

DESIGN AND CONSTRUCTION OF DIGITAL SYSTEM GAS PRESSURE MEASURING EQUIPMENT

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Abstract -- The increasing use of LPG gas in household and small industrial sectors demands an accurate, responsive, and real-time gas pressure measurement system to enhance operational safety. Limitations of conventional analog instruments in terms of accuracy, response time, and data recording highlight the need for digital-based solutions. This study aims to design and evaluate a gas pressure measurement device using an MQ-2 sensor and ESP32 microcontroller, addressing calibration methods, accuracy, and system performance compared to conventional tools. The research employs an experimental approach with a Design–Development–Deployment model, including system design, prototype development, sensor calibration, and performance testing through ADC data acquisition converted into kilopascal (kPa). The results indicate that the system can measure gas pressure in real-time with fast response and stable readings after calibration, showing improved efficiency over analog devices. This study contributes to the advancement of digital instrumentation systems that are practical, accurate, and have strong potential for further development into IoT-based monitoring systems.

Keywords:

gas pressure;
MQ-2 sensor;
ESP32;
digital system;
calibration

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I. INTRODUCTION

The development of digital instrumentation technology over the past decade has shown a significant transformation from analog systems to integrated sensor- and microcontroller-based systems. Digitalization enables measurement processes to be carried out in real-time, with higher accuracy, and supports systematic data-driven monitoring systems. In the context of modern industry, measurement systems no longer function solely as parameter reading tools, but also as part of control systems that play an important role in maintaining operational efficiency and safety [1]. One of the crucial parameters in various industrial sectors is gas pressure, which serves as a primary indicator in maintaining process stability, product quality, and the safety of fluid-based systems [2].

Although technological advancements have led to digital systems, the use of analog-based gas pressure measurement instruments is still widely found across various sectors. Analog instruments have limitations in measurement accuracy, are prone to human error, and are not capable of storing or directly integrating data with digital systems [3]. On the other hand, the development of sensors based on Micro-Electro-Mechanical Systems (MEMS) offers a solution with high sensitivity, smaller size, and the ability to integrate with microcontrollers for fast and precise data processing [4].

However, the implementation of gas pressure measurement systems that are practical, economical, and easy to use remains a challenge in current research. Various previous studies generally focus on detecting gas concentration in ppm units or developing Internet of Things (IoT)-based monitoring systems, without deeply examining the conversion of sensor data into physical gas pressure units such as kilopascal (kPa). In addition, some studies have not conducted a comprehensive evaluation of accuracy, stability, and performance comparison between digital systems and analog measuring instruments under real operational

conditions [3,5]. This gap indicates the need for research that not only develops devices but also quantitatively and applicatively evaluates system performance.

Based on these issues, this study aims to design and develop a digital-based gas pressure measurement device using an MQ-2 sensor and an ESP32 microcontroller, as well as to perform calibration to convert sensor data into pressure units (kPa) accurately. In addition, this study also aims to evaluate the performance of the device through analysis of accuracy, reading stability, and response time, and to compare it with conventional measuring instruments. The approach used is experimental, involving direct testing of the developed prototype.

The main contribution of this study lies in the development of an integrated, standalone (non-IoT) digital gas pressure measurement system capable of displaying data in real-time through a local interface. This research also provides scientific contributions in the form of a calibration model for voltage-to-pressure conversion as well as a quantitative evaluation of microcontroller-based system performance. Therefore, the results of this study are expected to enrich the field of digital instrumentation and serve as an applicable solution to support improved safety and efficiency in gas utilization across various sectors.

II. LITERATURE REVIEW

The literature review in this study is built upon the theoretical foundations of digital instrumentation, the characteristics of semiconductor gas sensors, and the basic concept of gas pressure as the main variable. Within the grand theory framework, modern measurement systems are based on the principle of signal digitalization, where physical quantities are converted into electrical signals and subsequently transformed into digital data for real-time analysis. This concept is reinforced by embedded system theory, which emphasizes the integration of sensors, microcontrollers, and user interfaces into a unified system. In this context, the microcontroller functions as the main processing unit that performs data acquisition, conversion, and visualization. At the middle-range theory level, the relationship between gas concentration, sensor resistance, and gas pressure is explained through the characteristics of semiconductor sensors based on tin dioxide (SnO_2), where changes in gas concentration affect sensor resistance, which is then converted into voltage and processed into pressure parameters [6,7]

Conceptually, gas pressure is explained through the ideal gas law, which states that pressure is directly proportional to the number of gas molecules and temperature at constant volume. This relationship forms the basis for interpreting changes in gas concentration as changes in pressure within a closed system. In addition, the concept of calibration is a crucial part of measurement systems, where the relationship between sensor output voltage and gas pressure is mathematically modeled using linear or logarithmic regression approaches. This calibration process enables the system to produce accurate and consistent data while reducing the influence of environmental variables such as temperature and humidity on sensor readings [8].

Several previous studies have examined the use of MQ-2 sensors and ESP32 microcontrollers in gas detection systems. Research by [9] developed an IoT-based air quality monitoring system using MQ-2 and MQ-135 sensors with an accuracy of up to 94%, but it is limited to measuring gas concentration in ppm without conversion to pressure. Furthermore, [10] designed a multi-gas monitoring system based on ESP32 with an accuracy of 92.7%, but it still relies on internet connectivity and does not provide a local display or pressure measurement. Developed a machine learning-based fire detection system with an accuracy of 96%, which shows improvement in early detection, but does not focus on gas pressure parameters.

Research by [11] proposed a fire prevention system based on MQ-2 sensors and ESP32 with Android notifications, which is effective in detecting gas leaks but does not perform quantitative pressure measurement. Meanwhile, [12] developed an air monitoring system in the mining industry by integrating gas and pressure sensors, but it does not specifically examine gas pressure conversion in kilopascal (kPa) units. The study by [13] also demonstrates real-time air quality monitoring capability based on ESP32, but does not include gas pressure calibration aspects. Overall, these studies show progress in gas detection and environmental monitoring, but have not fully integrated quantitative and applicable gas pressure measurement.

Research conducted by [14] developed a web-based information system for LPG gas distribution, which focuses on data management and monitoring aspects. In addition, [15] evaluated the implementation of information systems using a technology acceptance approach to support system usability and performance. However, these studies are still limited to system-level monitoring and information

processing, and have not addressed the quantitative measurement of gas pressure or the conversion of sensor data into physical units such as kilopascal (kPa).

Based on this review, there is a clear research gap, both theoretically and empirically. From a theoretical perspective, there are still limited studies that integrate the relationship between gas concentration, sensor resistance, and gas pressure into a single calibrated measurement model. Empirically, most studies still focus on gas detection in ppm units without converting the data into gas pressure in kilopascal (kPa). In addition, dependence on IoT-based systems remains a limitation for implementation in environments without network access. Performance evaluation aspects such as accuracy, stability, and response time have also not been comprehensively discussed under real operational conditions.

Therefore, this study contributes to addressing these gaps by developing a digital gas pressure measurement system based on an MQ-2 sensor and an ESP32 microcontroller, which is capable of quantitatively converting sensor data into kPa units and displaying the results in real-time through an LCD without relying on internet connectivity. The scientific contribution of this research lies in the integration of a calibration model, a digital measurement system, and experimental performance evaluation, thereby addressing the limitations of previous studies and strengthening the development of embedded system-based instrumentation.

III. METHOD

This study employs an experimental quantitative approach with the objective of evaluating the performance of a digital-based gas pressure measurement system in a measurable and objective manner. The experimental approach is chosen because it allows the researcher to control research variables and observe the causal relationship between the input in the form of gas concentration and the output in the form of gas pressure produced by the system. The development model used is Design–Development–Deployment, which includes the stages of system design, prototype realization, and direct performance testing of the device in a controlled environment.

The research was conducted in the Electronics Laboratory of the Faculty of Engineering, Universitas Negeri Gorontalo, as an environment that supports testing of sensor- and microcontroller-based systems. The research was carried out in stages, starting from the design process, assembly, calibration, to system testing. The selection of this location was based on the availability of adequate laboratory facilities to safely and systematically test gas pressure measurement instruments.

The population in this study consists of the developed sensor-based gas pressure measurement system, while the sample comprises data obtained from gas pressure readings of the prototype under various testing conditions. The sampling technique used is purposive sampling, where testing conditions are deliberately selected based on variations in LPG gas pressure generated within the test chamber. The number of samples is determined based on the need for repeated testing to obtain representative and stable data, which can be used for calibration and system performance analysis.

The research instruments consist of integrated hardware and software within the system. The hardware includes an MQ-2 sensor as the gas detector, an ESP32 microcontroller as the data processing unit, and an I2C LCD as the display medium for measurement results. In addition, a buzzer and LED are used as warning indicators, while a 220 Ω resistor and jumper wires support circuit stability. The measurement instruments also include a reference device in the form of a digital manometer for the calibration process. The main indicators measured include sensor output voltage, ADC values, and gas pressure in kilopascal (kPa). Data validity is ensured through calibration against a standard instrument, while reliability is tested through repeated measurements to ensure consistency of results.

The data collection technique is carried out through experimental observation using a systematic procedure. LPG gas is introduced into the test chamber using a regulator, after which the MQ-2 sensor detects changes in gas concentration and generates a voltage signal. This signal is converted by the ESP32 into digital data and displayed in real-time on the LCD. The sensor readings are recorded and compared with measurements from the digital manometer as a calibration reference. This process is repeated under various pressure conditions to obtain accurate and representative datasets.

Teknik analisis data dilakukan secara kuantitatif menggunakan pendekatan regresi untuk memperoleh hubungan matematis antara tegangan keluaran sensor dan tekanan gas. Model analisis yang digunakan meliputi regresi linier dan logaritmik untuk menentukan konstanta kalibrasi serta tingkat kesesuaian model yang dinyatakan melalui koefisien determinasi (R^2). Selain itu, analisis dilakukan terhadap parameter performa sistem seperti akurasi, stabilitas, dan respon waktu. Data diolah menggunakan

perangkat lunak pendukung seperti *Microsoft Excel* atau perangkat analisis numerik lainnya untuk mempermudah proses perhitungan dan visualisasi data.

Figure 1 presents the workflow of the digital gas pressure measurement system. The flowchart describes the sequence of processes starting from system initialization, sensor data acquisition, data conversion, decision-making, and output display in real-time.

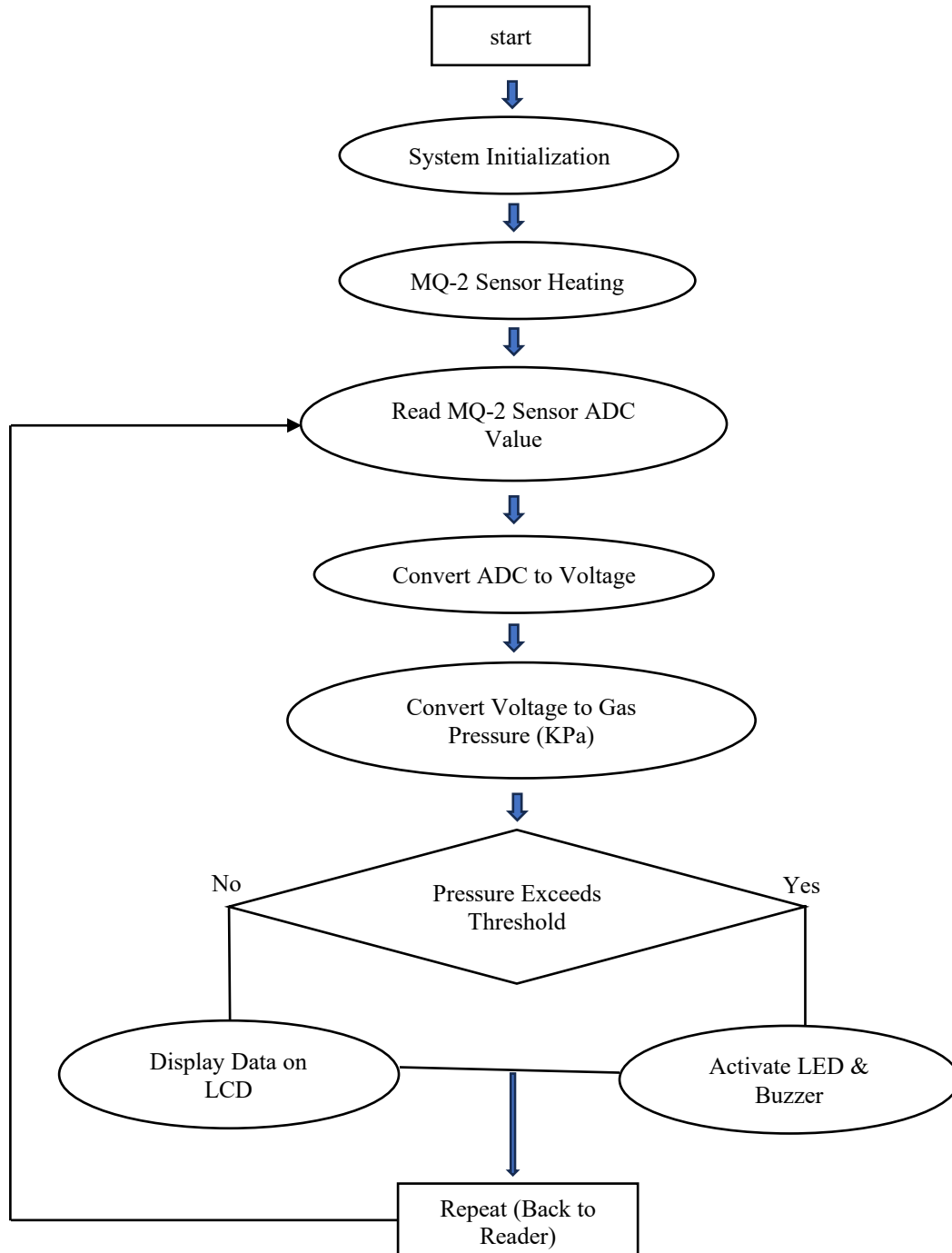


Figure 1 Flowchart

The process begins with system initialization, where all components such as the ESP32 microcontroller, MQ-2 sensor, LCD, buzzer, and LED are activated. After initialization, the MQ-2 sensor

undergoes a heating process to ensure stable and accurate readings. The system then reads the analog signal from the MQ-2 sensor in the form of ADC values. These values are converted into voltage, which is further processed into gas pressure values in kilopascal (kPa) using a calibration model.

Next, the system evaluates whether the measured pressure exceeds a predefined threshold. If the pressure is below the threshold, the system displays the measurement results on the LCD. If the pressure exceeds the threshold, the system activates warning indicators such as the LED and buzzer to alert the user. This process is continuously repeated, allowing the system to perform real-time monitoring of gas pressure and provide immediate feedback based on the measured conditions.

IV. RESULTS AND DISCUSSION

The results of the study indicate that the digital gas pressure measurement system based on the MQ-2 sensor and ESP32 microcontroller was successfully implemented and functions according to the design. Functional testing of each component shows that all parts of the system, including the sensor, microcontroller, LCD, buzzer, and LED, operate optimally in supporting data acquisition and visualization processes. At the integration stage, the system is able to read analog signals from the sensor and convert them into digital data displayed in real-time. The test results show that the sensor output values in the form of ADC can be converted into pressure units (kPa) through a calibration process using regression approaches, both linear and logarithmic.

Quantitatively, the experimental results show a consistent relationship between the increase in ADC values and the rise in gas pressure. Data from multiple tests indicate a stable trend of pressure increase with relatively small deviations between trials, which reflects good system consistency. In addition, the response time of the device is relatively fast, as the system is able to display pressure changes shortly after gas is introduced into the test chamber. The comparison results between the digital device and the analog instrument show that the readings are relatively close, although slight differences exist due to calibration factors and sensor sensitivity. This indicates that the developed digital system has a satisfactory level of accuracy and is suitable as an alternative to conventional measuring instruments.

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Table 1 presents the experimental data obtained from the gas pressure measurement system, including ADC values, converted voltage, and corresponding gas pressure in kilopascal (kPa). The data also include comparison results with analog measuring instruments to evaluate system accuracy.

Time(seconds)	ADC value	Pressure (kPa)	Information
0	220	5.4	Start of active tool
5	560	13.7	The pressure rises slowly
10	950	23.2	Pressure increases
15	1330	32.5	Pressure increases
20	1760	43.0	Pressure is relatively stable

Based on Table 1, it can be observed that the increase in ADC values is directly proportional to the increase in gas pressure. The measurement results show a consistent pattern with relatively small deviations, indicating good system stability and reliability.

Figure 2 illustrates the real-time measurement results obtained from the Arduino IDE, showing the relationship between gas pressure and time during the testing process.

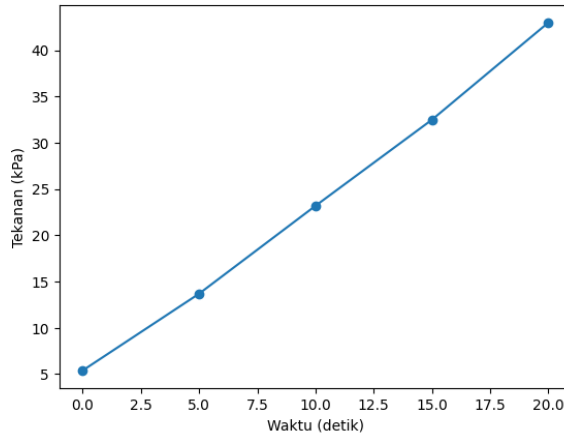


Figure 2 Experiment results graph

The graph shows a clear increasing trend, indicating a strong correlation between sensor output and gas. The graph shows the variation of gas pressure over time based on real-time data acquisition from the Arduino IDE. The results indicate that the system is able to respond quickly to changes in gas input, as shown by the rapid increase in pressure values after gas is introduced into the test chamber. The measurement trend appears stable with minimal fluctuations, indicating good system consistency and reliability during operation.

The discussion of the research results shows that the system performance is consistent with the basic theory of semiconductor sensors, where an increase in gas concentration leads to a decrease in sensor resistance and an increase in output voltage, which is then converted into pressure [6];[7]. This relationship is also consistent with the concept of the ideal gas law, which states that an increase in the number of gas molecules in a closed space will increase system pressure. Therefore, these findings strengthen the validity of the theoretical model used in converting sensor data into gas pressure.

Compared to previous studies, the results of this research demonstrate advantages in terms of system integration and quantitative gas pressure measurement. Unlike the studies by [9];[13] which focus only on gas concentration detection in ppm units, this study successfully develops a system capable of directly converting data into pressure units (kPa). In addition, the developed system does not rely on Internet of Things (IoT) connectivity, making it more flexible for use in limited conditions. These findings also complement the study by [12]), which integrated pressure sensors but did not specifically develop a gas pressure conversion model based on the MQ-2 sensor.

In the context of real-world applications, the developed system has important implications for improving gas usage safety, both in household and small industrial settings. The system's ability to display data in real-time and provide warnings through a buzzer and LED enables early detection of potentially hazardous gas pressure conditions. This aligns with the need for monitoring systems that are fast, accurate, and easy to use in supporting operational efficiency and safety.

Theoretically, this study contributes to the development of a gas sensor calibration model based on the relationship between voltage and pressure, and strengthens the concept of integrating sensor systems with microcontrollers in the field of digital instrumentation. Practically, this research produces a gas pressure measurement prototype that is simple, economical, and applicable, with the potential for further development into more advanced technology-based monitoring systems.

However, this study has several limitations. The testing was conducted only on LPG gas and within a laboratory scale, so the generalization of results to more complex industrial conditions remains limited. In addition, environmental factors such as temperature and humidity have not been analyzed in depth regarding their influence on sensor performance. Therefore, future research is recommended to develop IoT-based systems for remote monitoring, expand the types of gases tested, and conduct further analysis of environmental factors to improve system accuracy and reliability.

V. CONCLUSION

This study successfully designed and implemented a gas pressure measurement system based on an MQ-2 sensor and an ESP32 microcontroller that operates in real-time with good stability and accuracy. The test

results show that the system is capable of converting sensor output data in the form of voltage or ADC values into gas pressure in kilopascal (kPa) units through a measurable calibration process. In addition, the system demonstrates a fast response to changes in gas pressure and produces readings that are relatively close to those of analog measuring instruments, indicating that it is suitable as an alternative digital gas pressure measurement device.

Theoretically, these findings strengthen the concept of the relationship between gas concentration, changes in semiconductor sensor resistance, and gas pressure in a closed system, as well as the validity of regression approaches in the sensor calibration process. Practically, the developed system provides an applicable solution in the form of a simple, economical, and easy-to-use gas pressure measuring device, with the potential to improve safety and efficiency in gas usage at both household and small industrial scales.

The scientific contribution of this research lies in the integration of a quantitative calibration model with a microcontroller-based digital instrumentation system, which functions not only as a gas detection tool but also as a direct gas pressure measurement device. This study also enriches research in the field of embedded systems and digital instrumentation, particularly in developing methods for converting sensor data into measurable physical parameters.

However, several aspects still require further development. Future research is recommended to test the system on various types of gases beyond LPG, integrate Internet of Things (IoT) technology for remote monitoring, and analyze the influence of environmental factors such as temperature and humidity on sensor performance. In addition, the development of more complex and adaptive calibration models is needed to improve system accuracy and reliability under various operational conditions.

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