

# An Intelligent Voice-Activated Laboratory Control System Powered by ESP32 And Firebase

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**Abstract**—In today's world, technology is making everyday tasks easier and smarter, and laboratories are no exception. This project presents an *Intelligent Voice-Activated Laboratory Control System* built using the ESP32 and Firebase, designed to simplify the way electrical devices in a lab are managed. The system allows users to control seven lights, six fans, and three other devices in a convenient and efficient manner.

What makes this system unique is that it offers three different ways to control the devices. First, users can operate devices using voice commands through the VC02 voice recognition module, making the system easy to use and hands-free. Second, it provides an offline control option using the ESP32's Access Point mode, ensuring that the system works even without an internet connection. Finally, users can control and monitor devices remotely through a web application connected to Firebase, giving them access from anywhere.

The system uses two 8-channel relay modules to handle multiple devices at the same time. The web application also includes useful features like scheduling and timers, allowing devices to turn on or off automatically, which helps save energy and time.

Overall, this project creates a smart and reliable laboratory environment by combining convenience, flexibility, and efficiency. It reduces manual effort, improves control, and represents a practical step toward modern, automated laboratories.

manage. This project, *An Intelligent Voice-Activated Laboratory Control System Powered by ESP32 and Firebase*, is designed to solve these problems in a simple and practical way. The system allows users to control a total of 16 devices, including seven lights, six fans, and three other appliances, all from one smart platform using two 8-channel relay modules.

Three different ways to control the devices. First, users can simply speak commands, and the VC02 voice recognition module will turn devices on or off. This makes the system very easy to use, especially when hands are busy. Second, even if there is no internet, users can still control everything through the ESP32's offline Access Point mode. Third, when internet is available, users can control and monitor the lab from anywhere using a web application connected to Firebase. The web application also adds smart features like schedules and timers, which allow devices to operate automatically at specific times. This helps in saving energy and reduces the need for constant manual control. Overall, this project is a step toward creating a smart laboratory environment. It makes device control easier, saves time and energy, and brings modern automation into everyday lab usage in a simple and user-friendly way.

## I. INTRODUCTION

In many laboratories today, electrical devices like lights, fans, and other equipment are still controlled manually. This not only takes time and effort but can also lead to unnecessary energy wastage when devices are left on by mistake. With the growing use of smart technology and IoT, there is a need to make laboratories more efficient, convenient, and easy to

## II. METHODOLOGY

The system is developed by combining hardware and software to control laboratory devices efficiently. The ESP32 acts as the main controller, connected to two 8-channel relay modules to operate 16 devices like lights, fans, and other equipment. The VC02 module is used for voice recognition. The system works in three modes: voice control (using spoken commands),

offline control (through ESP32 Access Point), and online control (via web app and Firebase). The web app also provides features like schedules and timers for automation. Finally, the system is tested to ensure smooth, reliable, and user-friendly operation in all modes.

### III. HARDWARE COMPONENTS

This project uses simple and easily available hardware components to build a smart laboratory control system.

- **ESP32 Microcontroller**

This is the main part of the system, like its brain. It controls all the operations, connects to Wi-Fi, and manages both online and offline communication.



Figure 1. ESP32 Microcontroller

- **VC02 Voice Recognition Module**

This module allows users to control devices using voice commands. It listens to the user and sends the command to the ESP32 to take action.



Figure 2. VC02 Voice Recognition Module

- **8-Channel Relay Modules**

These are used to control electrical devices. With two relay modules, the system can handle up to 16 devices

like lights, fans, and other equipment by turning them ON or OFF.

- **Laboratory Devices (Loads):**

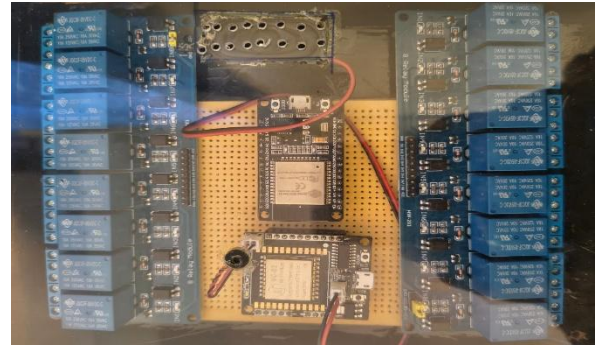
The system controls 7 lights, 6 fans, and 3 other devices in the lab, making the environment more automated and easier to manage.

- **Power Supply:**

A stable power source is used to run all the components smoothly without interruption.

- **Connecting Wires and PCB/Breadboard:**

These are used to connect all components properly and keep the setup organized.



### IV. SOFTWARE COMPONENTS

This project uses simple and powerful software tools to make the system smart, flexible, and easy to control.

- **Embedded C / Arduino IDE**

The ESP32 is programmed using Arduino IDE. It controls all operations like reading voice commands, switching relays, and communicating with the web app and Firebase.

- **Firebase (Cloud Database)**

Firebase is used for real-time data storage and communication. It connects the ESP32 with the web application, allowing users to control devices from anywhere and see instant updates.

- **Web Application**

A user-friendly web app is developed to control and monitor all laboratory devices. It provides features like ON/OFF control, scheduling, timers, and real-time status of devices.



- ESP32 Wi-Fi (AP Mode & Station Mode)  
The ESP32 uses built-in Wi-Fi for two purposes:
  - AP Mode: For offline control without internet
  - Station Mode: For online control using Firebase

- Voice Recognition Programming (VC02Configuration)

The VC02 module is programmed/trained with specific voice commands. These commands are mapped to particular devices for easy voice-based control.

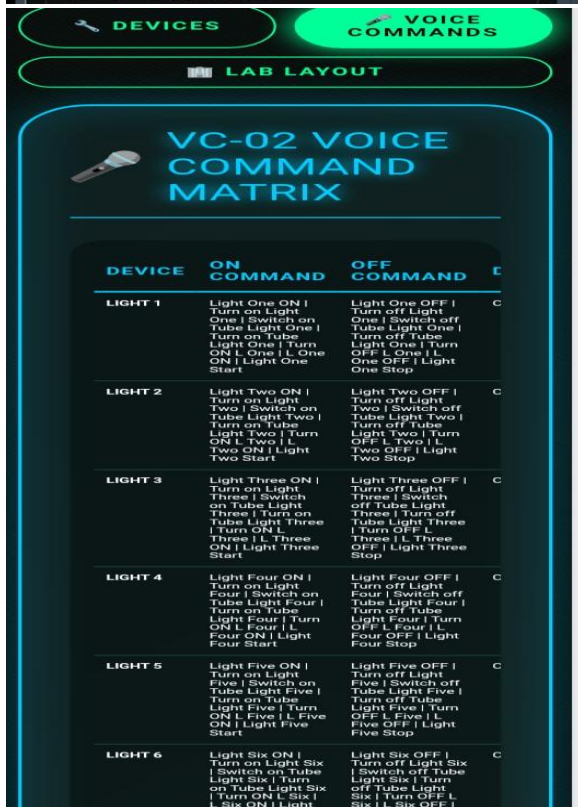
## V. MODELING AND ANALYSIS

The *Intelligent Voice-Activated Laboratory Control System* is designed by modeling both hardware and software interactions to ensure smooth and reliable operation. The system is structured in a modular way, where each component performs a specific function while working together as a complete system.

### System Modeling:

The system can be divided into three main parts: input, processing, and output.

- Input Layer: This includes the VC02 voice recognition module, web application inputs, and offline control through ESP32 Access Point. These inputs allow users to send commands in different ways.



- **Processing Layer:** The ESP32 acts as the central controller. It receives commands from all input sources, processes them, and decides which device needs to be controlled. It also communicates with Firebase for real-time data exchange.
- **Output Layer:** The relay modules act as the output interface. They receive signals from the ESP32 and control the electrical devices like lights, fans, and other equipment.

Working Model (Three Modes):

1. Voice Control Mode:

The VC02 module detects a spoken command and sends it to the ESP32. The ESP32 processes the command and activates the corresponding relay to control the device.

2. Offline Mode (AP Mode):

The ESP32 creates a local Wi-Fi network. Users connect to it and access a local web page to control devices without internet.

3. Online Mode (Firebase + Web App):

The ESP32 connects to Firebase via the internet. Commands from the web app are sent to Firebase and then to the ESP32, allowing remote control and monitoring.

VII. RESULTS AND DISCUSSION

The *Intelligent Voice-Activated Laboratory Control System* was successfully designed and tested to control 16 laboratory devices, including lights, fans, and other equipment. The system performed efficiently in all three modes of operation: voice control, offline control, and online control.

Results

The system performed efficiently in all three modes. Voice commands through the VC02 module were recognized with good accuracy, and devices responded quickly. The offline mode using ESP32 Access Point provided fast and reliable control without internet dependency. The online mode, integrated with Firebase and the web application, allowed real-time monitoring and remote operation from any location.

Discussion

The results show that the system is flexible and user-friendly due to multiple control options. Voice control adds convenience, especially for hands-free operation. Offline mode ensures the system remains functional even without internet, increasing reliability. Online mode enhances usability by allowing remote access and advanced automation features.

VI. FLOWCHART

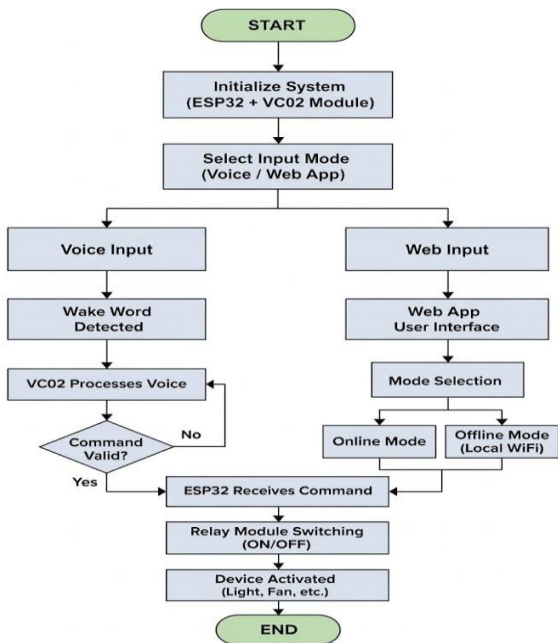


Figure3. Flowchart

Table 1: System Performance Metrics

Parameter	Voice Control (VC02)	Offline Mode (AP)	Online Mode (Firebase)
Response Time	~1-2 seconds	~1 second	~2-3 seconds
Accuracy	High (90-95%)	Very High (≈100%)	Very High (≈100%)
Internet Requirement	Not Required	Not Required	Required
Ease of Use	Easy	Easy	Very Easy
Reliability	High	Very High	High (depends on net)
Automation Features	Limited	Limited	Advanced (Schedules, Timers)
Range	Short (voice range)	Local Wi-Fi	Global (Remote Access)

## VIII. CONCLUSION

The *Intelligent Voice-Activated Laboratory Control System Powered by ESP32 and Firebase* successfully demonstrates how modern technology can make laboratory management smarter and more efficient. The system effectively controls 16 devices, including lights, fans, and other equipment, using a simple and user-friendly approach.

By providing three different control methods—voice control using the VC02 module, offline control through ESP32 Access Point, and online control via a web application with Firebase—the system offers great flexibility and reliability. Even if the internet is not available, the system continues to function smoothly, which makes it highly dependable.

The addition of features like scheduling and timers in the web application further enhances automation and helps in reducing energy wastage. The system also shows quick response, stable performance, and easy operation, making it suitable for real laboratory environments.

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