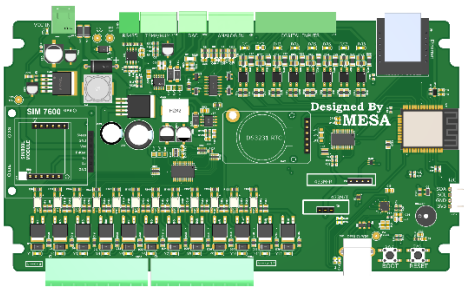
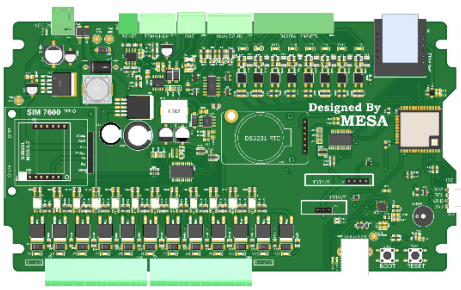
CORTEX LINK A8F-M

TECHNICAL USER MANUAL





Designed and Manufactured by MESA
Microcode Embedded Systems and Automation

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1. INTRODUCTION

1.1 Product Overview

The Cortex Link A8F-M ESP32 is a high-performance IoT controller board designed for versatile automation applications in both residential and industrial environments. Built around the powerful ESP32 dual-core processor, this controller offers extensive I/O capabilities, multiple communication interfaces, and seamless integration with popular development platforms.

1.2 Key Features

- **Powerful Processing**: ESP32 dual-core 32-bit processor @ 240MHz with 8MB flash memory
- **Extensive I/O**: 16 MOSFET outputs, 8 digital inputs, 4 analog inputs, 2 analog outputs
- **Versatile Connectivity**: Wi-Fi, Bluetooth, Ethernet, RS485/Modbus, optional GSM
- **Expansion Capability**: I2C interface, 1-Wire support, RF transmitter/receiver options
- **Integration-Ready**: Compatible with Arduino IDE, ESPHome, Home Assistant, MicroPython
- **Industrial-Grade Design**: Operating temperature -40°C to +85°C, CE certified, RoHS compliant

1.3 Applications

- **Smart Home Automation**: Lighting control, HVAC management, security systems
- **Industrial Control**: Equipment monitoring, process automation, data collection
- **IoT Solutions**: Remote monitoring, telemetry, sensor networks
- **Building Management**: Energy optimization, environmental control, access systems

1.4 Package Contents

- 1 × Cortex Link A8F-M ESP32 Board
- 1 × USB Cable (Type B)
- User Manual (digital download)

1.5 Product Availability

This product can be manufactured in any quantity upon request. For inquiries, bulk orders, or customization options, contact MESA directly via email or through our website.

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2. GETTING STARTED

2.1 Initial Setup

1. **Unbox and Inspect**: Carefully remove the board from packaging and inspect for any shipping damage
2. **Mount the Board**: Secure the board in its intended location using the mounting holes
3. **Connect Power**: Apply 9-12V DC to the power input terminals (observe polarity)
4. **Establish Communication**: Connect to the board via USB, Ethernet, or Wi-Fi

2.2 First-Time Configuration

2.2.1 USB Connection

1. Connect the USB cable to the board's USB-B port and your computer
2. Install appropriate USB drivers if needed
3. Open your serial terminal application (115200 baud, 8N1)
4. Press the RESET button to verify communication

2.2.2 Network Configuration

The default network configuration depends on your programming method:

For Arduino IDE projects:

- Upload a sketch that configures Wi-Fi credentials
- Monitor the serial output for the assigned IP address

For ESPHome projects:

- Configure network settings in the YAML file
- Upload the configuration via USB
- The device will connect to the specified network

2.3 Quick Test Procedure

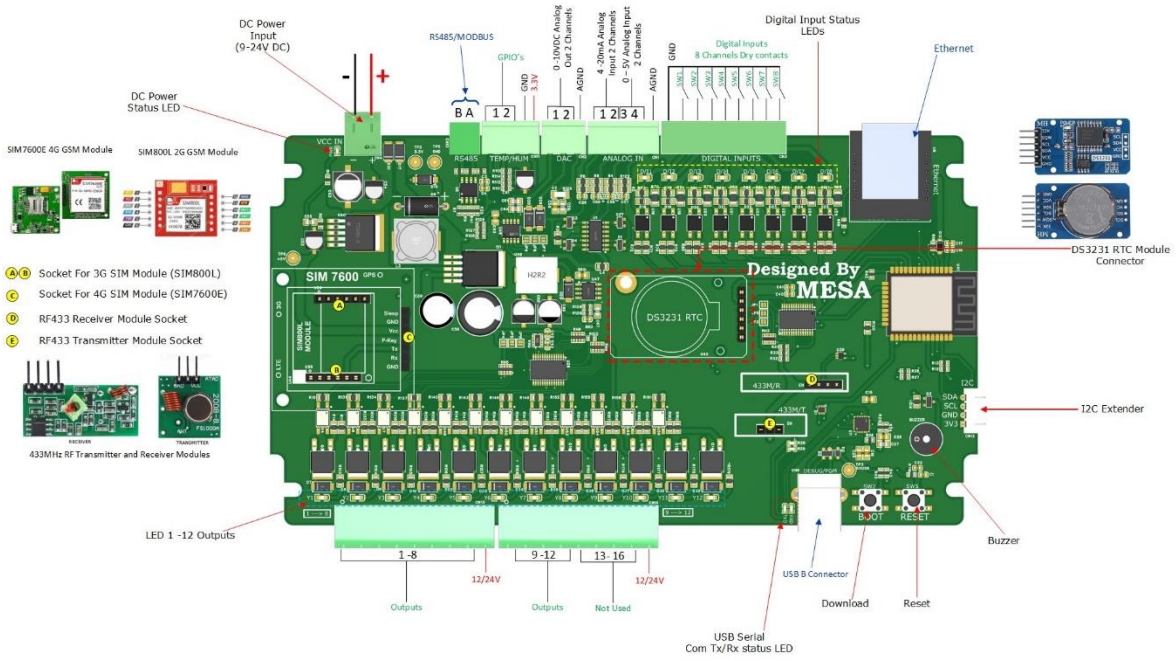
To verify your board is functioning correctly:

1. **Power Test**: Confirm the power LED illuminates when powered
2. **Communication Test**: Establish serial communication via USB
3. **I/O Test**: Run a basic test sketch to verify inputs and outputs
4. **Network Test**: Confirm connectivity via Wi-Fi or Ethernet

3. HARDWARE OVERVIEW

3.1 Board Layout

The Cortex Link A8F-M ESP32 board is organized into functional sections:



1. **Power Section**: Power input terminals and regulation circuitry
2. **Communication Interfaces**: RS485, Ethernet, GSM socket, RF module sockets
3. **Digital Input Section**: 8 optically isolated inputs with status LEDs
4. **Analog Input Section**: 4-20mA and 0-5V analog input terminals
5. **Output Section**: 16 MOSFET output channels with status LEDs
6. **ESP32 Module**: Main microcontroller with supporting components
7. **Programming Interface**: USB connector and programming buttons
8. **Expansion Interfaces**: I2C, 1-Wire, temperature/humidity sensor connections

3.2 Indicator LEDs

The board features multiple status LEDs:

- **Power LED**: Indicates power supply is connected and functional

- **Digital Input LEDs**: Show the status of each digital input
- **Output Status LEDs**: Indicate which outputs are active
- **Communication LEDs**: Display activity on communication interfaces
- **Status LEDs**: Show system status and programming mode

3.3 Connectors and Terminals

Connector	Description	Location
CN1	Analog Input Terminal Block (4-20mA & 0-5V)	Center-top of board
CN2	Analog Output Terminal Block (0-10V)	Center-top of board
CN3	Digital Input Terminal Block	Upper-right section
CN11	Temperature/Humidity Sensor Connection	Upper-middle section
RS485	Modbus RTU Communication Terminal	Upper-left section
Ethernet	RJ45 Network Connection	Right side
USB-B	Programming and Debug Interface	Bottom-right corner
Output Terminals	MOSFET Output Connections (1-16)	Bottom section
Power Input	9-12V DC Power Connection	Upper-left corner

3.4 Control Buttons

- **RESET**: Restarts the ESP32 microcontroller
- **BOOT**: Used to enter programming mode (hold while pressing RESET)

4. POWER REQUIREMENTS

4.1 Power Supply Specifications

- **Input Voltage**: 9V-12V DC
- **Current Requirements**:
    - Idle: ~100mA
    - All outputs active: ~1A (plus connected load current)
- **Power Connector**: 2-pin terminal block (observe polarity)
- **Protection**: Reverse polarity protection, overvoltage protection

4.2 Power Distribution

The board features multiple power rails:

- **12V Rail**: Powers the MOSFET outputs and analog circuitry
- **5V Rail**: Logic voltage for various components
- **3.3V Rail**: ESP32 and digital logic components

4.3 MOSFET Output Power

- **Output Voltage**: Follows the input power supply (9-12V typical, 24V maximum)
- **Current Rating**: 500mA per channel maximum
- **Isolation**: Outputs are isolated from microcontroller logic

4.4 Power Considerations

- Use a regulated power supply with sufficient current capacity
- Keep power wiring separate from signal wiring to reduce interference
- For high-power applications, consider additional external power distribution

5. INPUT/OUTPUT INTERFACES

5.1 Digital Inputs

The board features 8 optically isolated digital inputs:

- **Input Type**: Dry N/O (normally open) contacts
- **Isolation**: Optical isolation for noise immunity and ground fault protection
- **Indication**: LED status indicator for each input
- **Terminal**: CN3 terminal block
- **Addressing**: Controlled via MCP23017 I/O expander (U8)

5.1.1 Digital Input Wiring

Connect dry contact switches or sensors as follows:

1. Connect one side of the contact to the input terminal
2. Connect the other side to the GND terminal
3. When the contact closes, the input activates (active low)

5.2 Analog Inputs

The board provides 4 analog input channels:

- **Channels 1-2**: 4-20mA current loop inputs
- **Channels 3-4**: 0-5V voltage inputs
- **Resolution**: 12-bit ADC (4096 steps)
- **Terminal**: CN1 terminal block
- **Direct Connection**: These inputs connect directly to the ESP32 ADC pins

5.2.1 Analog Input Wiring

For 4-20mA sensors:

1. Connect the positive lead to the appropriate input terminal
2. Connect the negative lead to the corresponding GND terminal
3. Ensure the sensor is powered appropriately

For 0-5V sensors:

1. Connect the sensor output to the appropriate input terminal

2. Connect the sensor ground to the GND terminal
3. Keep cable lengths short to minimize noise

5.3 MOSFET Outputs

The board features 16 MOSFET output channels:

- **Output Type**: N-channel MOSFET low-side switch
- **Voltage Rating**: 12/24V DC maximum
- **Current Rating**: 500mA per channel
- **Control**: Via MCP23017 I/O expanders (U26)
- **Status**: LED indicators for each output

5.3.1 MOSFET Output Wiring

1. Connect the positive side of the load to the positive power supply
2. Connect the negative side of the load to the desired output terminal
3. The output activates the load by connecting it to ground

For inductive loads (relays, solenoids, motors):

- Use external flyback diodes to protect the MOSFET outputs
- Consider using external relays for higher current loads

5.4 Analog Outputs

The board provides 2 analog output channels:

- **Output Range**: 0-10V DC
- **Resolution**: 12-bit DAC
- **Control**: Via GP8413 DAC (U46)
- **Terminal**: CN2 terminal block

5.4.1 Analog Output Wiring

1. Connect the VOUT terminal to the controlled device's input
2. Connect the GND terminal to the controlled device's ground
3. Keep cable lengths short and use shielded cable for noise-sensitive applications

6. COMMUNICATION INTERFACES

6.1 Wi-Fi

The ESP32 includes integrated Wi-Fi capabilities:

- **Standard**: IEEE 802.11 b/g/n
- **Frequency**: 2.4 GHz
- **Security**: WPA/WPA2/WPA3
- **Modes**: Station mode, Access Point mode, or both
- **Antenna**: Internal PCB antenna with option for external antenna

6.1.1 Wi-Fi Configuration

Arduino IDE Example:

```
#include <WiFi.h>

const char* ssid = "YourNetworkName";
const char* password = "YourPassword";

void setup() {
 Serial.begin(115200);

 WiFi.begin(ssid, password);

 while (WiFi.status() != WL_CONNECTED) {
  delay(500);
  Serial.print(".");
 }

 Serial.println("");
 Serial.println("WiFi connected");
```

```
  Serial.println("IP address: " + WiFi.localIP().toString());
}
```

ESPHome Example:

```
wifi:
  ssid: "YourNetworkName"
  password: "YourPassword"

  # Optional fallback AP
  ap:
    ssid: "CortexLink Fallback AP"
    password: "fallbackpassword"
```

6.2 Ethernet

The board includes a W5500-based Ethernet interface:

- **Connector**: RJ45
- **Speed**: 10/100 Mbps
- **Configuration**: Automatic via DHCP or static IP
- **Control**: SPI interface from ESP32

6.2.1 Ethernet Configuration

```
#include <SPI.h>
#include <Ethernet.h>

byte mac[] = { 0xDE, 0xAD, 0xBE, 0xEF, 0xFE, 0xED };

void setup() {
  Serial.begin(115200);
  Serial.println("Initializing Ethernet...");
```

```
  Ethernet.init(5);  // CS pin connected to GPIO5

  if (Ethernet.begin(mac) == 0) {
    Serial.println("Failed to configure Ethernet using DHCP");
    // Try to configure using static IP if DHCP failed
    IPAddress ip(192, 168, 1, 177);
    IPAddress gateway(192, 168, 1, 1);
    IPAddress subnet(255, 255, 255, 0);
    IPAddress dns(8, 8, 8, 8);
    Ethernet.begin(mac, ip, dns, gateway, subnet);
  }

  Serial.print("IP address: ");
  Serial.println(Ethernet.localIP());
}
```

6.3 RS485/Modbus RTU

The board includes an RS485 interface for Modbus RTU communication:

- **Interface**: Half-duplex RS485
- **Controller**: MAX485 transceiver
- **Connections**: Terminal block with A, B terminals
- **Control**: DE/RE control via ESP32 GPIO27

6.3.1 RS485/Modbus Configuration

```
#include <ModbusMaster.h>

#define MAX485_DE 27
#define MAX485_RE 27
#define RX_PIN 16
#define TX_PIN 17

ModbusMaster node;

void preTransmission() {
  digitalWrite(MAX485_DE, 1);
  digitalWrite(MAX485_RE, 1);
}

void postTransmission() {
  digitalWrite(MAX485_DE, 0);
  digitalWrite(MAX485_RE, 0);
}
```

```
void setup() {
  pinMode(MAX485_DE, OUTPUT);
  pinMode(MAX485_RE, OUTPUT);
  digitalWrite(MAX485_DE, 0);
  digitalWrite(MAX485_RE, 0);

  Serial2.begin(9600, SERIAL_8N1, RX_PIN, TX_PIN);

  node.begin(1, Serial2);
  node.preTransmission(preTransmission);
  node.postTransmission(postTransmission);
}

void loop() {
  // Read 10 registers starting at 0x00
  uint8_t result = node.readHoldingRegisters(0x00, 10);

  if (result == node.ku8MBSuccess) {
    Serial.println("Read successful");
    for (int i = 0; i < 10; i++) {
      Serial.print("Register ");
      Serial.print(i);
      Serial.print(": ");
      Serial.println(node.getResponseBuffer(i));
    }
  }
  delay(1000);
}
```

6.4 Bluetooth

The ESP32 includes integrated Bluetooth capabilities:

- **Version**: Bluetooth 4.2 BR/EDR and BLE (Bluetooth Low Energy)
- **Applications**: Configuration, control, data transfer
- **Range**: Approximately 10 meters (33 feet)

6.5 GSM (Optional)

The board provides sockets for optional GSM modules:

- **Module Options**:
    - SIM800L (2G GSM/GPRS) - Socket A
    - SIM7600E (4G LTE) - Socket C
- **Connections**: Dedicated TX/RX pins to ESP32
- **Control**: Power and reset control via GPIO pins

6.5.1 GSM Module Setup

1. Insert the appropriate SIM module into the designated socket
2. Install an activated SIM card with data plan
3. Connect the GSM antenna to the module
4. Configure the module with your cellular provider's APN settings

6.5.2 GSM Code Example

```
#include <TinyGSM.h>

#define TINY_GSM_MODEM_SIM800
#define SerialAT Serial1

const char* apn = "internet";  // Your provider's APN
const char* user = "";       // APN username (if required)
const char* pass = "";       // APN password (if required)
```

```
TinyGsm modem(SerialAT);

void setup() {
 Serial.begin(115200);
 SerialAT.begin(115200, SERIAL_8N1, 26, 25);  // RX=GPIO26, TX=GPIO25

 Serial.println("Initializing modem...");
 modem.restart();

 String modemInfo = modem.getModemInfo();
 Serial.print("Modem: ");
 Serial.println(modemInfo);

 Serial.print("Waiting for network...");
 if (!modem.waitForNetwork()) {
  Serial.println(" fail");
  return;
 }
 Serial.println(" OK");

 Serial.print("Connecting to ");
 Serial.print(apn);
 if (!modem.gprsConnect(apn, user, pass)) {
  Serial.println(" fail");
  return;
 }
 Serial.println(" OK");
```

```
  Serial.print("GPRS status: ");
  Serial.println(modem.isGprsConnected() ? "connected" : "not connected");

  Serial.print("Signal quality: ");
  Serial.println(modem.getSignalQuality());
}
```

6.6 RF 433MHz

The board includes sockets for RF 433MHz communication:

- **Transmitter Socket**: Marked "E" on the board
- **Receiver Socket**: Marked "D" on the board
- **Control**: Dedicated GPIO pins for TX and RX
- **Applications**: Remote control, sensor communication, home automation

6.6.1 RF Module Code Example

```
#include <RCSwitch.h>

#define RF_TX_PIN 32
#define RF_RX_PIN 33

RCSwitch rfSwitch = RCSwitch();

void setup() {
  Serial.begin(115200);

  // Configure transmitter
  rfSwitch.enableTransmit(RF_TX_PIN);
```

```
  // Configure receiver
  rfSwitch.enableReceive(RF_RX_PIN);

  Serial.println("RF 433MHz initialized");
}

void loop() {
  // Transmit example
  rfSwitch.send(12345, 24);  // Send value "12345" with 24 bit protocol
  Serial.println("Transmitted: 12345");
  delay(1000);

  // Receive example
  if (rfSwitch.available()) {
    unsigned long value = rfSwitch.getReceivedValue();
    Serial.print("Received: ");
    Serial.println(value);
    rfSwitch.resetAvailable();
  }

  delay(1000);
}
```

---

7. PROGRAMMING & DEVELOPMENT

7.1 Development Environment Setup

7.1.1 Arduino IDE

1. **Install Arduino IDE**: Download from arduino.cc
2. **Add ESP32 Board Support**:
    - Go to File > Preferences
    - Add https://dl.espressif.com/dl/package_esp32_index.json to "Additional Boards Manager URLs"
    - Go to Tools > Board > Boards Manager
    - Search for "ESP32" and install the package
3. **Select Board Configuration**:
    - Board: "ESP32 Dev Module"
    - Upload Speed: 921600
    - Flash Frequency: 80MHz
    - Flash Mode: QIO
    - Flash Size: 8MB
    - Partition Scheme: Default 4MB with spiffs
4. **Install Required Libraries**:
    - Adafruit MCP23017 Arduino Library
    - ModbusMaster
    - RCSwitch
    - Other libraries as needed for your project

7.1.2 ESPHome

1. **Install ESPHome**:
2. pip install esphome
3. **Create Basic Configuration**: Create a YAML file with your device configuration
4. **Compile and Upload**:

5. esphome run your_config.yaml

7.1.3 PlatformIO

1. **Install Visual Studio Code**: Download from code.visualstudio.com
2. **Install PlatformIO Extension**: Search for "PlatformIO" in the Extensions marketplace
3. **Create New Project**:
    - Select ESP32 platform
    - Choose appropriate board (ESP32 Dev Module)
    - Configure framework (Arduino or ESP-IDF)

7.2 Programming Methods

7.2.1 USB Programming

1. Connect the USB cable to the board's USB-B port
2. Hold the BOOT button while pressing the RESET button to enter programming mode
3. Release both buttons
4. Select the correct COM port in your development environment
5. Upload your code

7.2.2 Over-the-Air (OTA) Programming

After initial setup via USB, you can program the board wirelessly:

Arduino OTA Example:

```
#include <WiFi.h>
#include <ArduinoOTA.h>

const char* ssid = "YourNetworkName";
const char* password = "YourPassword";

void setup() {
  Serial.begin(115200);
  WiFi.begin(ssid, password);
```

```
while (WiFi.status() != WL_CONNECTED) {
  delay(500);
  Serial.print(".");
}

ArduinoOTA.setHostname("cortexlink");
ArduinoOTA.setPassword("otapassword");

ArduinoOTA.onStart([]() {
  Serial.println("OTA update starting");
});

ArduinoOTA.onEnd([]() {
  Serial.println("OTA update complete");
});

ArduinoOTA.onError([](ota_error_t error) {
  Serial.printf("OTA Error[%u]: ", error);
  if (error == OTA_AUTH_ERROR) Serial.println("Auth Failed");
  else if (error == OTA_BEGIN_ERROR) Serial.println("Begin Failed");
  else if (error == OTA_CONNECT_ERROR) Serial.println("Connect Failed");
  else if (error == OTA_RECEIVE_ERROR) Serial.println("Receive Failed");
  else if (error == OTA_END_ERROR) Serial.println("End Failed");
});

ArduinoOTA.begin();
Serial.println("OTA ready");
```

```
}

void loop() {
  ArduinoOTA.handle();
  // Your code here
}
```

ESPHome OTA: Simply include the OTA component in your YAML:

```
ota:
  password: "otapassword"
```

7.3 Home Assistant Integration

7.3.1 ESPHome Integration

1. Build your configuration with ESPHome
2. Include the API component:
3. api: password: "your_api_password"
4. Flash the device
5. In Home Assistant, go to Configuration > Integrations
6. Click "+" and select "ESPHome"
7. Enter the device's IP address and API password

7.3.2 MQTT Integration

1. Configure the device to connect to your MQTT broker:
2. #include <WiFi.h>
3. #include <PubSubClient.h>
4.
5. WiFiClient espClient;
6. PubSubClient client(espClient);
7.
8. void setup() {

```
9.    // Connect to Wi-Fi (code omitted)
10.
11.  client.setServer("192.168.1.100", 1883);
12.  client.setCallback(callback);
13. }
14.
15. void loop() {
16.  if (!client.connected()) {
17.    reconnect();
18.  }
19.  client.loop();
20.
21.  // Publish data
22.  client.publish("home/sensor/temperature", "23.5");
23. }
24.
25. void callback(char* topic, byte* payload, unsigned int length) {
26.  // Handle incoming messages
27. }
28.
29. void reconnect() {
30.  while (!client.connected()) {
31.    if (client.connect("CortexLinkClient")) {
32.      client.subscribe("home/control/#");
33.    } else {
34.      delay(5000);
35.    }
36.  }
```

37. }
38. In Home Assistant, configure MQTT entities:
39. sensor:
40. - platform: mqtt
41. name: "Living Room Temperature"
42. state_topic: "home/sensor/temperature"
43. unit_of_measurement: "°C"

7.4 MicroPython Support

The Cortex Link A8F-M ESP32 supports MicroPython:

1. **Flash MicroPython Firmware**:
2. esptool.py --port COM3 erase_flash
3. esptool.py --port COM3 --baud 460800 write_flash -z 0x1000 esp32-20220117-v1.18.bin
4. **Upload MicroPython Scripts**: Use tools like Thonny IDE, rshell, or ampy to upload scripts
5. **MicroPython I/O Example**:
6. from machine import Pin, I2C
7. import time
8.
9. # Initialize I2C
10. i2c = I2C(0, scl=Pin(22), sda=Pin(21), freq=100000)
11.
12. # Scan for I2C devices
13. devices = i2c.scan()
14. print("I2C devices found:", [hex(device) for device in devices])
15.
16. # Example using onboard LED
17. led = Pin(2, Pin.OUT)

18.

19. while True:

20. led.value(1)

21. time.sleep(0.5)

22. led.value(0)

23. time.sleep(0.5)

---

8. INTEGRATION EXAMPLES

8.1 Smart Home Automation

8.1.1 Home Assistant Integration with ESPHome

```
# ESPHome configuration for smart home control
esphome:
  name: cortexlink
  platform: ESP32
  board: esp32dev

wifi:
  ssid: "YourWiFiSSID"
  password: "YourWiFiPassword"

api:
  password: "your_api_password"

ota:
  password: "your_ota_password"

i2c:
  sda: 21
  scl: 22
  scan: true

# Input configuration
mcp23017:
  - id: input_expander
```

```
    address: 0x21
  - id: output_expander
    address: 0x20

binary_sensor:
  - platform: gpio
    pin:
      mcp23017: input_expander
      number: 0
      inverted: true
    name: "Motion Sensor"
    device_class: motion

  - platform: gpio
    pin:
      mcp23017: input_expander
      number: 1
      inverted: true
    name: "Door Sensor"
    device_class: door

# Output configuration
switch:
  - platform: gpio
    pin:
      mcp23017: output_expander
      number: 0
    name: "Living Room Lights"
```

```
 - platform: gpio
   pin:
    mcp23017: output_expander
    number: 1
   name: "Kitchen Lights"

# Analog sensors
sensor:
 - platform: adc
   pin: GPIO36
   name: "Living Room Temperature"
   update_interval: 60s
   filters:
    - lambda: return (x * 3.3 / 4095.0) * 100.0;
   unit_of_measurement: "°C"
   accuracy_decimals: 1
```

8.1.2 Smart Lighting Control System

Arduino Code:

```
#include <WiFi.h>
#include <PubSubClient.h>
#include <Wire.h>
#include <Adafruit_MCP23017.h>

// Network and MQTT settings
const char* ssid = "YourWiFiSSID";
const char* password = "YourWiFiPassword";
```

```
const char* mqtt_server = "192.168.1.100";

// I/O setup
Adafruit_MCP23017 outputExpander;
Adafruit_MCP23017 inputExpander;

WiFiClient espClient;
PubSubClient client(espClient);

// Input and output mappings
const uint8_t MOTION_SENSOR_1 = 0;
const uint8_t MOTION_SENSOR_2 = 1;
const uint8_t LIGHT_SWITCH_1 = 2;
const uint8_t LIGHT_SWITCH_2 = 3;

const uint8_t LIGHT_OUTPUT_1 = 0;
const uint8_t LIGHT_OUTPUT_2 = 1;
const uint8_t LIGHT_OUTPUT_3 = 2;

// Timing variables
unsigned long lastMotionTime = 0;
const unsigned long AUTO_OFF_DELAY = 300000; // 5 minutes

void setup() {
  Serial.begin(115200);

  // Initialize I/O expanders
  Wire.begin();
```

```
 outputExpander.begin(0x20);
 inputExpander.begin(0x21);

 // Configure inputs and outputs
 for (uint8_t i = 0; i < 8; i++) {
  inputExpander.pinMode(i, INPUT);
  inputExpander.pullUp(i, HIGH);
 }

 for (uint8_t i = 0; i < 8; i++) {
  outputExpander.pinMode(i, OUTPUT);
  outputExpander.digitalWrite(i, LOW);
 }

 // Connect to Wi-Fi
 WiFi.begin(ssid, password);

 while (WiFi.status() != WL_CONNECTED) {
  delay(500);
 }

 // Connect to MQTT
 client.setServer(mqtt_server, 1883);
 client.setCallback(callback);
}

void callback(char* topic, byte* payload, unsigned int length) {
```

```
 String message = "";
 for (int i = 0; i < length; i++) {
  message += (char)payload[i];
 }

 // Handle light control commands
 if (String(topic) == "home/lights/living") {
  if (message == "ON") {
   outputExpander.digitalWrite(LIGHT_OUTPUT_1, HIGH);
   client.publish("home/lights/living/status", "ON");
  } else if (message == "OFF") {
   outputExpander.digitalWrite(LIGHT_OUTPUT_1, LOW);
   client.publish("home/lights/living/status", "OFF");
  }
 }
 // Add more topics as needed
}

void reconnect() {
 while (!client.connected()) {
  if (client.connect("CortexLinkClient")) {
   // Subscribe to control topics
   client.subscribe("home/lights/#");
   client.subscribe("home/system/#");
  } else {
   delay(5000);
  }
 }
```

```
}

void loop() {
 if (!client.connected()) {
  reconnect();
 }
 client.loop();

 // Check motion sensors
 bool motion1 = !inputExpander.digitalRead(MOTION_SENSOR_1);
 bool motion2 = !inputExpander.digitalRead(MOTION_SENSOR_2);

 if (motion1 || motion2) {
  // Motion detected
  lastMotionTime = millis();

  // Turn on lights if they're not already on
  if (outputExpander.digitalRead(LIGHT_OUTPUT_1) == LOW) {
   outputExpander.digitalWrite(LIGHT_OUTPUT_1, HIGH);
   client.publish("home/lights/living/status", "ON");
  }
 } else if (millis() - lastMotionTime > AUTO_OFF_DELAY) {
  // No motion for delay period, turn off lights
  outputExpander.digitalWrite(LIGHT_OUTPUT_1, LOW);
  client.publish("home/lights/living/status", "OFF");
 }

 // Check manual switches
```

```
 static bool prevSwitch1 = false;
 bool switch1 = !inputExpander.digitalRead(LIGHT_SWITCH_1);

 if (switch1 != prevSwitch1) {
  if (switch1) {
   // Toggle light state
   bool currentState = outputExpander.digitalRead(LIGHT_OUTPUT_1);
   outputExpander.digitalWrite(LIGHT_OUTPUT_1, !currentState);
   client.publish("home/lights/living/status", !currentState ? "ON" : "OFF");
  }
  prevSwitch1 = switch1;
 }

 delay(100);
}
```

8.2 Industrial Monitoring

8.2.1 Production Line Monitoring System

```
#include <WiFi.h>
#include <PubSubClient.h>
#include <Wire.h>
#include <Adafruit_MCP23017.h>
#include <ModbusMaster.h>

// Network settings
const char* ssid = "Factory_Network";
const char* password = "SecurePassword";
const char* mqtt_server = "192.168.10.50";
```

```
// Modbus settings
#define MAX485_DE 27
#define MAX485_RE 27
#define RS485_SERIAL Serial2

ModbusMaster modbus;
Adafruit_MCP23017 ioExpander;

// Sensor mappings
const uint8_t EMERGENCY_STOP = 0;
const uint8_t MACHINE_RUNNING = 1;
const uint8_t FAULT_INDICATOR = 2;

// Output mappings
const uint8_t WARNING_LIGHT = 0;
const uint8_t ALARM_BUZZER = 1;

// Modbus device addresses
const uint8_t TEMPERATURE_CONTROLLER = 1;
const uint8_t FLOW_METER = 2;
const uint8_t PRESSURE_SENSOR = 3;

// Analog input scaling
float scaleCurrentInput(uint16_t raw) {
  // Scale 4-20mA input to engineering units
  // Example for temperature range 0-100°C
  return (raw / 4095.0) * 16.0 + 4.0; // Convert to mA
  float percent = (mA - 4.0) / 16.0;  // Convert to percentage
```

```
  return percent * 100.0;          // Scale to temperature
}

void preTransmission() {
  digitalWrite(MAX485_DE, HIGH);
  digitalWrite(MAX485_RE, HIGH);
}

void postTransmission() {
  digitalWrite(MAX485_DE, LOW);
  digitalWrite(MAX485_RE, LOW);
}

void setup() {
  Serial.begin(115200);

  // Initialize I/O
  Wire.begin();
  ioExpander.begin(0x20);

  // Configure digital I/O
  for (uint8_t i = 0; i < 8; i++) {
    ioExpander.pinMode(i, INPUT);
    ioExpander.pullUp(i, HIGH);
  }

  for (uint8_t i = 0; i < 8; i++) {
    ioExpander.pinMode(i + 8, OUTPUT);
```

```
  ioExpander.digitalWrite(i + 8, LOW);
 }

 // Initialize RS485
 pinMode(MAX485_DE, OUTPUT);
 pinMode(MAX485_RE, OUTPUT);
 digitalWrite(MAX485_DE, LOW);
 digitalWrite(MAX485_RE, LOW);

 RS485_SERIAL.begin(9600, SERIAL_8N1, 16, 17);

 modbus.begin(1, RS485_SERIAL);
 modbus.preTransmission(preTransmission);
 modbus.postTransmission(postTransmission);

 // Connect to Wi-Fi
 WiFi.begin(ssid, password);

 // Connect to MQTT
 client.setServer(mqtt_server, 1883);
}

void loop() {
 // Ensure MQTT connection
 if (!client.connected()) {
  reconnectMQTT();
 }
 client.loop();
```

```
// Check digital inputs
bool emergencyStop = !ioExpander.digitalRead(EMERGENCY_STOP);
bool machineRunning = !ioExpander.digitalRead(MACHINE_RUNNING);
bool faultCondition = !ioExpander.digitalRead(FAULT_INDICATOR);

// Read temperature from Modbus device
uint8_t result = modbus.readHoldingRegisters(0x00, 2);
float temperature = 0;

if (result == modbus.ku8MBSuccess) {
  temperature = modbus.getResponseBuffer(0) / 10.0;
  client.publish("factory/line1/temperature", String(temperature).c_str());
}

// Read analog inputs
uint16_t pressureRaw = analogRead(34); // 4-20mA input
float pressure = scaleCurrentInput(pressureRaw);
client.publish("factory/line1/pressure", String(pressure).c_str());

// Process machine state
if (emergencyStop) {
  ioExpander.digitalWrite(WARNING_LIGHT, HIGH);
  ioExpander.digitalWrite(ALARM_BUZZER, HIGH);
  client.publish("factory/line1/status", "EMERGENCY_STOP");
} else if (faultCondition) {
  ioExpander.digitalWrite(WARNING_LIGHT, HIGH);
  ioExpander.digitalWrite(ALARM_BUZZER, machineRunning);
```

```
    client.publish("factory/line1/status", "FAULT");
  } else if (machineRunning) {
    ioExpander.digitalWrite(WARNING_LIGHT, LOW);
    ioExpander.digitalWrite(ALARM_BUZZER, LOW);
    client.publish("factory/line1/status", "RUNNING");
  } else {
    ioExpander.digitalWrite(WARNING_LIGHT, LOW);
    ioExpander.digitalWrite(ALARM_BUZZER, LOW);
    client.publish("factory/line1/status", "STOPPED");
  }

  // Temperature alarm
  if (temperature > 85.0) {
    ioExpander.digitalWrite(WARNING_LIGHT, HIGH);
    client.publish("factory/line1/alarm", "TEMPERATURE_HIGH");
  }

  delay(1000);
}

void reconnectMQTT() {
  while (!client.connected()) {
    if (client.connect("FactoryController")) {
      client.subscribe("factory/line1/commands");
    } else {
      delay(5000);
    }
  }
```

}

8.3 Remote Monitoring with GSM

```
#include <TinyGSM.h>
#include <Wire.h>
#include <Adafruit_MCP23017.h>

// Define modem type
#define TINY_GSM_MODEM_SIM800
#define SerialAT Serial1

// APN settings
const char* apn = "internet";
const char* user = "";
const char* pass = "";

// Server details
const char* server = "example.com";
const int port = 80;

TinyGsm modem(SerialAT);
TinyGsmClient client(modem);

Adafruit_MCP23017 ioExpander;

// Sensor pins
const int TEMP_SENSOR = 34;  // Analog input
const int LEVEL_SENSOR = 35; // Analog input
const int ALARM_INPUT = 0;   // Digital input on MCP23017
```

```
// Variables for sensor readings
float temperature, level;
bool alarm;

// Last upload time
unsigned long lastUploadTime = 0;
const unsigned long uploadInterval = 900000; // 15 minutes

void setup() {
  Serial.begin(115200);
  SerialAT.begin(115200, SERIAL_8N1, 26, 25); // RX=GPIO26, TX=GPIO25

  // Initialize I/O
  Wire.begin();
  ioExpander.begin(0x21);
  ioExpander.pinMode(ALARM_INPUT, INPUT);
  ioExpander.pullUp(ALARM_INPUT, HIGH);

  // Initialize modem
  Serial.println("Initializing modem...");
  modem.restart();

  String modemInfo = modem.getModemInfo();
  Serial.print("Modem: ");
  Serial.println(modemInfo);

  // Connect to mobile network
```

```
  Serial.print("Waiting for network...");
  if (!modem.waitForNetwork()) {
   Serial.println(" fail");
   return;
  }
  Serial.println(" OK");

  Serial.print("Signal quality: ");
  Serial.println(modem.getSignalQuality());

  Serial.print("Connecting to ");
  Serial.print(apn);
  if (!modem.gprsConnect(apn, user, pass)) {
   Serial.println(" fail");
   return;
  }
  Serial.println(" OK");
}

void loop() {
  // Read sensors
  temperature = readTemperature();
  level = readLevel();
  alarm = !ioExpander.digitalRead(ALARM_INPUT);

  // Print data to serial
  Serial.print("Temperature: ");
  Serial.print(temperature);
```

```
  Serial.println(" °C");

  Serial.print("Level: ");
  Serial.print(level);
  Serial.println(" %");

  Serial.print("Alarm: ");
  Serial.println(alarm ? "YES" : "NO");

  // Check if it's time to upload or if there's an alarm
  if (millis() - lastUploadTime > uploadInterval || alarm) {
    uploadData();
    lastUploadTime = millis();
  }

  delay(60000); // Check every minute
}

float readTemperature() {
  // Read 4-20mA temperature sensor
  int rawValue = analogRead(TEMP_SENSOR);
  float mA = (rawValue / 4095.0) * 16.0 + 4.0;

  // Example conversion for a sensor with range -50 to 150°C
  float temperature = ((mA - 4.0) / 16.0) * 200.0 - 50.0;
  return temperature;
}
```

```
float readLevel() {
  // Read 4-20mA level sensor
  int rawValue = analogRead(LEVEL_SENSOR);
  float mA = (rawValue / 4095.0) * 16.0 + 4.0;

  // Example conversion for a 0-100% level sensor
  float level = ((mA - 4.0) / 16.0) * 100.0;
  return level;
}

void uploadData() {
  Serial.println("Connecting to server...");

  if (!client.connect(server, port)) {
    Serial.println("Connection failed");
    return;
  }

  Serial.println("Connected to server");

  // Prepare the data in JSON format
  String data = "{\"device_id\":\"CL001\",\"temperature\":";
  data += String(temperature);
  data += ",\"level\":";
  data += String(level);
  data += ",\"alarm\":";
  data += alarm ? "true" : "false";
  data += "}";
```

```
  // Prepare the HTTP POST request
  String httpRequest = "POST /api/data HTTP/1.1\r\n";
  httpRequest += "Host: ";
  httpRequest += server;
  httpRequest += "\r\n";
  httpRequest += "Content-Type: application/json\r\n";
  httpRequest += "Content-Length: ";
  httpRequest += data.length();
  httpRequest += "\r\n\r\n";
  httpRequest += data;

  // Send the request
  client.print(httpRequest);

  // Wait for the response
  unsigned long timeout = millis();
  while (client.connected() && millis() - timeout < 10000L) {
    while (client.available()) {
      char c = client.read();
      Serial.print(c);
      timeout = millis();
    }
  }

  client.stop();
  Serial.println("\nDisconnected from server");
}
```

9. TROUBLESHOOTING

9.1 Common Issues and Solutions

9.1.1 Power Issues

Issue	Possible Causes	Solutions
Board does not power up	• Incorrect power connection • Insufficient power supply • Blown fuse or protection circuit	• Check power supply polarity • Verify power supply provides 9-12V DC with sufficient current • Check voltage at power input terminals
Power cycles or resets	• Voltage drops under load • Inadequate power supply • Short circuit in attached devices	• Use higher current power supply • Check for shorts in output connections • Monitor voltage under load

9.1.2 Communication Issues

Issue	Possible Causes	Solutions
Cannot connect via Wi-Fi	• Incorrect credentials • Wi-Fi signal issues • Network configuration problems	• Verify SSID and password • Check Wi-Fi signal strength • Try moving the device closer to router
No Ethernet connection	• Cable issues • Network configuration • W5500 module problems	• Try different Ethernet cable • Verify network settings

Issue	Possible Causes	Solutions
		• Check Ethernet LEDs for activity
RS485 communication fails	• Wiring issues • Incorrect settings • Termination problems	• Verify A/B terminal connections • Check baud rate and format settings • Add termination resistor if needed
GSM module not responding	• SIM card issues • Signal problems • APN configuration	• Verify SIM card is active • Check signal strength • Confirm APN settings

9.1.3 I/O Issues

Issue	Possible Causes	Solutions
Digital inputs not working	• Incorrect wiring • I2C address issues • Software configuration	• Verify input connections • Check MCP23017 address settings • Confirm pull-up resistor configuration
MOSFET outputs not switching	• Incorrect wiring • Load exceeds rating • I2C communication issue	• Check output connections • Verify load is within 500mA limit • Test I2C communication with I2C scanner
Analog inputs reading incorrect values	• Sensor wiring issue • Power supply problems	• Verify sensor connections • Check sensor power supply

Issue	Possible Causes	Solutions
	• Calibration needed	• Calibrate input scaling in software
Analog outputs not working	• Incorrect wiring • I2C address issues • Software configuration	• Check output connections • Verify I2C communication with DAC • Test with simple output program

9.2 Diagnostic Tools

9.2.1 I2C Scanner

Use this code to identify I2C devices on the bus:

```
#include <Wire.h>

void setup() {
  Serial.begin(115200);
  Wire.begin();

  Serial.println("I2C Scanner");
}
void loop() {
  byte error, address;
  int devices = 0;

  Serial.println("Scanning...");
for (address = 1; address < 127;
address++) {
   Wire.beginTransmission(address);
   error = Wire.endTransmission();
    if (error == 0) {
    Serial.print("I2C device found at
address 0x");
     if (address < 16)
      Serial.print("0");
     Serial.print(address, HEX);
     Serial.println();

     devices++;
   }
  }

 if (devices == 0)
   Serial.println("No I2C devices found");
   delay(5000);
}
```

9.2.2 GPIO Tester

Use this code to test ESP32 GPIO pins:

```
// Change PIN_TO_TEST to test different pins
#define PIN_TO_TEST 2

void setup() {
 Serial.begin(115200);
 pinMode(PIN_TO_TEST, OUTPUT);
 Serial.print("Testing GPIO ");
 Serial.println(PIN_TO_TEST);
}

void loop() {
 digitalWrite(PIN_TO_TEST, HIGH);
 Serial.println("Pin HIGH");
 delay(1000);

 digitalWrite(PIN_TO_TEST, LOW);
 Serial.println("Pin LOW");
 delay(1000);
}
```

9.2.3 Network Diagnostics

```
#include <WiFi.h>

const char* ssid = "YourNetworkName";
const char* password = "YourPassword";

void setup() {
 Serial.begin(115200);

 Serial.print("Connecting to ");
 Serial.println(ssid);

 WiFi.begin(ssid, password);
 int attempts = 0;
 while (WiFi.status() != WL_CONNECTED && attempts < 20) {
  delay(500);
  Serial.print(".");
  attempts++;
 }

 if (WiFi.status() == WL_CONNECTED) {
  Serial.println("");
  Serial.println("WiFi connected");
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());
```

```
  // Test network connectivity
  testConnectivity();
 } else {
  Serial.println("");
  Serial.println("WiFi connection failed");
  Serial.print("Status code: ");
  Serial.println(WiFi.status());
 }
}

void testConnectivity() {
 Serial.println("Testing network connectivity...");

 // Print connection details
 Serial.print("SSID: ");
 Serial.println(WiFi.SSID());

 Serial.print("Signal strength (RSSI): ");
 Serial.print(WiFi.RSSI());
 Serial.println(" dBm");

 Serial.print("MAC address: ");
 Serial.println(WiFi.macAddress());

 Serial.print("Subnet mask: ");
 Serial.println(WiFi.subnetMask());

 Serial.print("Gateway IP: ");
 Serial.println(WiFi.gatewayIP());

 Serial.print("DNS: ");
 Serial.println(WiFi.dnsIP());
}

void loop() {
 // Nothing in loop
}
```

9.3 LED Indicators

The board provides several LED indicators to help diagnose issues:

- **Power LED**: Indicates power supply is connected. If dim or off, check power supply.
- **Digital Input LEDs**: Illuminate when corresponding input is active. If not lighting when expected, check input wiring.
- **Output Status LEDs**: Indicate active outputs. If LED is on but load not working, check load wiring.
- **Communication LEDs**: Show activity on serial and network interfaces.

9.4 Firmware Recovery

If the board becomes unresponsive or the firmware is corrupted:

1. Connect the board via USB
2. Hold the BOOT button
3. Press and release the RESET button
4. Release the BOOT button
5. The board should now be in download mode
6. Use esptool.py to flash firmware:

```
esptool.py --chip esp32 --port COM3 --baud 921600 erase_flash

esptool.py --chip esp32 --port COM3 --baud 921600 write_flash -z 0x1000 firmware.bin
```

10. TECHNICAL REFERENCE

10.1 ESP32 Pin Mapping

ESP32 Pin	Function	Description
3	EN	Reset Button
4	GPIO36 (SENSOR_VP)	0-5V Analog Input Channel 1
5	GPIO39 (SENSOR_VN)	0-5V Analog Input Channel 2
6	GPIO34	4-20mA Analog Input Channel 1
7	GPIO35	4-20mA Analog Input Channel 2
8	GPIO32	433MHz RF Transmitter TX
9	GPIO33	433MHz RF Receiver RX
10	GPIO25	GSM SIM800L/SIM7600E TX
11	GPIO26	GSM SIM800L/SIM7600E RX
12	GPIO27	MAX485 TXRX Control for MODBUS
13	GPIO14	MCP23017 I2C INPUT Expander PORT A Interrupt
14	GPIO12	Not Used
16	GPIO13	MCP23017 I2C INPUT Expander PORT B Interrupt
23	GPIO15	DHT22 Temperature/Humidity Sensor Channel 2
24	GPIO2	Buzzer (BEEP)
25	GPIO0	BOOT Enable
26	GPIO4	DHT22 Temperature/Humidity Sensor Channel 1
27	GPIO16	RS485 MODBUS MAX485 RO pin (RXD)
28	GPIO17	RS485 MODBUS MAX485 DI pin (TXD)
29	GPIO5	ETHERNET W5500 MODULE SPI Chip Select

ESP32 Pin	Function	Description
30	GPIO18	ETHERNET W5500 MODULE SPI SCLK
31	GPIO19	ETHERNET W5500 MODULE SPI MISO
33	GPIO21	I2C SDA
34	RXD0	Debug/Programming (USB) RX
35	TXD0	Debug/Programming (USB) TX
36	GPIO22	I2C SCK
37	GPIO23	ETHERNET W5500 MODULE SPI MOSI

10.2 MCP23017 Pin Configuration

10.2.1 Input Interface (U8)

Pin	Name	Function
1-8	GPB0-GPB7	Digital Inputs 1-8 (CN3)
9	VDD	3.3V
10	VSS	GND
11	NC	Not Connected
12	SCK	I2C SCK
13	SDA	I2C SDA
14	NC	Not Connected
15	A0	Address Line 0
16	A1	Address Line 1
17	A2	Address Line 2
18	Reset	Reset

Pin	Name	Function
19	INTB	Connected to ESP32 GPIO13
20	INTA	Connected to ESP32 GPIO14
21-28	GPA0-GPA7	Various Special Functions

10.2.2 Output Interface (U26)

Pin	Name	Function
1-4	GPB0-GPB3	MOSFET Outputs 9-12 (Q11-Q14)
5-8	GPB4-GPB7	Not Connected
9	VDD	3.3V
10	VSS	GND
11	NC	Not Connected
12	SCK	I2C SCK
13	SDA	I2C SDA
14	NC	Not Connected
15	A0	Address Line 0
16	A1	Address Line 1
17	A2	Address Line 2
18	Reset	Reset
19	INTB	Not Connected
20	INTA	Not Connected
21-28	GPA0-GPA7	MOSFET Outputs 1-8 (Q3-Q10)

10.3 GP8413 Analog Output Interface (U46)

Pin	Name	Function
1	SCK	I2C SCK
2	SDA	I2C SDA
3	A0	Address Line 0
4	A1	Address Line 1
5	VCC	12V Supply
6	GND	GND
7	VOUT1	0-5V / 0-10V Analog Output Channel 1
8	VOUT2	0-5V / 0-10V Analog Output Channel 2
9	A4	Address Line 2
10	VSS	GND

10.4 I2C Address Configuration

Device	Function	Default Address	Address Selection
MCP23017 (U8)	Digital Inputs	0x21	JP1 short (0x21)
MCP23017 (U26)	MOSFET Outputs	0x20	Open jumpers (0x20)
GP8413 (U46)	Analog Outputs	0x58	Default 0x58

10.5 Technical Specifications

10.5.1 Electrical Specifications

Parameter	Specification
Input Voltage	9-12V DC (24V maximum)
Power Consumption	1W (idle), 10W (full load)
Digital Input Type	Optically isolated, dry contact
Digital Output Type	N-channel MOSFET, low-side switching
Output Rating	12/24V DC, 500mA per channel
Analog Input Range	4-20mA (CH1-2), 0-5V DC (CH3-4)
Analog Output Range	0-10V DC
RS485 Interface	Half-duplex, Modbus RTU compatible

10.5.2 Environmental Specifications

Parameter	Specification
Operating Temperature	-40°C to +85°C
Storage Temperature	-40°C to +100°C
Humidity	10% to 90% RH (non-condensing)
Altitude	Up to 2000m
Protection Rating	IP00 (requires enclosure)

10.5.3 Mechanical Specifications

Parameter	Specification
Dimensions	200mm × 110mm × 45mm (L × W × H)
Weight	Approximately 250g
Mounting	4× mounting holes (4mm diameter)
Terminal Connectors	Spring or screw terminals

11. APPENDICES

11.1 Certifications

- **CE Certified**: Compliant with European safety standards
- **RoHS Compliant**: Free from hazardous substances
- **FCC Compliant**: For RF communications

11.2 Warranty Information

The Cortex Link A8F-M ESP32 includes a standard 12-month warranty against manufacturing defects. Extended warranty options are available upon request.

11.3 Product Customization

The Cortex Link A8F-M ESP32 can be customized to meet specific requirements. Contact MESA directly for custom configurations, including:

- Modified I/O configurations
- Custom communication interfaces
- Specialized firmware
- Alternate enclosure options
- OEM branding

11.4 Technical Support

For technical support, contact MESA:

- Email: support@mesa-automation.com
- Website: www.mesa-automation.com
- Phone: [Contact Information]

11.5 Additional Resources

- Sample code repository: [GitHub Link]
- Application notes: [Website Link]
- Video tutorials: [YouTube Channel]
- User forum: [Forum Link]

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