT based idea which the banking sector can use to increase efficiency. (5 marks)
- d) Assuming, according to your proposal, the three sensors are resistive and make a combined circuit, draw the circuit and determine the total resistance, total current, current through each resistor, voltage across each resistor and the power dissipated in each sensor considering photoresistive sensors. (6 marks)
- e) With graphical representations, explain the factors affecting the resistance of these sensors if all of them are photoresistors. (6 marks)
- f) Implement the system using Arduino, LCD and a Bluetooth module as minimum. (4 marks)
- g) Assuming the system in e) above uses a photo-resistive sensor fabricated from a gold-based photosensitive film of length 60 cm. The sensor has a photo-resistive coefficient $\alpha = 0.0038 \text{ lux}^{-1}$ and a resistance $R_0 = 9.54 \times 10^{-4} \Omega$ at a reference illumination level. If the illumination level increases continuously by 80 lux, and the sensor follows the continuous photo-resistive model determine the new resistance of the sensor. (2 marks)

QUESTION TWO (15 MARKS).

- a) A resistive pressure transducer used in an industrial hydraulic system employs a thin metallic resistive element mounted on a flexible diaphragm. The resistive element has an initial resistance of 5.0Ω when no pressure is applied. When a system pressure of 120 kPa is applied to the diaphragm, it causes a mechanical deflection equivalent to an increase in the effective length of the resistive element by 0.06 mm. The original effective length of the resistive element is 50 mm. Calculate the resistance of the transducer when the pressure is applied. (4 Marks)
- b) If the instrument in a) above is to be extended for industrial process monitoring, develop (on paper) an Arduino-based system that can continuously measure and display the hydraulic system pressure using the resistive pressure transducer. (4 Marks)
- c) If the transducer in a) above has an initial resistance of 300Ω before pressure is applied. It is connected in a simple RC oscillator circuit with a capacitor of $0.01 \mu\text{F}$, producing an initial oscillation frequency of 100 kHz. When a hydraulic pressure of 140 kPa is applied, the diaphragm deflects, causing the resistive element to increase its resistance by 0.3%. Determine the change in frequency of the oscillator after the pressure is applied. (4 Marks)
- d) Explain any three factors that need to be considered when choosing the transducer for the system in a) above. (3 Marks)

QUESTION THREE (15 MARKS)

- a) Based on a resistive transducer and a microcontroller, develop and implement a simple automotive instrumentation system for monitoring the position of a car turbocharger wastegate (or variable-geometry turbo vane position). (3 marks)
- b) Implement, on paper, the system in a) above with a remote-control capability and two additional actuators required for a car turbocharger instrumentation and protection system

- to include a labelled wiring (block) diagram and program code indicating the functions of the additional components. (4 marks)
- c) Develop an algorithm to generate a graph that describes the sensor output in relation to the input. (4 Marks)
- d) Suppose the turbo actuator position sensor is implemented using a linear resistive transducer mechanically coupled to the turbo waste-gate / VGT actuator rod. The resistive element has a cross-sectional area of 0.35 mm^2 and a total effective track length of 1.2 mm . Assume the resistive material has a resistivity of $1.1 \times 10^{-6} \Omega \cdot \text{m}$. (2 Marks)
- e) Describe two other applications of the system in b) above. (2 marks)

QUESTION FOUR (15 MARKS)

As an instrumentation engineer, you are tasked with designing a system for continuous air-quality monitoring in an industrial workspace. The system should employ suitable gas sensors and signal-conditioning circuits to measure the concentration of hazardous gases in real time. The conditioned sensor signals are to be acquired by a microcontroller and processed to obtain accurate gas-concentration values, which must be displayed continuously on a local display unit. The system should also generate audio and visual alarms whenever the measured concentration exceeds predefined safety thresholds in order to protect personnel and equipment. In addition, the instrumentation system should incorporate a communication module, such as Bluetooth, Wi-Fi or LoRa, to enable reliable transmission of the measured data to a remote monitoring platform or mobile device for supervision, data logging and timely intervention.

- a) Describe the devices you require to implement the system describing their relation to instrumentation making sure you include a remedial device in the system. (2 marks)
- b) Sketch the wiring and schematic diagrams of the system. (3 marks)
- c) Write the code to generate the necessary signals. (2 marks)
- d) Sketch the relation between the possible parameters that affect the design of the remedial device. (2 marks)
- e) Describe, with mathematical relations, the type of device that can be used to compare two levels of voltage generated by the system in a) above. (2 marks)
- f) For the system in b) above, a capacitive sensor is proposed to detect particulate matter or changes in humidity that affect gas concentration. Describe how the capacitance of the sensor varies with the environmental parameter and explain how this change can be converted into a measurable voltage signal for the microcontroller. Additionally, sketch a simple circuit diagram showing the capacitive sensor, signal-conditioning stage, and microcontroller interface. (4 marks)

QUESTION FIVE (15 MARKS)

- a) Given a microphone, a speaker and an Arduino microcontroller, describe how these devices can be connected together to model a multimedia system. With the aid of an appropriate software implement the system and describe it as an audio signal instrument indicating the corresponding waveforms at each stage of the system. (4 marks)
- b) In an electrical instrumentation system, the output voltage of a given transducer after signal conditioning is modelled by,

$$x(t) = 10\sin(1256t) + 5\cos(946t) + 20\sin(628t)$$

Briefly explain what this signal represents in an instrumentation system and simulate the signal. (3 marks)

- c) Obtain the optimum stream of bits for its first 4 samples. (2 marks)
- d) You have been requested to implement the signal in b) above using Arduino and a buzzer, describe how you could connect the devices together and write an Arduino IDE program to run it effectively. (2 marks)
- e) If the piezoelectric transducer used in the instrumentation system in (d) above is represented by its series equivalent electrical model, consisting of a motional inductance L_m , a motional resistance R_m , and a motional capacitance C_m connected in series, and the transducer is tuned to series resonance using a Q-meter. The resonant frequency of operation is 500 Hz. The motional capacitance is adjusted to 350 pF and the Q-meter indicates a quality factor of 90. If the series motional resistance of the transducer is 0.5Ω , determine the effective motional inductance L_m of the piezoelectric transducer and the effective motional resistance at resonance. (4 Marks)