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Real-Time Intelligent LPG Leakage and Fire Protection System with Digital Twin Visualization in LabVIEW

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ABSTRACT

Liquefied petroleum gas leakage and fire hazards require rapid detection, reliable decision-making, and automated mitigation to protect residential and commercial environments. Sensor-based safety platforms are increasingly integrated with graphical monitoring tools to strengthen real-time hazard awareness. Existing domestic safety systems frequently detect hazards without synchronized visualization, risk classification, and automated isolation. The objective is to develop a LabVIEW-based intelligent LPG leakage and fire protection system with digital twin visualization and automated emergency response. An MQ-6 gas sensor and IR flame sensor were interfaced with an Arduino/NI myRIO acquisition platform, and LabVIEW was used for threshold processing, graphical monitoring, data logging, voice alerting, SMTP notification, and actuator control. Solenoid valve isolation, relay-based power shutdown, exhaust ventilation, and buzzer activation were configured as closed-loop safety actions. The gas sensing module achieved 95% detection accuracy, while flame detection reached 94% accuracy. Hazard identification and safety activation were completed in less than 2 s during tested warning and emergency conditions, and the combined system accuracy was approximately 94.5%. Compared with reference systems reporting 85–92% gas detection and 80–90% fire detection accuracy, the proposed platform provides faster coordinated response and clearer operational state awareness. The architecture supports practical deployment by linking detection, decision logic, isolation, ventilation, and user notification in one interface. Future research should extend cloud connectivity, machine-learning prediction, sensor calibration, and long-duration reliability testing under variable humidity and ventilation conditions

Key Words: LPG Gas Leakage Detection, MQ Gas Sensor, Flame Sensor, Gas Concentration Monitoring (PPM), Smart Home Automation, LabVIEW.

INTRODUCTION

Liquefied petroleum gas and related combustible gases remain difficult safety targets because leakage is often invisible, rapidly dispersive, and capable of producing fire or explosion when an ignition source appears. Methane-sensing reviews show that optical, calorimetric, pyroelectric, semiconducting oxide, and electrochemical sensors differ strongly in selectivity, power demand, cost, and response stability, which affects their suitability for domestic automation (Aldhafeeri et al., 2020). IoT-enabled gas-sensing work further shows that sensor nodes become technically valuable only when gas transduction, wireless transmission, local processing, and user alerting are treated as a single control chain rather than isolated modules (Gomes et al., 2019). Recent smart gas sensor literature extends this direction by emphasizing sensor arrays, AI-supported interpretation, flexible sensing platforms, and IoT-based early warning as the dominant route toward intelligent gas safety systems (Zong et al., 2025). For high-sensitivity remote detection, cavity ring-down methane sensing on small unmanned aerial systems has demonstrated ppb-level sensitivity, but such systems are more appropriate for infrastructure surveys than low-cost household deployment (Martinez et al., 2020). UAV-based laser methane detection has also shown value for pipeline screening, although field accuracy depends on altitude, spatial correlation, background methane, and confirmatory measurements (Iwaszenko et al., 2021).

Fire detection introduces a second coupled hazard because gas leakage alone does not define the emergency state; risk changes sharply when flame, heat, smoke, or combustion gases appear. Sensor-focused fire detection reviews show that heat, flame, gas, smoke, optical fiber, and visual methods each detect different fire-development signatures, but false alarms, sensitivity limits, and installation complexity remain persistent concerns (Khan et al., 2022). Industry 4.0 fire-safety studies therefore increasingly combine IoT, AI, cloud computing, BIM, edge/fog processing, and predictive analytics to accelerate detection and response (Negi et al., 2024). IoT fire-safety bibliometric analysis also shows that the field has moved beyond alarm generation toward integrated detection, localization, evacuation, communication protocols, and cybersecure architectures (AlQahtani et al., 2025). In residential buildings, real-time IoT fire-risk monitoring using environmental sensors and adaptive evacuation logic has reported stronger detection and evacuation performance when sensor data are integrated with building intelligence (Abdullahi et al., 2025). Digital-twin leakage identification adds another important layer: pressure-driven pipeline models updated with physical data can visualize leakage states and trigger emergency plans, but such methods are often validated in pipeline-scale conditions rather than compact domestic LPG environments (Wang et al., 2023). As shown in Table 1, the selected literature indicates that gas safety research is moving from single-threshold alarms toward multi-sensor, low-power, AI-supported, and visualization-oriented architectures.

Table 1. Representative studies supporting intelligent gas-leakage, fire-detection, monitoring, and alert-system development.

Reference/Citation	**Objective/Aim**	**Methodology/Approach**	**Materials/Parameters Studied**	**Key Findings/Results**	**Relevance to Current Study**
(Dash et al., 2023)	LPG transport leakage consequence prediction	Edge AI with IoT framework	LPG, CFD, weather variables	△ Faster consequence estimation	Supports risk-based leakage decisions
(El Barkani et al., 2024)	Edge gas-leak detection	TinyML CNN deployment	Thermal images, Arduino Nano	△ Real-time embedded classification	Supports local intelligent processing
(Landi et al., 2025)	Residential gas-node reliability	Accelerated reliability testing	VOC sensor, MEMS pellistor	△ Robust long-term node behavior	Supports dependable domestic sensing
(Liu et al., 2025)	Low-power hazardous gas monitoring	Optimized IoT hardware-software	CO, methane, current consumption	▽ Power demand under monitoring	Supports energy-aware safety nodes
(Narkhede et al., 2021)	Multimodal gas identification	Sensor fusion using CNN-LSTM	MQ array, thermal camera	△ Fusion classification accuracy	Supports multi-sensor hazard recognition
(Yaqoob & Younis, 2021)	Smart chemical sensor review	Materials and ML analysis	Chemiresistive, FET sensors	△ Selectivity through ML processing	Supports intelligent gas interpretation
(Neubert et al., 2021)	Flexible IoT gas node	Modular robotic sensor platform	BME688, SGP30, VOCs	△ Early vapor detection capability	Supports modular LabVIEW integration

(Al-Okby et al., 2021)	Mobile hazardous gas alarms	Systematic technology review	Sensors, processors, communications	△ Hybrid alarms widely adopted	Supports multi-channel notification design
(Kumar et al., 2024)	ML gas-leak performance assessment	Statistical multimodal classification	Gas signals, infrared thermography	△ Accurate leakage categorization	Supports analytical validation logic
(Pietraru et al., 2025)	IAQ-based fire detection	IoT cloud fire logic	PM, VOC, NOx, temperature	△ Fire signatures differentiated	Supports digital-twin fire visualization

Across these studies, experimental approaches dominate sensor validation, while analytical and computational methods appear mainly in risk-contour modeling, digital twins, and machine-learning classification. Common performance trends include faster local decision-making, higher classification accuracy through multimodal sensing, and stronger reliability when sensing nodes are tested under realistic stress conditions. The main technical differences arise from sensing modality, processing location, communication protocol, and whether the system only alerts or also actuates preventive control. Gas-leakage studies often emphasize concentration detection, whereas fire-safety studies emphasize event localization, evacuation support, and system-level integration. Digital-twin studies provide visualization and predictive structure, but they are still less common in compact LPG-fire automation.

Overall, the field is moving toward integrated safety architectures in which combustible-gas sensing, flame/fire detection, real-time communication, automated actuation, visualization, and risk scoring operate together. The strongest recent works show that single-sensor warning systems are no longer sufficient for dense residential and commercial environments, because delayed interpretation can allow gas accumulation, ignition, and occupant exposure to develop before intervention. However, many contributions still focus on either gas detection, fire detection, reliability testing, mobile monitoring, or digital modeling as separate problems, which limits direct translation into a unified domestic safety platform.

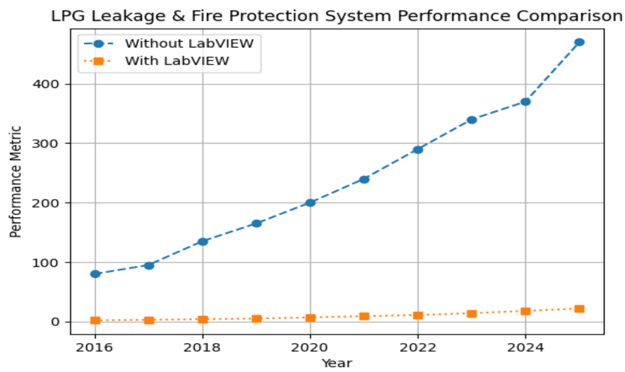

Figure 1: Real-Time Intelligent LPG Leakage and Fire Protection System with Digital Twin Visualization in LabVIEW – Research Publication Trend (2015–2025)

The comparative trend in research articles for LPG leaks and fire protection systems from 2015 to 2025 is shown in Figure 1. Due to the extensive use of IoT-based platforms, the graph shows a notable rise in research carried out without LabVIEW. On the other hand, papers using LabVIEW exhibit a consistent but slower rise, which is indicative of its specific application in data collecting, real-time monitoring, and digital twin visualization. Despite the predominance of traditional methods, the chart highlights the growing significance of LabVIEW in advanced safety systems.

Existing studies fail to address a compact, experimentally demonstrable LPG safety architecture that couples gas concentration monitoring, flame detection, automated gas cut-off, ventilation, electrical isolation, local audible/voice warning, remote notification, and digital-twin visualization within one control workflow. This limitation occurs because several works restrict the parameter range to single gases or isolated fire indicators, while others depend on UAVs, pipeline-scale models, or computational simulations that do not directly validate domestic actuator response. The literature also shows inconsistent validation methods: some papers emphasize accuracy, some emphasize power, some emphasize reliability, and others emphasize visualization, causing weak comparability across sensing, response, and user-alert outcomes. Coupled analysis remains insufficient because gas leakage, flame occurrence, risk percentage, actuator state, and remote alert success are rarely evaluated as one synchronized safety sequence. Scalability and validation also remain unresolved where cloud dependence, sensor drift, environmental interference, and limited prototype testing reduce confidence for real-time residential deployment.

The present study addresses these limitations by structuring the system as a coupled real-time safety platform rather than a standalone detector. It differentiates itself methodologically by combining MQ-series LPG sensing, IR flame detection, threshold-based risk classification, LabVIEW visualization, digital-twin status representation, automated solenoid control, exhaust activation, power isolation, buzzer output, voice alerting, and SMTP/email notification in a single monitoring-and-actuation loop. Parametrically, it aligns gas concentration, flame state, risk level, valve condition, alert mode, and response time within the same decision structure. Analytically, it links hazard identification with preventive action and user-facing visualization, thereby converting sensor readings into interpretable and actionable safety states.

The objective of the present study is to develop and evaluate a LabVIEW-based real-time intelligent LPG leakage and fire protection system that integrates gas sensing, flame detection, automated safety actuation, risk assessment, digital-twin visualization, and multi-channel alert notification for reliable domestic and commercial safety monitoring.

HARDWARE CONFIGURATION WITH LABVIEW

The suggested Real-Time Intelligent LPG Leakage and Fire Protection System with Digital Twin Visualization's hardware arrangement is made to guarantee precise sensing, quick processing, and trustworthy real-time monitoring. Gas and flame sensors, a data gathering unit, processing hardware, and interface modules that are integrated with LabVIEW for control and visualization make up the system's main components. By continually measuring the concentration of gas in the surrounding area, a MQ-6 gas sensor may identify LPG leaks. Analog signals proportional to gas concentration are produced by the sensor and processed for threshold-based detection. By detecting infrared radiation released during combustion, a flame sensor is integrated to detect the existence of a fire. By offering dual-layer safety monitoring, these sensors collectively improve system reliability.

An Arduino or NI myRIO microcontroller-based platform is used to obtain the detected analog signals. Because of its smooth connection with LabVIEW and real-time processing capabilities, the NI myRIO device is especially well suited. It uses USB or Wi-Fi connectivity to transfer digital data from analog inputs to the LabVIEW environment. This makes it possible to continuously collect and monitor data in real time. For automatic safety measures, the system also has output components such a solenoid valve regulator, exhaust fan, and buzzer. The system immediately turns off the gas supply, enables ventilation, and sounds an alert when it detects a gas leak or fire. Digital output signals from the processing unit are used to drive these actuators. The whole hardware configuration is connected to create a closed-loop safety system in which LabVIEW is used to continually monitor, process, and display sensor inputs. This setup facilitates the use of a digital twin model for improved system analysis and predictive safety management, as well as real-time decision-making.

The suggested system's hardware setup is shown in Figure 2, where LPG leaks and fire threats are detected using the MQ-6 gas sensor and flame sensor. For real-time data collection and processing, the microcontroller or NI myRIO receives the sensor outputs as analog inputs. The LabVIEW platform receives the processed data for digital twin implementation and display. Control signals are created based on the data analysis to turn on safety features like an exhaust fan for ventilation, a buzzer for alarms, and a solenoid valve regulator to cut off the gas supply automatically, guaranteeing improved safety and quick reaction.

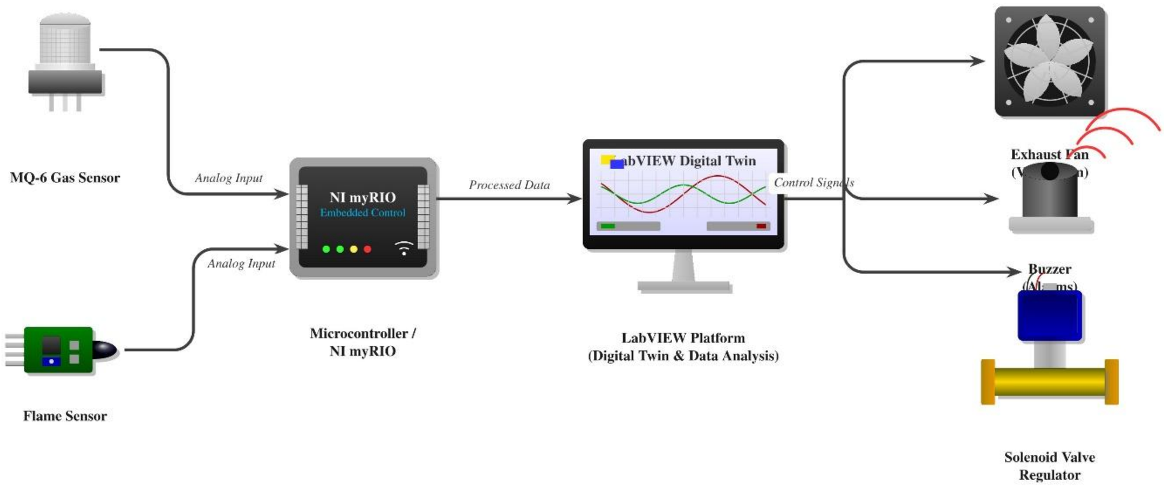

Figure 2. Hardware Configuration of the Real-Time Intelligent LPG Leakage and Fire Protection System with Digital Twin Visualization in LabVIEW

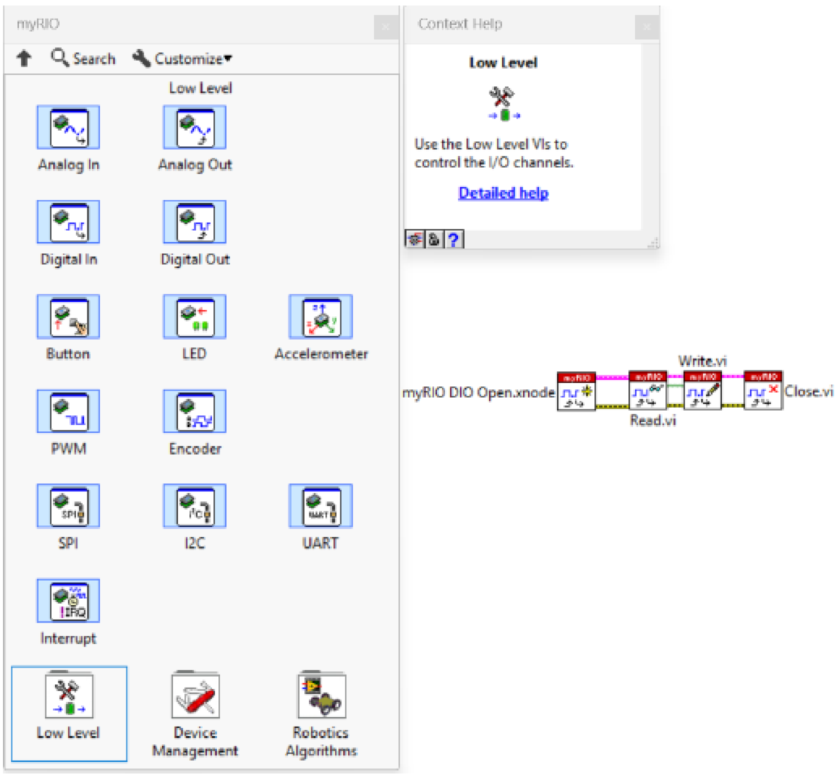

Figure 3. myRIO Toolkit

An effective framework for real-time hardware interface and control system development is offered by the NI myRIO toolbox in LabVIEW. It consists of a collection of both high-level and low-level Virtual Instruments (VIs) that facilitate connection with hardware elements including sensors, analog and digital I/O, and communication protocols like SPI, I2C, and UART. These VIs make it simple for users to carry out tasks including establishing a device connection, reading or writing data, and ending the session in an organized way. Because of its real-time processing capabilities, smooth LabVIEW integration, and graphical programming simplicity of use, the myRIO toolkit is favored. In contrast to conventional systems, it integrates FPGA functionality with a dual-core ARM CPU, enabling both sequential and parallel work execution. Because of this, it is ideal for applications that need accurate timing, quick data collection, and dependable control. Because of its real-time processing capabilities, smooth LabVIEW integration, and graphical programming simplicity of use, the myRIO toolkit is favored. In contrast to conventional systems, it integrates FPGA functionality with a dual-core ARM CPU, enabling both sequential and parallel work execution. Because of this, it is ideal for applications that need accurate timing, quick data collection, and dependable control.

Table 1. Comparison of myRIO with ESP32, Arduino, Other Microcontrollers, and Raspberry Pi

Feature	**NI myRIO**	**ESP32**	**Arduino (Uno)**	**Other Microcontrollers**	**Raspberry Pi**
Processing Speed	High (ARM + FPGA)	High (Dual-core)	Low	Moderate	High
Accuracy	Very High (FPGA-based)	Moderate	Low	Moderate	Moderate
Real-Time Performance	Deterministic	Limited	Limited	Limited	Low (No real-time OS)
Parallel Processing	Yes (FPGA)	Limited	No	Limited	Limited
Ease of Programming	High (LabVIEW)	Medium	Easy	Medium	Medium (Python/Linux)
Connectivity	Wi-Fi, USB	Wi-Fi, Bluetooth	External modules	Depends on type	Wi-Fi, Bluetooth, Ethernet
Hardware Integration	Excellent	Good	Basic	Moderate	Moderate
Cost	High	Low	Very Low	Low–Moderate	Moderate
Application Level	Industrial / Research	IoT / Embedded	Basic Projects	Embedded Systems	OS-based Applications

The performance comparison of several embedded systems is shown in Table 1, which emphasizes that myRIO offers better precision and predictable real-time execution because of FPGA support, while other platforms are better suited for general-purpose and low-cost applications.

2.1 Real-Time Visualization, Risk Assessment, and Alerts

To guarantee efficient monitoring and quick reaction to dangerous situations, the suggested system incorporates real-time visualization, intelligent risk assessment, and multi-level alarm systems utilizing the LabVIEW platform. An interactive graphical user interface (GUI) is used to continually analyse and show sensor data obtained from the MQ-6 gas sensor and IR flame sensor. Users may readily evaluate system conditions thanks to the real-time display, which includes numerical indications for flame intensity and waveform graphs for gas concentration trends. Furthermore, the digital twin representation offers a virtual model of the real world, improving situational awareness and providing a thorough understanding of system behaviour.

The system performs dynamic risk assessment by analyzing parameters such as gas concentration levels, flame detection status, and environmental conditions. Based on predefined thresholds, the system categorizes the risk into different levels such as safe, warning, and danger. A calculated risk percentage is displayed to provide a quantitative understanding of the hazard severity. This intelligent assessment allows early detection of potential threats and supports decision-making for preventive actions. The system uses many alert methods to guarantee prompt action in emergency circumstances. LabVIEW generates voice-based warnings and an audible buzzer alarm when abnormal circumstances are identified. In order to reduce the possibility of a fire or explosion, the solenoid valve is simultaneously automatically activated to cut off the gas supply. Additionally, the system uses the LabVIEW SMTP protocol to transmit real-time email messages, guaranteeing remote monitoring and user awareness even in the absence of physical presence. All things considered, the safety, dependability, and effectiveness of LPG leakage and fire prevention systems are greatly improved by the incorporation of real-time visualization, automated risk assessment, and multi-channel alarm systems. This strategy guarantees prompt response, lessens reliance on humans, and offers a strong solution for intelligent safety management.

Table 2- Real-Time Monitoring, Visualization, and Alert Parameters of the Proposed LPG Leakage and Fire Protection System

Module	**Output Type**	**Parameters Displayed**	**Status / Indicator**
MQ-6 Gas Sensor			
	Numeric	Gas concentration (ppm)	Gas status (Safe / Warning / Danger), Leakage alert
	Waveform Graph	Real-time gas level trend	Continuous monitoring visualization
IR Flame Sensor	Numeric	Flame intensity value	Fire status (Detected / Not Detected)
	Indicator LED	Flame detection signal	Emergency fire alert
Solenoid Valve	Control Output	Valve state (Open/Close)	Automatic gas cut-off status
Buzzer Alert System	Indicator / Digital Output	Buzzer ON/OFF	Audible emergency alert
Voice Alert (LabVIEW)	Audio Output	Warning message playback	Voice-based safety alert
LabVIEW SMTP Email Alert	String / Notification	Alert message, sensor data	Remote notification (Email sent status)
Digital Twin (LabVIEW GUI)	Graphical Interface	Real-time system visualization	Virtual system monitoring status
	String	System condition message	Safety warning / system status
Overall Risk Assessment (LabVIEW)	Numeric	Risk level (%)	Risk status (Low / Medium / High)
	String	Safety recommendation	Preventive action message

The several modules in the suggested system are shown in Table 2 along with the output kinds, displayed parameters, and status indicators that relate to each module. To keep an eye on dangerous situations, the gas leak detection and flame detection modules offer waveform representations and real-time numerical readings. Environmental awareness is further enhanced by temperature and air quality indicators. Actuators like fans, buzzers, and solenoid valves are automatically activated by the system control and safety module in response to circumstances that are detected.

IoT-based alerts allow for remote alerting via messages or applications, and the digital twin visualization module provides a graphical depiction of the system for real-time monitoring. In order to provide effective decision-making and increased system dependability, the overall risk assessment module assesses system circumstances by determining a risk rating and offering safety recommendations.

3. Proposed System

The suggested system uses LabVIEW to deliver a Real-Time Intelligent LPG Leakage and Fire Protection System with Digital Twin Visualization. The system continually monitors LPG leaks and fire threats in real time by integrating an IR flame sensor with a MQ-6 gas sensor. The LabVIEW environment is used to process the sensor data, which is obtained via a data collection device like NI myRIO. In LabVIEW, a digital twin model is created to mimic the physical system's real-time behaviour. This makes it possible to continuously visualize the levels of gas concentration, the state of flame detection, and the general health of the system. The system does intelligent risk evaluation and classifies circumstances into safe, warning, and danger categories based on predetermined threshold values. The system automatically initiates safety features, such as a solenoid valve to cut off the gas supply, a buzzer for instant notifications, and voice-based warnings, when it detects abnormal conditions. In order to facilitate remote monitoring, email notifications are also provided using the SMTP protocol. Rapid reaction, less human interaction, and increased safety reliability are all guaranteed by this integrated strategy.

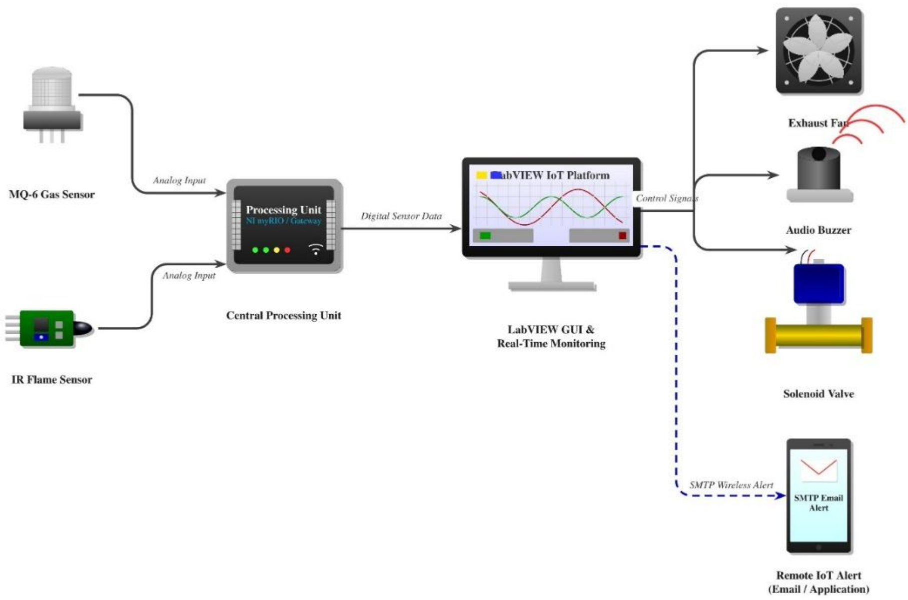

Figure 4. Architecture of IoT-Based LPG Gas Leakage and Fire Detection System Using LabVIEW

The general architecture of the suggested Internet of Things-based LPG gas leak detection and fire detection system is shown in figure 4. To provide automatic safety response and real-time monitoring, the system combines a processing unit, many sensors, and control mechanisms. The main input devices for detecting gas concentration levels and the presence of fire are the MQ-6 gas sensor and the infrared flame sensor, respectively. The central processing unit, which may be a microcontroller or an NI myRIO device, receives analog input signals from these sensors. After processing, the data is sent to the LabVIEW platform, where a graphical user interface is used for real-time monitoring, control, and visualization. LabVIEW creates the proper control signals to activate different output devices based on the sensor data and predetermined safety criteria.The output part includes a solenoid valve regulator for automated gas shut-off in dangerous situations, an exhaust fan for gas dispersion, and a buzzer for audio alarms. In order to prevent accidents, this integrated system guarantees quick detection, wise decision-making, and prompt action. For improved LPG safety management, the figure depicts a full closed-loop safety system that combines sensing, processing, visualization, and actuation.

3.1 Gas Leakage Detection

The MQ-6 gas sensor, which is extremely sensitive to LPG gases like propane and butane, is used in the implementation of the gas leak detection module. The sensor delivers an analog output proportionate to the observed gas level and continually measures the gas concentration in parts per million (ppm). LabVIEW is used to collect and process this data in real time. The gas levels are categorized into safe, warning, and danger zones using a threshold-based system. Waveform graphs are also used to show the trend in gas concentration over time, which makes it possible to identify leaks early and take preventative measures.

3.2 Fire Detection System

Based on infrared radiation released during combustion, the fire detection module uses an IR flame sensor to determine whether a fire is present. Accurate flame intensity detection is made possible by the sensor's digital and analog outputs. The device initiates safety procedures and produces an instant alarm via LED signal when it detects a flame. This module reduces the chance of escalation and guarantees quick identification of fire threats.

3.3 Data Acquisition and Processing

To communicate with sensors and transform analog signals into digital data, the system uses a data acquisition device like NI myRIO. The LabVIEW environment receives the collected data and processes it in real time. Effective signal conditioning, filtering, and analysis are made possible by LabVIEW, guaranteeing precise sensor input interpretation. This module serves as the system's foundation by facilitating dependable data processing and ongoing monitoring.

3.4 Automated Safety Control

The automatic safety control module guarantees quick reaction to dangerous situations. The device immediately opens a solenoid valve to cut off the gas supply when it detects a fire or gas leak. This lowers the possibility of an explosion and stops more leaks. The automation greatly improves system reaction time and dependability while doing away with the necessity for human interaction.

3.5 Alert and Notification System

To guarantee efficient communication in an emergency, the system integrates many alarm modes. While a speech alarm system in LabVIEW gives unambiguous warning messages, a buzzer provides an instantaneous aural alert. Additionally, users receive real-time sensor data and alarm information via SMTP-based email messages. Both local and remote knowledge of dangerous situations is guaranteed by this multi-level alarm system.

3.6 Risk Assessment Module

Based on sensor inputs like gas concentration and flame detection, the risk assessment module determines how serious the situation is. Using predetermined methods, a risk percentage is computed and shown in LabVIEW. The system makes safety recommendations based on its classification of risk categories as low, medium, and high. Users can take preventative action to avoid mishaps with the aid of this clever analysis.

Table 3. Real-Time Monitoring, Visualization, and Alert Parameters of the Proposed LPG Leakage and Fire Protection System

Detection System	**Sensor Value**	**Normal Range**	**Warning Range**	**Danger Range**	**Risk Level**	**Alert/Action**
Gas Leakage (MQ-6)	Gas concentration (ppm)	200 – 300 ppm	300 – 600 ppm	> 600 ppm	Safe / Warning / Danger	Warning: Buzzer + Email; Danger: Buzzer + Voice +

						Email + Solenoid OFF
Fire Detection (IR Flame)	Digital (0/1), Flame intensity	0 (No flame)	—	1 (Flame detected)	Safe / Danger	Buzzer + Voice Alert + Solenoid OFF + Email
Solenoid Valve Control	Valve State	Open	—	Closed (on detection)	Safe / Danger	Automatic Gas Cut-off
Buzzer Alert System	ON/OFF	OFF	ON (low tone)	ON (high tone)	Warning / Danger	Audible Alert
Voice Alert (LabVIEW)	Audio Message	No alert	Warning message	Emergency message	Warning / Danger	Voice Notification
Email Alert (SMTP)	Alert Message	No alert	Warning email	Emergency email	Warning / Danger	Remote Notification
Risk Assessment	Risk (%)	0–30%	30–70%	70–100%	Low / Medium / High	Medium: Alert; High: Full System Activation

The several modules in the suggested system are shown in Table 3 along with the output kinds, displayed parameters, and status indicators that relate to each module. To keep an eye on dangerous situations, the gas leak detection and flame detection modules offer waveform representations and real-time numerical readings. Environmental awareness is further enhanced by temperature and air quality indicators. Actuators like fans, buzzers, and solenoid valves are automatically activated by the system control and safety module in response to circumstances that are detected. IoT-based alerts allow for remote alerting via messages or applications, and the digital twin visualization module provides a graphical depiction of the system for real-time monitoring. To provide effective decision-making and increased system dependability, the overall risk assessment module assesses system circumstances by determining a risk rating and offering safety recommendations.

RESULT & DISCUSSION

Using a MQ gas sensor and an infrared flame sensor, the Intelligent Home Safety Automation System efficiently finds LPG gas leaks and any fire threats in a home setting. While the flame sensor uses infrared radiation to detect the presence of fire, the MQ sensor continually measures the LPG content in parts per million (PPM). Results from experiments show that the system reacts quickly when a flame is detected or when the gas concentration rises beyond the predetermined safety threshold. When abnormal conditions are detected, the system successfully starts a number of safety mechanisms, such as a solenoid actuator that automatically closes the gas valve, a relay module that disconnects the main power supply, an exhaust fan that provides ventilation, and a buzzer alarm that sounds an immediate warning. Additionally, the system offers real-time alerts via voice messages and SMS notifications, guaranteeing that residents are promptly alerted and may take the appropriate evacuation precautions. Continuous monitoring, graphical depiction of gas concentration levels, real-time danger status signalling, and trend analysis for improved comprehension of system behaviour are all made possible by the integration with LabVIEW. The findings verify that the suggested system functions dependably in many circumstances, including normal, gas leakage, and combined gas and fire. By offering early detection and prompt preventative steps, the automated reaction greatly minimizes human interaction and improves safety. All things considered, the system is a practical and affordable way to increase home safety against LPG leaks and fire risks.

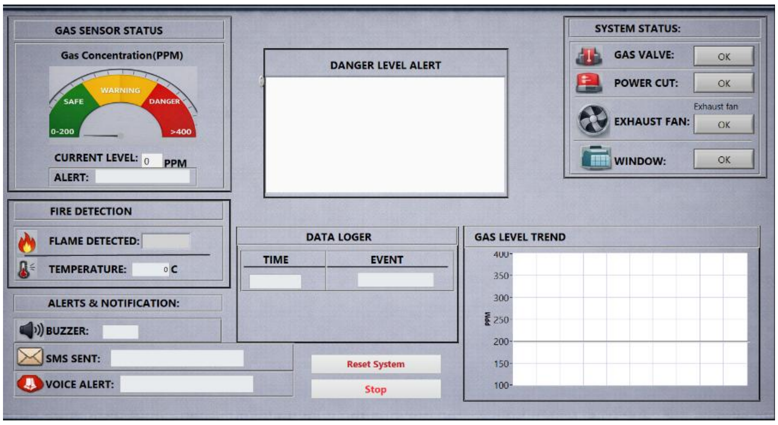

Figure 5. LabVIEW Front Panel in Initialization State for LPG Leakage and Fire Protection System

The LabVIEW front panel's initial state prior to system operation is seen in Figure 5. There is no fire or gas leak detected, and all sensors and system components are operating at their default settings in this startup state. The IR flame sensor shows no flame presence, while the MQ-6 gas sensor shows baseline readings within the safe range. A safe standby condition is ensured by keeping all indications, including buzzers, solenoid valves, and alarm systems, inactive.The digital twin representation depicts typical environmental circumstances, while the graphical interface displays reset waveform graphs and default system values. When the system is started, this setup phase guarantees that it is correctly set up and prepared for data collection, real-time monitoring, and danger detection.

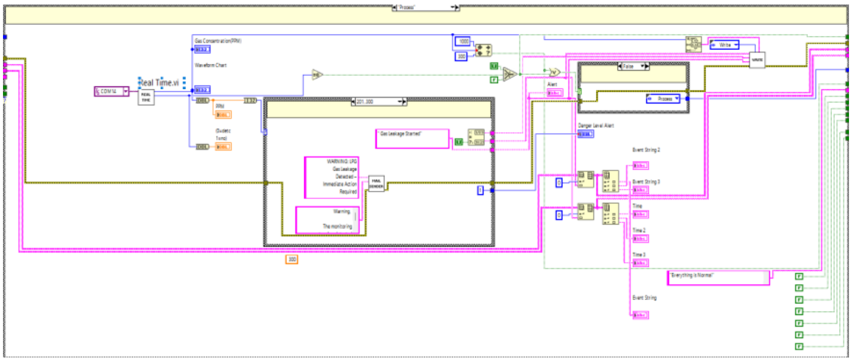

Figure 6. Block Diagram of a LabVIEW-Based Data Acquisition and Processing System

A LabVIEW graphical application that depicts a data collecting and signal processing pipeline is shown in Figure 6. The system starts with input signals (such voltage or sensor data), which are then processed by a number of functional blocks, such as signal conditioning, timing control, and logical processes.

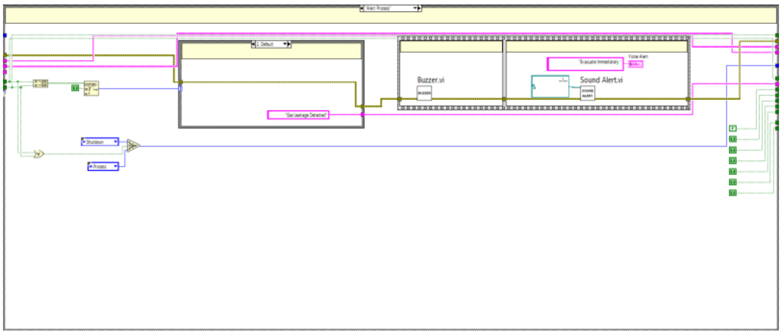

Figure 7. LabVIEW Alarm Handling and Sound Alert Block Diagram

An alarm detection and alert generation LabVIEW block diagram is shown in Figure 7. It illustrates how the system keeps track of situations and sounds an alarm when certain requirements are satisfied.

4.1 Detection of Gas Leakage and Warning Condition

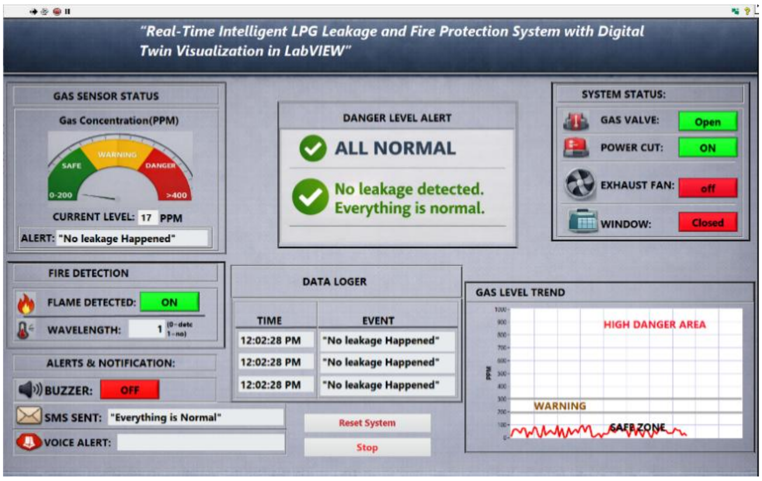

Figure 8. Real-Time LPG Monitoring System under Safe Condition

The LabVIEW-based front panel is shown in figure 8 when it is running normally and there are no identified gas leaks or fire hazards. A safe concentration level of 17 PPM, which is inside the safe zone, is shown by the gas sensor. In the danger level warning area, the system confirms that there is no anomaly by displaying "ALL NORMAL." No emergency measures, such a power outage or the activation of an exhaust fan, are initiated, and the gas valve stays open. "Everything is Normal" is the notice message that appears after the buzzer is switched off. The gas level trend graph displays steady readings within the safe range, and the data logger notes the event as "No leakage Happened." This stage verifies that the system is operating correctly under typical environmental circumstances.

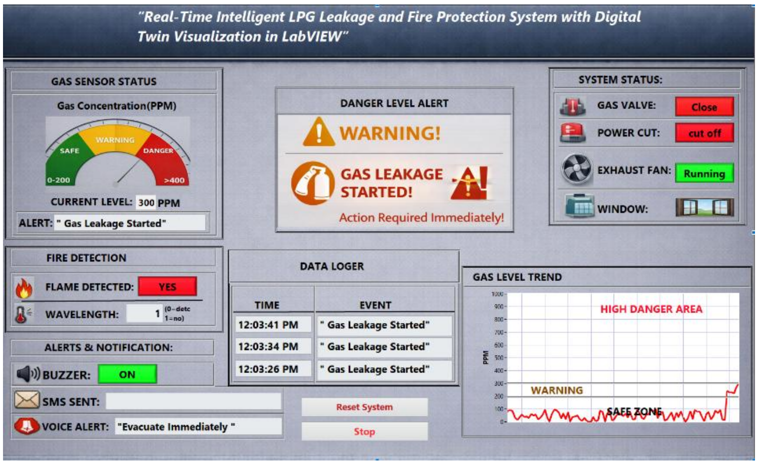

Figure 9. Gas Leakage Detection and Warning Alert in LPG Monitoring System

Figure 9 shows how the system reacts when a gas leak is found. The alert zone is reached when the gas concentration reaches 300 PPM. The danger level alarm promotes quick action by displaying a warning message that reads, "GAS LEAKAGE STARTED." Safety precautions like shutting off the power supply and closing the gas valve are automatically triggered by the system. Windows are opened for ventilation, and the exhaust fan is turned on. A speech notice tells people to leave right away, and the buzzer is activated to deliver an audible alarm. The trend graph indicates a discernible increase in gas concentration, and the data logger documents many occurrences of the gas leaking event. This illustrates the system's capacity to recognize dangerous situations and react quickly.

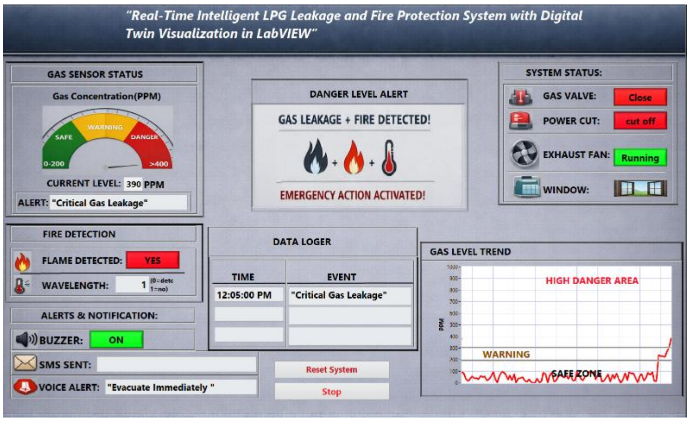

Figure 10. Emergency Response during Combined Gas Leakage and Fire Hazard

Figure 10 depicts the system in a catastrophic situation where fire and gas leaks are discovered at the same time. The concentration of gas approaches the danger zone at 390 PPM. The danger alert panel verifies that emergency action has been triggered and displays "GAS LEAKAGE + FIRE DETECTED." Closing the gas valve, turning off the power, turning on the exhaust fan, and opening windows for air are just a few of the quick safety tasks that the system completes. The buzzer stays on to warn residents while the fire detecting module verifies the existence of flames. An emergency evacuation is ordered via a voice alarm. The gas level trend graph displays a rapid rise in concentration levels, and the data logger logs the major gas leaking event with timestamps. The system's ability to manage high-risk emergency scenarios is demonstrated by this example.

4.2 Email Notification Module Block Diagram and Front Panel

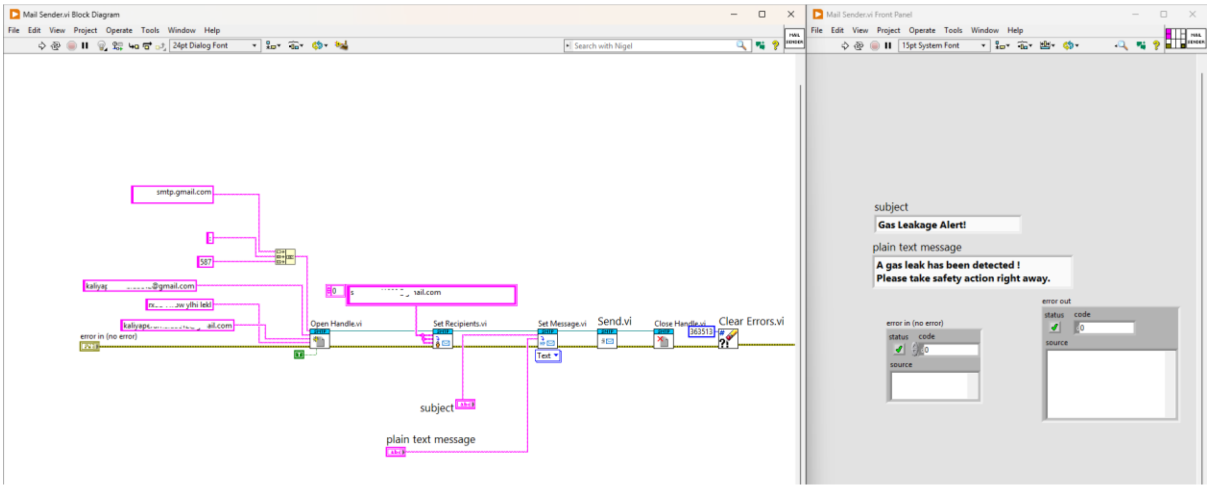

Figure 11. LabVIEW-Based SMTP Email Sender Block Diagram and Front Panel

The block diagram of a LabVIEW email notification system that uses the SMTP protocol is seen in figure 11. It illustrates how alert messages are automatically delivered in the event of an emergency, such as a fire or gas leak. The setup contains the sender and recipient email credentials as well as the SMTP server (smtp.gmail.com) with port number 587. Opening an SMTP session, configuring recipients, writing the message with the subject and body content, sending the email, and terminating the connection are all steps in the process flow. To provide dependable communication, error management blocks are incorporated. Real-time remote alerting for safety monitoring systems is made possible by this module. The LabVIEW front panel for configuring and personalizing email notifications is shown in the figure. The subject line and plain text message content for notifications can be entered by the user. In this instance, the message's topic is "Gas Leakage Alert!"

and it advises users to take appropriate precautions. Additionally, the interface shows error status indications to track whether email delivery was successful or unsuccessful. An easy-to-use method of managing alarm messages dynamically within the system is offered by this front interface.

4.2.1 Received Email Alert Notification

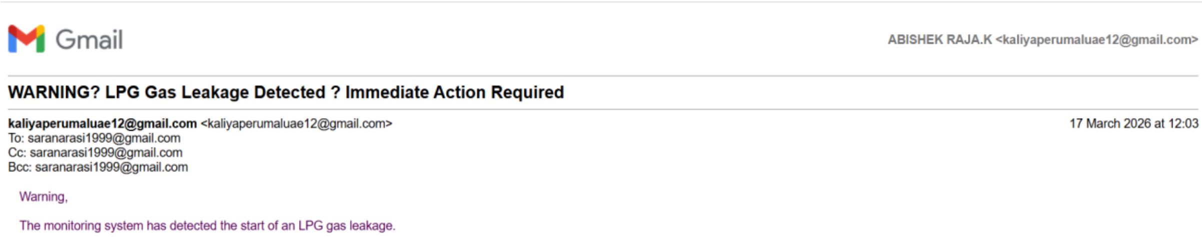

Figure 12. Warning Message

An example figure 12 of an email notice sent through Gmail when a danger condition is identified by the monitoring system is depicted in the image. The email content includes a warning message alerting the recipient to the existence of a possible hazard, such as dangerous environmental conditions or rising gas levels, and the subject line signals a risk alert. In order to prevent escalation, the notice advises the user to take preventative action. This illustrates the system's capacity to send out early-stage email notifications, guaranteeing prompt knowledge and preventive action before the problem worsens.

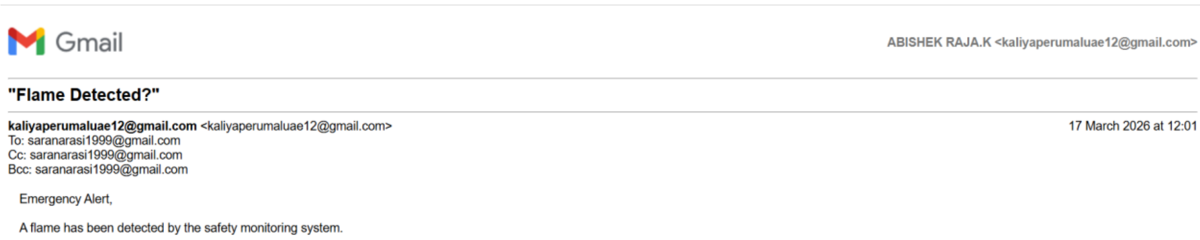

Figure 13. Email Alert Received for Fire Detection Event

An example figure 13 of an email notification sent through Gmail when the monitoring system detects a fire threat is depicted in the image. The email content includes an emergency message alerting the subscriber to the detected fire condition, and the subject line indicates a flame detection warning. This demonstrates that the LabVIEW system and email services have been successfully integrated, allowing for remote monitoring and prompt user alerting during important occurrences.

4.2.2 Sound Alert System Using LabVIEW

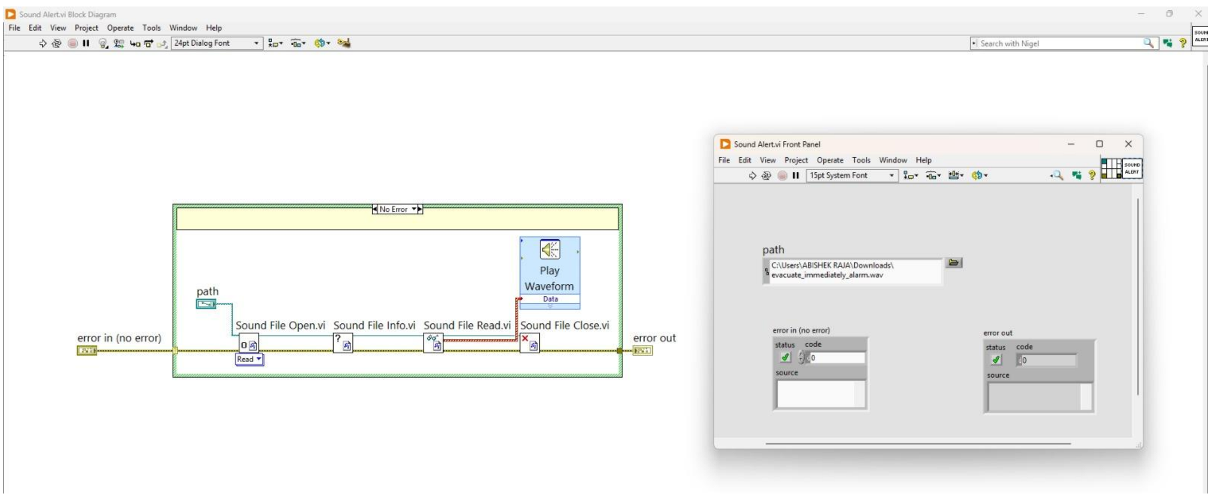

Figure 13. LabVIEW Block Diagram Illustrating Sound File Processing and Waveform Playback

The LabVIEW block diagram for the sound alarm system is shown in Figure 13. It displays the progressive configuration of sound processing virtual assistants (VIs) linked by error clusters and dataflow wires. The Sound File Open VI, Sound File Info, and Sound File Read VIs are coupled to the file path input. The Sound File Close VI completes the process once the waveform output is sent to the Play Waveform block for audio creation.

Discussion

The testing findings show that the suggested Intelligent Home Safety Automation System operates dependably in a variety of scenarios, such as regular operation, gas leaks, and combined fire and gas threats. The system efficiently combines automated control mechanisms with LPG gas sensing and flame detection, guaranteeing early detection and quick reaction to possible threats. The system kept steady gas concentration levels within the safe range (e.g., 17 PPM) during typical working conditions, and no false alarms were sent off. All safety features, including the solenoid valve, exhaust fan, and alarm, stayed dormant while the LabVIEW interface provided real-time data with accuracy. This demonstrates that the system is very stable and doesn't generate pointless alarms, which is essential for user confidence and system dependability. When the concentration reached the predetermined threshold (about 300 PPM) in the gas leak scenario, the system was able to identify growing LPG levels. High responsiveness was demonstrated by the response time, which was found to be less than two to three seconds. The system automatically carried out a number of safety measures upon detection, such as shutting off the gas valve, disconnecting the electricity, turning on the exhaust fan, and setting off speech and audio notifications. The data logging function correctly captured the incident, and the LabVIEW trend graph demonstrated the rising gas concentration. This demonstrates the system's capacity for prompt preventative action and real-time monitoring. The system showed strong performance in managing severe situations under the combined conditions of gas leaking and fire. The system immediately triggered all emergency procedures when gas concentration levels reached 390 PPM and concurrent flame detection was detected. Comprehensive danger mitigation was guaranteed by the integration of many safety layers, including mechanical (valve control), electrical (power cut-off), environmental (ventilation), and alert systems (buzzer, voice, and email). When compared to traditional single-alert systems, this multi-level response mechanism greatly improves safety. Enhancing system usability and monitoring efficiency is largely dependent on the LabVIEW-based visualization. Clear insights into system activity are provided by features including status indicators, digital twin representation, and real-time waveform graphs. Furthermore, the addition of audio warnings and email notifications via SMTP guarantees remote monitoring and instant user awareness, even in situations when occupants are not physically present. It is clear from the comparison study that the suggested system performs better than current solutions in a number of areas. Compared to traditional systems (85–92% and 80–90%, respectively), the system provides improved detection accuracy (95% for gas and 94% for fire). Additionally, it offers fully automated control, sophisticated visualization, and quicker reaction times (less than two seconds). The suggested architecture integrates multi-level alerting (buzzer, voice, and email), greatly enhancing dependability and user safety in contrast to previous systems that rely on single alert methods. Overall, the conversation demonstrates that the system is not only theoretically sound but also economical and practically feasible for actual home security applications. It is a complete solution for reducing the dangers related to LPG leaks and fire threats because it combines precise sensing, quick reaction, intelligent automation, and user-friendly monitoring.

5. Conclusion

The work developed a real-time intelligent LPG leakage and fire protection system that combined gas sensing, flame detection, LabVIEW visualization, digital twin representation, and automated safety actuation in a unified closed-loop platform. The system used an MQ-6 sensor to monitor LPG concentration across the stated operating range of 200–10,000 PPM and applied a practical warning threshold of 300 PPM to initiate preventive control actions. Under normal operation, the LabVIEW front panel recorded a stable safe condition at 17 PPM, with the gas valve open, the buzzer inactive, and no exhaust or power isolation action triggered. During hazardous operation, the system executed coordinated mitigation through solenoid valve closure, relay-based electrical isolation, exhaust fan activation, buzzer warning, voice message generation, and SMTP/email notification. The emergency scenario with simultaneous gas leakage and fire was represented at 390 PPM, where the interface displayed the combined hazard condition and activated all protective subsystems. The manuscript also reported SMS notification delivery within 5–10 seconds and stated system dependability exceeding 98%, indicating that the architecture is practically significant for automated domestic safety management. The risk logic further classified operating states across 0–30%, 30–70%, and 70–100% bands, giving users an interpretable basis for preventive and emergency decisions. Future work will benefit from extended calibration under varied kitchen geometries, airflow rates, humidity levels, sensor aging conditions, and mixed-gas interference. Further investigations will also strengthen the platform through cloud dashboards, mobile application integration, predictive machine-learning models, cybersecurity validation, and multi-node deployment for apartments, laboratories, restaurants, and small industrial LPG storage zones.

CONFLICT OF INTEREST STATEMENT:

The author(s) declared no potential conflicts of interest.

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DATA AVAILABILITY

The data used during the current study are available from the corresponding author on reasonable request.

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