Power Pal - Wide Input Range (14.5 to 52 V) Triple Output (3.3, 5 and 12 V) High Power, High Efficiency DC-DC Buck Converter

1 Features

- Triple-output synchronous DC-DC power module
- 14.5–52 V steady-state input (supports 5S–12S lithium packs)
- Simultaneous outputs (at 25 °C):
  - 12 V @ 10 A (16 A*)
  - 5 V @ 5 A (6 A*)
  - 3.3 V @ 5 A (6 A*)
- VIN pass-through / dedicated VIN terminal
- External Enable (EN) input, microcontroller compatible
- Power-Good (PGOOD) status output and LED
- Adjustable output voltage trim to account for load or cable drop
- 80 ms soft start
- Screw-terminal power connections
- Protection features:
  - Input reverse polarity protection (ideal-diode controller + MOSFET)
  - Input TVS surge protection
  - TVS protection on all outputs
  - Overcurrent limiting (regulator current limit)
  - Overtemperature shutdown
  - Undervoltage lockout / cutoff
- Optional fan header for active cooling tied to the 12V output

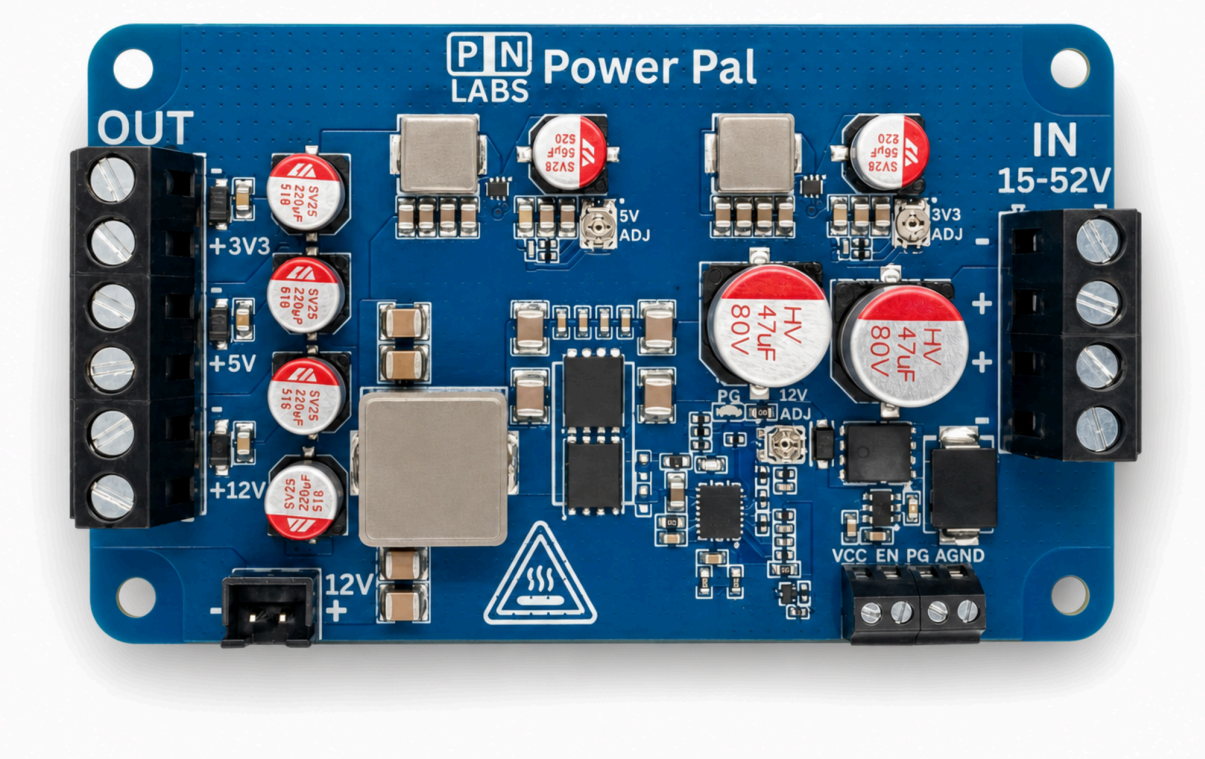
2 Applications

- Prototyping and test equipment
- Robotics and autonomous systems
- Battery-powered electronics (5S–12S lithium)
- Industrial and embedded controllers
- Motor control systems
- Non-isolated PoE auxiliary rails

3 Description

The PN Labs Power Pal is a triple-output synchronous DC-DC power module with a 14.5–52 V steady-state input (5S–12S lithium compatible), delivering simultaneous outputs of 12 V (10 A, up to 16 A*), 5 V (5 A, up to 6 A*), and 3.3 V (5 A, up to 6 A*), plus a dedicated VIN pass-through terminal. With many highly desirable features like external enable, power-good status with LED, adjustable output trim, and 80 ms soft start, it is highly suitable for a wide array of applications. Power Pal features a comprehensive protection scheme including reverse polarity, input and output TVS diodes, overcurrent limiting on all output rails, overtemperature shutdown and undervoltage lockout. Screw-terminal connections and an optional 12 V fan header support active cooling when required.

**with active cooling at 25°C ambient*



4 Revision History

January 6, 2026 - Initial Release

August 15, 2026, 2026 - Input voltage range corrected to 14.5 V throughout. UVLO rising and falling threshold labels corrected. 12 V peak output current aligned with the overcurrent limit. 5 V and 3.3 V overcurrent limits restated as module output trip points. Added cooled output current ratings, PGOOD drive limits, output trim limits, and battery pack cutoff guidance. Corrected long cable damping guidance in Section 8.6. VCC pin renamed.

5 Description (Continued)

The PN Labs Power Pal is a wide-input, triple-output synchronous DC-DC power module designed to deliver stable, high-current power for demanding embedded and industrial applications. It accepts a 14.5 V to 52 V steady-state input and provides simultaneous regulated outputs of 12 V (10 A, up to 16 A*), 5 V (5 A, up to 6 A*), and 3.3 V (5 A, up to 6 A*), making it well suited for multi-voltage systems powered from a single high-voltage source.

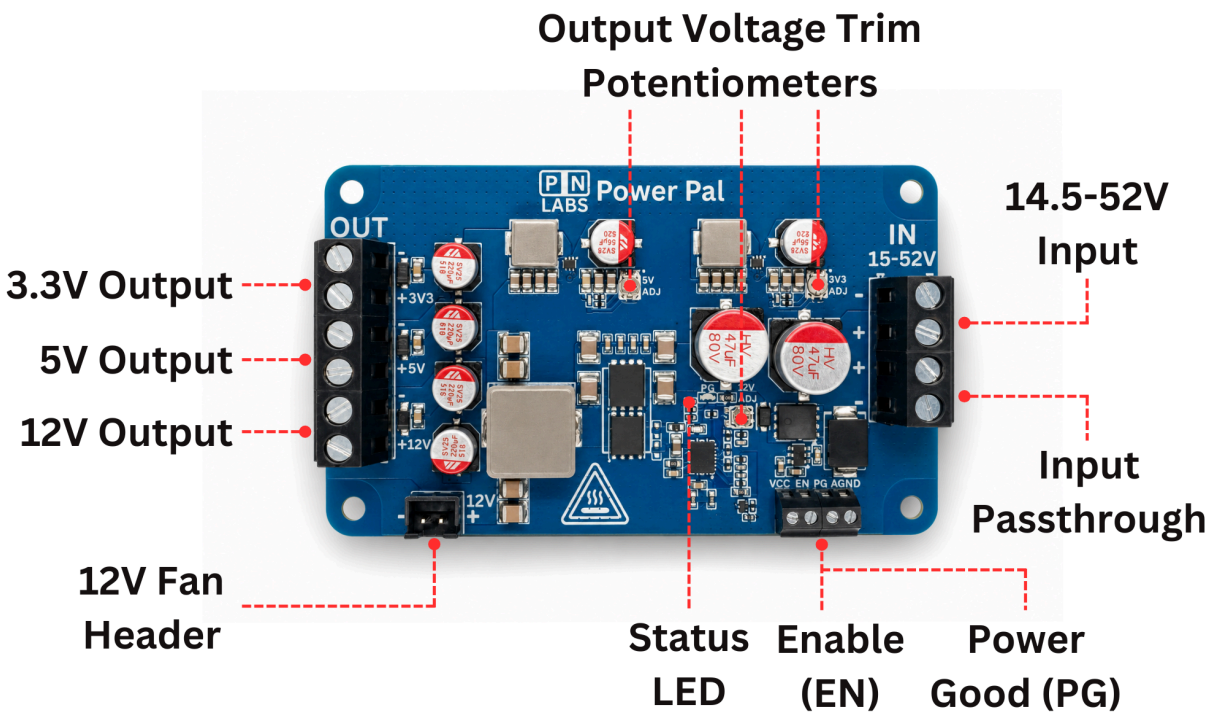
Note on battery operation: the undervoltage lockout releases the outputs at approximately 13.4 V. A 5S lithium pack reaches the 14.5 V minimum input at roughly 2.9 V per cell and the lockout point at roughly 2.7 V per cell, so the module stops delivering power before the pack is fully discharged. Size the pack accordingly if full discharge capacity is required.

Power Pal uses a two-stage cascaded architecture with a high-voltage buck feeding a 12 V intermediate bus and point-of-load regulation for the 5 V and 3.3 V rails. A dedicated VIN pass-through terminal simplifies system wiring, while external enable, power-good status with LED, adjustable output trim, and an 80 ms soft start support flexible integration with reduced inrush current.

Comprehensive protection features include reverse-polarity protection, input and output TVS surge protection, overcurrent limiting, overtemperature shutdown, and undervoltage lockout. Screw-terminal connections enable easy installation, and an optional 12 V fan header supports active cooling for higher output power applications.

**with active cooling at 25°C ambient*

6 Pin Configuration and Functions



NAME	TYPE	DESCRIPTION
EN*	Input	Active low enable input pin. Low or floating = ON, High = OFF. To hold the module ON, drive EN below 1 V or leave it open. To hold the module OFF, drive EN above 2.5 V and below the 20 V absolute maximum. Read section 8.2 for more information.
PGOOD	Output	Power-good monitor. Asserts low if the feedback voltage is not within a specified window threshold or overtemperature, overcurrent, undervoltage or reverse polarity protection has triggered. Not intended to supply any meaningful current. PGOOD is pulled high through a high impedance and can source no more than 0.1 mA, so it cannot drive an LED, an optocoupler, or any input that includes a pull-down resistor. Connect it only to a high impedance logic input, or buffer it with a MOSFET or comparator stage. PGOOD voltage closely follows the 12V output level unless there is a fault, in which case it is pulled to GND. If not used, this pin can be left open or connected to GND. High = power OK, Low = power BAD. PGOOD pin goes low when EN = HIGH / the regulator is disabled.
VREF / VCC	Output	Internal rail used for control circuitry and logic reference. Fed from 12V output. Can supply up to 20mA when the regulator is enabled.

AGND	Ref	Ground reference for EN, PGOOD, and VREF signals.

* EN is an active low input. The asterisk denotes active low polarity.

7 Specifications

7.1 Absolute Maximum ratings

Tested at 25 °C ambient temperature.

Parameter	Min	Max	Unit
Input voltage, VIN (transient, non-repetitive)	–65	65	V
Output 1 current, 12 V rail	—	20	A
Output 2 current, 5 V rail	—	7	A
Output 3 current, 3.3 V rail	—	7	A
Total output power (all rails combined)	—	250	W
EN pin voltage	–20	20	V
Storage temperature	–55	105	°C
Operating ambient temperature (stress limit; see Section 7.2 for the functional range)	–30	80	°C

Stresses beyond those listed under Section 7.1 may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Section 7.2. Exposure to absolute maximum rated conditions for extended periods may affect device reliability. In particular, the input TVS begins conducting above 54 V: input voltages above the 52 V steady-state maximum in Section 7.2 must be transient only, and continuous operation above 52 V will damage the module.

7.2 Recommended Operating Conditions

Tested at 25 °C ambient temperature.

Parameter	Min	Nom	Max	Unit
Input voltage, VIN (steady-state)	14.5	—	52	V

Ambient temperature, Ta	-10	25	45	°C
12 V output current	0	—	10	A
5 V output current	0	—	5	A
3.3 V output current	0	—	5	A
Total output power (all rails combined)	—	—	162	W
Total output power, with active cooling (all rails combined)	—	—	240	W

7.3 Electrical Characteristics

Tested at 25 °C ambient temperature and no active cooling unless otherwise stated.

Parameter	Min	Typ	Max	Unit
Input UVLO threshold, VIN rising (turn on)	—	13.7	—	V
Input UVLO threshold, VIN falling (turn off)	—	13.4	—	V
Input quiescent current, EN = LOW/ FLOAT, no load	—	70	78	mA
Input quiescent current, EN = HIGH (regulator disabled)	—	30	—	µA
EN Input Threshold (Active Low / Float)	1	1.6	2.5	V
EN Pin Voltage Maximum	—	—	20	V
VREF Voltage Output, EN = LOW/ FLOAT	—	11.10	—	V
VREF source current (max)	—	—	20	mA
12 V Output Voltage (factory setting)	11.90	12.00	12.10	V
12 V Output voltage adjustment range*	11.8	—	12.2	V
12 V Output current (continuous)	—	—	10	A
12 V Output current (peak or active cooling)	—	16	20	A

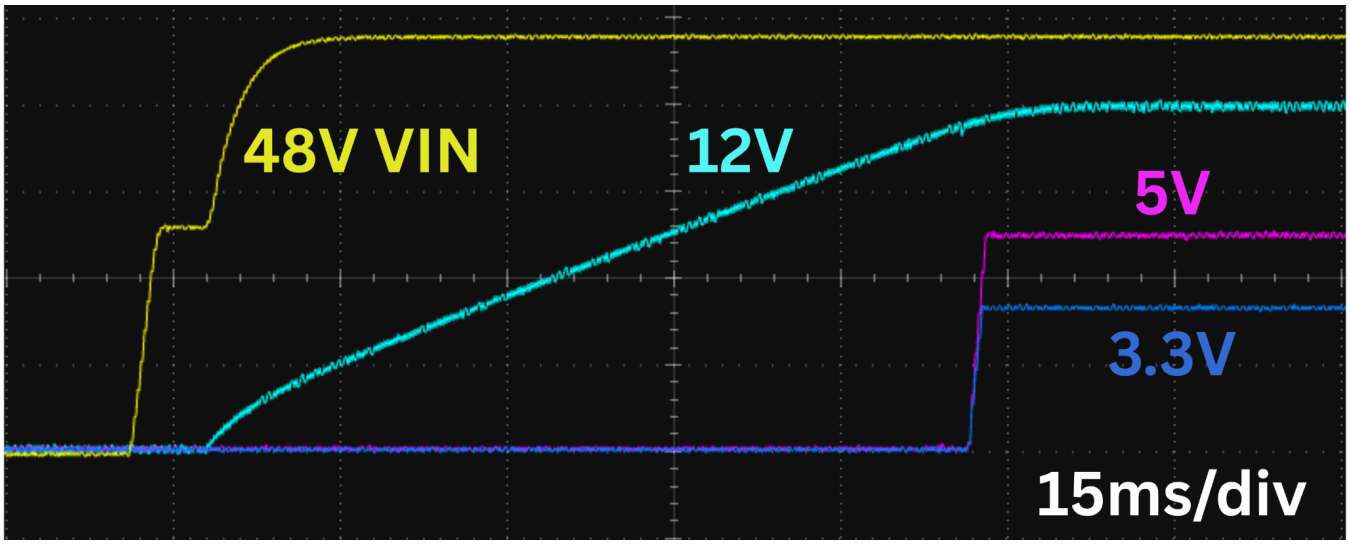
12 V Overcurrent limit	—	20	—	A
12 V Output ripple + noise (20 MHz BW)	—	—	50	mVpp
5 V Output Voltage (factory setting)	4.95	5.00	5.05	V
5 V Output voltage adjustment range*	4.8	—	5.2	V
5 V Output current (continuous)	—	—	5	A
5 V Output current (peak or active cooling)	—	—	6	A
5 V Overcurrent limit (output trip point)	7.1	8.5	10.1	A
5 V Output ripple + noise (20 MHz BW)	—	—	40	mVpp
3.3 V Output Voltage (factory setting)	3.27	3.30	3.33	V
3.3 V Output voltage adjustment range*	3.1	—	3.5	V
3.3 V Output current (continuous)	—	—	5	A
3.3 V Output current (peak or active cooling)	—	—	6	A
3.3 V Overcurrent limit (output trip point)	6.9	8.3	9.9	A
3.3 V Output ripple + noise (20 MHz BW)	—	—	50	mVpp
Efficiency, 12 V @ 10 A, 48 VIN	—	94.5	—	%
Efficiency, 5 V @ 5 A, 48 VIN	—	83.4	—	%
Efficiency, 3.3 V @ 5 A, 48 VIN	—	77.1	—	%
Switching frequency (12 V stage)	—	256	—	kHz
Switching frequency (5 V stage)	—	600	—	kHz
Switching frequency (3.3 V stage)	—	600	—	kHz
Soft-start time	—	80	—	ms
PGOOD deassert delay on disable/fault	—	25	—	µs
PGOOD output voltage	—	12 V rail	—	V

PGOOD source current	—	—	0.1	mA
12 V stage overtemperature shutdown threshold	—	175	—	°C
5 V and 3.3 V stage overtemperature shutdown threshold	—	155	—	°C
Thermal shutdown hysteresis	—	20	—	°C

*The trim potentiometers are very low tolerance so the adjustment ranges will differ significantly between modules. Only rely on the module to support adjustment to +/- 0.2V from the nominal output voltage.
Output ripple and noise are measured at 48 V input with the rail under test at its full rated continuous current, 20 MHz measurement bandwidth, using a probe tip and ground spring at the output terminals.

7.4 Startup and Rail Sequencing Waveform

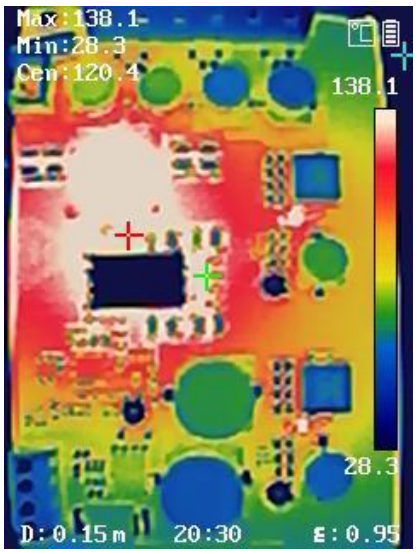
This capture shows the Power Pal startup behavior with a 48 V input applied. The 12 V rail ramps first with a controlled soft-start, followed by the 5 V and 3.3 V rails once the intermediate bus is established. The sequencing minimizes inrush current and ensures downstream rails only are enabled after stable upstream regulation. The time scale is 15 ms/div.



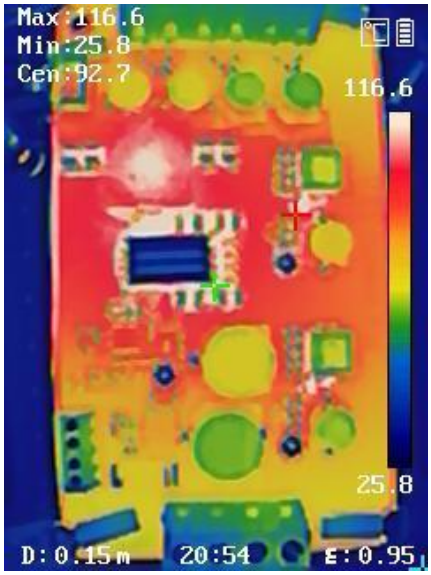
7.5 Thermal Information

At 25 °C ambient temperature and no active cooling unless otherwise stated.

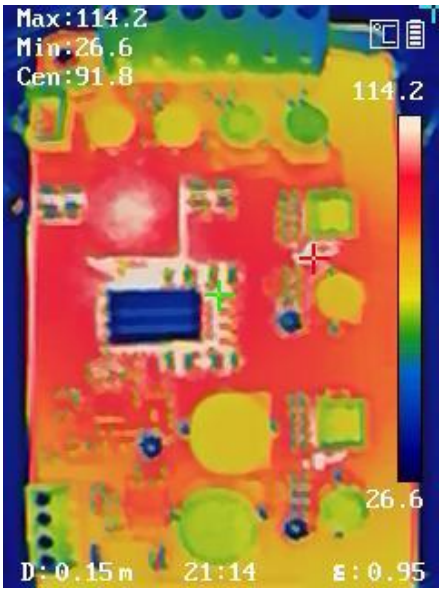
Maximum tested load without cooling: 52V input 12V @ 10A + 5V @ 5A + 3.3V @ 5A , tested with resistive loads ran continuously for 10 minutes:



24V input 12V @ 10A + 5V @ 5A + 3.3V @ 5A resistive loads ran continuously for 10 minutes:



17V input 12V @ 10A + 5V @ 5A + 3.3V @ 5A resistive loads ran continuously for 10 minutes:



Peak measured surface temperature stays below 120 °C for high loads at 17 and 24 V input and below 140 °C at the maximum input voltage (52 V). These are short term test results and are not a recommendation for continuous operation. For sustained operation at these load levels, use the 12 V fan header. Without active cooling, observe the ambient temperature and total output power limits given in Section 7.2 and reduce output power as ambient temperature rises.

The Power Pal can get hot enough to burn you during normal operation. If operating the Power Pal:

- With a high input voltage > 40 V
- With a high output current ~75% of full load
- In hot ambient conditions > 35 °C

Be cautious when handling.

8 Application Notes and Important Usage Guidelines

8.1 Output voltage adjustment:

When adjusting the output voltage trim potentiometers, use a non-conductive screwdriver. The potentiometers are single-turn and sensitive to over-rotation. Adjust gently to avoid mechanical damage or unintended voltage changes. Do not trim the 12 V rail above 13.0 V. The 12 V output also supplies the module's internal control rail and the PGOOD pull-up, both of which are limited to 14 V absolute maximum, and exceeding the trim limit can permanently damage the module.

8.2 Enable (EN) Pin:
The EN pin includes an internal 100 kΩ pull-down to GND and is active low. Leaving EN floating or pulling it low enables all outputs, while driving EN high disables the module. Because EN is active low, the module powers up by default whenever input voltage is present. To make the module default to OFF so that a downstream controller must actively enable it, connect VIN to EN through a 300 kΩ series resistor. This forms a divider with the internal pull-down that holds EN above the input threshold across the full 14.5 to 52 V input range while staying below the 20 V pin maximum. Pulling EN to AGND then enables the module.

If toggling EN from a microcontroller or other logic level pin, ensure that the HIGH state voltage is above 2.5 V and that the LOW state voltage is below 1 V. EN can also be driven by an open drain output or a simple switch to AGND.

8.3 Screw terminal wiring:
The screw terminals accept down to 12 AWG conductors. Use wire gauges appropriate for the expected current and terminal block rating; at the full 12 V rating the input and 12 V output conductors carry more than 10 A. Ensure all terminal screws are fully tightened. Undersized wire or loose connections can result in excessive heating, voltage drop, or intermittent operation.

8.4 Power sequencing and connections:
Always power down the regulator before connecting or disconnecting loads. Connect all circuitry only when the system is unpowered to avoid electrical stress, arcing, or unintended transient events.

8.5 Inductive loads (motors, solenoids, relays):
Always provide proper suppression for inductive loads. Brushed motors and solenoids must include a flyback diode with adequate forward current rating. For improved noise suppression, place RC snubbers or LC chokes directly at the motor terminals. For higher-energy spikes, add a TVS diode across the motor leads.

8.6 Long input or output wiring:
Long power leads increase series inductance, which can prevent the regulator from sourcing fast transient currents and may cause ringing or instability.

- Use twisted pairs for both supply and return to minimize loop area.
- Add bulk capacitance close to the Power Pal input and near the load.
- For very long input cables, add a damping network across the input terminals at the board edge: an aluminium electrolytic capacitor of at least four times the module's

ceramic input capacitance, or a smaller electrolytic in series with a 0.5 to 2 Ω resistor. This damps the line's characteristic impedance and prevents resonance with the MLCC input capacitors. Do not place a series resistor in the main input current path: at full load the input current exceeds 10 A, and even 0.5 Ω would dissipate more than 50 W.

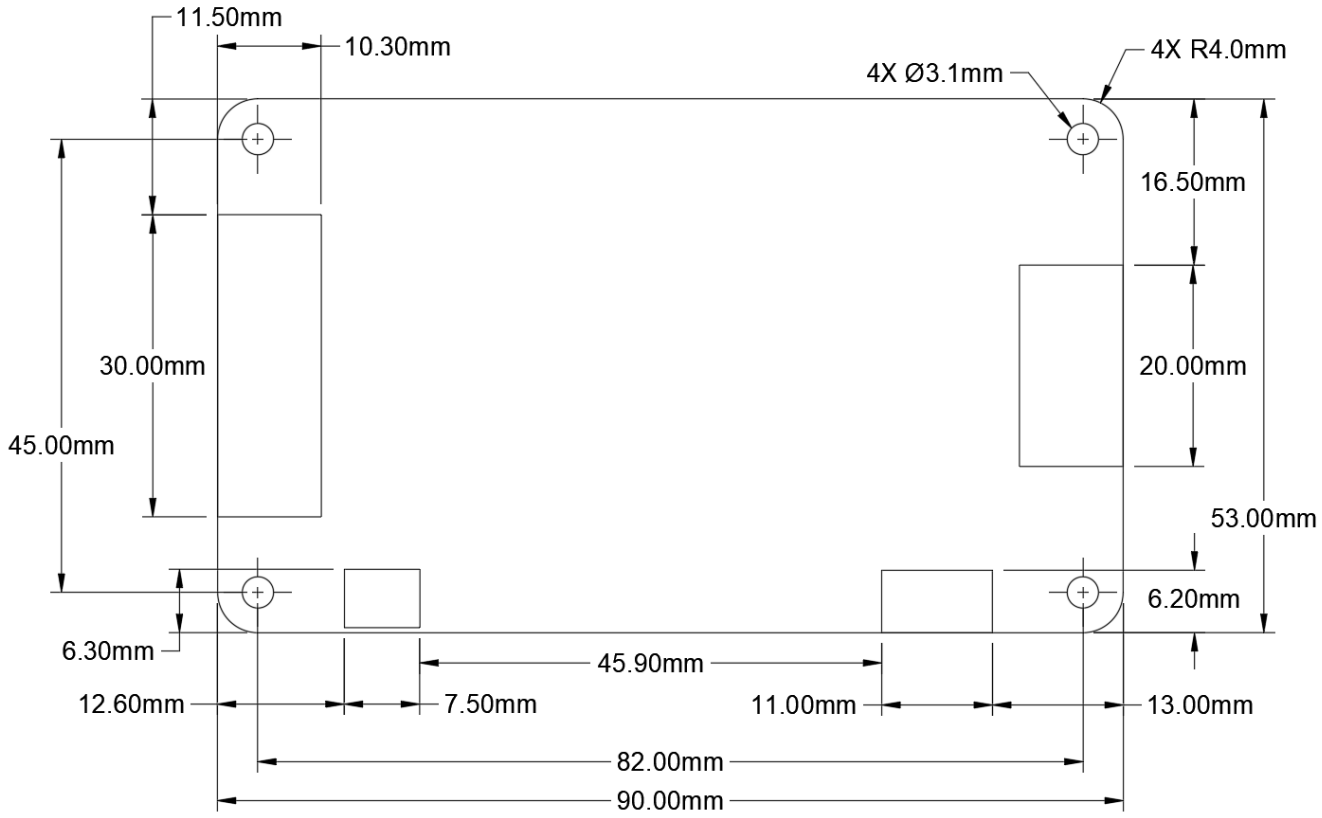
8.7 Regenerative or back-feeding loads:
If any downstream load can feed energy back into the supply rail (for example regenerative motor controllers or long leads being disconnected under load), add an ideal-diode MOSFET or Schottky diode at the affected output rail. This prevents reverse energy from feeding into the regulator or other rails.

8.8 Additional bulk output capacitance:
Caution should be exercised when adding extra bulk output capacitance. Increasing output capacitance and its associated ESR introduces additional poles and zeros in the control loop, which can shift loop crossover frequency and phase margin and may reduce stability. If additional capacitance is required, stability should be verified under the intended operating conditions.

8.9 Low input voltage and battery cutoff:
The module stops switching when the input falls to approximately 13.4 V. Under heavy load, cable and connector resistance can drop the voltage at the input terminals below this threshold even when the source is still above it, causing the outputs to cycle. Keep input wiring short and adequately sized, and add bulk capacitance at the input if the source has significant impedance.

8.10 Responsibility and damage prevention:
Failure to follow these application guidelines may result in improper operation or damage to the Power Pal or connected equipment. PN Labs assumes no responsibility for damage resulting from operation outside the recommended conditions or application practices.

9 Mechanical Dimensions



The height from the bottom of the FR4 to the tallest component is 15.85mm.
A STEP file of the board, matching the current hardware revision, can be downloaded from the Power Pal product page at pnlabs.ca