MiniPLC-32uE

Hardware User Manual

ESP32-S3 Based Industrial PLC Controller

8 Digital Inputs / 4 Relay Outputs

Revision 2.0

2026

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1. Overview

MiniPLC-32uE is a compact industrial PLC controller based on the ESP32-S3 microcontroller. It is designed for industrial automation, IoT applications, and control systems. The device features 8 digital inputs, 4 relay outputs, multiple communication interfaces (Ethernet, RS-485, RS-232, USB-C, WiFi), and supports ladder logic programming compatible with Mitsubishi FX2N instruction set.

The MiniPLC-32uE combines the power of the ESP32-S3 dual-core processor with industrial-grade I/O interfaces, making it suitable for factory automation, building management, agricultural automation, and various IoT control applications.

1.1 Board Layout

Figure 1: MiniPLC-32uE Board (Top View, Transparent Enclosure)

The MiniPLC-32uE consists of two stacked PCBs inside a transparent industrial enclosure:

- Upper board (CPU Board) - ESP32-S3 module, Ethernet W5500, Status LEDs, Buzzer
- Lower board (I/O Board) - Relay outputs, Input circuits, RS-485 isolator, Power supply, Analog input

Component Identification (Top View)

Looking at the board from the top as shown in Figure 1, the key components are identified below:

CPU Board (Upper)

Component	Location	Description
ESP32-S3-WROOM-1U	Top-right area	Main processor module with metal shield and U.FL antenna connector
Status LEDs	Center-left	Five LEDs stacked vertically: PWR, RUN, NET, WAR, ERR
W5500 Ethernet IC (U8)	Top-center	Ethernet controller IC with 25 MHz crystal (Y2)
RJ45 Connector (J16)	Right edge	HR911105A RJ45 jack with integrated magnetics (located on the right side of the board)
Buzzer (LS3)	Top-right corner	Piezo buzzer for audible alarm
Voltage Regulator (U4)	Left area	3.3V LDO regulator with input/output capacitors
Electrolytic Cap (C8)	Left of center	220uF/6.3V, main power filter capacitor
26-pin Header (J4)	Between boards	CPU-to-I/O board interconnect connector

I/O Board (Lower)

Component	Location	Description
OMRON Relays (K1-K4)	Left side	Four blue OMRON relays for Y0-Y3 outputs (5A/250VAC)
ADUM1201 (U2, U8)	Center-bottom	Digital isolators for RS-485 galvanic isolation
BS0505 (U3)	Left of center	Isolated DC-DC converter for RS-485 power supply
CH340C (U10)	Center-bottom	USB-to-UART bridge IC for USB-C serial communication
DS1307 (U11)	Left-bottom	Real-time clock IC with 32.768 kHz crystal (Y1)
FM24C256 (U1)	Center-right	FRAM non-volatile memory (32KB, I2C)
MCP3221 (U5)	Right area	12-bit ADC for analog input (I2C)
LMV321 (U6)	Right area	Op-amp buffer for analog input signal conditioning
Switching Regulator (U14)	Left area	DC-DC step-down converter with 33uH inductor (L1)
USB-C Connector (J1)	Bottom edge	USB Type-C for programming and RS-232 communication

Terminal Block Pinout

The MiniPLC-32uE has two rows of green screw terminal blocks for external wiring connections:

Top Terminal Block (Input/Power Side)

The top terminal block provides connections for digital inputs, power input, and some signal connections.

Reading from LEFT to RIGHT as viewed from the front:

Pin	Label	Description
1	+VCC	Power input positive (+24VDC)

2	GND	Power input ground
3	WAR	Warning output signal
4	I0	Digital Input 0 (X0)
5	I1	Digital Input 1 (X1)
6	I2	Digital Input 2 (X2)
7	I3	Digital Input 3 (X3)
8	I4	Digital Input 4 (X4)
9	I5	Digital Input 5 (X5)
10	I6	Digital Input 6 (X6)
11	I7	Digital Input 7 (X7)
12	VR5D	Sensor power supply (+5V for sensors)
13	485-TX	RS-485 A+ (Data+)
14	485-RX	RS-485 B- (Data-)

Note: The pin labels and order shown above are approximate readings from the board photo. Please verify with the actual board silkscreen markings.

Bottom Terminal Block (Output/Communication Side)

The bottom terminal block provides connections for relay outputs, analog input, and I2C expansion.

Reading from LEFT to RIGHT as viewed from the front:

Pin	Label	Description
1	VV1	Relay common voltage input (load power, e.g. 24VDC/220VAC)
2	GND1	Relay common ground / load return
3	A1+	Analog Input 1 positive (0-3.3V to MCP3221 ADC)
4	GND	Analog input ground reference
5	SDA	I2C Data (expansion bus)
6	SCL	I2C Clock (expansion bus)
7	Q0	Relay Output 0 (Y0) - Normally Open contact
8	Q1	Relay Output 1 (Y1) - Normally Open contact
9	Q2	Relay Output 2 (Y2) - Normally Open contact
10	Q3	Relay Output 3 (Y3) - Normally Open contact

Note: The pin labels and order shown above are approximate readings from the board photo. Please verify with the actual board silkscreen markings.

Additional Connectors

Besides the main terminal blocks, the following connectors are also visible:

Connector	Description
JST Connector (bottom-right, white)	RTC battery connector (CR2032 / backup battery for DS1307)
JST Connector (bottom-right, white)	Expansion / auxiliary power connector
RJ45 Jack (right edge)	Ethernet 10/100 Mbps (W5500) with Link/Activity LEDs
USB-C (bottom edge)	Programming, serial monitor, and RS-232 communication via CH340C

2. Specifications

CPU	ESP32-S3-WROOM-1U-N16R8 (Dual-core Xtensa LX7, up to 240 MHz)
Flash Memory	16 MB (QIO, 80 MHz)
PSRAM	8 MB (OPI - Octal SPI)
Non-volatile Memory	FRAM FM24C256 (256 Kbit / 32 KB) via I2C
Real-Time Clock	DS1307 with 32.768 kHz crystal, battery backup
Digital Inputs	8 channels (X0-X7) with input filter
Relay Outputs	4 channels (Y0-Y3), OMRON relay
Analog Input	1 channel (MCP3221, 12-bit ADC via I2C)
Ethernet	W5500 (10/100 Mbps) via SPI, RJ45 with HR911105A connector
RS-485	1 port (isolated via ADUM1201), half-duplex
RS-232	1 port (via CH340C USB-to-UART), USB-C connector
Serial Ports	UART2 (TX2/RX2), UART3 (TX3/RX3)
WiFi	2.4 GHz 802.11 b/g/n (AP / STA mode)
Buzzer	1x Piezo buzzer (IO1)
Status LEDs	4x (PWR, RUN, NET, WAR, ERR)
Power Supply	24VDC (via DC-DC step-down to 5V/3.3V)
Programming	Ladder Logic (FX2N compatible), Modbus RTU/TCP
Mounting	DIN rail mount
Enclosure	Transparent cover, industrial plastic

3. Hardware Components

3.1 CPU Module - ESP32-S3-WROOM-1U-N16R8

The heart of MiniPLC-32uE is the ESP32-S3-WROOM-1U-N16R8 module from Espressif. This module features a dual-core Xtensa LX7 processor running at up to 240 MHz, 16 MB of flash memory (QIO mode at 80 MHz), and 8 MB of PSRAM (OPI mode). It supports WiFi 802.11 b/g/n and Bluetooth 5.0 (LE).

Key features:

- Dual-core Xtensa LX7, up to 240 MHz
- 16 MB Flash (QIO, 80 MHz)
- 8 MB PSRAM (Octal SPI)
- WiFi 2.4 GHz 802.11 b/g/n
- Bluetooth 5.0 (LE)
- External antenna connector (U.FL/IPEX)
- USB Serial JTAG interface (disabled for GPIO 39-42 usage)

3.2 Status LEDs

MiniPLC-32uE has 5 status LEDs located on the CPU board for system monitoring:

LED	GPIO Pin	Description
PWR	-	Power indicator - ON when power is supplied
RUN	IO48	PLC running status - Blinks when PLC program is executing
NET	IO35	Network status - ON when network communication is active
WAR	IO36	Warning - ON when a warning condition exists
ERR	IO37	Error - ON when an error condition exists

3.3 Digital Inputs (X0-X7)

The MiniPLC-32uE provides 8 digital input channels (X0 through X7). The inputs are directly connected to ESP32-S3 GPIO pins and read through a software input filter (debounce) with configurable filter time. The default filter time is 10 ms. Inputs are active-low (connect to GND to activate).

Input	GPIO Pin	Description
X0 (I0)	IO5	Digital Input 0
X1 (I1)	IO19	Digital Input 1
X2 (I2)	IO3	Digital Input 2
X3 (I3)	IO47	Digital Input 3
X4 (I4)	IO9	Digital Input 4

X5 (I5)	IO41	Digital Input 5
X6 (I6)	IO40	Digital Input 6
X7 (I7)	IO42	Digital Input 7

Note: GPIO pins 39, 40, 41, 42 are shared with the USB JTAG interface. The firmware disables USB JTAG at boot to release these pins for I/O use.

3.4 Relay Outputs (Y0-Y3)

The MiniPLC-32uE provides 4 relay output channels (Y0 through Y3) using OMRON relays. Each relay output has a flyback diode (1N4148) for inductive load protection and is driven by a transistor (BC817/BC856B).

Output	GPIO Pin	Description
Y0 (O0)	IO15	Relay Output 0
Y1 (O1)	IO8	Relay Output 1
Y2 (O2)	IO18	Relay Output 2
Y3 (O3)	IO17	Relay Output 3

Relay specifications:

- Type: OMRON mechanical relay
- Contact rating: 5A @ 250VAC / 5A @ 30VDC
- Protection: Flyback diode (1N4148) across coil
- Driver: BC817 NPN transistor

3.5 Communication Interfaces

3.5.1 RS-485 (Isolated)

The RS-485 interface uses an ADUM1201 digital isolator for galvanic isolation, providing protection against ground loops and electrical noise. The RS-485 transceiver supports half-duplex communication.

Signal	GPIO Pin	Description
TX (RS-485)	IO7 (UTX2)	Transmit data to RS-485 bus
RX (RS-485)	IO16 (URX2)	Receive data from RS-485 bus

RS-485 features:

- Galvanic isolation via ADUM1201
- Isolated power via BS0505 DC-DC converter
- Half-duplex communication
- Termination resistor: 120 ohm (R19)
- Supports Modbus RTU protocol
- Default baud rate: 19200 bps (configurable)

3.5.2 RS-232 / USB-C

A USB-C connector (J1) provides RS-232 level serial communication via a CH340C USB-to-UART bridge IC (U10). This port is used for programming, monitoring, and Modbus RTU communication.

USB-C / CH340C features:

- USB-C connector with ESD protection
- CH340C USB-to-UART converter
- Auto-detect baud rate support
- Used for firmware upload and serial monitoring
- Default monitor speed: 19200 bps

3.5.3 Serial Ports (UART)

In addition to the USB serial port, the MiniPLC-32uE has dedicated UART ports:

Port	GPIO Pins	Label	Usage
UART0	TXD0 / RXD0	Default (USB Serial)	System console (via USB-C)

UART2	IO7 / IO16	TX2 / RX2	RS-485 communication
UART3	IO6 / IO4	TX3 / RX3	General purpose serial

3.5.4 Ethernet (W5500)

The MiniPLC-32uE includes a W5500 Ethernet controller (U8) connected via SPI. It supports 10/100 Mbps wired Ethernet with an RJ45 connector (HR911105A, J16) that includes built-in magnetics and LED indicators.

Signal	GPIO Pin	Description
SPI_RST	IO21	W5500 Reset
SPI_CS	IO10	SPI Chip Select
SPI_MOSI	IO11	SPI Master Out Slave In
SPI_CLK	IO12	SPI Clock
SPI_MISO	IO13	SPI Master In Slave Out
SPI_INT	IO14	W5500 Interrupt

Ethernet features:

- W5500 hardware TCP/IP stack
- 10/100 Mbps auto-negotiation
- RJ45 connector (HR911105A) with integrated magnetics
- Link, Activity, Speed, and Duplex LED indicators
- 25 MHz crystal oscillator
- Supports Modbus TCP, MQTT, HTTP protocols
- ESD protection via 1N/2kV capacitor (C26)

3.5.5 WiFi

The ESP32-S3 module provides built-in WiFi 2.4 GHz 802.11 b/g/n capability. The MiniPLC-32uE uses an external antenna via U.FL connector for better signal reception in industrial environments.

Default WiFi AP settings:

- SSID: MiniPLC-32uE
- Password: 12345678
- IP Address: 192.168.4.1
- Subnet: 255.255.255.0

3.6 Power Supply

The MiniPLC-32uE is designed to operate with a 24VDC industrial power supply. The input power is regulated using a switching DC-DC converter (U14) with a 33uH inductor (L1) to step down to 5V, and a linear regulator (U4) to provide the 3.3V required by the ESP32-S3 and other logic ICs.

Power supply features:

- Input voltage: 24VDC (nominal)
- Onboard switching regulator (step-down to 5V)
- Linear regulator (5V to 3.3V) for CPU and ICs
- Reverse polarity protection (SS14 Schottky diodes)
- Isolated RS-485 power via BS0505 DC-DC converter
- Electrolytic filter capacitors for noise suppression
- PWR LED indicator

3.7 FRAM Memory (FM24C256)

The FM24C256 is a 256 Kbit (32 KB) Ferroelectric RAM (FRAM) connected via I2C bus. FRAM provides non-volatile data storage with virtually unlimited write endurance (10^14 read/write cycles), making it ideal for storing PLC data registers, configuration, and retentive data.

Signal	GPIO Pin	Description
SDA	IO39	I2C Data (via TW-SDA1)
SCL	IO20	I2C Clock (via TW-SCL1)

3.8 Real-Time Clock (DS1307)

The DS1307 (U11) is a real-time clock IC connected via I2C bus. It provides year, month, day, hour, minute, and second timekeeping with battery backup for continuous operation during power loss.

RTC features:

- DS1307 RTC IC
- 32.768 kHz crystal (Y1)
- Battery backup (Vbat pin)
- I2C interface (shared bus with FRAM)
- SQW/OUT square wave output

3.9 Analog Input (MCP3221)

The MCP3221 (U5) is a 12-bit SAR ADC connected via I2C bus. It provides one analog input channel with signal conditioning via an LMV321 (U6) op-amp buffer.

Analog input features:

- MCP3221 12-bit ADC
- Resolution: 4096 steps
- Input signal conditioning via LMV321 op-amp
- I2C interface (shared bus)

3.10 Buzzer

A piezo buzzer (LS3) is connected to IO1 via a driver circuit (BC817 transistor with 1N4148 flyback diode). It can be used for audible alarms and notification sounds.

Signal	GPIO Pin	Description
BUZZER	IO1	Buzzer output (active HIGH)

4. Pin Mapping (ESP32-S3 GPIO Assignment)

The following table shows the complete GPIO pin assignment of the ESP32-S3 in the MiniPLC-32uE:

GPIO	Function	Type	Description
IO1	BUZZER	Output	Piezo buzzer driver
IO3	X2 (I2)	Input	Digital Input 2
IO4	RX3	UART	Serial port 3 receive
IO5	X0 (I0)	Input	Digital Input 0
IO6	TX3	UART	Serial port 3 transmit
IO7	TX2 (UTX2)	UART	RS-485 transmit
IO8	Y1 (O1)	Output	Relay Output 1
IO9	X4 (I4)	Input	Digital Input 4
IO10	SPI_CS	SPI	W5500 Chip Select
IO11	SPI_MOSI	SPI	W5500 MOSI
IO12	SPI_CLK	SPI	W5500 Clock
IO13	SPI_MISO	SPI	W5500 MISO
IO14	SPI_INT	SPI	W5500 Interrupt
IO15	Y0 (O0)	Output	Relay Output 0
IO16	RX2 (URX2)	UART	RS-485 receive
IO17	Y3 (O3)	Output	Relay Output 3
IO18	Y2 (O2)	Output	Relay Output 2
IO19	X1 (I1)	Input	Digital Input 1
IO20	SCL1	I2C	I2C Clock (FRAM, RTC, ADC)
IO21	SPI_RST	SPI	W5500 Reset
IO35	NET LED	Output	Network status LED
IO36	WAR LED	Output	Warning status LED
IO37	ERR LED	Output	Error status LED
IO39	SDA1	I2C	I2C Data (FRAM, RTC, ADC)
IO40	X6 (I6)	Input	Digital Input 6
IO41	X5 (I5)	Input	Digital Input 5
IO42	X7 (I7)	Input	Digital Input 7
IO47	X3 (I3)	Input	Digital Input 3
IO48	RUN LED	Output	Run status LED

5. Connector Pinout - J4 (Main Connector)

J4 is the main 26-pin connector that connects the CPU board to the I/O board. It carries all signal connections between the processor and the input/output circuitry.

Pin	Signal	Description
1	3V3	3.3V Power
2	3V3	3.3V Power
3	STS-1	Status LED 1
4	VCC	5V Power
5	I1	Digital Input 1 (X1)
6	GND	Ground
7	O2	Relay Output 2 (Y2)
8	O1	Relay Output 1 (Y1)
9	GND	Ground
10	O3	Relay Output 3 (Y3)
11	URX2	UART2 RX (RS-485 RX)
12	O0	Relay Output 0 (Y0)
13	UTX2	UART2 TX (RS-485 TX)
14	I0	Digital Input 0 (X0)
15	TW-SDA1	I2C Data
16	TW-SCL1	I2C Clock
17	I2	Digital Input 2 (X2)
18	I4	Digital Input 4 (X4)
19	I3	Digital Input 3 (X3)
20	I6	Digital Input 6 (X6)
21	I5	Digital Input 5 (X5)
22	I7	Digital Input 7 (X7)
23	-	Not connected
24	-	Not connected
25	-	Not connected
26	-	Not connected

6. Board Connector Pinout - J12 (I/O Board)

J12 is the 26-pin connector on the I/O expansion board (Schematic_Board_R2). It mirrors J4 on the CPU board and provides connections to the relay outputs, opto-isolated inputs, RS-485 interface, and other peripherals.

Pin	Signal	Description
1	3V3	3.3V Power (from CPU board)
2	3V3	3.3V Power
3	STS-1	Status signal
4	VCC	5V Power
5	I1	Input 1 signal
6	GND	Ground
7	O2	Output 2 signal (to relay K3)
8	O1	Output 1 signal (to relay K2)
9	GND	Ground
10	O3	Output 3 signal (to relay K4)
11	URX2	RS-485 RX (via ADUM1201 isolator)
12	O0	Output 0 signal (to relay K1)
13	UTX2	RS-485 TX (via ADUM1201 isolator)
14	I0	Input 0 signal
15	TW-SDA1	I2C Data (to MCP3221, etc.)
16	TW-SCL1	I2C Clock
17	I2	Input 2 signal
18	I4	Input 4 signal
19	I3	Input 3 signal
20	I6	Input 6 signal
21	I5	Input 5 signal
22	I7	Input 7 signal
23	-	Reserved
24	-	Reserved
25	-	Reserved
26	-	Reserved

7. Communication Configuration

7.1 Modbus RTU (RS-485)

The MiniPLC-32uE supports Modbus RTU communication over RS-485. Communication parameters are configured via special data register D8120.

D8120 Communication Format Register:

Bit	Parameter	Values
b0	Data Length	0: 7 bits, 1: 8 bits
b2-b1	Parity	00: None, 01: Odd, 11: Even
b3	Stop Bits	0: 1 bit, 1: 2 bits
b7-b4	Baud Rate	0001:300, 0100:600, 0101:1200, 0110:2400, 0111:4800, 1000:9600, 1001:19200
b12-b10	Interface	000: RS-485/RS-422, 010: RS-232C
b13	Checksum	0: No checksum, 1: Auto checksum
b14	Protocol	0: No protocol, 1: Special protocol
b15	Format	0: Format 1, 1: Format 4

Default: D8120 = 0x4096 (19200 bps, 7 data bits, even parity, 1 stop bit)

Related special registers:

- D8121 - Slave station number (up to 16)
- D8127 - First address of exchange data
- D8128 - Exchange data volume
- D8129 - Network communication timeout

7.2 WiFi Configuration

The MiniPLC-32uE starts in WiFi Access Point (AP) mode by default:

Parameter	Default Value
SSID	MiniPLC-32uE
Password	12345678
IP Address	192.168.4.1
Gateway	192.168.4.1
Subnet Mask	255.255.255.0

7.3 Serial Monitor

Connect via USB-C and use a serial terminal with the following settings:

Parameter	Value
Baud Rate	19200
Data Bits	7
Parity	Even
Stop Bits	1
Flow Control	None

8. Wiring Diagrams

8.1 Digital Input Wiring

Digital inputs are active-low. Connect the signal source between the input terminal and GND. When the input is connected to GND (LOW), the corresponding X register becomes ON (TRUE). Each input has a software debounce filter.

Wiring example (NPN sensor or dry contact):

```
Sensor/Switch ----+---- Input terminal (I0-I7)
                  |
                 GND
```

8.2 Relay Output Wiring

Each relay output (Y0-Y3) has a normally-open (NO) contact. Connect the load between the common (COM) and the relay terminal. The relay can switch both AC and DC loads within its rated capacity.

Relay output ratings:

- Maximum switching voltage: 250VAC / 30VDC
- Maximum switching current: 5A
- Protection: Built-in flyback diode on relay coil

8.3 RS-485 Wiring

The RS-485 interface uses a 2-wire half-duplex connection. Connect A (+) to A and B (-) to B of the other device. A 120 ohm termination resistor is included on-board.

```
MiniPLC-32uE        Remote Device
A (+) ---------- A (+)
B (-) ---------- B (-)
```

8.4 Power Supply Wiring

Connect 24VDC power supply to the power input terminals. Observe correct polarity (+ and -).

Power requirements:

- Input voltage: 24VDC (typical)
- Power consumption: approximately 5W (without load)
- Reverse polarity protection: Yes (Schottky diode)

9. Dimensions & Mounting

The MiniPLC-32uE is housed in a compact industrial enclosure with a transparent cover that allows visual inspection of the PCB and status LEDs. The enclosure is designed for DIN rail mounting (standard 35mm DIN rail).

Mounting:

- DIN rail mount (35mm standard)
- 4x mounting holes on enclosure corners
- Transparent protective cover
- Screw terminal blocks for I/O connections
- Plug-in terminal blocks for easy wiring

Appendix A: I2C Device Addresses

The following I2C devices are on the shared I2C bus (SDA1/SCL1):

Device	Type	Address	Function
FM24C256	FRAM (32 KB)	0x50	Non-volatile data storage
DS1307	RTC	0x68	Real-time clock
MCP3221	ADC (12-bit)	0x4D	Analog input

I2C bus configuration:

- Clock speed: 100 kHz (Standard mode)
- Timeout: 50 ms
- Pull-up resistors: 2.2K ohm (onboard)

Appendix B: CPU Schematic

The following schematic shows the CPU board circuit of the MiniPLC-32uE, including the ESP32-S3 connections, Ethernet W5500, status LEDs, and buzzer.

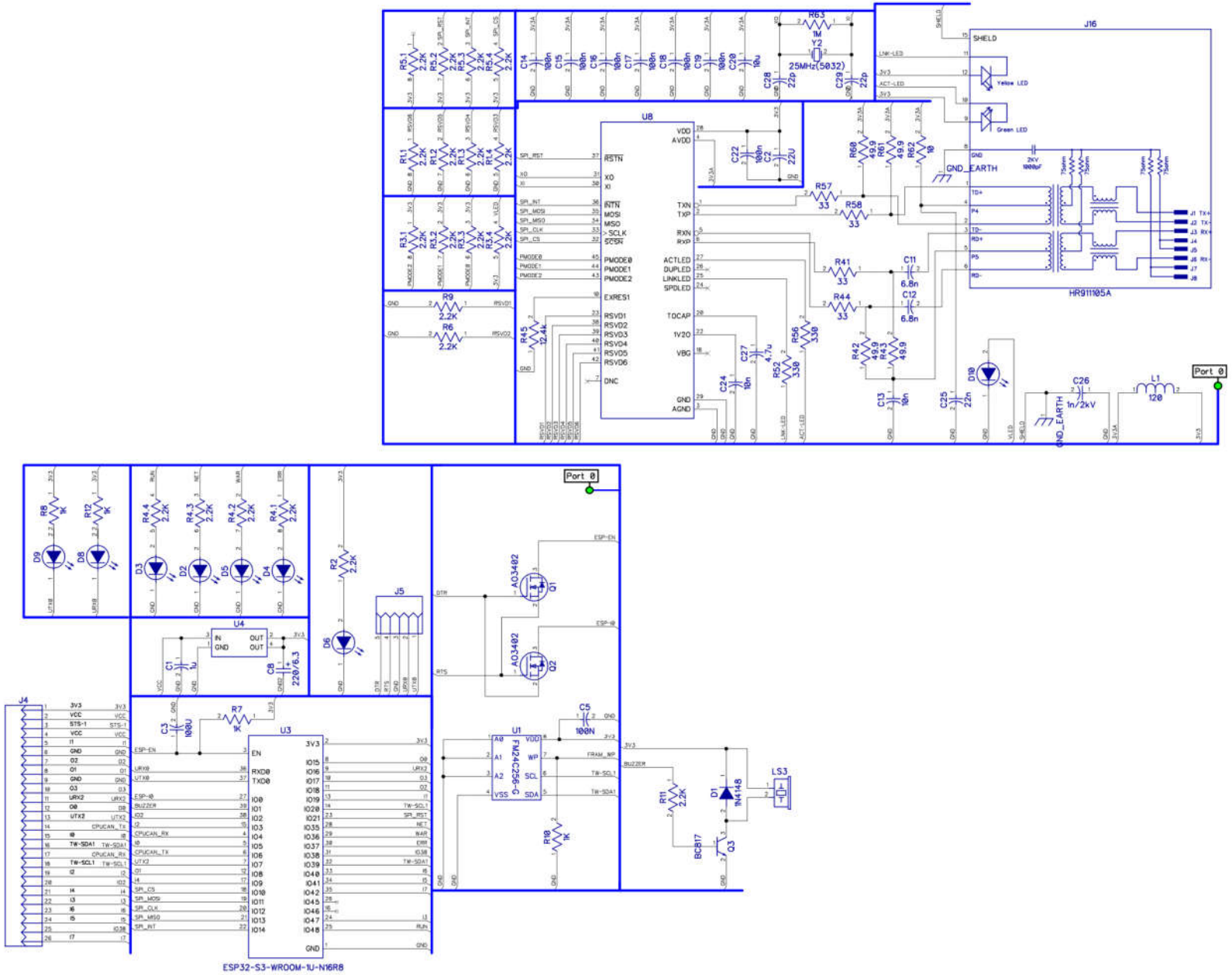

Figure 2: CPU Board Schematic – MiniPLC-32uE