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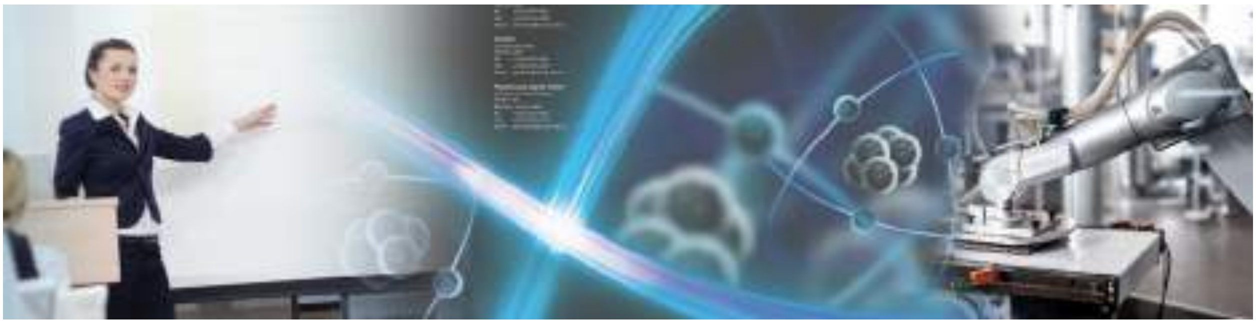

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ЗМІСТ

Review and selection of optimal sensors for building a production facility microclimate monitoring system

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Anotation: The study examines modern sensors for monitoring the microclimate of industrial premises, such as temperature, humidity, pressure, CO_2 concentration, dust, noise, and light sensors. A review of their characteristics and selection criteria, such as accuracy, cost, reliability, power consumption, and ease of integration, was conducted. The selection of specific sensors for the indoor (BME280 + MH-Z19D) and outdoor (BMP290L + SHT40) modules is justified. The obtained results demonstrate an optimal balance between functionality, accuracy, and cost-effectiveness for building a microclimate monitoring system.

***Key words*:** microclimate monitoring, sensors, temperature, humidity, pressure.

I. INTRODUCTION

Microclimate monitoring is a key task for ensuring the safety and comfort of production processes [1-3]. Controlling parameters such as temperature, humidity, pressure, gas concentration, dust levels, noise levels, and illumination allows for the timely detection of deviations and the optimization of working conditions. Modern sensors enable the creation of distributed data acquisition systems with high accuracy and low power consumption.

In industrial production environments, the automation of microclimate control processes is particularly relevant [4-6]. The integration of sensor modules into control systems enables continuous monitoring of environmental parameters and an immediate response to deviations from established norms [7]. This not only increases the efficiency of the production process but also reduces risks to personnel health and equipment.

Particular attention is required for modern robotic complexes operating in enclosed workshops and on open sites [8-12]. Accurate microclimate control is critically important for their stable and safe operation: from temperature and humidity, which affect electronics and batteries, to the level of dust or the gas composition of the air, which determine the reliability of sensory navigation systems. Microclimate sensors are becoming an integral part of intelligent production platforms and robotic systems.

Thus, the selection of optimal sensors is critical for creating intelligent monitoring systems capable of operating both indoors and outdoors, ensuring reliability, scalability, and the ability to integrate with modern automated and robotic platforms.

II. A REVIEW OF MODERN SENSORS

Building an effective microclimate monitoring system requires the correct selection of sensors that provide high accuracy, reliability, and compatibility with modern automation platforms.

Therefore, we will conduct a detailed review of the modern sensors selected for monitoring the key parameters of the industrial environment: temperature, humidity, pressure, gas concentration, dust level, noise, and illumination.

Sensors such as the BME280, MH-Z19D, BMP290L, and SHT40 will be considered, along with a photoresistor with a resistive divider for auxiliary screen brightness adjustment.

We will begin with the BME280 (Bosch), which is a multifunctional sensor selected for measuring temperature, humidity, and atmospheric pressure. The BME280 sensor is distinguished by its low power consumption, available I^2C and SPI interfaces, and broad support among microcontroller platforms.

The BME280 sensor has a small package size (2,5 × 2,5 mm) (Fig. 1), allowing for its integration into mobile devices, robotic systems, and compact monitoring modules.

Fig. 1. BME280 sensor (Bosch)

The BME280 sensor is factory calibrated, ensuring long-term measurement stability without the need for frequent maintenance. Therefore, an important characteristic was its resistance to electromagnetic interference, which is crucial in industrial environments.

Next, we will consider the MH-Z19D sensor (Winsen) (Fig. 2), which belongs to sensors based on the NDIR principle and is used to measure CO_2 concentration in a range up to 5000 ppm. Thanks to its UART/PWM interfaces and operational stability, it is an optimal solution for monitoring air quality in industrial premises. Furthermore, it can be easily integrated into modular systems due to its standard interfaces.

Fig. 2. MH-Z19D sensor

The MH-Z19D sensor consumes approximately 15–20 mA in operating mode, making it suitable for embedded and IoT systems. Its operating temperature range of 0 to +50 °C allows for use in most industrial environments.

The BMP290L sensor (Bosch) was selected for precise atmospheric pressure measurement. The BMP290L sensor features a low noise level.

We will now consider the SHT40 (Sensirion) (Fig. 3), which is used for high-precision temperature and humidity measurements. Its key advantages are compact size, high accuracy, and low power consumption, making it suitable for autonomous systems.

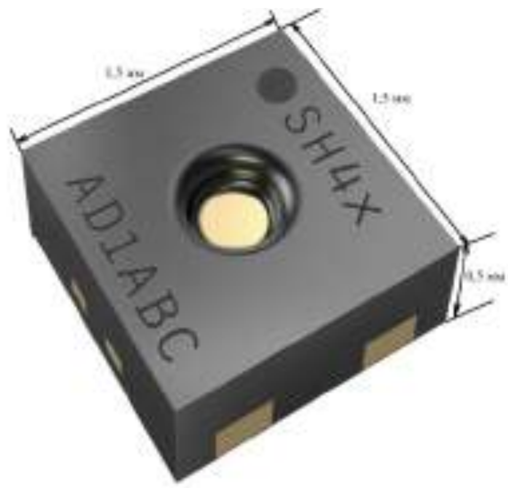

Fig. 3. SHT40 sensor

The SHT40 (Sensirion), with its ultra-compact dimensions (1,5 × 1,5 × 0,54 mm), is one of the most modern temperature and humidity sensors. Its high accuracy and small footprint allow for integration into miniature devices, IoT systems, and robotic complexes where saving space and energy is crucial.

A photoresistor with a resistive divider is used to measure the light level. This is a simple and economical way to implement automatic brightness adjustment for the weather station's display, enhancing the device's user convenience.

Thus, the selected set of sensors covers all the necessary microclimate parameters (temperature, humidity, pressure, CO_2 level) and also ensures the system interface's adaptability through automatic display brightness control.

III. CRITERIA FOR SELECTING MICROCLIMATE SENSORS

In modern production environments, effective microclimate monitoring is impossible without comprehensive digitalization, which involves the collection, processing, and analysis of sensor data in real-time to support automated solutions and process optimization [13-16].

The selection of sensors for an industrial premises microclimate monitoring system must be based on a number of key criteria.

1. Measurement Accuracy and Stability. This criterion is paramount, as the accuracy of the data directly impacts the reliability of monitoring and decision-making. For temperature and humidity sensors, not only initial accuracy but also long-term stability of readings over years of operation is important. For barometers, low pressure measurement error is critical, enabling the detection of even minor changes.

2. Cost and Availability. In industrial systems, sensors are typically used in significant quantities, so their price affects the economic feasibility of the project. It is also important that the sensor is widely available on the market and has a stable supply chain, as this reduces the risk of dependency on a single supplier.

3. Reliability and Durability. Sensors must operate stably in conditions of increased dust, humidity, or temperature fluctuations. Particular attention should be paid to protection from environmental influences, as well as the quality of the housing and the stability of calibration.

4. Power Consumption. Since some system modules may operate autonomously on batteries or be powered by energy-efficient sources, minimizing energy consumption is important. Sensors with low power consumption extend the operating time without recharging and reduce operational costs.

5. Ease of Integration. This criterion covers the availability of standard interfaces (I²C, SPI, UART), clear documentation, example libraries, and ready-made drivers for popular microcontroller platforms. The simpler the integration, the faster the system can be developed and scaled, and the easier it is to maintain during operation.

Thus, the combination of these criteria enables a well-founded selection of sensors that not only meet technical requirements but are also economically viable and convenient to implement. Tables 1, 2, 3, 4, and 5 present the main characteristics of the selected sensors according to the key criteria: accuracy, cost, reliability, power consumption, and ease of integration.

Table 1. KEY CHARACTERISTICS OF THE BME280 SENSOR

Sensor	BME280
Parameter	T, RH, P
Accuracy	T ±1 °C, RH ±3 %, P ±1 hPa
Cost	Medium
Reliability	High, time-tested
Power Consumption	Low
Ease of Integration	Very simple (I²C/SPI, ready-made libraries)

Table 2. KEY CHARACTERISTICS OF THE MH-Z19D SENSOR

Sensor	MH-Z19D
Parameter	CO_2
Accuracy	±50 ppm + 5 %
Cost	Medium
Reliability	High, NDIR principle, stable
Power Consumption	Medium (requires preheating)
Ease of Integration	Simple (UART/PWM, many examples available)

Table 3. KEY CHARACTERISTICS OF THE BMP290L SENSOR

Sensor	BMP290L
Parameter	P
Accuracy	±0,3 hPa
Cost	Higher than BMP280
Reliability	Very high (stability, low noise)
Power Consumption	Low
Ease of Integration	Simple (compatible with Bosch line, I²C/SPI)

Table 4. KEY CHARACTERISTICS OF THE SHT40 SENSOR

Сенсор	SHT40
Parameter	T, RH
Accuracy	T ±0,2 °C, RH ±1,8 %
Cost	Medium-High
Reliability	High, modern sensor
Power Consumption	Very low
Ease of Integration	Simple (I²C, official libraries)

Table 5. KEY CHARACTERISTICS OF THE PHOTORESISTOR

Photoresistor	MH-Z19D
Parameter	Illumination
Accuracy	Low (relative values)
Cost	Very low
Reliability	Medium (depends on conditions)
Power Consumption	Very low
Ease of Integration	Very simple (analog ADC input)

After analyzing the key characteristics of the sensors, it can be concluded that each sensor has its own advantages and limitations depending on the selection criteria.

Thus, the BME280 provides an optimal balance of functionality, accuracy, and ease of integration, making it a convenient choice for indoor microclimate monitoring. The MH-Z19D is a reliable solution for CO_2 measurement, although it requires more energy and a pre-heating period before operation. The BMP290L demonstrates high accuracy and stability in measuring atmospheric pressure, which is critically important for the external module. The SHT40 is notable for its low power consumption and high accuracy, making it suitable for long-term use in outdoor conditions. The photoresistor with a resistive voltage divider is the simplest and most cost-effective solution for light level control, sufficient for implementing automatic display brightness adjustment.

Therefore, the selected set of sensors ensures complete coverage of the necessary microclimate parameters with an optimal balance of accuracy, cost, and power consumption.

IV. CONCLUSIONS

This work reviewed modern sensors for monitoring the microclimate parameters of an industrial premises. Key selection criteria-accuracy, cost, reliability, power consumption, and ease of integration – were considered, enabling a well-founded choice of sensors for practical application.

Analysis of the primary sensor characteristics showed that the BME280 is an optimal solution for indoor modules, as it combines temperature, humidity, and pressure measurement functions in a single package with relatively low cost and simple integration. The MH-Z19D sensor provides stable CO_2 level monitoring by utilizing reliable NDIR technology, which is critically important for assessing air quality and ventilation efficiency in industrial settings. For the outdoor module, the combination of the BMP290L and SHT40 is advisable. The former offers high accuracy and long-term stability in atmospheric pressure measurement, while the latter features a modern component base, high accuracy, and very low power consumption, making it suitable for prolonged use in external conditions.

The use of a photoresistor with a resistive divider for auxiliary light level control was separately justified. Although this approach does not provide high metrological accuracy, it is simple, inexpensive, and entirely sufficient for implementing automatic brightness adjustment of the weather station's display, thereby enhancing the system's ergonomics.

Overall, the selected set of sensors enables the construction of a microclimate monitoring system that covers all key parameters: temperature, relative humidity, atmospheric pressure, CO_2 concentration, and light level for interface adaptation. This system achieves a balance between measurement accuracy, economic feasibility, and energy efficiency. The proposed solutions are easily integrated with modern microcontroller platforms, creating a foundation for further functional expansion and project scalability.

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