ROHINI COLLEGE OF ENGINEERING
DEPARTMENT OF BIOMEDICAL ENGINEERING

24BM402 Biomedical Sensors and Data Acquisition Systems

UNIT V – REAL-WORLD BIOMEDICAL DAQ APPLICATIONS AND STANDARDS

5.1 Interfacing Sensors and Wireless Modules

1. Introduction

- In the field of biomedical engineering, continuous and accurate monitoring of physiological parameters plays a crucial role in diagnosing diseases, tracking patient health, and providing timely medical intervention. Traditionally, patient monitoring was limited to hospitals where bulky equipment and wired systems were used. However, with advancements in electronics and communication technologies, modern healthcare systems have shifted towards compact, portable, and wireless solutions.
- Biomedical sensors are used to measure various physiological parameters such as body temperature, heart rate, blood pressure, oxygen saturation (SpO_2), and electrical activity of the heart (ECG). In real-world healthcare applications, monitoring a single parameter is not sufficient. For example, in critical care units, multiple parameters must be monitored simultaneously to assess the overall condition of a patient.
- This requirement leads to the use of multiple sensors integrated into a single system. These sensors generate signals that must be processed, analyzed, and transmitted. A microcontroller acts as the central processing unit that collects data from all sensors, processes it, and controls the overall system operation.
- To enable remote monitoring and real-time data access, wireless communication modules such as Bluetooth, Wi-Fi, Zigbee, and GSM are used. These modules allow data to be transmitted from the patient to healthcare providers, making telemedicine and remote healthcare possible.
- Thus, interfacing multiple sensors with microcontrollers and wireless modules forms the backbone of modern biomedical instrumentation systems.

2. Data Acquisition System (DAS)

- A Data Acquisition System (DAS) is an integrated system used to collect, measure, and analyze data from physical or biological sources. In biomedical applications, DAS plays a vital role in converting physiological signals into meaningful digital data that can be analyzed and stored.
- The primary function of a DAS is to acquire signals from sensors, condition those signals to remove noise and improve quality, convert them into digital form, and then process or transmit the data.

2.1 Components of DAS

A typical biomedical data acquisition system consists of the following components:

1. Sensors

Sensors are the input devices that detect physiological parameters and convert them into electrical signals. For example, a temperature sensor converts body temperature into voltage.

2. Signal Conditioning Unit

The signals obtained from sensors are often weak, noisy, and not suitable for direct processing. Therefore, signal conditioning is required to amplify, filter, and modify the signals.

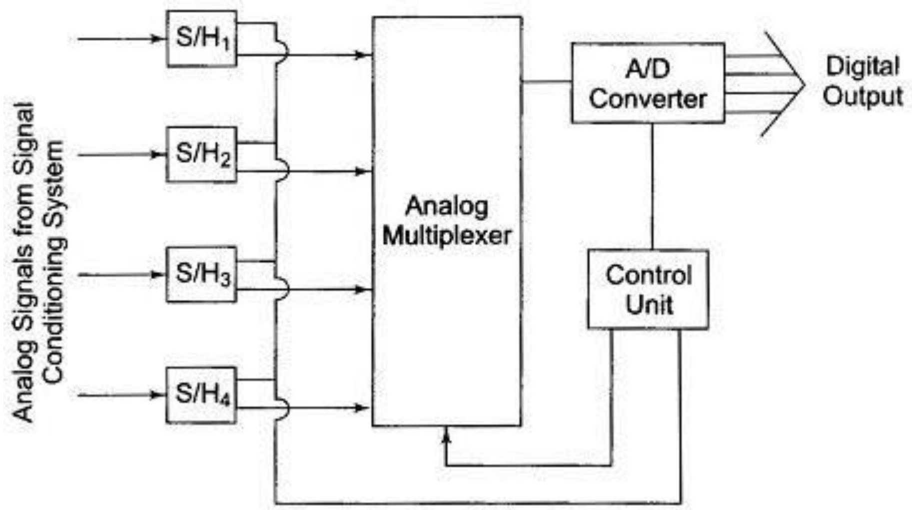

Fig. 14.4 Data Acquisition and Conversion System

3. Analog-to-Digital Converter (ADC)

Most sensors produce analog signals, but microcontrollers can process only digital signals. ADC converts analog signals into digital form.

4. Microcontroller

The microcontroller processes the digital data, performs calculations, and controls data transmission.

5. Output/Display/Storage

The processed data can be displayed on a screen, stored in memory, or transmitted wirelessly.

2.2 Working of DAS

The working of a DAS begins with sensors detecting physiological signals. These signals are then passed through a signal conditioning unit to improve their quality. The conditioned signals are converted into digital form using an ADC. The microcontroller processes this data and sends it to a display device or wireless module for further transmission.

3. Biomedical Sensors

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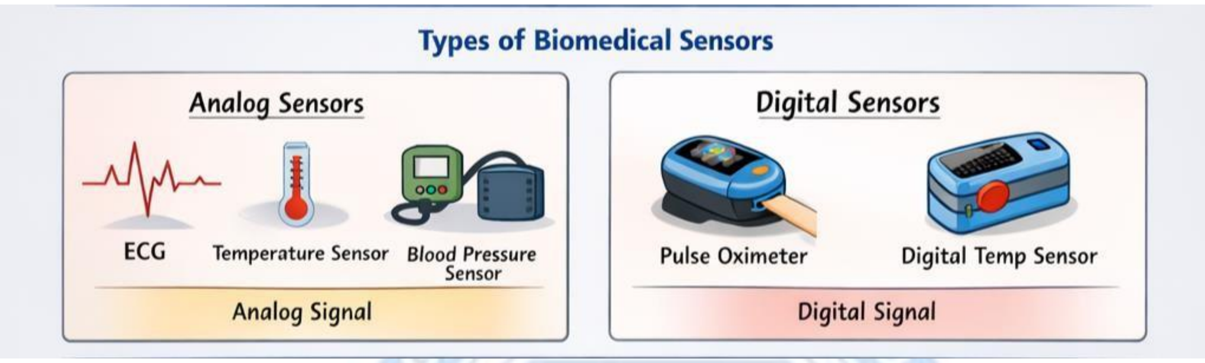
Biomedical sensors are devices that detect biological signals and convert them into electrical signals. These sensors are essential for monitoring patient health and diagnosing medical conditions.



3.1 Classification Based on Output

1. Analog Sensors

- Analog sensors produce continuous signals that vary with time. These signals represent the magnitude of the measured parameter.
- For example, a temperature sensor like LM35 produces a voltage that is directly proportional to temperature. Similarly, ECG sensors produce continuous waveforms representing heart activity.
- Since microcontrollers cannot directly process analog signals, these signals must be converted into digital form using an ADC.

2. Digital Sensors

- Digital sensors provide output in binary form (0s and 1s). These sensors have built-in ADCs and signal processing circuits, making them easier to interface with microcontrollers.
- For example, digital temperature sensors and pulse oximeters provide processed digital data, which can be directly read by the microcontroller using communication protocols.

3.2 Classification Based on Measured Parameter

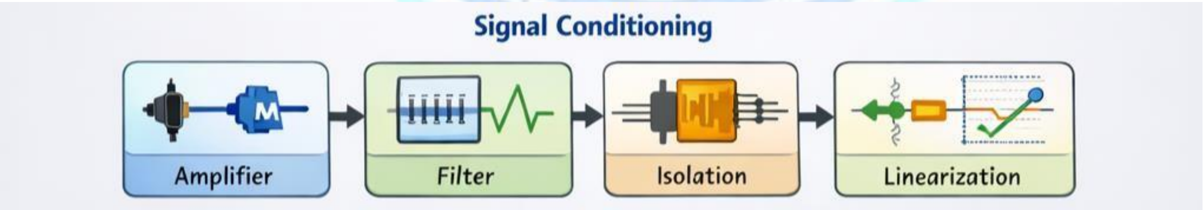
Biomedical sensors can also be classified based on the type of parameter they measure:

- Temperature Sensors: Measure body temperature
- Pressure Sensors: Measure blood pressure
- Optical Sensors: Used in pulse oximetry
- Bioelectric Sensors: Measure ECG, EEG signals

Each type of sensor has its own working principle and interfacing requirements.

4. Signal Conditioning

Signal conditioning is an essential step in biomedical instrumentation because raw signals obtained from sensors are often weak and contaminated with noise.



4.1 Need for Signal Conditioning

- The signals generated by biomedical sensors are usually very small in amplitude and can be affected by noise from the environment, power supply, or other electronic devices. Without proper conditioning, these signals cannot be accurately processed.
- Signal conditioning ensures that the signal is strong, clean, and suitable for further processing.

4.2 Types of Signal Conditioning

Amplification

- Amplification increases the strength of weak signals. For example, ECG signals are in the millivolt range and require amplification before processing.
- Operational amplifiers (Op-Amps) are commonly used for this purpose.

Filtering

- Filtering removes unwanted noise and interference from signals. Biomedical signals are often affected by power line interference (50/60 Hz noise).
- ➢ Different types of filters are used:
- Low-pass filters remove high-frequency noise
- High-pass filters remove low-frequency drift
- Band-pass filters allow only a specific range of frequencies

Isolation

Isolation is important for patient safety. It prevents electrical shocks by isolating the patient from the electrical system.

Linearization

Some sensors produce nonlinear outputs. Linearization techniques are used to convert these outputs into linear signals for easier processing.

5. Microcontroller

A microcontroller is a small, programmable device used to control embedded systems. It acts as the brain of the biomedical data acquisition system.

5.1 Features of Microcontroller

- Central Processing Unit (CPU)
- Memory (RAM and ROM)

- Input/Output ports

- Built-in ADC
- Timers and counters

5.2 Role in Biomedical Systems

The microcontroller collects data from multiple sensors, processes it, and controls communication with external devices. It can perform tasks such as data filtering, calculation, and decision-making.

6. Interfacing Sensors with Microcontroller

Interfacing refers to the process of connecting sensors to the microcontroller in such a way that data can be accurately transferred and processed.

6.1 Interfacing Analog Sensors

Analog sensors produce continuous signals that must be converted into digital form.

The process involves:

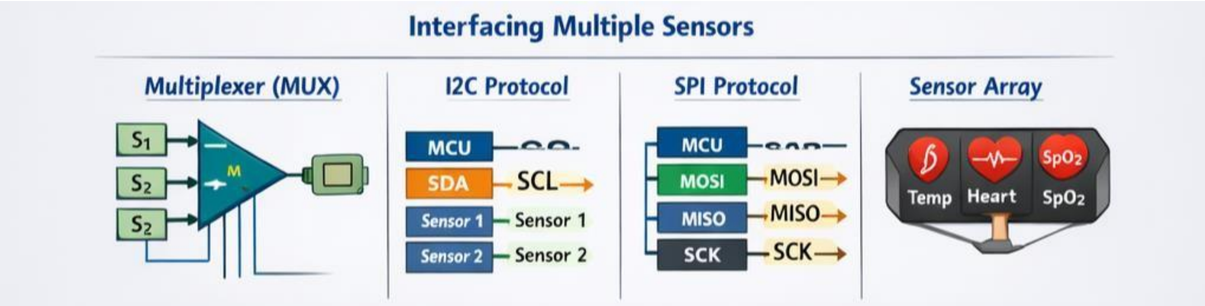
- Signal conditioning
- Analog-to-digital conversion
- Data processing

The ADC converts the analog signal into a digital value that represents the sensor reading.

6.2 Interfacing Digital Sensors

- Digital sensors communicate using standard protocols such as I2C, SPI, and UART.
- These protocols define how data is transmitted between the sensor and microcontroller.

7. Interfacing Multiple Sensors



In practical biomedical systems, multiple sensors are used simultaneously. This requires efficient interfacing techniques.

7.1 Challenges

- Interfacing multiple sensors presents several challenges:
- Limited number of input pins
- Signal interference
- Timing and synchronization issues
- Increased power consumption

7.2 Solutions

To overcome these challenges, different techniques are used:

Multiplexing

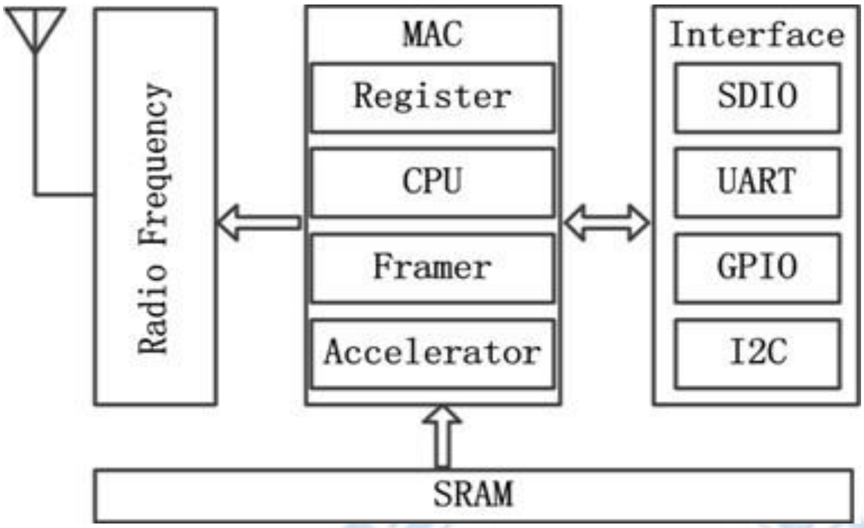
A multiplexer allows multiple sensor signals to share a single input channel. It selects one sensor at a time for processing.

Communication Protocols

Protocols like I2C and SPI allow multiple devices to communicate over shared lines, reducing the number of required connections.

8. Wireless Modules

Wireless modules enable communication between the biomedical system and external devices without physical connections.



8.1 Importance

Wireless communication allows:

- Remote monitoring
- Real-time data access
- Increased patient mobility

8.2 Types

Bluetooth

- Used for short-range communication in wearable devices.

Wi-Fi

- Used for high-speed data transfer and internet connectivity.

Zigbee

- Used in low-power sensor networks.

GSM

- Used for long-distance communication and alerts.

9. Interfacing Microcontroller with Wireless Modules

- The microcontroller communicates with wireless modules using serial communication protocols such as UART.

- The process involves sending processed sensor data to the wireless module, which then transmits it to a remote device.

10. Applications

- Remote patient monitoring systems
- Wearable health devices
- ICU monitoring systems
- Telemedicine applications

11. Advantages

- Continuous monitoring
- Improved accuracy
- Remote accessibility
- Reduced healthcare cost

12. Limitations

- Noise interference
- Power consumption issues
- Data security concerns
- Connectivity limitations

13. Conclusion

Interfacing multiple sensors with microcontrollers and wireless modules is a fundamental concept in biomedical engineering. It enables the development of advanced healthcare systems that provide accurate, real-time, and remote monitoring of patients. With the integration of modern technologies such as IOT and wireless communication, these systems are becoming more efficient, portable, and accessible.