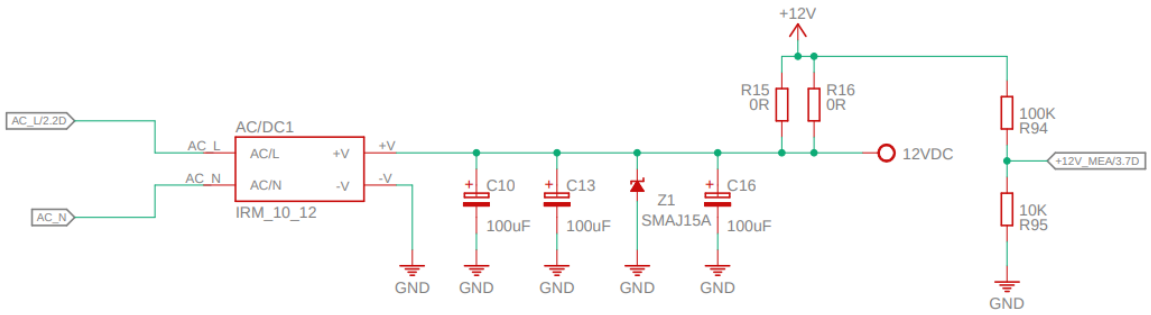
ENERGIS – 1.5U Size 10 Inch Rack PDU CIRCUIT DESCRIPTION

RELAY BOARD

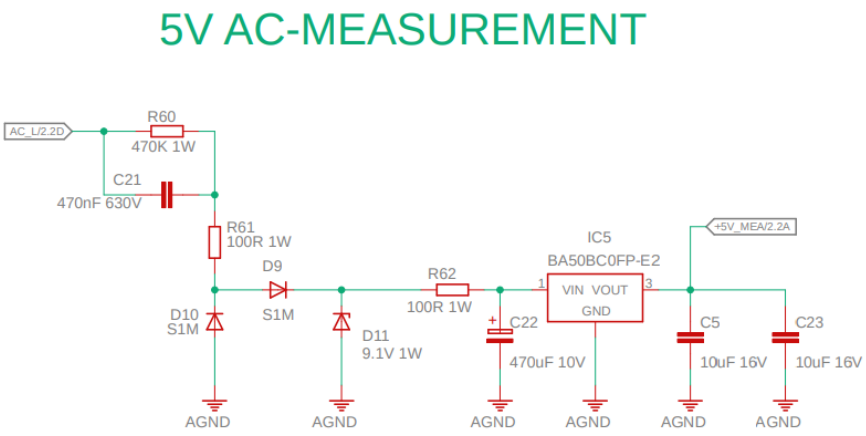
1. Power supply section

Key Components

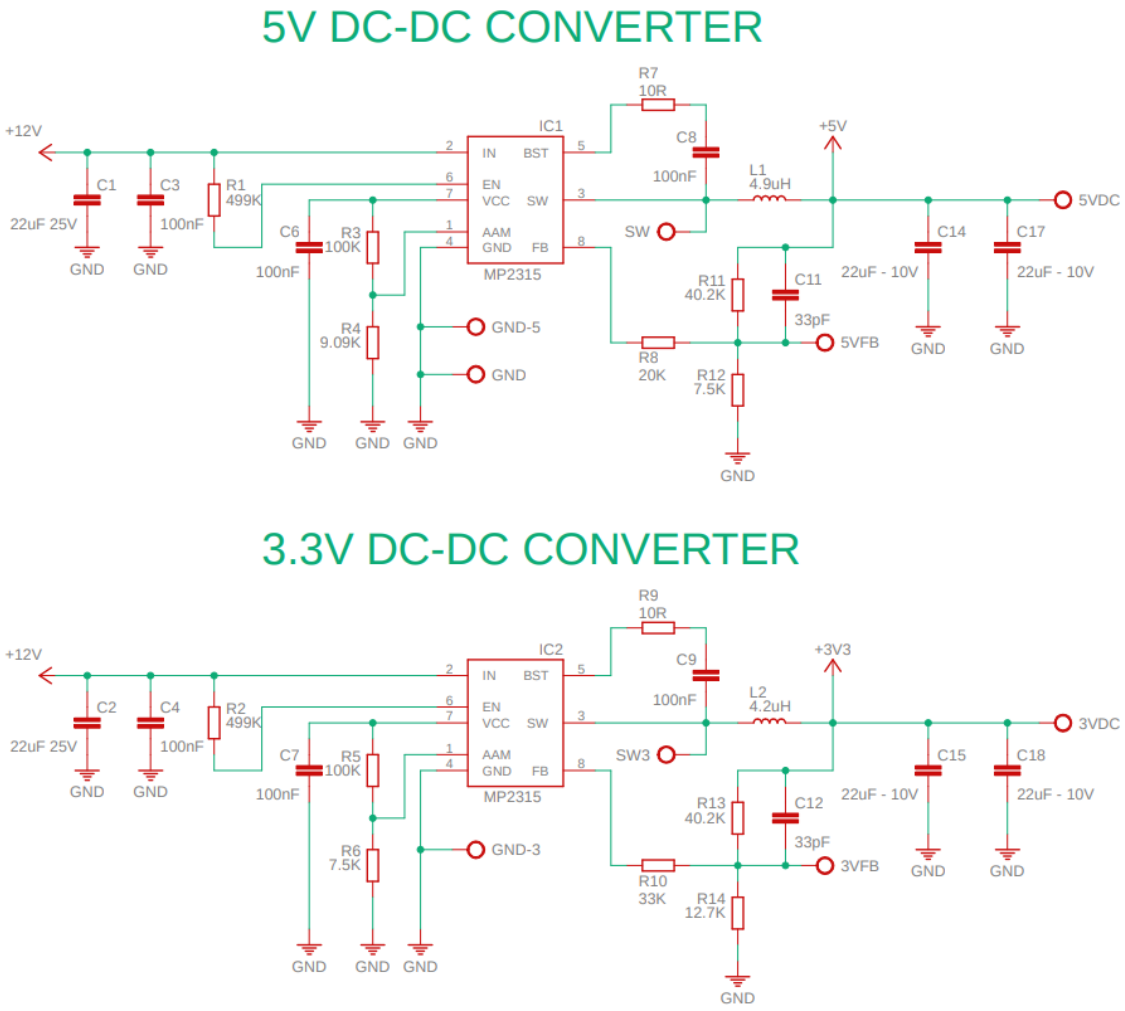
1. Flyback Converter – IRM_10_12
    - Converts AC mains to an isolated DC voltage to +12 V.
    - Supplies the rest of the board, including further regulation stages.
    - 1/11 Divider to MCU ADC



2. 5V LDO Regulator – BA50BC0FP-E2 (Measurement Supply)
    - Generates a stable 5 V rail used exclusively by the AC measurement circuitry.
    - References AGND (mains neutral), for measurements with the HLW8032 ICs.



3. MP2315-Based DC-DC Converters (Digital Rails)
    - Provide +5 V and +3.3 V from the 12 V supply. Then these supply lines are distributed through all PCBs.



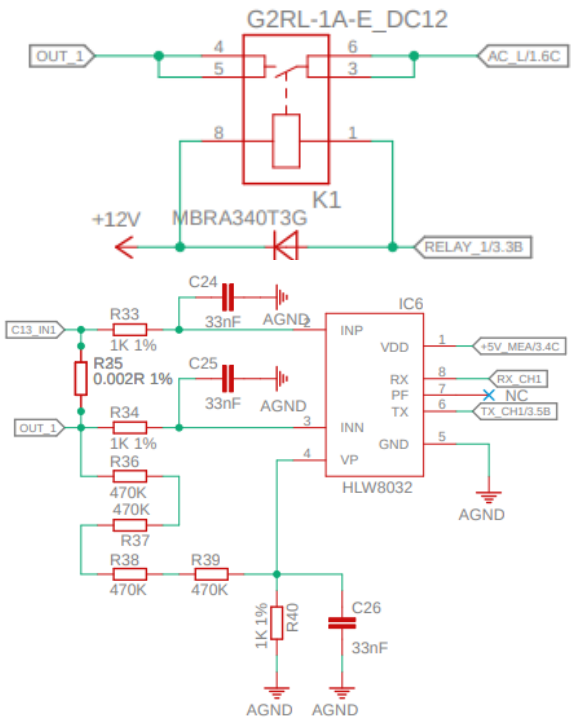
Grounding and Test Provisioning

- AGND vs. GND
    - AGND is tied to the AC mains neutral, acting as the reference for the measurement circuits.
    - GND is the board's internal digital ground, kept separate from AGND to avoid noise coupling.
- JP Jumpers
    - Allow AGND to be disconnected from its PCB trace during testing, permitting independent verification or calibration of the measurement section.

2. Output relay and ac measurement section

Relay Switching Network

- Eight Relay Outputs: The design provides eight dedicated relays for switching external loads.



AC Voltage Measurement

- Voltage Divider
  - Four 470 kΩ resistors in series, plus a 1 kΩ resistor to ground, form the main divider.
  - A 33 nF capacitor stabilizes the scaled voltage and filters high-frequency noise.
  - The HLW8032 measures this reduced AC voltage, referencing AGND for accurate RMS calculations.

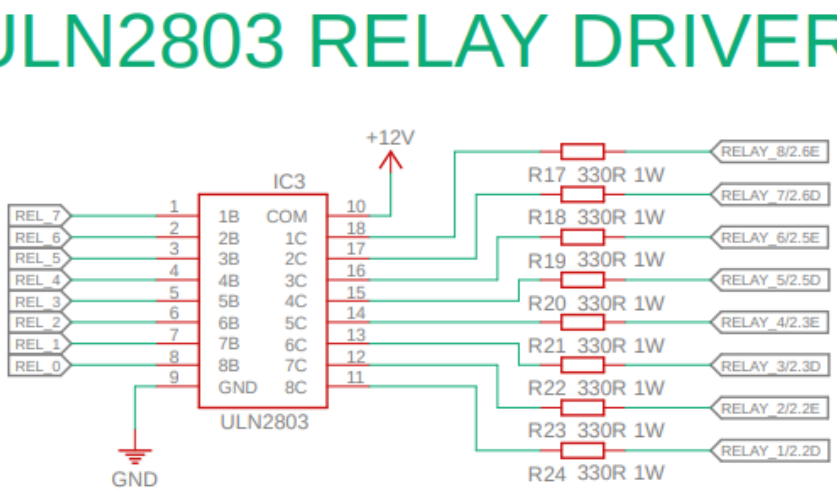
AC Current Sensing

- Low-Ohmic Sensing
  - Two 0.002 Ω (1% tolerance) resistors in parallel yield an effective 0.001 Ω.
  - Distributing the current across two resistors halves the power each must dissipate.
- 1 kΩ Series Resistor
  - Incorporated per the HLW8032's requirements to limit the current in the measurement path.

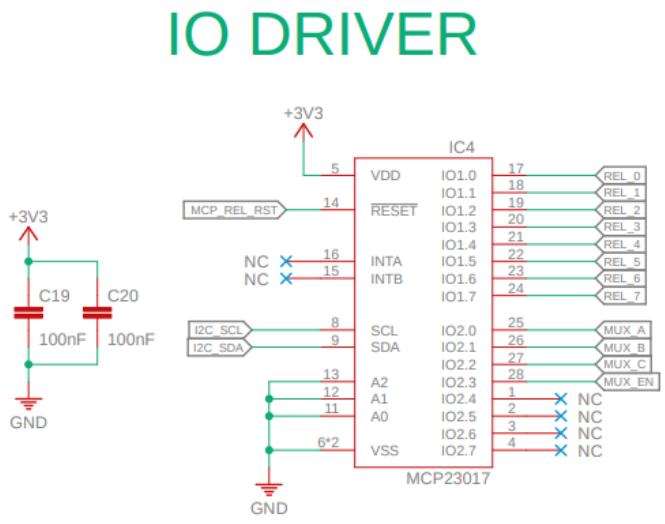
3. Control interfaces

Relay Driving and I/O Expansion

- ULN2803 Driver Array
  - Drives the relay coils with open-collector transistor outputs.
  - The 330 Ω resistor in each coil path sets the nominal relay current.

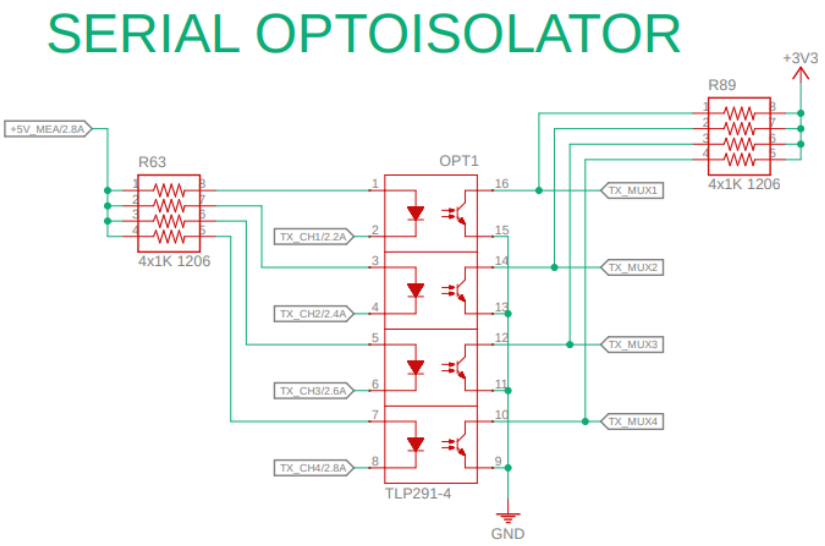


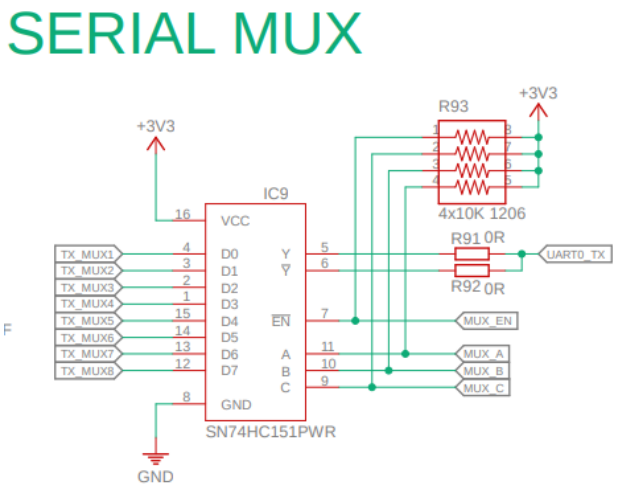
- MCP23017 I/O Expander
  - Adds additional digital outputs beyond what the MCU can provide directly.
  - Controls both the ULN2803 relay lines and the serial multiplexer selection lines.



Serial Multiplexer for Measurement Data

TX Line Selection: Each HLW8032 chip outputs a serial TX signal. These signals are then fed into the TLP291-4 optoisolator, to galvanically isolate the high-voltage/measurement sections from the low voltage digital interfaces. The SN74HC151 multiplexer selects which HLW8032 TX line is routed to the MCU's single serial receive pin. The MCP23017 configures which HLW8032 channel is active at any given time.





MUX_EN	MUX_C	MUX_B	MUX_A	Z
1	X	X	X	L
0	0	0	0	D0
0	0	0	1	D1
0	0	1	0	D2
0	0	1	1	D3
0	1	0	0	D4
0	1	0	1	D5
0	1	1	0	D6
0	1	1	1	D7

4. Calculations & HLW8032 measurement factors

Voltage Divider Calculations

- Configuration
  - Four 470 kΩ in series (1.88 MΩ total) and one 1 kΩ to ground.
- Division Ratio

$$Voltage\ Coefficient = \frac{1k\Omega}{1.88M\Omega + 1K\Omega} = \frac{1}{1881} \approx 0.00053$$

- Example at 230V

$$230V\ \cdot \frac{1}{1881} = 0.122V\ RMS$$

The 33 nF capacitor filters high-frequency noise before the HLW8032 input.

Current Sensing Calculations

- Effective Resistance

$$R_{eff} = \frac{0.002\Omega}{2} = 0.001\Omega$$

- Voltage Drop Example
  - For 16A:

$$V_{sense} = 16A\ \cdot 0.001\Omega = 0.016V$$

- Power Dissipation
  - Each resistor carries 10 A, so power per resistor:

$$P = (8A)^2 \cdot 0.002\Omega = 0.128W$$

HLW8032 Measurement Factors

- Voltage & Current Coefficients
  - The HLW8032 uses internal registers (Voltage Parameter REG, Current Parameter REG) combined with external resistor ratios to compute RMS voltage, RMS current, and power.
- Power Calculation
  - Active Power = Effective Voltage × Effective Current × Power Factor.
  - Apparent Power = Effective Voltage × Effective Current.
  - The HLW8032 internal logic derives power factor from these relationships.

MP2315 Configuration for +5 V and +3.3 V

- Typical Feedback Setup
  - The MP2315 has a reference of ~0.8 V.
  - For +5 V output, the feedback divider ratio is ~6.25:1; for +3.3 V, ~4.125:1.
- Switching Frequency & Efficiency
  - Operates at ~300 kHz, enabling smaller inductors and reducing conduction losses.

DISPLAY BOARD

The board is designed to interface with a 3.5-inch TFT LCD while accepting user input via pushbuttons and expanding the MCU's I/O through an MCP23017. The system is powered by a 3.3 V rail for all logic and peripherals, with a dedicated 5 V rail solely for driving the TFT backlight via PWM control.

1. Overview

Key Functional Blocks:

- Pushbutton Input: Tactile switches (marked "TC-6601-5.0-160") with associated RC debounce networks.
- LCD Interface: Digital signals (LCD_RES, LCD_CS, LCD_MOSI, LCD_MISO, LCD_SCLK, LCD_DC) are routed directly to the board connector without additional buffering or filtering.
- Backlight Driver: Utilizes a PWM-controlled BSS138 MOSFET in combination with 56 Ω resistors for proper TFT backlight drive.
- I/O Expansion: An MCP23017 provides additional digital I/O via the I^2C bus.

2. Power, Decoupling, and Supply Distribution

Decoupling:

Local decoupling is provided by 10 µF and 100 nF capacitors placed at strategic points across the board. These maintain stable voltage levels and filter high-frequency noise on both the 3.3 V and 5 V rails.

Supply Distribution:

The +3.3 V rail is distributed to all digital circuitry, including the LCD interface, pushbuttons, and the MCP23017. The +5 V rail is dedicated to the TFT backlight driver, ensuring a stable supply for PWM brightness control.

3. Pushbutton Circuitry

Debounce Network:

Each pushbutton is paired with a 10 K resistor and a 100 nF capacitor forming an RC network to debounce the mechanical switch and deliver a clean digital signal. Pushbuttons are identified as KEY0, KEY1, KEY2, and KEY3, each providing discrete input signals to the system.

4. TFT LCD Interface and Backlight Driver

LCD Signal Interface:

The LCD signals—LCD_RES, LCD_CS, LCD_MOSI, LCD_MISO, LCD_SCLK, and LCD_DC—are routed directly from the board's circuitry to the board connector. No intermediate buffering or filtering is applied to these signals.

Backlight Driver:

The TFT backlight is driven by a PWM-controlled BSS138 MOSFET. This driver circuit uses 56 Ω resistors in series with the MOSFET to regulate the current supplied from the dedicated +5 V rail. PWM control adjusts the brightness of the TFT backlight while maintaining consistent operation.

5. I/O Expansion and Test Provisions

MCP23017 I/O Expander:

The MCP23017 is used to extend the MCU's limited I/O capabilities. It interfaces with the MCU via the I^2C bus (with pull-up resistors to 3.3 V) and is responsible for managing additional digital signals related to the LCD and pushbutton inputs.

Board Connector and Test Points:

A dedicated board connector provides the interface for the 3.5-inch TFT LCD module, aggregating all necessary signal and power lines. Test points are provided at critical nodes (such as power rails, I^2C lines, and pushbutton inputs) to facilitate debugging, system validation, and in-circuit testing.

6. LED Indicators

Channel Status LEDs (8x): Each channel has a dedicated LED. Indicates ON/OFF status for each of the eight channels.

Fault LED: Lights up when a system fault is detected or flagged by the firmware.

Network Indicator LED: Reflects network connectivity status.

Power On LED: Illuminates when the board is powered.