Smart Greenhouse PCB Design

1 - Abstract

This technical report presents the design of a smart greenhouse system based on a custom PCB. The purpose of the system is to create a controlled environment for plant growth by monitoring and regulating key parameters such as air temperature, humidity, Co_2 concentration and light intensity. The system integrates multiple sensors and actuators, with a central microcontroller managing data acquisition and control logic. In addition to automatic operation, the PCB supports manual override for direct control of actuators.

2 - Introduction

Greenhouses provide controlled environments that enhance plant growth, extend cultivation periods, and increase crop yield. Traditional greenhouse systems often rely on manual monitoring, leading to inefficiencies in resource usage such as water, energy, and fertilizers. This project aims to automate greenhouse monitoring and control using a PCB-based system that integrates sensors and actuators. By automating environmental control, the system ensures optimal plant conditions, reduces manual effort, and improves sustainability, while still allowing manual override when needed.

3 - Objectives

a- Automate monitoring of environmental parameters.

b- Control actuators such as fans, heaters, motors, misting system and LEDs.

c- Design and implement a reliable PCB for integration of sensors and control circuits.

d- Provide scalability for larger greenhouse applications.

e- Support manual override for actuators, ensuring operation in case of system failure or for testing purposes.

4 - System Requirements

a- The main microprocessor is ESP32-Wroom-32D.

b- Monitor:

- Air temperature.
- Humidity.
- Co_2 concentration.
- Light intensity.

c- Control:

- Heating (Ceramic Heaters).
- Cooling and ventilation (Fans).
- Humidity (Misting Systems).
- Grow lights and shading systems (Motors and LEDs).

d- Manual Control Mode:

- Switches/buttons to manually turn actuators on/off.
- Small LEDs indicators that show actuator status.

5 - System Architecture

The system follows modular architecture:

a- Microprocessor

The ESP32-WROOM-32D module was selected as the central controller for the greenhouse system due to its integrated Wi-Fi and Bluetooth connectivity, sufficient processing capability, and wide range of peripheral interfaces. It enables reliable monitoring and control of environmental parameters such as air temperature and humidity while supporting both manual and automatic operation modes. The module provides adequate GPIO pins to interface with sensors and actuators, including fans, heaters, and relays, and its low-power features ensure energy efficiency. Furthermore, its strong community support and available software libraries make it highly suitable for rapid development and long-term maintainability of the greenhouse control system.

b- Sensors

- DHT22 to measure the temperature and humidity in the greenhouse.
- MQ-135 to measure Co_2 in air.
- BH1750 to measure light intensity.

c- Actuators

- DC Heater to change the temperature of the greenhouse.
- AC Fan which is responsible for the cooling of the greenhouse.
- DC LEDs which are responsible for the lighting of greenhouse.
- AC Tubular Motor to control the shading system.

6 - Components Specifications

a- Solid State Relay (RE47 → 150 EGP)

- We will use RE47 for 220v ceramic heater as it's more precise, no mechanical parts, fast switching (PWM) and also great for resistive loads.
- Input voltage: 3-32V DC; Output voltage: 24-380V AC.
- Output current: 40A; Working Voltage: 250V, Net Weight: 113g;
- Item size: 6.2 × 4.5 × 2.3cm (L*W*H).

b- Electromagnetic Relay (SLA30 → 100 EGP)

- This relay will be used for the high loads connected to a contactor before the load as AC Motor and AC Fan.
- 30A relay module that takes 5V as input, normally open interface maximum load AC 250V/30A, DV 30V/30A.
- Optical coupling isolation, driving ability is strong, stable performance.
- Item size: 5 × 3.3 × 2.5 cm.

c- DHT22 (200 EGP)

- The operating voltage is 5V.
- The operating current: 0.3mA (measuring) 60uA (standby)
- The output signal is digital data.
- It's mounted on a PCB module with a pull-up resistor and decoupling capacitor.
- The output format is 40-bit digital data (16-bit humidity + 16-bit temperature + checksum).
- Operating Range is -40 °C to 80 °C, 0-100% RH.
- Accuracy is ± 0.5°C, ± 2%RH.
- Item Size: 1.4 × 1.8 × 0.55 cm.

d- MH-Z19B (around 1000EGP)

- The operating voltage is 4.5V ~ 5.5V.
- The output signal is UART (TTL interface level 3.3V) OR PWM.
- The digital output voltage is 0 – 5V.
- Operating range is 0~5000 ppm.
- Accuracy is ± (50 ppm + 3% reading value).
- Note MQ-135 is cheap but not recommended for CO_2 , it's used to detect the air quality in general which may not be suitable for a big scale greenhouse.

e- TSL2561 (around 800 EGP)

- This sensor represents a cutting-edge digital light senor, suitable for diverse lighting conditions, integrates both infrared and full spectrum diodes.
- Power Supply: 5Vdc.
- Data range: 0.1~40000 LUX.
- Typical accuracy: ±10-15%.
- Resolution: up to 0.1 LUX.
- Note BH1750 is cheaper and covers wider range of light (1~65535 LUX.) but it's less accurate and can't separate IR and visible light.

7 - Control Modes

To select manual or automatic mode, we need to use SPDTs (6A 125VAC).

The switching scheme allows:

a- A single global SPDT switch to determine the operating mode (Automatic vs. Manual).

b- Three actuator-specific SPDT switches to enable manual override of the fan, motor, and heater.

c- All logic-level signals from the switches to be processed by the ESP32, ensuring safe, low-voltage control while maintaining user-friendly operation.

8 - Status Indicators

a- Power/Start LED (Green): Indicates that the ESP32 board is powered and running.

b- Error LED (Red): Signals system fault or abnormal operation.

c- Alarm LED (Yellow/Orange): Activates when environmental thresholds (e.g., high temperature, CO_2, etc.) are exceeded.

9 - Components Abstract

a- ESP32-WROOM-32D.

b- 2 SSR for Ceramic Heaters.

c- 8 Electromagnetic Relays for Loads.

d- (Temperature & Humidity – CO_2 – Lighting) Sensor.

e- 4 SPDT switches.

f- 3 LEDs for each actuator.

g- 3 Indicator LEDs.

10 - Power System Design

The PCB requires a stable power distribution network to support low-voltage control circuits and high-voltage actuator driving. The power system includes:

a- Primary Power Source: 220V AC mains input.

b- Step-down Conversion:

- 220V AC to 12V DC power supply module for relays, contactors, and actuators requiring 12V.
- 12V to 5V DC buck converter to power sensors such as DHT22, MH-Z19B, and TSL2561.
- 12V to 3.3V Low Dropout Regulator (LDO) or DC-DC buck converter to supply the ESP32-WROOM-32D.

c- Isolation and Protection:

- Fuses and circuit breakers for overcurrent protection.
- Optocouplers for isolation between ESP32 GPIOs and relays/SSR.
- Decoupling capacitors placed near microcontroller and sensor power lines to reduce noise.

d- Reboot and Reset Controls:

- A dedicated reset push-button for the ESP32 to allow system restart without cutting power.
- A reboot button used with reset to put ESP32 in programming mode.