Multi-Phase Power Board Hardware User Guide

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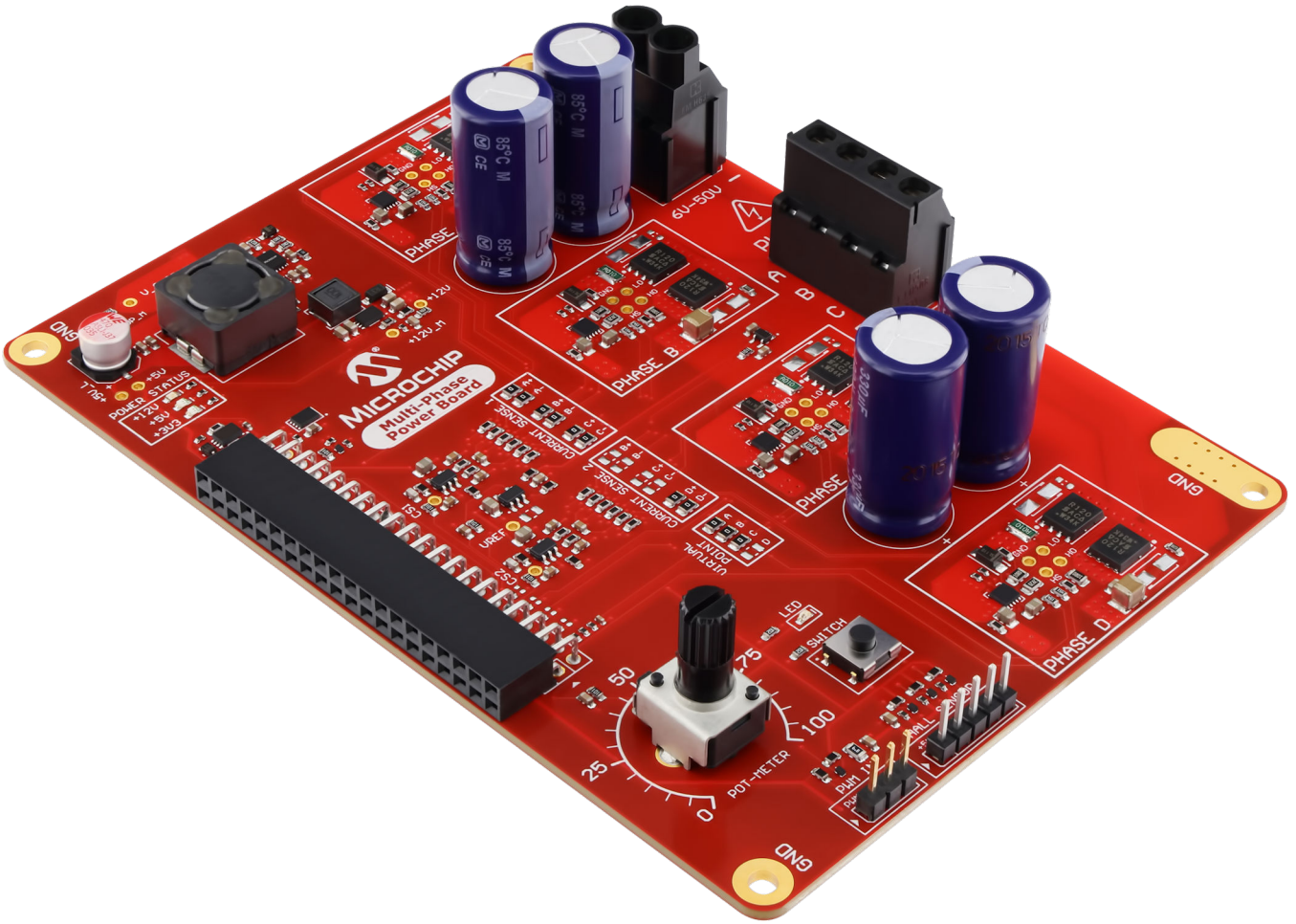
Preface



- **Website** - Purchase this product, kit information, latest user guide, and design documentation
- **Microchip Direct** - Purchase this product
- **Schematics** - Board schematics and history
- **Altium Project** - Altium Design files for the latest board revision
- **Design Documentation** - Production files for every revision

Table of Contents

1. Overview

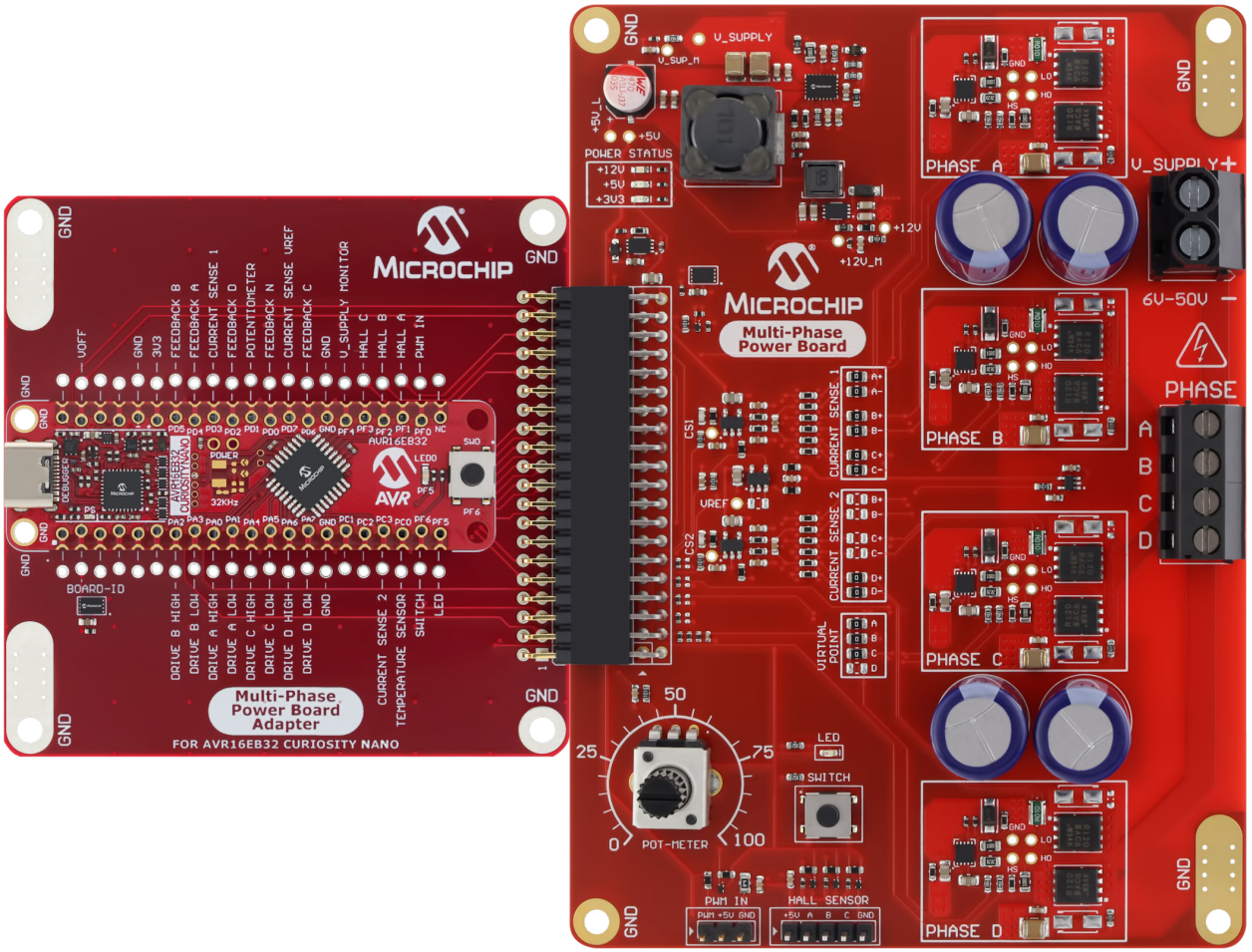
1.1 Ecosystem Overview

The Multi-Phase Power Board (MPPB) features a modular design and relies on adapter boards to produce the necessary drive signals, enabling the evaluation of various configurations.

Figure 1-1 shows an example setup of the following products connected for a complete motor control solution:

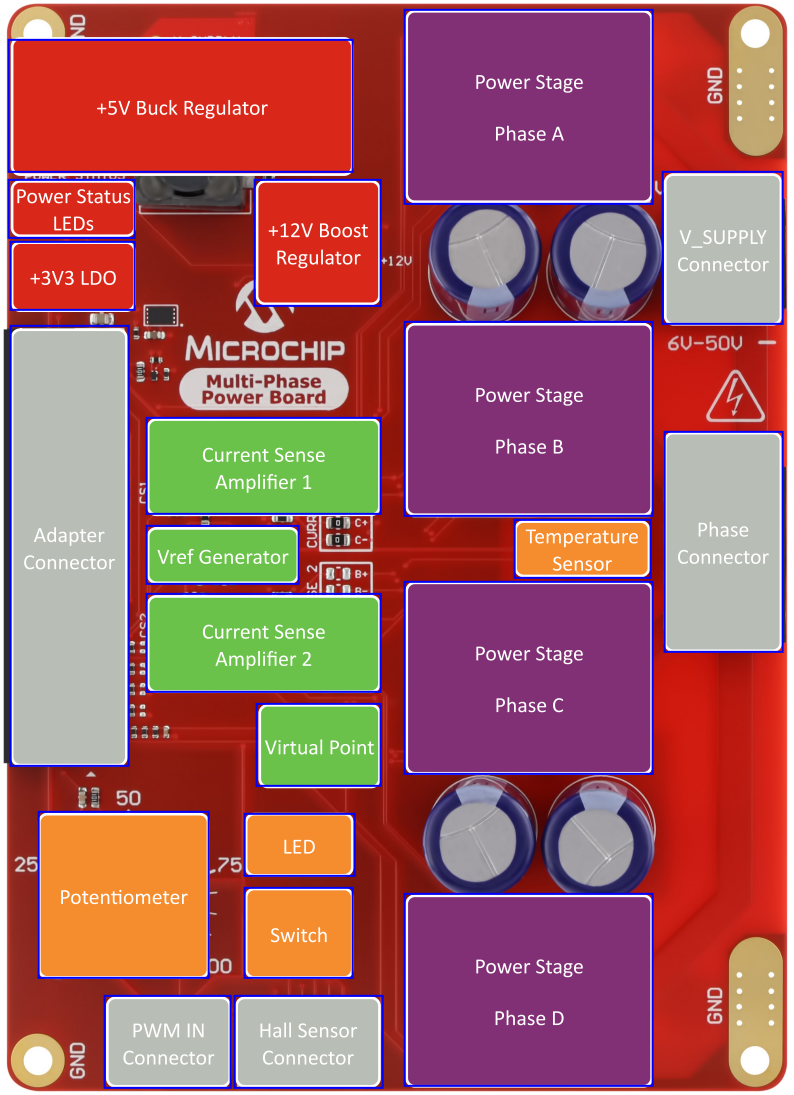
- Multi-Phase Power Board (EV35Z86A)
- AVR16EB32-CNANO MPPB Adapter (EV88N31A)
- AVR16EB32 Curiosity Nano (EV73J36A)

Figure 1-1. A Complete System: Multi-Phase Power Board with Adapter Board and Curiosity Nano



1.2 MPPB Overview

Figure 1-2. Multi-Phase Power Board Overview



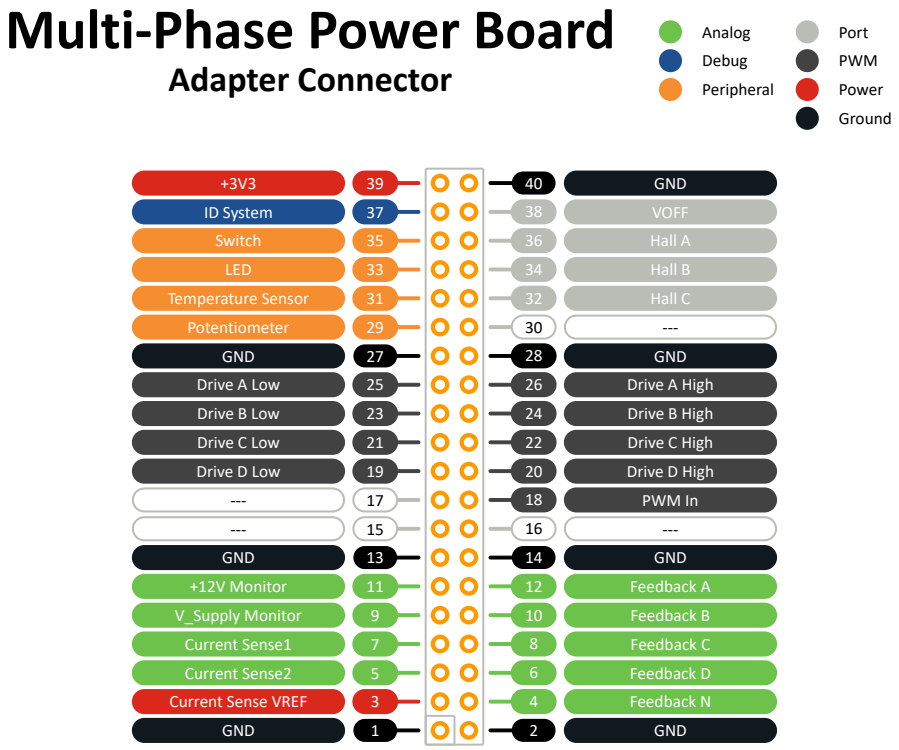
1.3 MPPB Feature List

- Power stage for motor control
- Board-to-board connector for Multi-Phase Power Board Adapters
- Wide voltage range
  - Supports 6-50V external power input
  - Rated for 10A at 24V
- Four output phases
  - Individually controllable
  - MIC4605 half-bridge MOSFET driver
  - Voltage feedback from each phase
- User-configurable virtual point
- Two current sense channels
  - User-configurable phase selection
  - Using MCP6021 Operational amplifiers
- On-Board Peripherals
  - MCP9701 temperature sensor
  - Potentiometer
  - User LED and push button
  - Optional external PWM input
  - Optional HALL sensor input
- Board identification in MPLAB® X IDE
- On-board Power Supplies
  - MIC28512 5V 2A Synchronous buck regulator, steps down input voltage
  - MCP1754 3.3V 150 mA LDO to power connected adapter, peripherals and I/O
  - MCP1661 12V 200 mA PWM Boost Regulator powering the MOSFET drivers

2. Adapter Connector

All features of the Multi-Phase Power Board are accessible through the Adapter connector, a 2x20 position, 100-mil (2.54mm) pitch right-angled socket connector.

Figure 2-1. Adapter Connector Pin-out



Position on Adapter Connector	Name	Function
1	GND	Power and signal return
2	GND	Power and signal return
3	CURRENT SENSE VREF	On-board voltage reference output
4	FEEDBACK N	Virtual Neutral point voltage feedback
5	CURRENT SENSE 2	Current sense amplifier 2 output
6	FEEDBACK D	Phase D voltage feedback
7	CURRENT SENSE 1	Current sense amplifier 1 output
8	FEEDBACK C	Phase C voltage feedback
9	V_SUPPLY MONITOR	Main supply voltage monitor
10	FEEDBACK B	Phase B voltage feedback
11	+12V MONITOR	12V boost regulator voltage monitor
12	FEEDBACK A	Phase A voltage feedback

.....continued

Position on Adapter Connector	Name	Function
13	GND	Power and signal return
14	GND	Power and signal return
15	–	Not connected
16	–	Not connected
17	–	Not connected
18	PWM IN	PWM-IN signal (level shifted)
19	DRIVE D LOW	Phase D low side control input
20	DRIVE D HIGH	Phase D high side control input
21	DRIVE C LOW	Phase C low side control input
22	DRIVE C HIGH	Phase C high side control input
23	DRIVE B LOW	Phase B low side control input
24	DRIVE B HIGH	Phase B high side control input
25	DRIVE A LOW	Phase A low side control input
26	DRIVE A HIGH	Phase A high side control input
27	GND	Power and signal return
28	GND	Power and signal return
29	POTENTIOMETER	Adjustable voltage divider analog output
30	–	Not connected
31	TEMPERATURE SENSOR	On-board temperature sensor analog output
32	HALL C	Hall sensor C-channel (level shifted)
33	LED	On-board LED active-low input
34	HALL B	Hall sensor B-channel (level shifted)
35	SWITCH	On-board switch active-low output
36	HALL A	Hall sensor A-channel (level shifted)
37	ID SYSTEM	Provides board information to MPLAB-X IDE
38	VOFF	Open-drain output indicates whether MPPB board is powered
39	+3V3	+3.3V supply output
40	GND	Power and signal return

3. Peripherals

3.1 User LED

There is one user-controllable LED available on the Multi-Phase Power Board. The LED is red and can be activated by pulling the connected I/O line low.

Table 3-1. LED Connection

Position on Adapter Connector	Silk Screen Marking
33	LED

3.2 User Switch

The Multi-Phase Power Board features a push-button switch, which pulls the connected I/O line low when pressed.

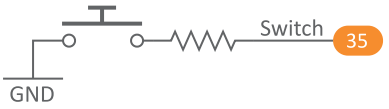


Table 3-2. Switch Connection

Position on Adapter Connector	Silk Screen Marking
35	SWITCH

3.3 User Potentiometer

There is a 10 kΩ potentiometer on the Multi-Phase Power Board. It is connected as a voltage divider and supplies a linearly adjustable voltage to the Adapter connector.

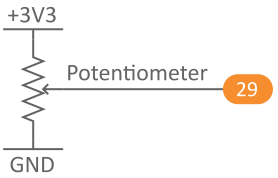


Table 3-3. Potentiometer Connection

Position on Adapter Connector	Silk Screen Marking
29	POT-METER

3.4 Temperature Sensor

An MCP9701 analog temperature sensor is located in the power stage of the Multi-Phase Power Board, close to the phase connector.

The output voltage is a linear function of the measured temperature:

$$V_{OUT}[\mathrm{mV}] = 19.5 \times \mathrm{T}[^{\circ}\mathrm{C}] + 400$$

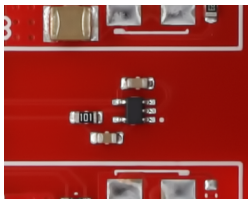


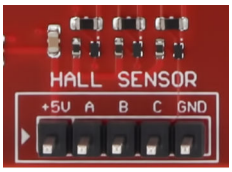
Table 3-4. Temperature Sensor Connection

Position on Adapter Connector	Location
31	Between phase B and C

3.5 Hall Sensor Header

The Hall sensor connector is a 5-pin 100-mil header for connecting push-pull or open-drain hall sensors.

Pull-up resistors set idle signals to 5V, while level shifters adjust the hall signals to 3.3V for the Adapter connector.



Info: The bi-directional level shifters allow the Hall sensor pins to function as both inputs and outputs.

Table 3-5. Hall Sensor Connections

Position on Hall Sensor Connector	Silk Screen Marking	Position on Adapter Connector
1	+5V	–
2	A	36
3	B	34
4	C	32
5	GND	–

3.6 PWM Input Header

The PWM input header is a 3-pin 100-mil header with a pinout compatible with standard hobby servos.

A pull-up resistor sets the idle signal to 5V, while a level shifter adjusts the PWM signal to 3.3V for the Adapter connector.

A 6.8Ω resistor between the +5V pin and the on-board +5V regulator acts as protection against accidental short circuits.

Info: The bi-directional level shifter allows the PWM header to function as both an input and output.

Table 3-6. PWM Header Connections

Position on PWM In Connector	Silk Screen Marking	Position on Adapter Connector
1	PWM	18
2	+5V	–
3	GND	–

4. Power Stage

The Multi-Phase Power Board power stage features four identical output channels. These are known as the board's “Phases” and are labeled A through D.

Each phase can be independently controlled through the adapter connector, and provides options for voltage and current feedback.

Power Stage Performance	
Voltage Range	6V to 50V
Power(1)	10A at 24V

Note:
1: Typical performance in base configuration.

4.1 Phase Output

Each output phase consists of two N-channel power MOSFETs (SIR120DP by Vishay) arranged in a half-bridge configuration. The gates are controlled by a Microchip MIC4605-1 half-bridge MOSFET driver, allowing individual control of the high and low side MOSFETs while providing shoot-through protection.

The control signals are available through the adapter connector. Pull-down resistors are mounted close to the MIC4605, so neither MOSFET is active by default, causing the phase output to float.

Each phase has a ten mΩ low-side current sense resistor routed into the on-board current sense system.

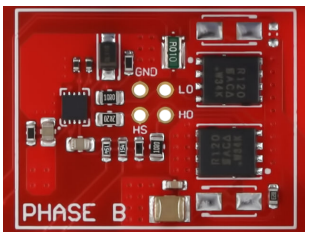


Figure 4-1. Half Bridge Functional Diagram

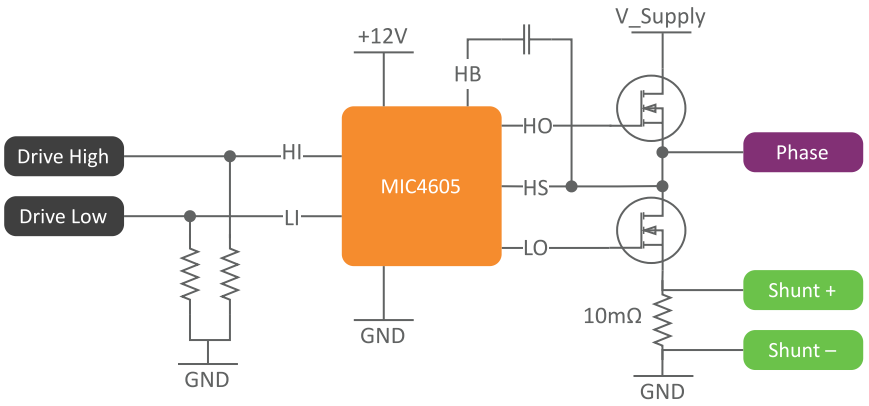


Table 4-1. Key MOSFET Parameters

SIR120DP Summary	
V_{DS}	80V
$R_{DS(ON)}$ max. at V_{GS}= 10V	0.00355Ω
Q_g typ.	48.5 nC
I_D	106A

Table 4-2. Half Bridge Drive Connections

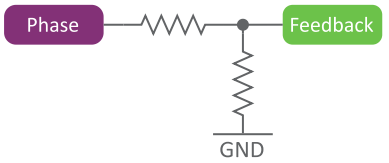
Phase	Signal	Position on Adapter Connector
A	Drive A High	26
	Drive A Low	25
B	Drive B High	24
	Drive B Low	23
C	Drive C High	22
	Drive C Low	21
D	Drive D High	20
	Drive D Low	19

4.2 Voltage Feedback

The MPPB's power stage provides voltage feedback options for each phase and includes a configurable virtual neutral point for back EMF measurements.

4.2.1 Phase Voltage Sense

The instantaneous output voltage of each phase is routed through a resistor divider before being exposed on the adapter connector.



Info: The phase output voltages are divided by 16 to bring them within 0-3.3V for the full V_Supply range.

Table 4-3. Phase Voltage Connections

Phase	Signal Name	Position on Adapter Connector
A	Feedback A	12
B	Feedback B	10
C	Feedback C	8
D	Feedback D	6

4.2.2 Virtual Neutral Point

The 3-phase virtual neutral point is implemented using resistors and provides an instantaneous average voltage of the three phases connected to it.

In the out-of-box configuration, phases A, B and C are connected to the virtual neutral. Other configurations are possible by modifying the board and moving the 0805-size 0-Ohm resistors.

Info: The virtual neutral point output voltage is divided by 16 to bring it within 0-3.3V for the full V_Supply range.

Figure 4-2. Virtual Neutral Point

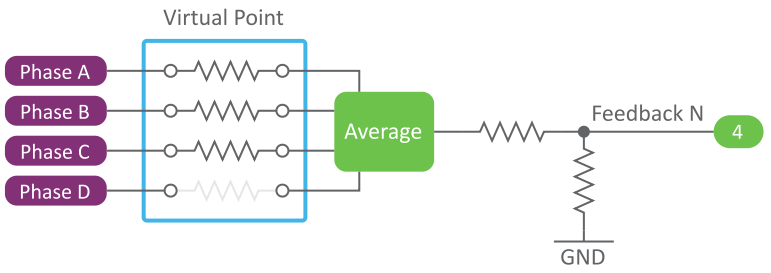


Table 4-4. Virtual Point Connection

Phase	Signal Name	Position on Adapter Connector
Virtual Neutral Point	Feedback N	4

4.3 Phase Current Sense

The Multi-Phase Power Board features two independent current sense amplifiers, implemented using MCP6021op-amps in a differential summing configuration around a reference voltage.

The number of phases connected to each amplifier is configurable and will influence the transfer function as per Table 4-5.

Table 4-5. Amplifier Transfer Functions

# Phases Connected	Amplifier Gain	Transfer Function
1Ph	15	$V_{CS} = V_{REF} - \frac{3}{20} I_{PH1}$
2Ph	10	$V_{CS} = V_{REF} - \frac{1}{10}(I_{PH1} + I_{PH2})$
3Ph	7.5	$V_{CS} = V_{REF} - \frac{3}{40}(I_{PH1} + I_{PH2} + I_{PH3})$

4.3.1 Current Sense Amplifier 1

Current Sense Amplifier 1 can connect to phases A, B and C. In the out-of-box configuration, it is connected to all three. Other configurations are possible by modifying the board and moving the 0805-size 0-Ohm resistors.

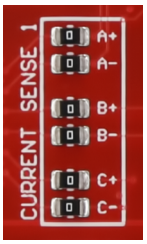


Figure 4-3. Current Sense 1 Block Diagram

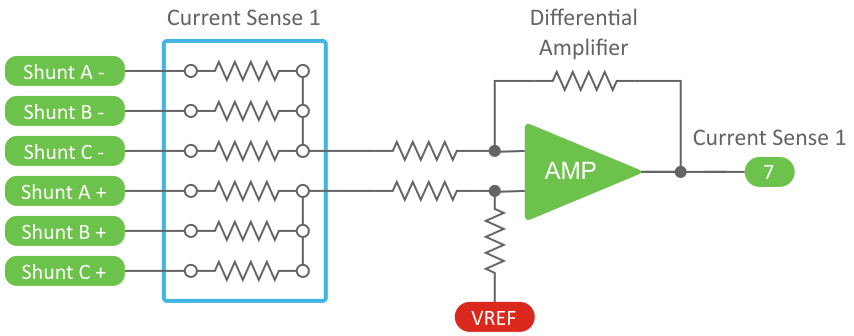


Table 4-6. Current Sense 1 Connection

Position on Adapter Connector	Silk Screen Marking
7	CS1

4.3.2 Current Sense Amplifier 2

Current Sense Amplifier 2 can connect to phases B, C and D. In the out-of-box configuration it is connected only to phase D. Other configurations are possible by modifying the board and moving the 0805-size 0-Ohm resistors.

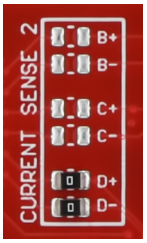


Figure 4-4. Current Sense 2 Block Diagram

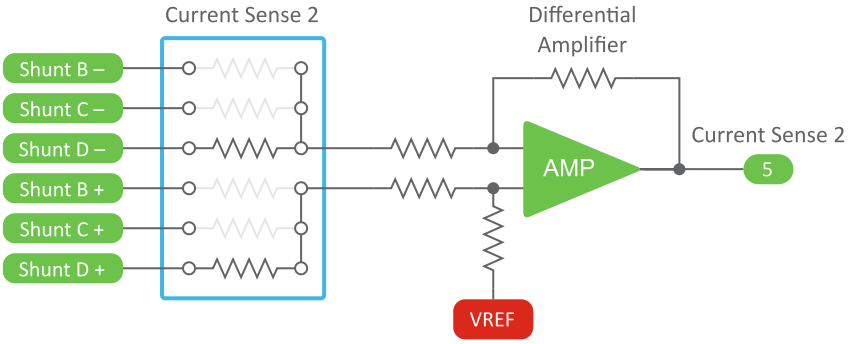


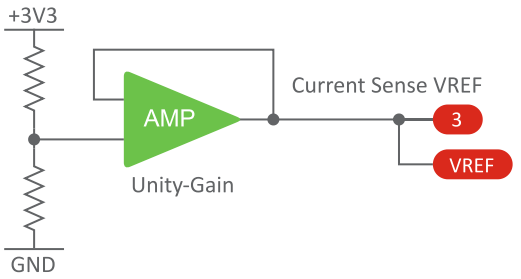
Table 4-7. Current Sense 2 Connection

Position on Adapter Connector	Silk Screen Marking
5	CS2

4.3.3 Voltage Reference

The voltage reference generates the midpoint voltage for the current sense amplifiers. It is implemented as a voltage divider feeding into an MCP6021 op-amp configured as a unity gain amplifier.

The Vref circuit output is also available on the adapter connector as an ADC reference.



Info: The voltage reference output voltage is 1.65V.

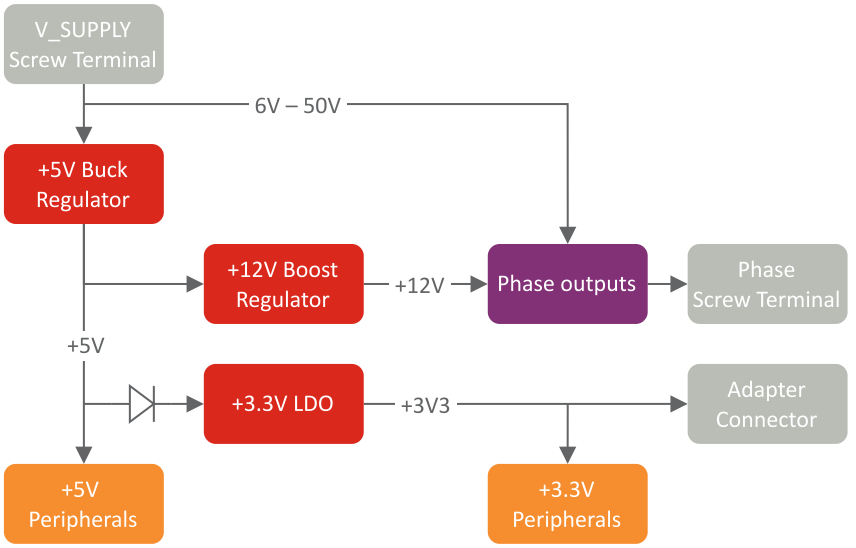
Table 4-8. Vref Connection

Position on Adapter Connector	Silk Screen Marking
3	VREF

5. Voltage Regulators

The Multi-Phase Power Board is powered entirely from the V_SUPPLY screw terminal. All required voltages are generated on-board from the main 6-50V supply through a series of regulators.

Figure 5-1. Power Supply Overview



5.1 Power Domains

There are four power domains in use on the Multi-Phase Power Board.

V_SUPPLY

V_SUPPLY can be from 6V to 50V and is applied to the board via the V_SUPPLY screw terminal. It is the primary power source for the rest of the board and the voltage used to drive the Phase Outputs. This power domain can be measured using a Voltage Monitor.

+5V

V_SUPPLY is stepped down to +5V by a MIC28512 buck regulator. In addition to being a source for the other voltage regulators, +5V is used for:

- HALL SENSOR header
- PWM IN header
- VOFF System

+12V

The MCP1661 boost regulator generates a +12V output which powers the MOSFET gate drivers in the MOSFET gate drivers in the power stage. This power domain can be measured through a Voltage Monitor.

+3V3

+3V3 is the main logic level of the Multi-Phase Power Board. It is generated by an MCP1754 LDO and used by the following peripherals:

- Adapter connector
- LED
- Potentiometer
- Temperature sensor

- Current Sense amplifiers
- VREF Circuit

Limits

Table 5-1. Voltage Rail Limits

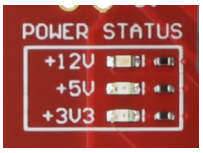
Domain	V_{min}	V_{max}	I_{max}
V_SUPPLY	6V	50V	30A
+5V	4.81V	5.17V	2A
+12V	11.40V	12.55V	200 mA
+3V3	3.23V	3.37V (1)	150 mA

Note:
1: The +3V3 rail is reverse blocking and tolerant of voltages up to 5.5V.

5.2 Power Status LEDs

The power status section of the MPPB features three LEDs that indicate which of the on-board power domains have a voltage present:

- +12V Blue LED
- +5V Green LED
- +3V3 Yellow LED



5.3 Voltage Monitors

You can monitor the V_SUPPLY and +12V voltage domains on the Multi-Phase Power Board from the adapter connector via fixed voltage dividers.

Table 5-2. Voltage Monitor Connections

Position on Adapter Connector	Net	Divisor
9	V_SUPPLY	16
11	+12V	4

5.4 Voff Functionality

The Voff (Voltage-Off) signal is an open drain output from the Multi-Phase Power Board that indicates whether the MPPB is powered. The signal is held low as long as the +5V rail is present, indicating that the MPPB supplies +3.3V to the Adapter connector.

This functionality is used to inhibit other power sources on connected adapters from conflicting with the MPPB's on-board regulators.

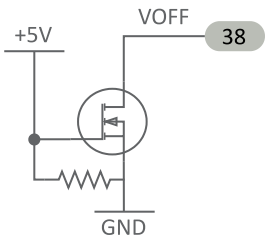


Table 5-3. Voff Connection

Position on Adapter Connector	Silk Screen Marking
38	VOFF

6. Adapter Boards

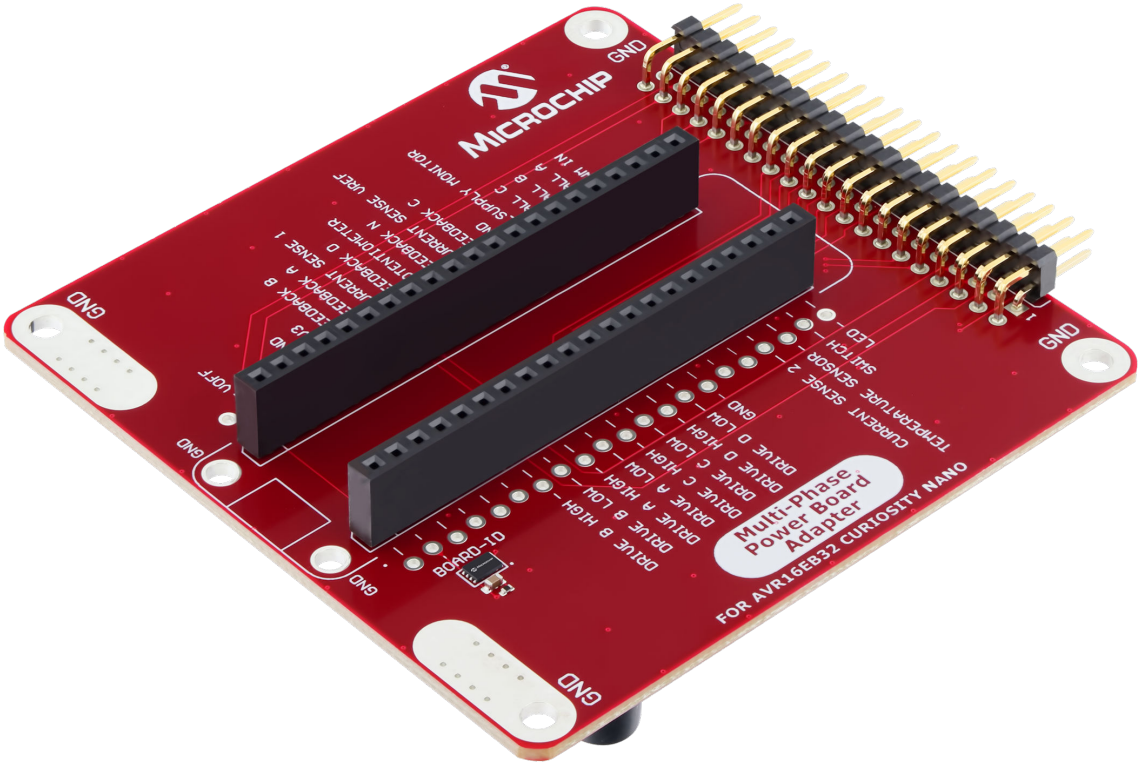
Adapter boards compatible with the Multi-Phase Power Board system.

6.1 AVR16EB32-CNANO Adapter

Multi-Phase Power Board Adapter for AVR16EB32 Curiosity Nano acts as a bridge between an AVR16EB32 Curiosity Nano board and the MPPB.

A full solution for the AVR16EB32 requires the following three development kits:

- Multi-Phase Power Board (EV35Z86A)
- AVR16EB32-CNANO MPPB Adapter (EV88N31A)
- AVR16EB32 Curiosity Nano (EV73J36A)

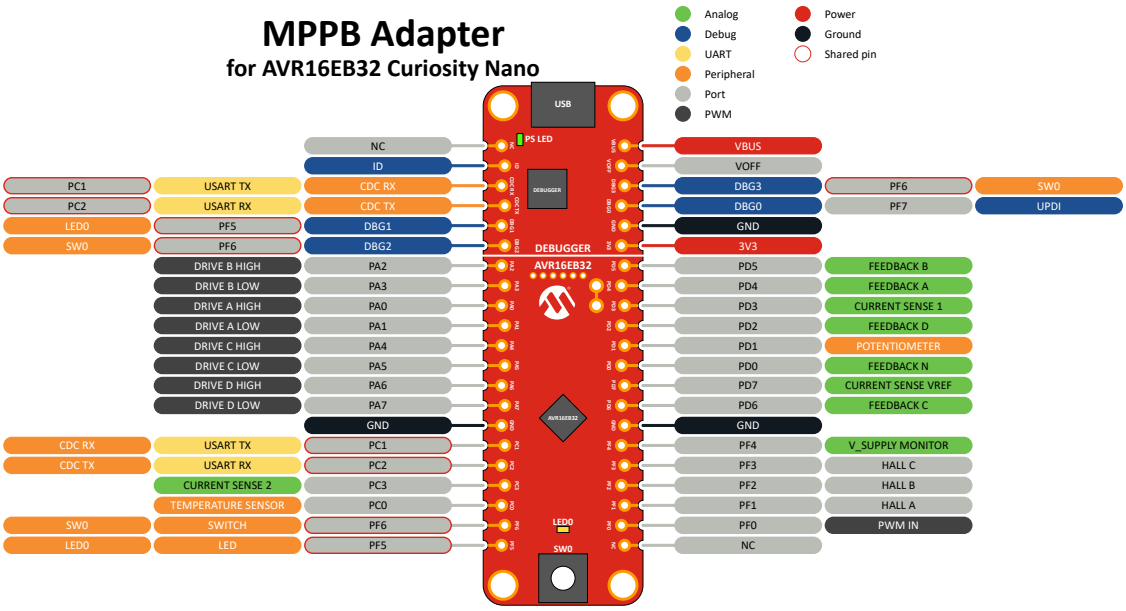


- **Website** - Purchase this adapter, board information, and design documentation
- **Schematics** - Board schematics and history
- **Altium Project** - Altium Design files for the latest board revision
- **Design Documentation** - Production files for every revision

6.1.1 AVR16EB32-CNANO Adapter Pinout

The adapter maps the Curiosity Nano edge connector pins to the MPPB board features according to Figure 6-1.

Figure 6-1. AVR16EB32-CNANO MPPB Adapter Pin Mapping



6.1.2 AVR16EB32-CNANO Adapter Revision History

Details on finding Product ID and Revision: Identifying Product ID and Revision. The product identifier of the AVR® EB adapter is 02-01017.

Revision 2

This is the initially released revision of the AVR16EB32-CNANO MPPB Adapter.

7. Revision History

Hardware and Document Revision History.

7.1 Hardware Revision History and Known Issues

This user guide provides information about the latest available revision of the board. The following sections contain information about known issues, a revision history of older revisions, and how older revisions differ from the latest revision.

7.1.1 Identifying Product ID and Revision

There are two ways to find the revision and product identifier of the Multi-Phase Power Board and its Adapters: The MPLAB X IDE Kit Window or the sticker on the bottom of the PCB.

The Kit Window appears in MPLAB X IDE when connecting a Curiosity Nano development board to the computer. An additional page for the MPPB and Adapters shows when the CNANO is plugged into the socket on the board.

The first nine digits of the serial number, listed under kit information, contain the product identifier and revision.

Tip: If closed, you can open the Kit Window in MPLAB X IDE through the menu bar **Window** > **Kit Window**.

The same information is found on the sticker on the bottom side of the PCB. The data matrix code on the sticker contains a string with the product identifier, revision and serial number.

The product identifier and revision of the MPPB are printed in plain text as 02-00671/rr, where "rr" represents the revision. The serial number is printed on the following line.

The string in the data matrix code has the following format:

"nnnnnnnrrssssssss"

n = product identifier

r = revision

s = serial number

7.1.2 Revision 3

Revision 3 removes all 5% resistors and replaces them with equivalent 1% alternatives:

Resistor	Value
R104, R110, R505	1 kΩ
R120, R400, R402, R404, R406, R408, R409, R410, R411	150 kΩ
R100, R113, R116, R118, R305_CS1, R305_CS2	100Ω

7.1.3 Revision 2

Revision 2 of the Multi-Phase Power Board.

Revision 2 is the initially released board revision of the Multi-Phase Power Board.

7.2 Document Revision History

Doc. Rev.	Date	Comments
A	08/2024	Initial document release

8. Appendix

Schematics, Assembly Drawing

8.1 Schematics

Figure 8-1. Top Level

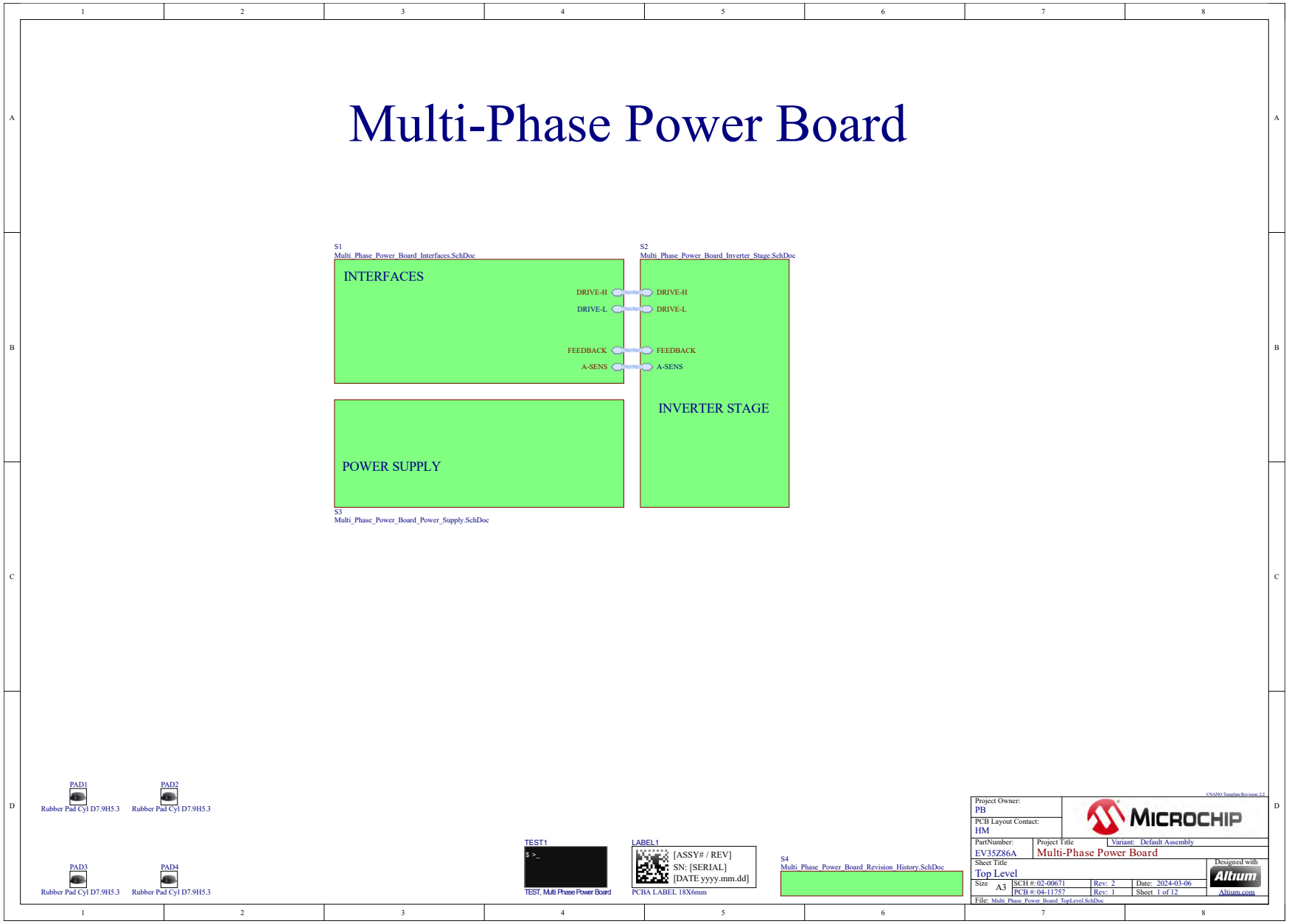


Figure 8-2. Interfaces

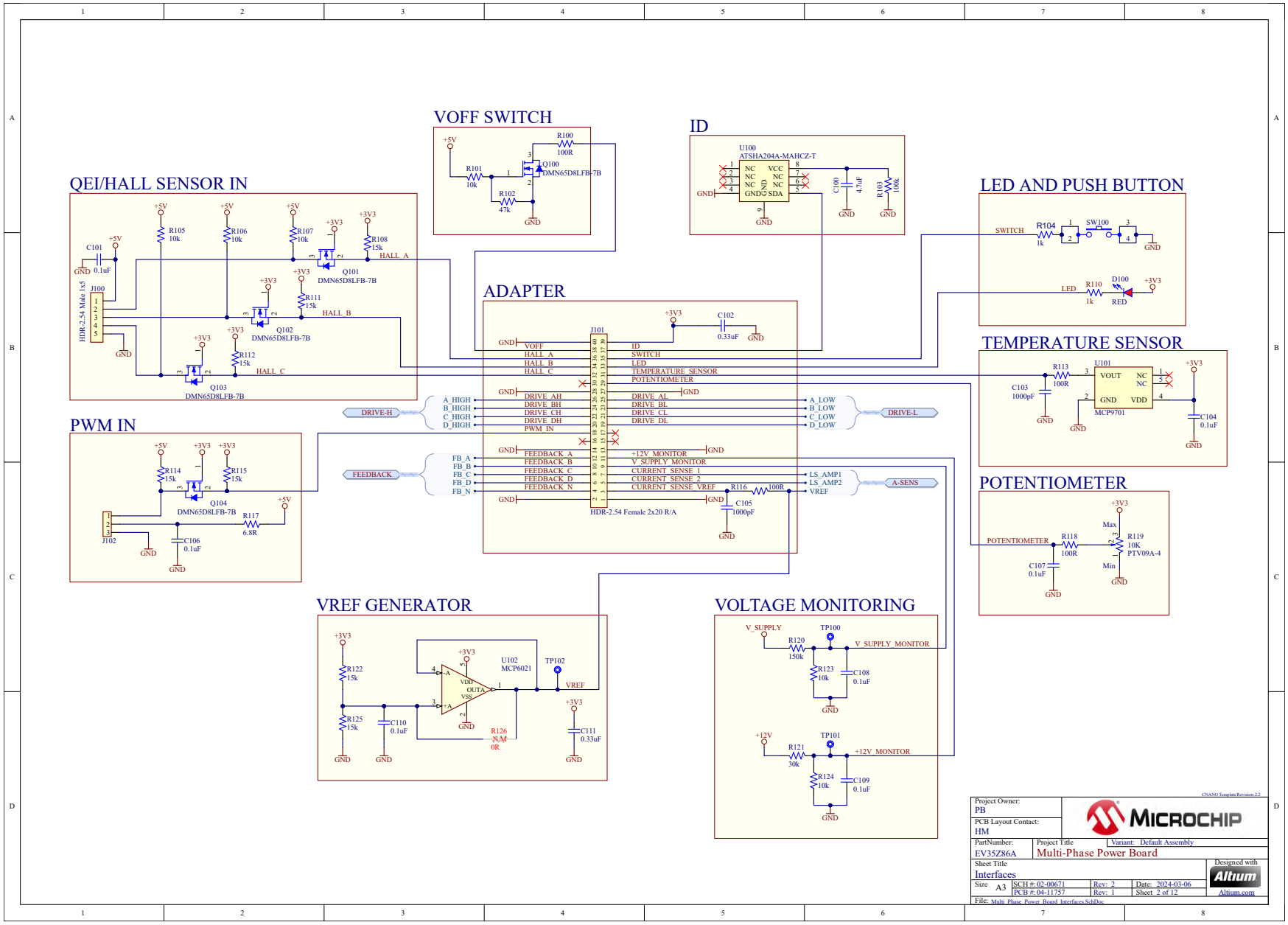


Figure 8-3. Inverter Stage

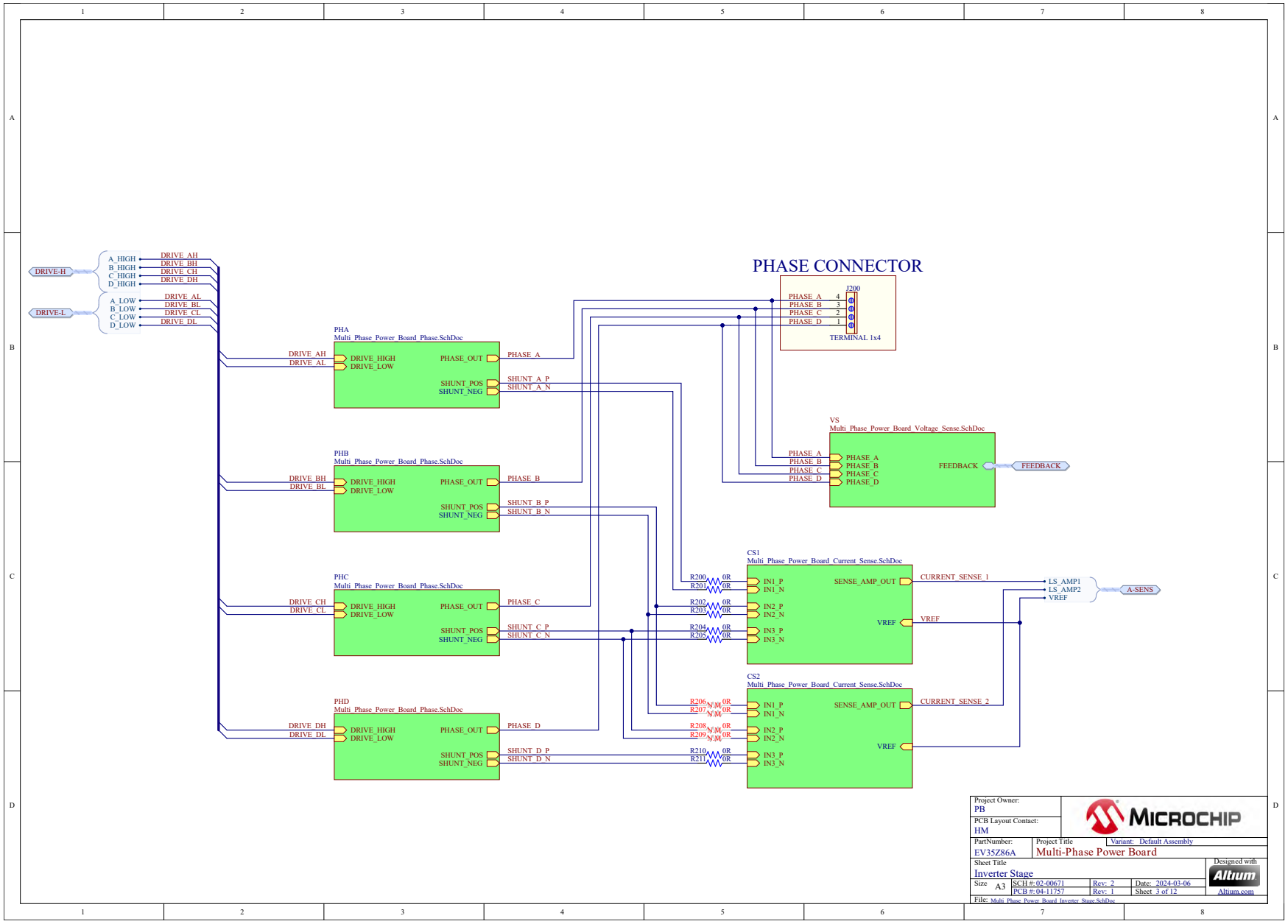


Figure 8-4. Phase x 4

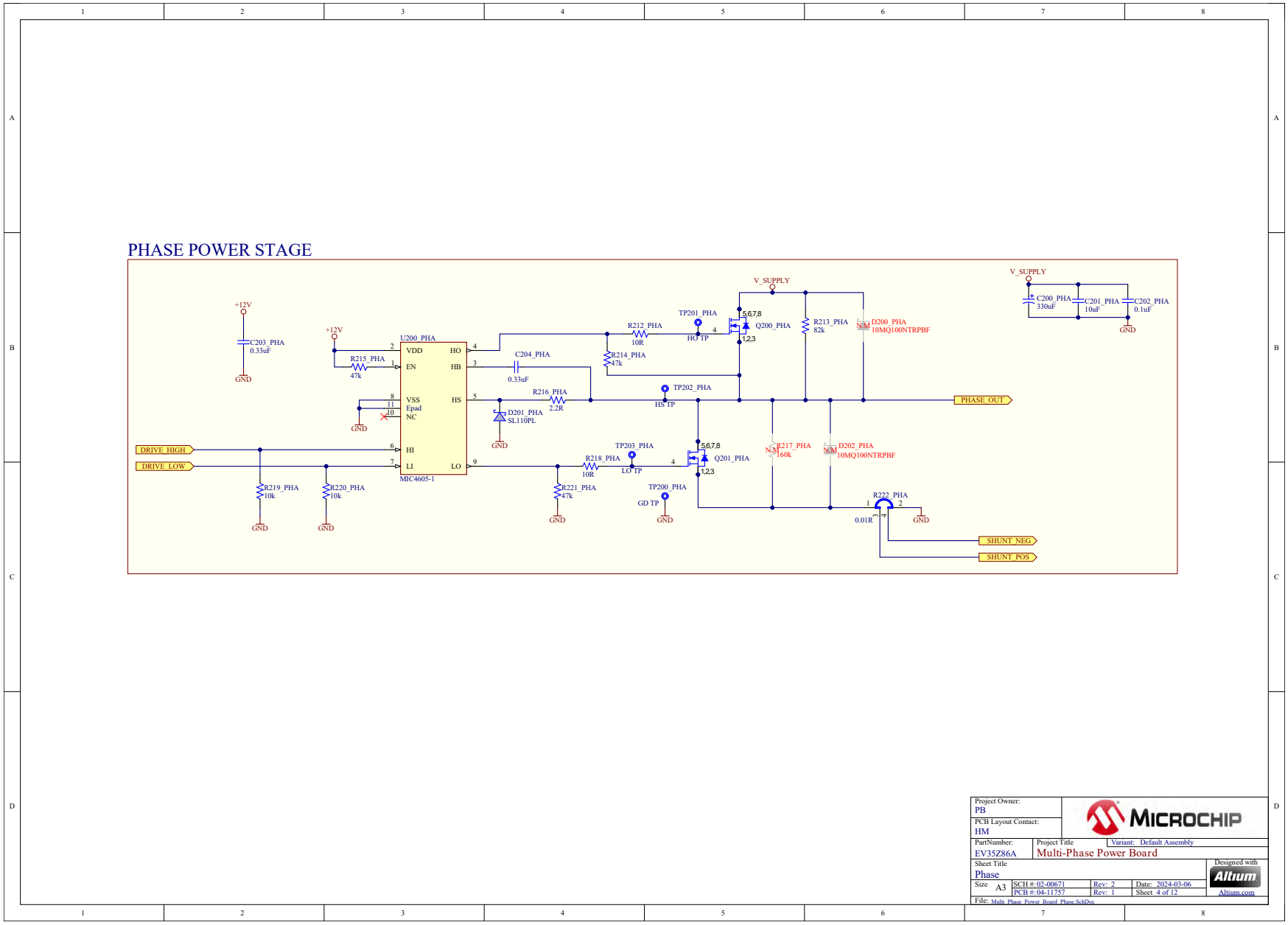


Figure 8-5. Current Sense x 2

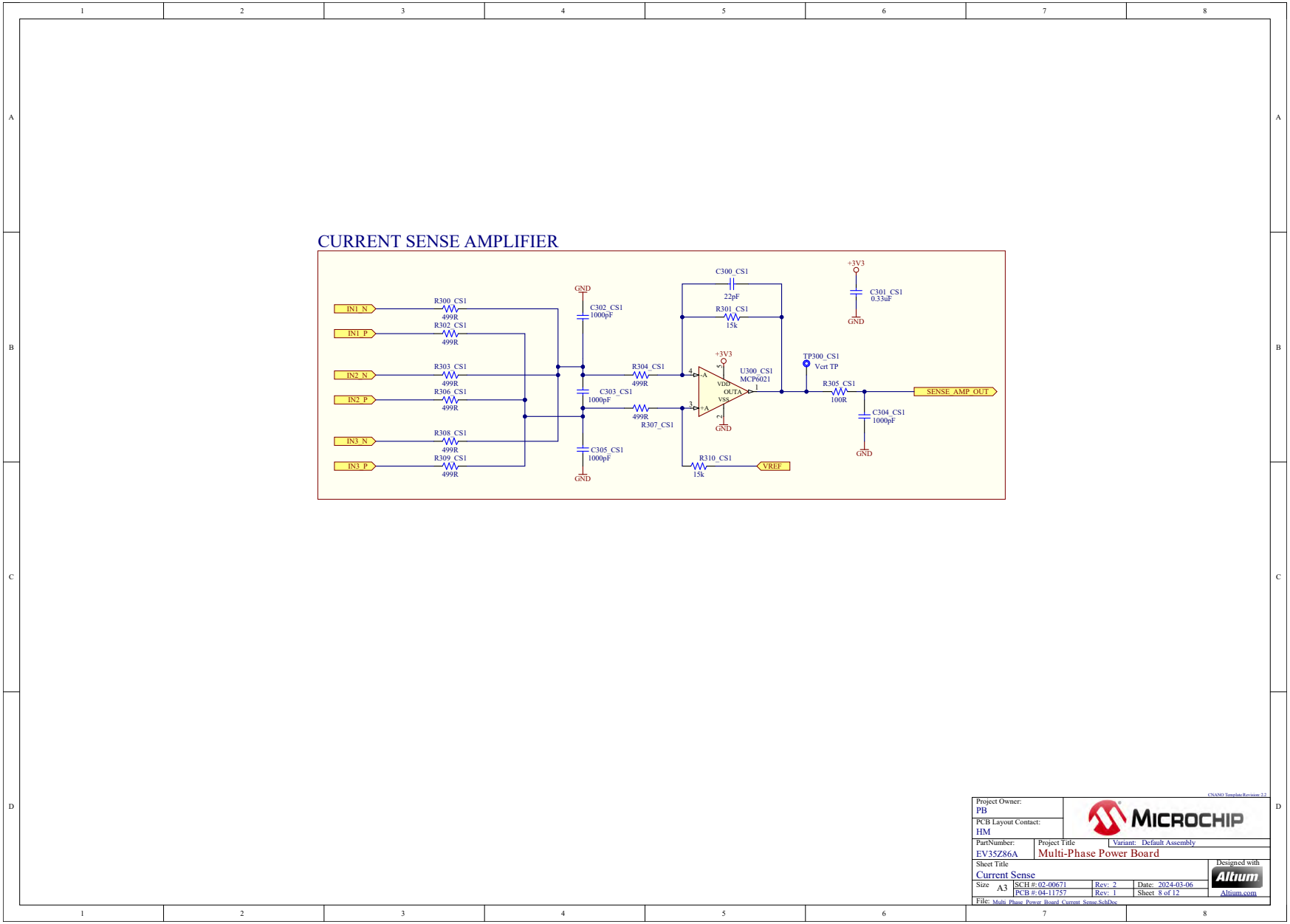


Figure 8-6. Voltage Sense

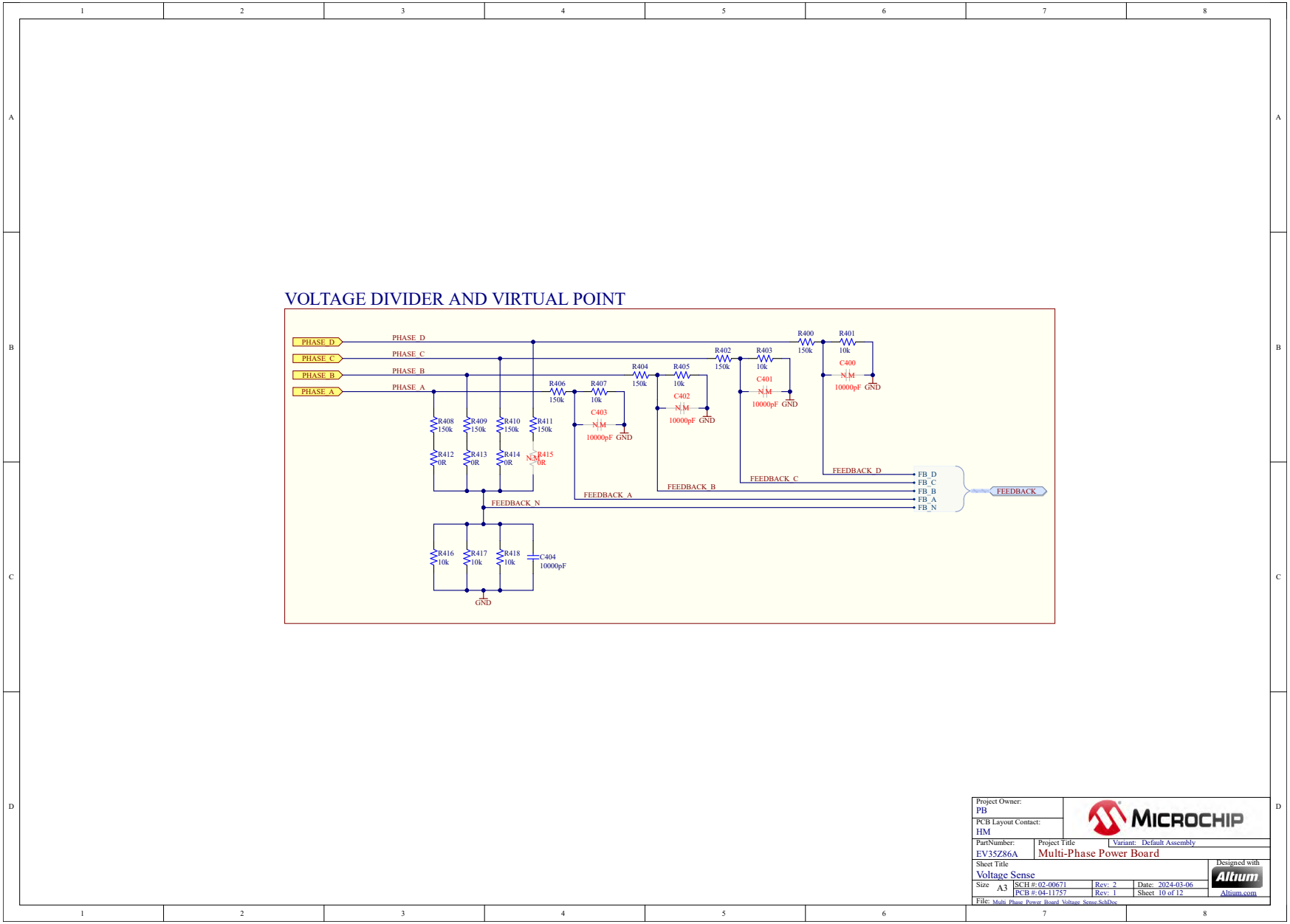
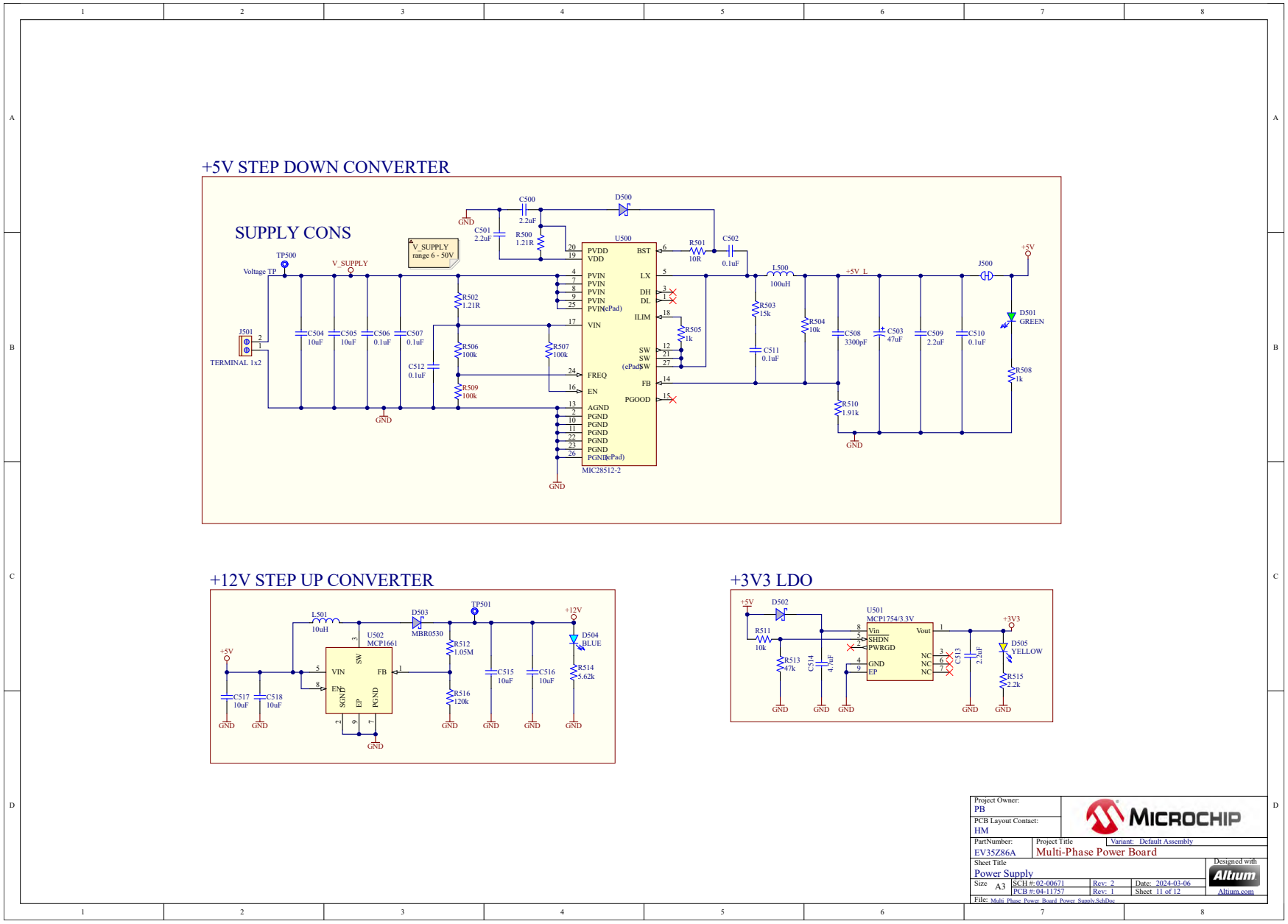


Figure 8-7. Power Supply



8.2 Assembly Drawings

Figure 8-8. Top Assembly

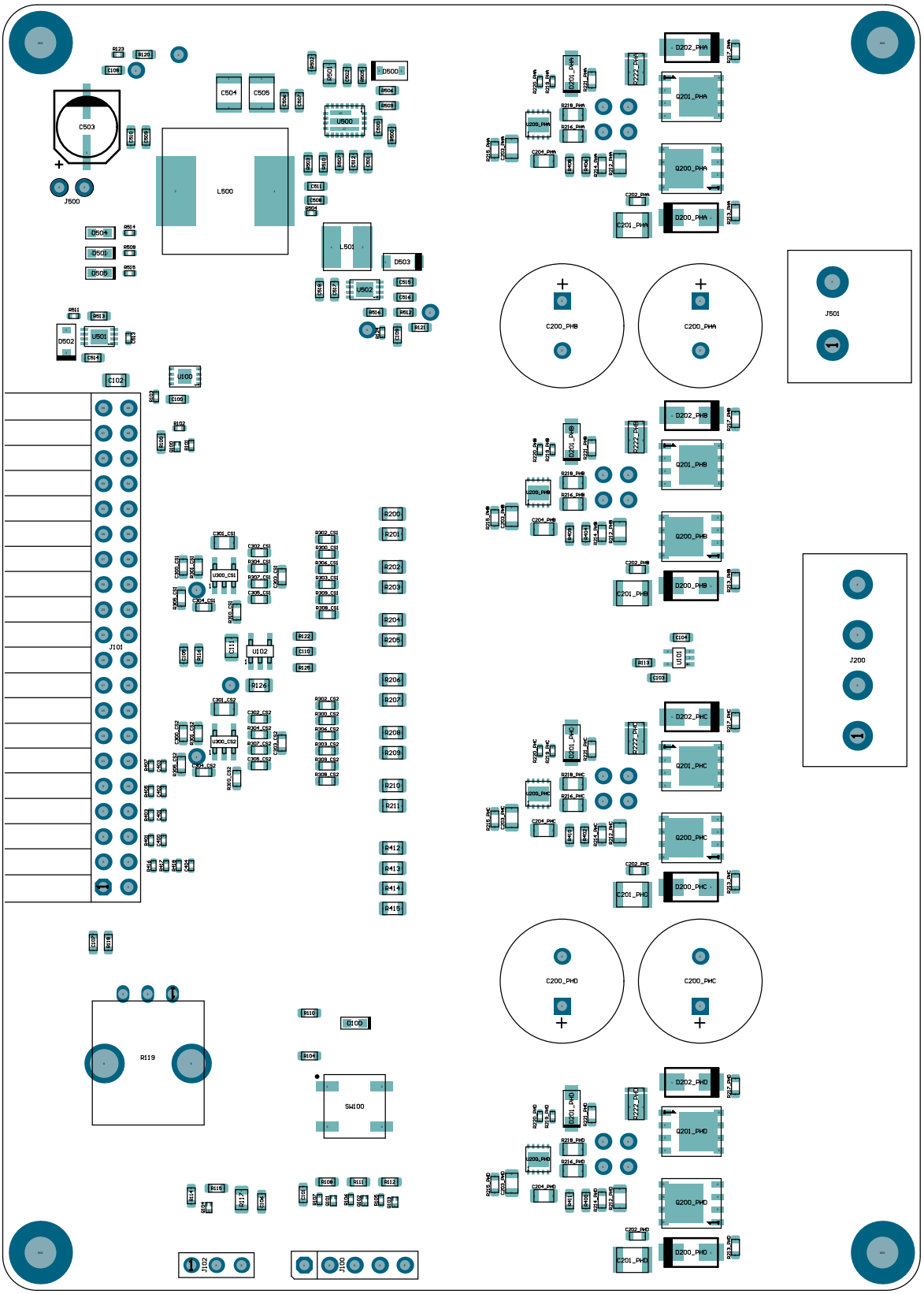
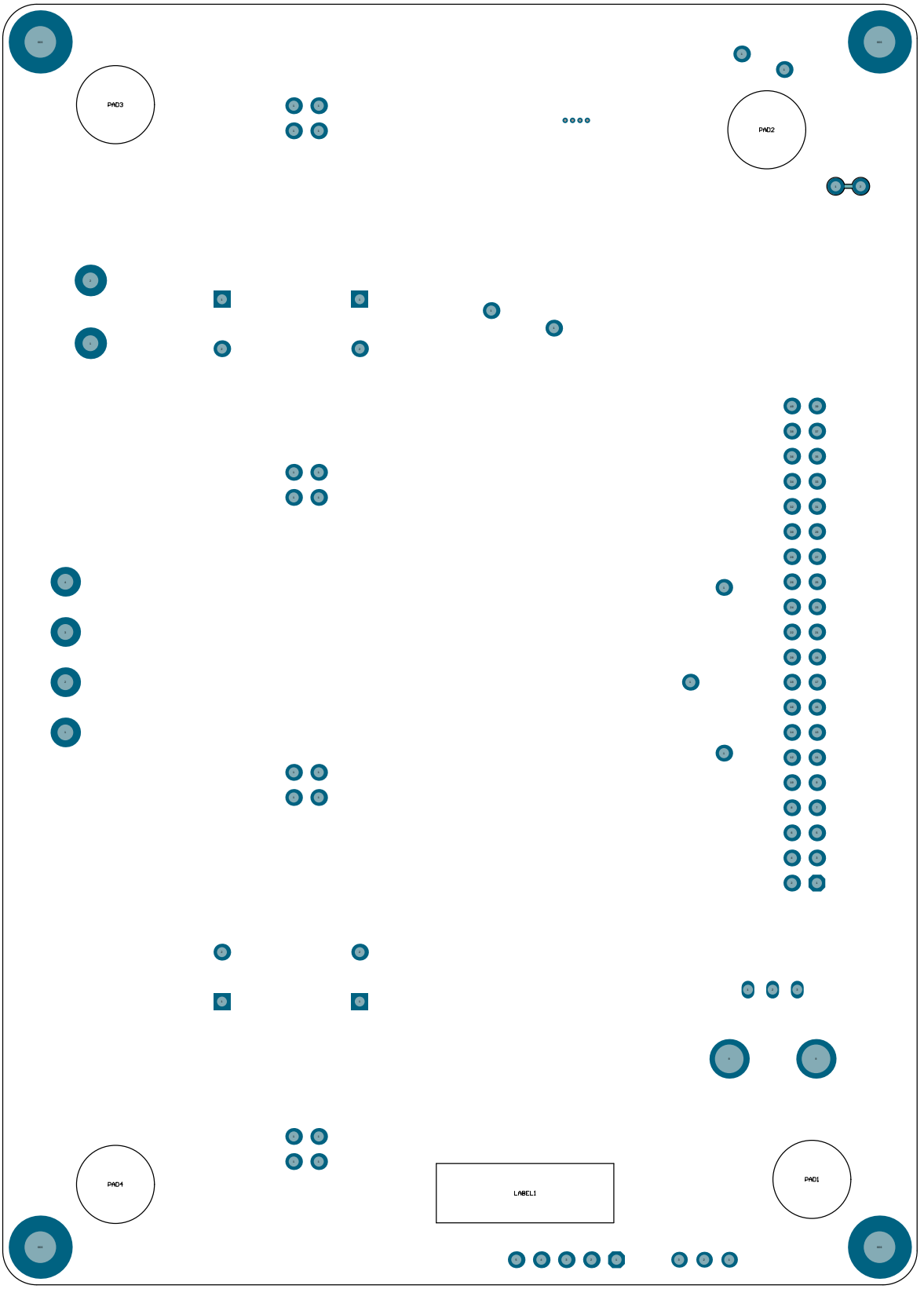


Figure 8-9. Bottom Assembly



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