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Universal Offline Voice-Controlled Automation

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A B S T R A C T

This study presents the development of a universal offline voice-controlled automation system that functions without requiring an internet connection. The system utilizes sophisticated speech recognition and natural language processing methods tailored for offline environments to maintain user privacy, ensure operational reliability, and support use in areas with limited connectivity. The VC02 module plays a key role in translating spoken commands into executable actions and the VC02 module, with its low power consumption and advanced offline speech recognition capabilities, processes voice commands locally, converting them into actionable outputs for managing machinery, lighting, HVAC systems, and other automated processes. By incorporating lightweight neural networks and edge computing technologies, the system delivers high accuracy in understanding and executing spoken commands across various applications, such as smart home devices, industrial automation, and personal digital assistants. Emphasizing adaptability, scalability, and compatibility across different platforms, this solution offers a secure and effective alternative to cloud-based voice automation technologies. The paper details the system's structural design, interfacing techniques, and practical deployments, highlighting the VC02 module's effectiveness in delivering precise and responsive voice command performance. Overall, the findings underscore the transformative potential of offline voice-activated solutions in boosting efficiency and accessibility across a variety of automation domains.

Keywords: *VC02 Voice Recognition Module, ESP32, Relay, Triac, Power Management SMPS 5v 5Amp*

Introduction

Automation is significantly transforming contemporary systems by optimizing operations across industrial and household environments Incorporating voice control into these systems has further enhanced user interaction, allowing for hands-free functionality and improved overall efficiency. This paper presents the design and development of a flexible, offline voice-controlled automation system titled "Universal Voice-Controlled Automation Using VC02, ESP32, Triac to TTL, and Additional Components." The system enables hands-free control of various household and industrial devices, significantly enhancing convenience and accessibility-particularly for users with mobility challenges. The system utilizes voice recognition technology to convert spoken commands into executable actions, allowing effortless control of devices like lights, fans, motors, and security systems Central to this functionality is the VC02 Voice Control Module, which accurately detects voice inputs and communicates directly with the ESP32 to carry out the corresponding operations. The Triac to TTL converter bridges the communication gap between modern voice modules and industrial ESP32, ensuring compatibility across components. This project is designed to support a wide range of applications, from smart home systems managing lighting, security, and HVAC, to industrial settings controlling conveyors, pumps, and manufacturing equipment. Its scalability and flexibility are driven by the ESP32, which accommodates increasingly sophisticated automation needs. Additionally, the integration of voice control offers a user-friendly and accessible interface, making it especially beneficial for individuals with mobility impairments. Through the integration of technologies, this voice-controlled automation system that can be universally compatible is a visionary way of approaching automation. With the integration of voice recognition features and robust communication protocols, its potential as a pioneering residential and industrial automation solution is highlighted

Structure:

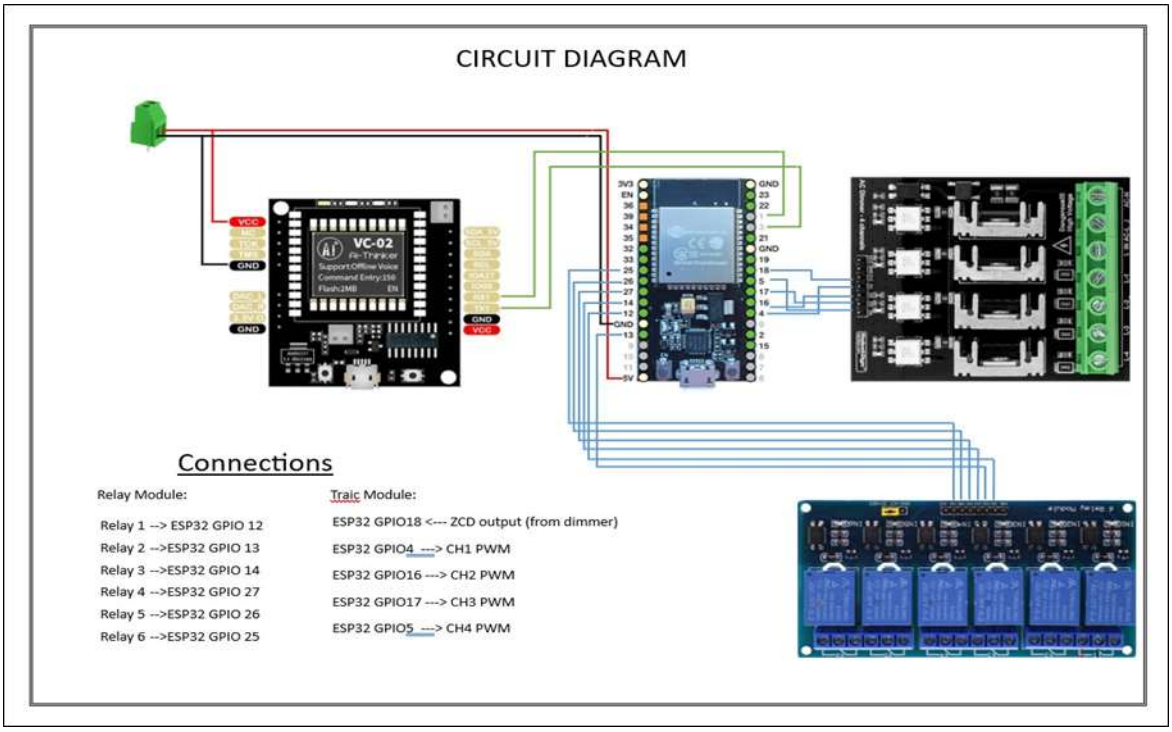


Fig.1 Circuit Diagram

The above circuit diagram represents the architecture of the 'Universal offline voice-controlled automation. Here's a detailed explanation of the

components and their interactions:

- **ESP32 Microcontroller** – Acts as the central controller for voice commands and switching operations.

Role in the Circuit: Upon receiving a command from VC-02, the ESP32 processes it and takes appropriate action either toggling a relay or adjusting the duty cycle for the dimmer modules. It also uses interrupts from the ZCD signal to synchronize PWM pulses with the AC mains, ensuring efficient and flicker-free dimming.

- **VC-02 Voice Recognition Module** – Captures and processes voice commands.

Role in the Circuit: The VC-02 module continuously listens for voice inputs. Upon recognizing a valid command, it sends a specific serial message to the ESP32, which interprets the command and controls the connected load accordingly (relay activation or dimmer adjustment).

- **6-Channel Relay Module** – Controls ON/OFF devices like lights, fans, or appliances.

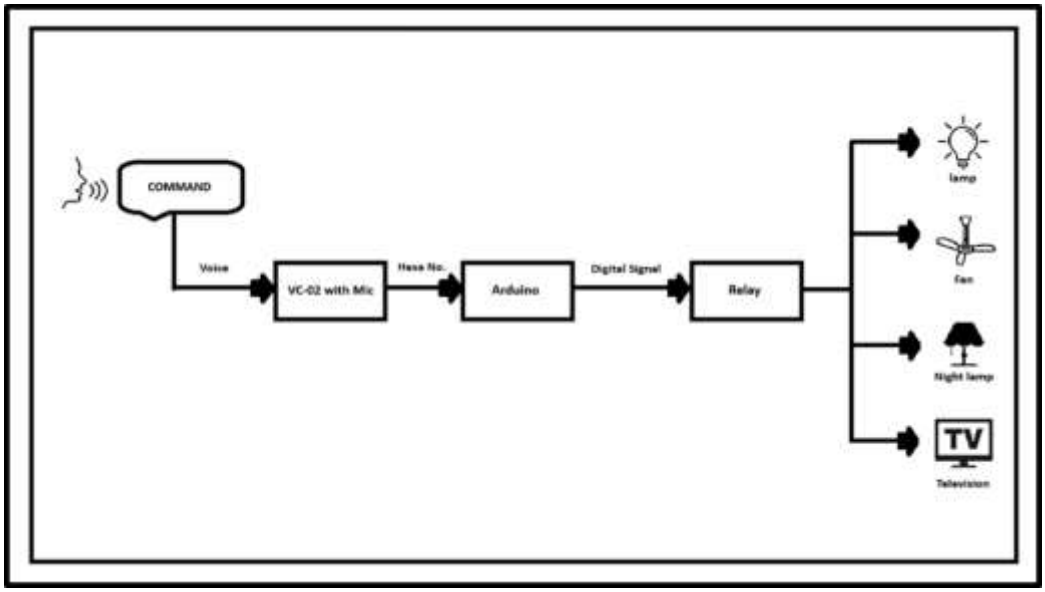
Role in the Circuit: Each relay corresponds to an individual appliance. Based on voice commands, the ESP32 energizes the appropriate relay, turning connected AC devices ON or OFF.

- **4-Channel Triac-based Dimmer Module** – Controls brightness of dimmable AC loads.

Role in the Circuit: The ZCD output triggers an interrupt on ESP32 at every AC cycle zero crossing. Based on user command (via VC- 02), the ESP32 delays the firing of a PWM pulse, thus controlling how much of the AC cycle the load receives. Longer delays mean dimmer output, and shorter delays provide brighter output.

- **Power Management:** The ESP32 is powered via its onboard 5V USB connector.VC-02 module is powered with a 3.3V supply from ESP32. Relay module is powered separately using the 5V output from ESP32, ensuring the relay coil currents do not interfere with ESP32 operation

Methodology:



The block diagram illustrates a voice-controlled home automation system that enables the operation of household appliances using simple voice commands. This system is designed to increase convenience, accessibility, and comfort, especially for the elderly or physically challenged individuals. The process begins when the user speaks a command such as "Turn on the fan" or "Switch off the light." This voice input is detected by a VC-02 module with a built-in microphone, which is trained to recognize a predefined set of voice instructions.

The VC-02 voice recognition module converts the recognized command into a specific hexadecimal code that represents the intended action. This code is then sent to an Arduino microcontroller, which acts as the central processing unit of the system. The Arduino receives the hexadecimal code and identifies the corresponding task—whether it's turning a device on or off. It then generates an appropriate digital signal based on the interpreted command.

This digital signal is passed to a relay module, which serves as an electronic switch to control the connected electrical appliances. The relay receives the digital input from the Arduino and accordingly switches the required appliance. The appliances that can be controlled include a lamp, fan, night lamp, and television. Each device is connected to the relay, which controls the flow of current to turn them on or off.

Overall, this system provides a simple and effective solution for smart home automation. By utilizing voice commands, users can operate multiple devices without the need for physical switches or remotes. This not only enhances convenience but also promotes energy efficiency and safety by allowing control over devices from a distance. The combination of voice recognition, microcontroller processing, and relay switching makes this system a practical application of modern embedded and automation technologies.

Working:

The VC-02 module listens for voice commands and converts them into serial data, which it sends to the ESP32 via UART (using TX and RX pins). Once the ESP32 receives this data, it understands the command and acts accordingly. For devices that only need to be turned on or off, like regular lights or fans, the ESP32 sends signals from its GPIO pins (GPIO12 to GPIO25) to the relay module. Each relay works like a digital switch, toggling the connected appliance on or off.

When it comes to dimmable devices, like smart lights or fan speed controllers, the ESP32 uses Pulse Width Modulation (PWM) signals from specific GPIO pins (GPIO4, GPIO16, GPIO17, GPIO5) to control brightness or speed. The dimmer module also provides a Zero Cross Detection (ZCD) signal to the ESP32 on GPIO18, which helps ensure the dimming is smooth and in sync with the AC power cycle. This helps avoid flickering and unwanted noise.

To use the system, you just speak a command like “Turn on light one” or “Dim light two.” The system processes the command and carries it out-no switches or remotes needed. It’s a practical solution for smart homes, especially helpful for the elderly or for saving energy."

Components used:

1. VC-02 Voice Recognition Module:

The VC-02 is an advanced offline voice recognition module designed for integration into embedded systems and smart devices that require voice control without relying on internet connectivity. It supports up to 150 custom voice commands and offers speaker-independent recognition, making it ideal for a

wide range of users without the need for individual training. Equipped with a built-in microphone and a UART communication interface, the VC-02 can be easily connected to popular microcontrollers such as the ESP32, Arduino, or STM32. Its low power consumption, fast response time, and reliable performance make it suitable for applications like home automation, voice-activated appliances, and interactive robotics. The module allows users to upload custom command sets through a PC configuration tool, enabling personalized and flexible voice control in offline environments.

Fig.2 VC-02 Voice recognition Module

2. ESP32 Microcontroller:

The ESP32 is a highly capable and flexible microcontroller created by Express if Systems, frequently used in IoT and embedded systems. It boasts a dual-core 32-bit Xtensa® LX6 processor with speeds up to 240 MHz and includes built-in Wi-Fi and Bluetooth (both classic and BLE), making it perfect for wireless communication projects. This microcontroller offers an extensive range of peripherals, such as GPIOs, UART, SPI, I2C, PWM, ADCs, DACs, touch sensors, and timers, allowing seamless integration with different sensors, actuators, and modules. It also supports deep sleep and light sleep modes for efficient power usage in battery-operated devices. Thanks to its strong performance, energy efficiency, and reliable connectivity, the ESP32 is a popular choice for smart home automation, including voice-controlled gadgets, remote monitoring, and wireless appliance control.

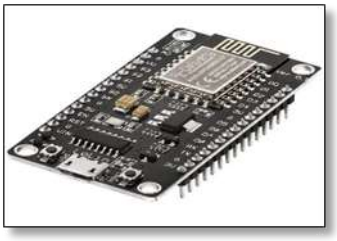


Fig.3 ESP32 Microcontroller

3. Relay Module (6-Channel/8-Channel:

It is an electronic switch that enables a microcontroller, like the ESP32, to manage several high-voltage devices using low-voltage digital signals. Each module channel controls a separate relay, functioning as an electrically controlled switch. These relays are commonly triggered by optocouplers or transistors, which ensure electrical isolation between the control circuit and the high-voltage output for added safety. The module is suitable for switching both AC and DC devices such as fans, lights, and other appliances. Available in configurations like 6 or 8 channels, it's ideal for applications that need to operate multiple devices at once, including home automation setups. The module typically features status LEDs for each relay, screw terminals for secure wiring, and header pins for connecting to microcontrollers. Operating on 5V, it is compatible with platforms like the ESP32, Arduino, and Raspberry Pi.

Fig.4 Relay

4. **Triac-Based 4 or 2-Channel Dimmer Module**:

The Triac-Based 4 or 2-Channel Dimmer Module is a dedicated electronic component designed to manage the brightness of AC-powered devices such as incandescent lights, halogen lamps, and some fan types. Unlike standard relay modules that merely turn devices ON or OFF, this dimmer module enables fine-tuned and gradual control of power using phase angle modulation, allowing for accurate dimming. Each channel features a TRIAC (Triode for Alternating Current), a semiconductor component that controls power flow by adjusting the point at which the AC signal begins conduction. The

module usually incorporates an opto-isolator for zero-cross detection and electrical isolation, ensuring safe integration with microcontrollers like the ESP32.

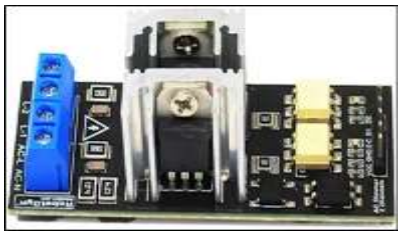


Fig.5 Triac based 4 or 2-channel Dimmer Module

5. **Power Management SMPS 5V 5Amp:**

The Power Management SMPS (Switched-Mode Power Supply) 5V 2A module is a small, high-efficiency unit that converts high-voltage AC input (typically 110V or 220V) into a steady 5V DC output with up to 2A current capacity. It's well-suited for supplying power to low-voltage devices such as microcontrollers (like the ESP32), sensors, relay modules, and other components used in embedded systems or smart home applications. Unlike traditional linear regulators, this SMPS module works by rapidly switching power transistors on and off, using inductors, capacitors, and transformers to maintain consistent voltage, resulting in greater efficiency. Its 5V 5A output supports multiple devices simultaneously while ensuring voltage stability. Built-in protections—such as short-circuit, over-voltage, and thermal shutdown—boost its safety and reliability. The module's compact design makes it ideal for use in custom enclosures and DIY electronics projects requiring a reliable and efficient 5V power supply.

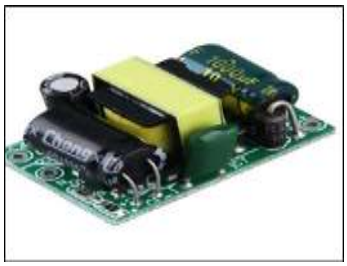


Fig.6 Power Management SMPS 5v 5Amp

6. Connecting wires:

Connecting wires are essential components that facilitate electrical links between various devices and system elements. They are available in a variety of materials, thicknesses (gauges), and insulation types to meet specific application needs. Copper is the preferred conductor material due to its superior electrical conductivity and flexibility. These wires are typically insulated with materials such as PVC or silicone to prevent short circuits and promote safe usage. Offered in a range of colors, they help simplify identification during setup and maintenance. From small-scale electronics projects to extensive industrial installations, connecting wires play a critical role in transmitting power and signals, ensuring smooth and reliable device operation.

Fig.7 Connecting wires

6. Result:

Fig.11 Project Model

7. Conclusion:

The Universal Offline Voice-Controlled Automation system showcases an effective, efficient, and privacy-oriented solution for managing electrical appliances using voice commands without the need for internet access. Utilizing the VC-02 voice recognition module alongside the ESP32 microcontroller, relay modules, and triac-based dimmer circuits, the project presents a flexible and cost-efficient platform suitable for various real-life applications, such as smart home systems, industrial automation, and accessibility enhancements.

This initiative emphasizes the value of local data processing, which not only improves response speed but also strengthens user privacy and makes the system more viable for areas with limited or no internet connectivity. While the system currently has some constraints related to the range of commands and scalability, it lays a solid groundwork for independent automation setups. Potential upgrades—like incorporating response feedback, broader command recognition, or integrating simple graphical user interfaces—could enhance its usability and reach.

In summary, the project effectively tackles major issues in voice-based automation by delivering a strong offline framework that upholds privacy, cost-effectiveness, and dependability, making it a significant step forward in both embedded systems innovation and practical automation solutions.

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