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ELECTRONICS AND COMMUNICATION ENGINEERING

U24EC203-SENSORS AND ACTUATORS

TITLE *:*

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Case Study: Blood Oxygen (SpO_2) Sensor

1. Introduction

Blood Oxygen (SpO_2) sensors are vital biomedical devices used to measure the oxygen saturation level in a person's blood. This measurement indicates how effectively oxygen is being transported from the lungs to the body's tissues. Monitoring SpO_2 is essential in healthcare, especially for patients suffering from respiratory diseases like asthma, pneumonia, or COVID-19.

These sensors are typically found in wearable health devices such as smartwatches, fitness bands, and hospital pulse oximeters.

2. Working Principle

The SpO_2 sensor works based on the photoplethysmography (PPG) principle. It uses light absorption characteristics of hemoglobin to determine oxygen levels.

Red Light (660 nm) and Infrared Light (940 nm) are emitted through the skin, usually at a fingertip or earlobe.

The photodetector on the opposite side measures the amount of light absorbed by the blood.

Oxygenated and deoxygenated blood absorb light differently:

Oxyhemoglobin (HbO_2) absorbs more infrared light.

Deoxyhemoglobin (Hb) absorbs more red light.

The ratio of absorbed light at both wavelengths is calculated by the sensor to determine the SpO_2 percentage.

Formula used:

$$SpO_2 = \frac{HbO_2}{HbO_2 + Hb} \times 100$$

3. Components Used

Common modules and ICs used in SpO_2 measurement include:

MAX30102 / MAX30105: Integrated pulse oximeter and heart-rate sensor modules that include LEDs, photodiodes, optical elements, and low-noise electronics.

Pulse Oximeter Module: A device that combines sensor, display, and microcontroller for standalone measurement.

Microcontroller (Arduino / ESP32 / STM32): Processes sensor data and calculates SpO_2 values

4. Application Areas

Healthcare Monitoring: Continuous patient SpO_2 tracking in ICUs and during surgeries.

Wearable Devices: Smartwatches and fitness bands for real-time health insights.

COVID-19 Monitoring: Detecting low oxygen saturation in patients with respiratory infections.

Sports & Fitness: Measuring oxygen levels to assess physical performance

5. Advantages

✅ Non-invasive and painless measurement.

✅ Low power consumption and portable.

✅ Real-time monitoring and data logging possible.

✅ High accuracy with digital signal processing.

6. Limitations

⚠️ Affected by motion artifacts or poor blood circulation.

⚠️ May give inaccurate readings if the sensor is not in proper contact with skin.

⚠️ Sensitive to ambient light interference.

7. Real-World Example

During the COVID-19 pandemic, the use of pulse oximeters skyrocketed in hospitals and homes. These devices helped detect "silent hypoxia" — a condition where patients' oxygen levels drop dangerously low without visible symptoms. By early detection using SpO_2 sensors, timely medical intervention saved countless lives.

8. Conclusion

Blood Oxygen (SpO_2) sensors have revolutionized modern healthcare. Their integration into wearable and IoT-based systems enables continuous monitoring of vital parameters without hospitalization. In the future, advancements in optical sensing and AI analytics will make these sensors even more accurate, compact, and accessible.