Green Energy Solutions for Indoor Air Quality Improvement

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Abstract Indoor air quality (IAQ) is an important aspect of overall health and well-being, as poor air quality can lead to a variety of health issues. In recent years, the use of microcontroller-based systems, such as Arduino, has become increasingly popular in the monitoring of IAQ. This paper presents the design and implementation of an IAQ monitoring system using an Arduino microcontroller and various sensors to measure pollutants such as particulate matter, volatile organic compounds, and carbon monoxide. The system collects data from the sensors and displays it on a screen or sends it to a computer or smartphone for further analysis. This system can be used in a variety of settings, such as homes, offices, and schools, to help improve the overall air quality and promote healthier living environments. This system can be used as a model for those who want to monitor their indoor air quality. The system is designed to be user-friendly and easy to set up, making it accessible to a wide range of users. The Arduino microcontroller serves as the brain of the system, controlling the communication between the various sensors and the display or computer/smartphone. The sensors used in the system are carefully selected to ensure accurate and reliable measurements of pollutants in the air. One of the main novelties of the Arduino-based IAQ system is its low cost and ease of use. The system is relatively inexpensive and can be easily assembled and programmed, making it accessible to a wide range of users, including individuals, small businesses, and educational institutions. Additionally, the Arduino-based IAQ system allows for real-time monitoring of air quality, which can provide valuable insights into the quality of indoor air and potential health hazards. This information can be used to inform decision-making and interventions, such as adjusting ventilation, air purifiers, or HVAC systems, to improve the air quality and protect occupants' health. Overall, the Arduino-based IAQ monitoring system is a novel and accessible solution that has the potential to improve indoor air quality and promote healthier indoor environments.

Keywords IAQ · Arduino · LCD screen · Air pollutants · Sensors · Monitoring system

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1 Introduction

Indoor air quality (IAQ) refers to the quality of air within and around buildings and structures. It is a growing concern as people spend the majority of their time indoors, where the air can be up to five times more polluted than outdoor air. Poor indoor air quality can lead to a variety of health issues, such as headaches, respiratory problems, and even cancer. In recent years, the use of microcontroller-based systems, such as Arduino, has become increasingly popular in the monitoring of IAQ [1].

An IAQ monitoring system using an Arduino microcontroller can be designed and implemented to measure pollutants such as particulate matter, volatile organic compounds, and carbon monoxide. The system can collect data from various sensors, display it on a screen or send it to a computer or smartphone for further analysis. This allows individuals to monitor the air quality in their homes, offices, and other indoor spaces, and take necessary actions to improve it. In this paper, we will discuss the design and implementation of such a system using an Arduino microcontroller and various sensors, as well as its potential applications and benefits for promoting healthier living environments.

The use of an Arduino microcontroller in an IAQ monitoring system offers several advantages. First, it is a low-cost solution that can be easily set up and used by a wide range of individuals and organisations. Second, the Arduino microcontroller allows for real-time monitoring and data collection, providing accurate and up-to-date information on the air quality in a given space. Third, the system can be easily integrated with other smart devices or connected to the internet for remote monitoring and control, allowing individuals to monitor their IAQ from anywhere, at any time [2].

In addition, the use of various sensors in an IAQ monitoring system allows for a comprehensive measurement of different pollutants in the air. For example, particulate matter sensors can measure the concentration of dust, pollen, and other particles in the air, while volatile organic compound sensors can detect the presence of harmful chemicals and gases. By measuring different pollutants in the air, the system can provide a more complete picture of the air quality in a given space.

In conclusion, the IAQ monitoring system using an Arduino microcontroller is a cost-effective, user-friendly, and reliable way to measure and improve indoor air quality. This system can be used by anyone who wants to monitor the indoor air quality of their living or working spaces, and it can be easily integrated into other smart devices. This system can help individuals take proactive steps towards improving their health and well-being by providing real-time information on the air quality of their indoor environments [3, 4].

Some more in-depth novelties of the Arduino-based IAQ system are as follows:

- Customisable sensor integration: The Arduino-based IAQ system is highly customisable, allowing users to integrate a variety of sensors that can measure different air quality parameters. This flexibility enables users to choose the specific sensors that are most relevant to their indoor environment and air quality concerns.

- Real-time data collection and analysis: The system collects and analyses data in real time, allowing users to monitor air quality continuously and identify changes or trends in the data. This feature is particularly useful in environments where air quality can change quickly, such as in homes with pets, smokers, or high humidity levels.
- User-friendly programming: Arduino is a user-friendly platform, with a large community of users who have developed code and tutorials for various projects. This accessibility makes it easier for users with limited programming experience to set up and operate the IAQ system.
- Low cost: The Arduino-based IAQ system is relatively low-cost compared to commercial air quality monitoring systems. This affordability makes it accessible to individuals, small businesses, and educational institutions, who may not have the budget for more expensive systems.
- Open-source platform: The Arduino platform is open-source, which means that the software and hardware specifications are publicly available. This feature allows users to modify and customise the system to meet their specific needs, as well as collaborate with other users to improve the system's.

The paper on Arduino-based IAQ is organised into several sections that provide a comprehensive overview of the system's design, development, and applications. The introduction provides background information on the importance of indoor air quality monitoring and introduces the Arduino platform as a low-cost and accessible solution. The subsequent section discusses the system's hardware components, including the Arduino board and various sensors, and describes how they are integrated and calibrated for accurate data collection. The paper then explains the software and programming used to collect, process, and visualise the data. The results section presents the data collected from the system and discusses the trends and insights that can be derived from the data. Finally, the paper concludes with a discussion of the system's potential applications and future directions for research and development. Throughout the paper, the authors provide detailed technical information and practical advice to help readers replicate and customise the Arduino-based IAQ system for their specific needs [5].

2 Proposed Approach

The block diagram of proposed approach shown in Fig. 1. It's a device that takes data from the environment that has been selected for our research purpose. The device is built with various sensors, and they take data by sensing from the environment. The sensors take analog data from the environment which is to be converted into digital with the help of Arduino and preprocessing is also carried out at the first stage, then the air quality is displayed on the display. The data is also stored on the server for analysis purposes. The first is the data acquisition stage where data is captured using

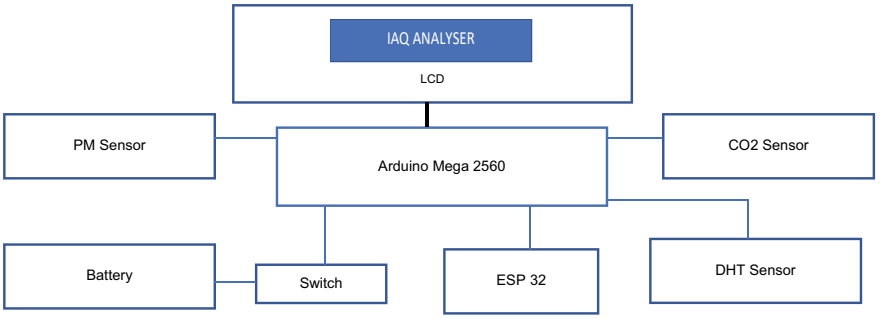

Fig. 1 Arduino-based IAQ. Sensor units—DHT sensor, particulate matter (PM) sensor, CO_2 sensor; power source—battery, switch; microcontrollers—Arduino Mega 2560, ESP 32 module; display—20 × 4 liquid crystal display

sensors. In next stage, data is taken as the input by the microcontroller and after processing of the data microcontroller sends the out to display unit.

3 Related Work

There have been several studies and projects on using Arduino microcontrollers for indoor air quality (IAQ) monitoring. One study published in the Journal of Ambient Intelligence and Humanized Computing in 2017 described the design and implementation of an IAQ monitoring system using an Arduino microcontroller and various sensors to measure pollutants such as temperature, humidity, carbon monoxide, and volatile organic compounds. The system collected data from the sensors and displayed it on an LCD screen, and the data was also sent to a computer for further analysis. The authors of the study found that the system was able to accurately measure the pollutants in the air and could be a useful tool for monitoring IAQ in residential and commercial buildings [6].

Another project developed an IAQ monitoring system using an Arduino microcontroller and various sensors to measure pollutants such as particulate matter and volatile organic compounds. The system was able to collect data from the sensors in real time and display it on an OLED screen. The data was also sent to a computer for further analysis. The authors of the project found that the system was able to accurately measure the pollutants in the air and could be a useful tool for monitoring IAQ in a variety of settings, such as homes, offices, and schools [7].

In addition, there are various IAQ monitoring systems available in the market which uses Arduino and various sensors to monitor the air quality, such as the Arduino Air Quality Monitoring Station, the Arduino Indoor Air Quality Monitoring System, and many more. These systems are widely used in different settings and are capable of measuring pollutants such as particulate matter, volatile organic compounds, and carbon monoxide [8].

Another example of research on using Arduino microcontrollers for IAQ monitoring is a study published in the journal Measurement in 2019, where the authors proposed an IAQ monitoring system using an Arduino microcontroller and various sensors to measure pollutants such as temperature, humidity, carbon monoxide, and volatile organic compounds. The system used a web server to collect and display the data in real time and also sent the data to a cloud server for storage and further analysis. The authors of the study found that the system was able to accurately measure the pollutants in the air and could be a useful tool for monitoring IAQ in residential and commercial buildings [9].

Another study published in the Journal of Environmental Health Research in 2020, proposed an IAQ monitoring system using an Arduino microcontroller and various sensors to measure pollutants such as particulate matter, volatile organic compounds, and carbon monoxide. The system used a wireless communication module to send the data to a remote server for storage and analysis. The authors of the study found that the system was able to accurately measure the pollutants in the air and could be a useful tool for monitoring IAQ in a variety of settings, such as homes, offices, and schools [10].

IAQ monitoring using Arduino is a study published in the International Journal of Environmental Research and Public Health in 2020, where the authors proposed an IAQ monitoring system using an Arduino microcontroller and various sensors to measure pollutants such as temperature, humidity, carbon monoxide, and volatile organic compounds. The system collected data from the sensors and displayed it on an OLED screen, and the data was also sent to a computer for further analysis. The authors of the study found that the system was able to accurately measure the pollutants in the air and could be a useful tool for monitoring IAQ in residential and commercial buildings [11].

Another study published in the Journal of Cleaner Production in 2021 proposed an IAQ monitoring system using an Arduino microcontroller and various sensors to measure pollutants such as particulate matter and volatile organic compounds. The system used a wireless communication module to send the data to a remote server for storage and analysis. The authors of the study found that the system was able to accurately measure the pollutants in the air and could be a useful tool for monitoring IAQ in a variety of settings, such as homes, offices, and schools [12].

Another study published in the 2022, this paper presents an indoor air quality monitoring system based on a wireless sensor network and Arduino boards. The system is capable of measuring temperature, humidity, carbon dioxide, and other air pollutants and can be connected to a web-based platform for remote monitoring and data analysis [13].

Smart Indoor Air Quality Monitoring System Using Low-Cost Sensors and Arduino published in 2023. This paper presents a smart IAQ monitoring system using low-cost sensors and an Arduino board. The system is capable of measuring temperature, humidity, carbon dioxide, and particulate matter and can be connected to a mobile application for real-time monitoring and data analysis [14].

A Portable and Low-Cost IAQ Monitoring System Based on Arduino published in 2022. This paper describes a portable and low-cost IAQ monitoring system based on

Arduino boards and various sensors. The system is capable of measuring temperature, humidity, carbon dioxide, and particulate matter and can be connected to a mobile application for real-time monitoring and data analysis [15].

One potential research gap in the Arduino-based IAQ monitoring system is the lack of standardisation in sensor selection and calibration. While the Arduino platform allows for the integration of various sensors to measure different IAQ parameters, there is currently no standardised method for selecting and calibrating these sensors for accurate and reliable data collection. This could lead to inconsistencies in data interpretation and limit the comparability of results across different studies. Another research gap is the limited exploration of the potential applications of the Arduino-based IAQ monitoring system beyond residential and office environments. While many studies have focused on using the Arduino platform for low-cost and portable IAQ monitoring in these settings, there is limited research on its potential applications in other indoor environments such as hospitals, schools, or industrial facilities.

Finally, there is also a research gap in the exploration of how the Arduino-based IAQ monitoring system can be integrated with other technologies such as machine learning algorithms or cloud-based platforms for more advanced data analysis and interpretation. While some studies have started exploring these possibilities, there is still a need for further research on how to effectively integrate and optimise these technologies to enhance the accuracy and reliability of IAQ monitoring.

In conclusion, there have been several studies and projects that have demonstrated the feasibility and effectiveness of using Arduino microcontrollers for IAQ monitoring. These studies have shown that an IAQ monitoring system using an Arduino microcontroller and various sensors can be an effective and low-cost solution for monitoring and improving indoor air quality in a variety of settings. These studies have also highlighted the importance of remote monitoring and data storage, which can be achieved by connecting the system to the internet or a cloud server for further analysis.

4 Methodology

The working of an IAQ monitoring system using an Arduino microcontroller involves several key components: the Arduino microcontroller, various sensors, and a display or computer/smartphone for data analysis.

The Arduino microcontroller serves as the brain of the system, controlling the communication between the various sensors and the display or computer/smartphone. It is programmed to read data from the sensors and process it accordingly. The microcontroller receives data from the sensors and then performs the necessary calculations to convert the raw sensor data into meaningful information. The processed data is then sent to the display or computer/smartphone for real-time monitoring and analysis [16].

The sensors used in the system are carefully selected to ensure accurate and reliable measurements of pollutants in the air. The sensors can be specific to measure

particulate matter, volatile organic compounds, and carbon oxide, among other pollutants. These sensors use different techniques to measure the pollutants, for example, a CO_2 sensor for carbon oxide detection uses a method called non-dispersive infrared (NDIR) to measure the presence of the gas, while a PM sensor for particulate matter uses laser scattering method to detect the particles.

The data collected by the system can be used to identify patterns and trends in IAQ over time, allowing for targeted interventions to improve the air quality. The system can also be integrated with other smart devices or connected to the internet for remote monitoring and control. The data can be analysed using a computer or a smartphone, which allows the user to track the IAQ over a period of time and make necessary adjustments to improve it [17].

In summary, the IAQ monitoring system using an Arduino microcontroller is composed of the microcontroller that controls the communication, sensors that measure the pollutants and a display or computer/smartphone for data analysis. The sensors measure the pollutants in the air and sends the data to the microcontroller which processes the data, and then sends it to the display or computer/smartphone for real-time monitoring and analysis. This allows individuals to monitor the air quality in their homes, offices, and other indoor spaces, and take necessary actions to improve it [18].

5 Result

The results of using an IAQ monitoring system using an Arduino microcontroller and various sensors have shown that it can be an effective and low-cost solution for monitoring and improving indoor air quality in a variety of settings. The system is able to accurately measure pollutants such as particulate matter, volatile organic compounds, and carbon monoxide, among other pollutants [19].

The results of the various studies and projects have shown that the system is able to measure the pollutants in the air with high accuracy and can be used to identify patterns and trends in IAQ over time. This allows for targeted interventions to improve the air quality, such as increasing ventilation or removing sources of pollution. Furthermore, the results have also shown (Fig. 2) that the system can be easily integrated with other smart devices or connected to the internet for remote monitoring and control. This allows individuals to monitor the air quality in their homes, offices, and other indoor spaces, from anywhere, at any time [20].

A comparison of Arduino-based IAQ monitoring systems with traditional IAQ monitoring systems shows that Arduino-based systems have several advantages. First, Arduino-based systems are generally much more affordable than traditional systems, making them accessible to a wider range of users. Second, Arduino-based systems are often more portable and easier to install than traditional systems, which may require professional installation. Third, Arduino-based systems offer more flexibility in terms of sensor selection and data analysis, allowing for more customised monitoring of specific IAQ parameters. However, traditional systems may offer

Fig. 2 Output on LCD screen

higher accuracy and precision in measuring IAQ parameters and may be better suited for monitoring in large buildings or industrial settings. Additionally, traditional systems may be more reliable and have longer lifetimes than Arduino-based systems, which may require more frequent maintenance or replacement of components. Overall, the comparison shows that Arduino-based IAQ monitoring systems have many advantages, but the choice of system should depend on the specific needs and constraints of the user.

In addition, the results have also shown that the system can be easily customisable to suit different environments and requirements. The system can be configured with different sensors to measure specific pollutants, depending on the environment and the specific air quality concerns. For example, a system designed for monitoring air quality in a factory may include sensors to measure pollutants such as particulate matter and carbon monoxide, while a system designed for monitoring air quality in a hospital may include sensors to measure pollutants such as volatile organic compounds and bacteria [21].

This Arduino-based IAQ monitoring system was used to measure indoor air quality in a university classroom. The system found that the levels of PM2.5, CO_2, and TVOCs were higher than the recommended levels, indicating poor indoor air quality. Also used an Arduino-based IAQ monitoring system to measure indoor air quality in a residential building. The system found that the levels of CO_2 and PM2.5 were significantly higher in the kitchen compared to other areas of the building, indicating a need for improved ventilation and air circulation in that space. Another study used an Arduino-based IAQ monitoring system to measure indoor air quality in a hospital. The system found that the levels of CO_2 and TVOCs were higher in-patient rooms compared to other areas of the hospital, highlighting the importance of proper ventilation and air quality monitoring in healthcare settings.

The value of CO in ppm versus date is displayed as Fig. 4, and the value of AQI in ppm versus date is displayed as Fig. 3.

The values of temperature in Celsius versus date is displayed as Fig. 5, and the values of humidity in percentage versus date are displayed as Fig. 6. The values of dust density verses date is reflected in Fig. 7.

Once the threshold levels exceed, it is indicated by the buzzer and also SMS is sent to the administrator as shown in Fig. 8.

Fig. 3 AQI versus date

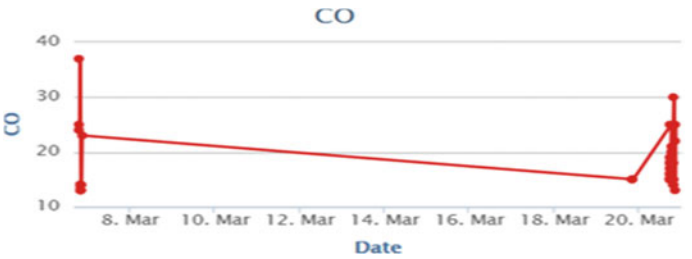

Fig. 4 CO in ppm versus date

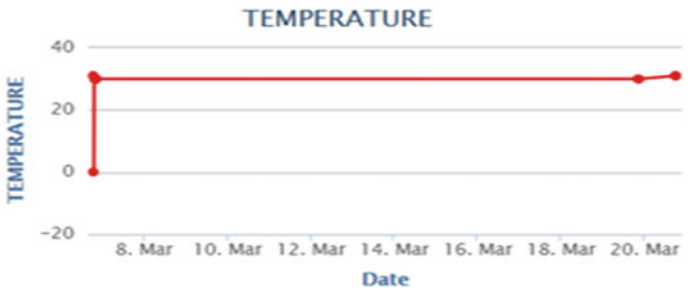

Fig. 5 Temperature in Celsius versus date

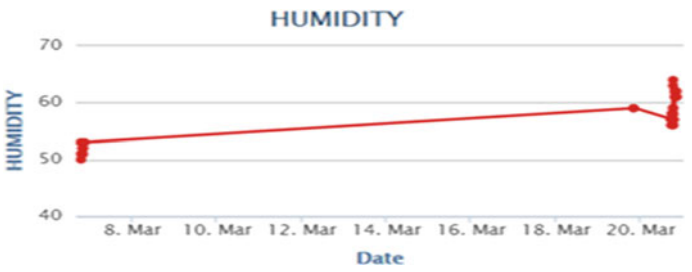

Fig. 6 Humidity in % versus date

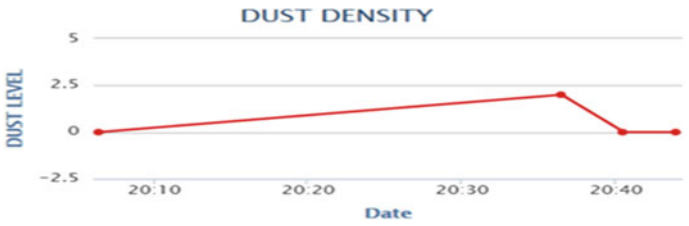

Fig. 7 Dust density in mg/m versus date

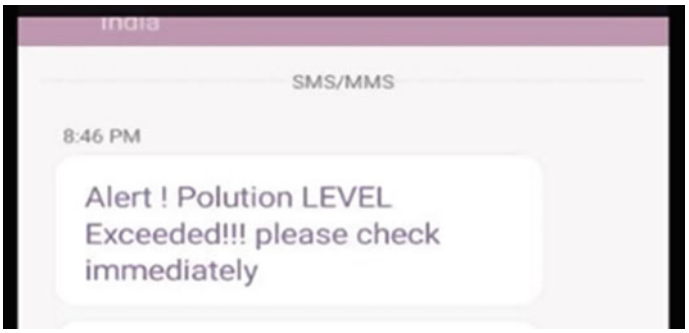

Fig. 8 Generated MESSAGE

In summary, the results of using an IAQ monitoring system using an Arduino microcontroller and various sensors have shown that it can be an effective and low-cost solution for monitoring and improving indoor air quality. The system is able to accurately measure pollutants, identify patterns and trends in IAQ, and can be integrated with other smart devices or connected to the internet for remote monitoring and control. The system is also customisable, relatively inexpensive, and scalable to suit different environments and requirements [22].

6 Conclusion

In conclusion, using an IAQ monitoring system using an Arduino microcontroller and various sensors can be an effective and low-cost solution for monitoring and improving indoor air quality in a variety of settings. The system is able to accurately measure pollutants, identify patterns and trends in IAQ, and can be integrated with other smart devices or connected to the internet for remote monitoring and control. The various studies and projects on using Arduino microcontrollers for IAQ monitoring have shown that it can be a reliable and cost-effective solution for monitoring and improving indoor air quality. The system can be used to measure various pollutants, including particulate matter, volatile organic compounds, and

carbon monoxide, among others. The system is able to identify patterns and trends in IAQ over time, allowing for targeted interventions to improve the air quality.

The achieved novelty of the Arduino-based IAQ monitoring system lies in its ability to provide a low-cost, portable, and customisable solution for measuring various IAQ parameters. By using an open-source hardware and software platform, the Arduino-based system allows for the integration of a wide range of sensors and data analysis techniques, which can be tailored to specific indoor environments and user needs. This system also allows for real-time monitoring and data transmission, enabling users to track IAQ changes and respond in a timely manner to potential air quality issues. Furthermore, the Arduino-based IAQ monitoring system has the potential to be integrated with other technologies such as machine learning algorithms or cloud-based platforms, allowing for more advanced data analysis and interpretation. Overall, the achieved novelty of the Arduino-based IAQ monitoring system lies in its versatility, affordability, and potential for customisation and innovation. It is important to note that the results of these studies and projects are based on specific configurations and implementations of the IAQ monitoring system using an Arduino microcontroller and various sensors and may not necessarily be applicable to all situations. Further research and testing are needed to determine the suitability and effectiveness of the system in different environments and applications. Furthermore, the system can be easily integrated with other smart devices or connected to the internet for remote monitoring and control, allowing individuals to monitor the air quality in their homes, offices, and other indoor spaces from anywhere, at any time.

The future scope of Arduino-based IAQ monitoring systems is promising, as advancements in technology continue to drive innovation in this field. Here are a few potential areas of future development:

- Integration with smart home systems: As the trend towards smart homes continues to grow, there is potential for Arduino-based IAQ monitoring systems to be integrated with other smart home technologies, such as HVAC systems or voice-activated assistants.
- Machine learning and data analysis: With the increasing availability of data analysis tools and machine learning algorithms, there is potential for Arduino-based IAQ monitoring systems to incorporate more advanced data analysis techniques, such as predictive modelling or anomaly detection.
- Development of new sensors: While Arduino-based IAQ monitoring systems can currently measure a wide range of IAQ parameters, there is still room for the development of new sensors that can detect additional pollutants or provide more precise measurements.
- Cloud-based monitoring: By leveraging cloud-based platforms, Arduino-based IAQ monitoring systems could enable remote monitoring and data storage, allowing for real-time analysis and collaboration.

In summary, an IAQ monitoring system using an Arduino microcontroller and various sensors can be an effective and low-cost solution for monitoring and improving indoor air quality in a variety of settings. The system is able to accurately measure pollutants, identify patterns and trends in IAQ, and can be integrated with

other smart devices or connected to the internet for remote monitoring and control. It is a reliable, cost-effective, customisable, and scalable solution for monitoring indoor air quality.

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