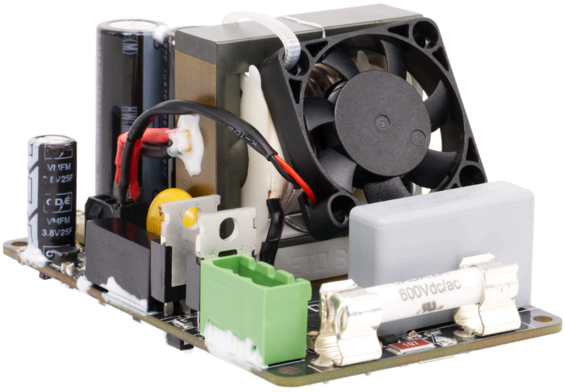
DCDCv9-3 Datasheet

Description

The DCDCv9-3 is a galvanically isolated DC/DC converter, designed to convert voltages from 200 V to 600 V down to 24 V with max. 500 W continuous output power. The low weight of 167 grams and the small footprint of a credit card (85.6 x 54 mm) are well suited to the automotive industry for supplying low-voltage systems from HV Batteries. The dynamic operating frequency between 90 and 200 kHz ensures high efficiency for various loads as well as good EMI compliance due to the resonant LLC soft switching topology. Customized versions allow output voltages from 12 V to 48 V.

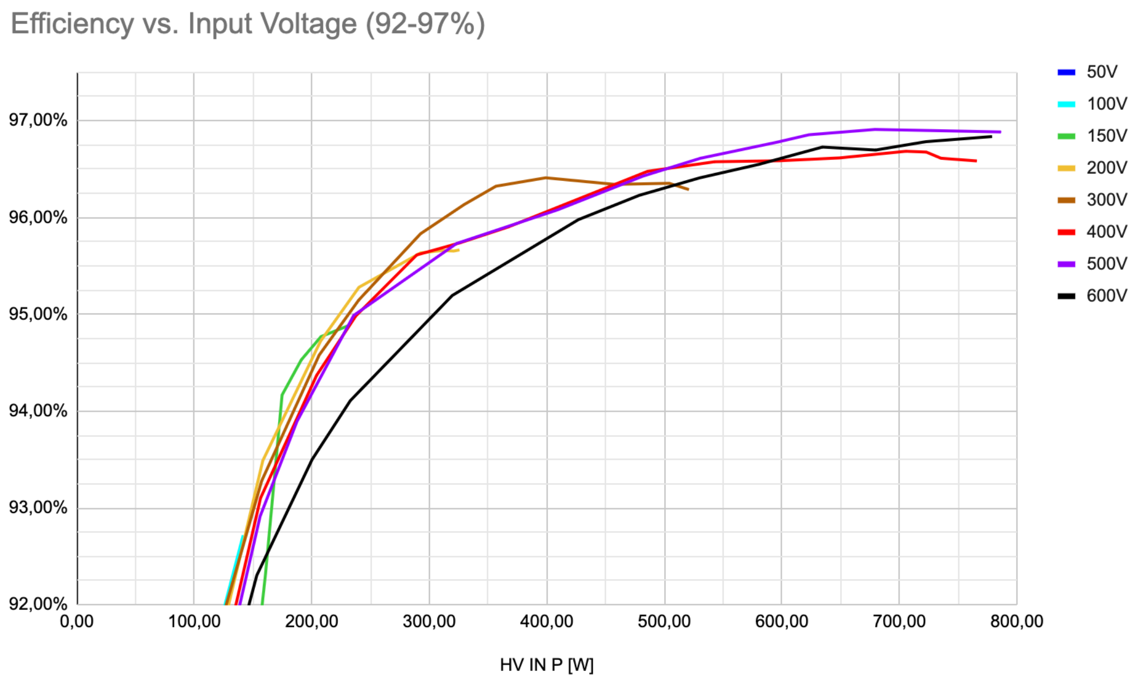


Features

- Maximum output power (400 V to 600 V): 750 W for 60 seconds, 600 W for 180 seconds, 500 W continuous, max. output power (200 V): 300 W, max. output power (300 V): 500 W
- Efficiency up to 96.9 % at 500 W and 500 V Input Voltage
- active rectification (NCP4305AMTTWG)
- undervoltage, overvoltage and overcurrent protection
- low no-load power dissipation (7 W - 9 W)
- built-in solid-state precharge
- very low standby leakage current (75 nA at 600 V)
- isolated enable pins with self recharging start-up capacitor
- cost efficient UCC25600 LLC controller
- reliable 4 A/6 A UCC21520 Gate Driver
- optional back side connectors for on-PCB mount
- minimum isolation distance 4.5 mm (According to rule EV 4.3.6, Table 5, Conformal Coating: 600 V DC min. 4 mm spacing required)
- *FSG-Rules 2025 conform*

Applications

- Low-Voltage System supply for 400V/600V battery powered electric vehicles
- CV Benchtop power supply



Absolute Maximum ratings

Ambient Temperature = 21 °C (unless otherwise noted)

Symbol	Parameter	Typ.	Unit
V_{in}	Input Voltage	610	V
I_{in}	Input Current	2000	mA
V_{out}	Output withstand Voltage	35	V
I_{out}	Output Current for 1 Minute	31.25	A
P_{out}	Output Power for 1 Minute	750	W
P_{out}	Continuous Output Power	500	W
P_{tot}	Total Power Dissipation at T_{amb} = 21°C	25	W
f_{sw}	Switching Frequency	350	kHz
T_{op}	Operating Ambient Temperature Range	0 to 60	°C
T_{stg}	Storage Temperature Range	0 to 125	°C
V_{iso}	Isolation Voltage between HV and LV for 1 Minute	3000	V AC RMS

Electrical Characteristics

All Values are Measurements from a sample size of 1

Input Characteristics

<table>
<tr><th>Parameter</th><th colspan="2">Test Conditions</th><th>Typ.</th><th>Unit</th></tr>
<tr><td rowspan="7">Under Voltage Protection</td><td colspan="2">enable, R67+R68 = 1.7 MΩ</td><td>199</td><td>V</td></tr>
<tr><td colspan="2">disable, R67+R68 = 1.7 MΩ</td><td>206</td><td>V</td></tr>
<tr><td rowspan="5">enable delay
R67+R68 = 1.7 MΩ
C47 = 22 nF</td><td>V_{in} = 200 V</td><td>234</td><td>ms</td></tr>
<tr><td>V_{in} = 300 V</td><td>52</td><td>ms</td></tr>
<tr><td>V_{in} = 400 V</td><td>28</td><td>ms</td></tr>
<tr><td>V_{in} = 500 V</td><td>19</td><td>ms</td></tr>
<tr><td>V_{in} = 600 V</td><td>14</td><td>ms</td></tr>
<tr><td rowspan="2">Over Voltage Protection</td><td colspan="2">enable, R65+R66 = 543 kΩ</td><td>609</td><td>V</td></tr>
<tr><td colspan="2">disable, R65+R66 = 543 kΩ</td><td>598</td><td>V</td></tr>
<tr><td rowspan="5">Leakage Current
DCDC = Disabled</td><td colspan="2">V_{in} = 200 V</td><td>15</td><td>nA</td></tr>
<tr><td colspan="2">V_{in} = 300 V</td><td>28</td><td>nA</td></tr>
<tr><td colspan="2">V_{in} = 400 V</td><td>41</td><td>nA</td></tr>
<tr><td colspan="2">V_{in} = 500 V</td><td>56</td><td>nA</td></tr>
<tr><td colspan="2">V_{in} = 600 V</td><td>75</td><td>nA</td></tr>
<tr><td rowspan="9">Input Current</td><td rowspan="4">DCDC = Enabled
V_{in} < UVP</td><td>V_{in} = 50 V</td><td>75</td><td>µA</td></tr>
<tr><td>V_{in} = 100 V</td><td>151</td><td>µA</td></tr>
<tr><td>V_{in} = 150 V</td><td>228</td><td>µA</td></tr>
<tr><td>V_{in} = 200 V</td><td>305</td><td>µA</td></tr>
<tr><td rowspan="5">DCDC = Enabled
V_{in} > UVP
no Fan
dead time = 80 °</td><td>V_{in} = 200 V</td><td>40.0</td><td>mA</td></tr>
<tr><td>V_{in} = 300 V</td><td>27.2</td><td>mA</td></tr>
<tr><td>V_{in} = 400 V</td><td>20.8</td><td>mA</td></tr>
<tr><td>V_{in} = 500 V</td><td>16.7</td><td>mA</td></tr>
<tr><td>V_{in} = 600 V</td><td>11.34</td><td>mA</td></tr>
</table>

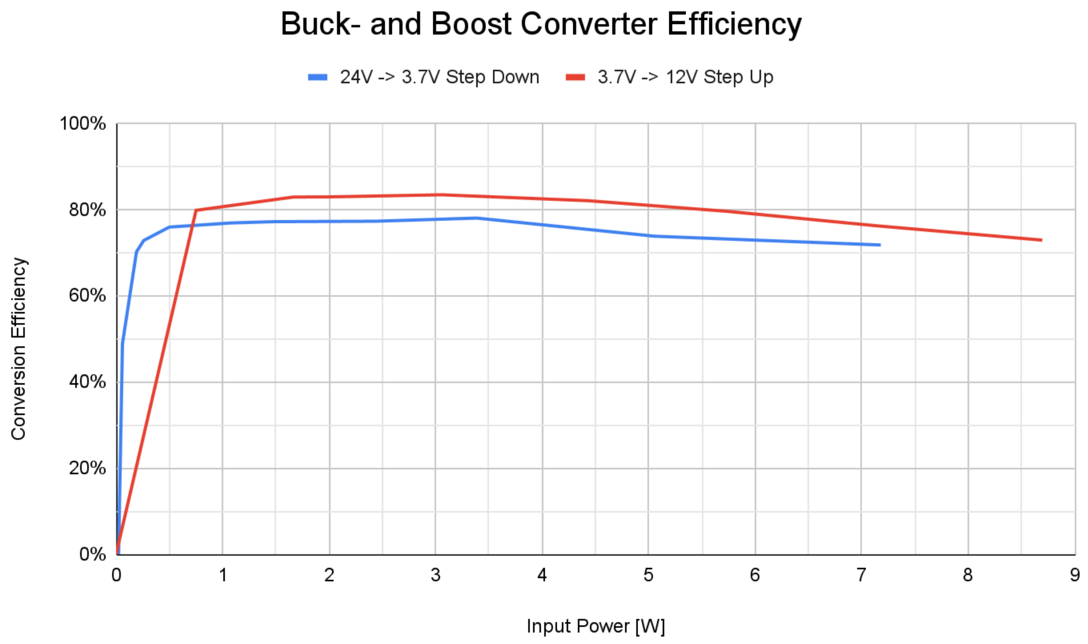
Parameter	Test Conditions		Typ.	Unit
Reverse Input Voltage	reverse polarity	I_{In} = 0.1 A	-4.48	V
		I_{In} = 0.5 A	-5.04	V
		I_{In} = 1 A	-5.34	V
		I_{In} = 2 A	-5.83	V
Input Voltage Ripple	V_{in} = 400 V	I_{out} = 0 A	0.741	Vrms
			7.1	Vpp
		I_{out} = 10 A	0.96	Vrms
			8.51	Vpp
		I_{out} = 20 A	0.52	Vrms
			7.86	Vpp
		I_{out} = 30 A	0.73	Vrms
			6.97	Vpp
	V_{in} = 500 V	I_{out} = 0 A	5.56	Vpp
	V_{in} = 600 V	I_{out} = 0 A	3.0	Vpp

Output Characteristics

Parameter	Test Conditions		Typ.	Unit
Output	Voltage Ripple V_{in} = 400 V	I_{out} = 0 A	5.1	mVrms
		I_{out} = 0 A	152	mVpp
		I_{out} = 10 A	9.1	mVrms
		I_{out} = 10 A	189	mVpp
		I_{out} = 20 A	13.2	mVrms
		I_{out} = 20 A	230	mVpp
		I_{out} = 30 A	18.9	mVrms
		I_{out} = 30 A	310	mVpp
Voltage Regulation	output Voltage		24.09 to 24.16	V
	minimum HV input for 24 V Output, set by f_{min} = 94 kHz		180	V
	Overshoot test with 4700 µF Load (uncharged), see Documentation Chapter *Control loop*	V_{in} = 400 V	1.7	Vp
		V_{in} = 500 V	0.83	Vp
		V_{in} = 600 V	0.34	Vp
	Undershoot test with 300 W Load drop, see Documentation Chapter *Control loop*	V_{in} = 400 V	38	mVp
		V_{in} = 500 V	38	mVp
		V_{in} = 600 V	43	mVp

Internal Power Supply

Parameter	Test Conditions		Typ.	Unit
Start-up Supply	Charging Voltage with C_{start1} installed	DCDC = Disabled	3.71	V
		DCDC = Enabled, V_{in} = 600 V, 3.7 V Fan OFF	3.69	V
		DCDC = Enabled, V_{in} = 600 V, 3.7 V Fan ON	3.68	V
	C_{start1} Shipping Voltage		3.65	V
	I_{out} with fully charged C_{start1} V_{out} = 24V	DCDC = Disabled	-1.05	mA
		DCDC = Enabled	-22.3	mA
		DCDC = Enabled with 3.7 V Fan	-50	mA
	C_{start1} Discharge current, DCDC = Enabled, $U_{Cstart1}$ = 3.7 V	V_{in} = 0 V (UVP)	101	mA
		V_{in} = 200 V	198	mA
		V_{in} = 300 V	207	mA
		V_{in} = 400 V	219	mA
		V_{in} = 500 V	236	mA
		V_{in} = 600 V	215	mA
	Hold-Up time, DCDC = Enabled, V_{in} = 0 V, V_{out} = 0 V		114	s
	V_{out} Buck-Converter disable threshold		3.5	V
	5 V LED / Buck-Converter disable time by discharging C11+C13 from 24 V, DCDC = Disabled		172	s
	Hold-Up time (storage time, no recharge), DCDC = Disabled		> 6	Months
	Voltage after 6 months (no recharge), DCDC = Disabled		3,676	V
Boost-Converter	UVP		2.535	V
LV Current	DCDC = Enabled, P_{out} = 0 W, V_{in} = 0 V	I_{LV} LV Side	27.8	mA
LV Voltage	DCDC = Enabled, P_{out} = 0 W, V_{in} = 0 V	U_{LV} LV Side	12.204	V
		9 V LDO	9.055	V
		HV Side	12.475	V
		HV Side after D11	11.79	V
		HV Side after D14	12.108	V
MOSFET top supply Voltage (VDDA-VSSA)	DCDC = Enabled, P_{out} = 0 W	V_{in} = 0 V	11.71	V
		V_{in} = 300 V	11.82	V
		V_{in} = 400 V	11.96	V
		V_{in} = 500 V	11.40	V
		V_{in} = 600 V	10.66	V
Maximum internal low power control signal Voltage	DCDC = Enabled, P_{out} = 0 W	V_{in} + MOSFET top supply Voltage		



High Voltage Precharge and Discharge

Parameter	Test Conditions		Typ.	Unit
Precharge	Close delay		5.0 to 5.3	ms
	Close Voltage Jump		9	V
	Open Delay		7	ms
	Mad-Scruti-Test (Enable/Disable as fast as possible)		PASS	:)
	Precharge Time V_{DC_link} = 0 V to V_{in}	V_{in} = 200 V	68	ms
		V_{in} = 300 V	103	ms
		V_{in} = 400 V	141	ms
		V_{in} = 500 V	180	ms
		V_{in} = 600 V	221	ms
Passive Discharge	Discharge Time V_{in} to $V_{DC\_link} \leq 60$ V	V_{in} = 200 V	1.592	s
		V_{in} = 300 V	2.120	s
		V_{in} = 400 V	2.540	s
		V_{in} = 500 V	2.795	s
		V_{in} = 600 V	3.045	s

Oscillator (UCC25600)

Parameter	Test Conditions		Typ.	Unit
Soft Start	f_{sw}	without C42/R59	190.6	kHz
		C42 = 22 µF, R59 = 1 kΩ	347	kHz
	length f_{sw} 350 kHz to 94 kHz	without C42/R59	263	ms
		C42 = 22 µF, R59 = 1 kΩ	242	ms
Dead time	potentiometer position	min.	119	ns
		middle	274	ns
		max.	505	ns
		dead-room	60	°
		efficiency optimum V_{in} = 200 V to 600 V	80	°
min. f_{sw}	frequency Potentiometer shipped		40	kHz
	Adjustable minimum		20	kHz
	Adjustable maximum		330	kHz
	Adjusted for operation		90	kHz
Overcurrent Protection	Voltage measured over C_{res} = 22.4 nF, R60 = 82 kΩ, C44 = 22 nF		290	V

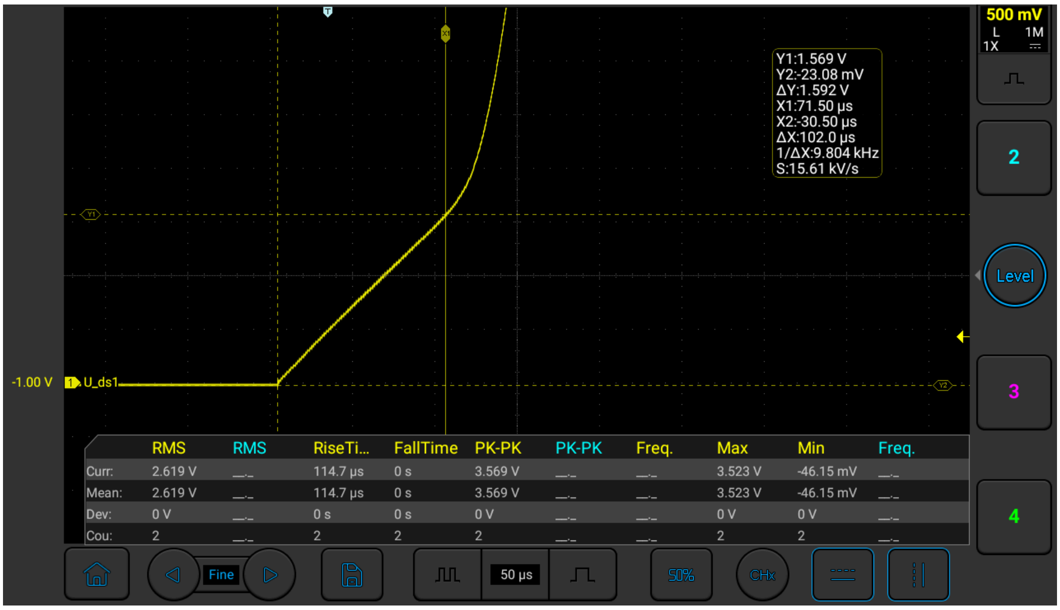
Thermal Properties

Module	Parameter		Typ.	Unit
Overtemperature protection	U6 = TL072 R35 = 330 kΩ, R36 = 4.7 kΩ C28 = 100 nF, C48 = 10 nF	Lock-out while operation	106.9	°C
		Lock-out at start-up	104.0	°C
Fan control	U6 = TL072 R31 = 4.7 kΩ, R18 = 470 kΩ	enable	71	°C
		disable	61	°C
	Sensor Loss behavior		always on	
Fan current	Manufacturer: UltraFan Type: XD3007D5H	V_{Fan} = 3.7 V	150	mA
SR Temperature	open Air, V_{Fan} = 3.7 V V_{in} = 500 V	I_{out} = 0 A, after 10 min	53.4	°C
		I_{out} = 10 A, after 10 min	65.5	°C
		I_{out} = 20 A, after 10 min	77.6	°C
		I_{out} = 25 A, after 5 min	101.7	°C
		I_{out} = 25 A, after 10 min	102.9	°C
		I_{out} = 30 A, after 1 min	102	°C
SR Temperature Hotbox Test	converter inside a box with T_{amb} = 60 °C must be able to deliver P_{out} = 500 W at V_{in} = 500 V for 30 minutes, restarted after 5 seconds must be possible		104.7	°C

Transformer

Module	Parameter		Typ.	Unit
Turns Ratio	W1, W2, W3		28 : 2 : 2	
Litz Wire Length W1 (SN: 67)	Type: 120 x 0.1 mm ø 0.92 mm^2 1.4 mm		1780	mm
Litz Wire Length W2 (SN: 68)	Type: 600 x 0.071 mm ø 2.38 mm^2 2.4 mm		185	mm
Litz Wire Length W3 (SN: 69)	Type: 600 x 0.071 mm ø 2.38 mm^2 2.4 mm		165	mm
Inductance W1	100 kHz 4 Vpp sine, AD2 Shunt = 10 Ω		166.3	µH
Leakage Inductance W1	100 kHz 4 Vpp sine, AD2 Shunt = 10 Ω	W2 shorted	56.32	µH
		W3 shorted	56.11	µH
		W2+W3 shorted	53.85	µH
Inductance	100 kHz 4 Vpp sine AD2 Shunt = 10 Ω	W2	1.057	µH
		W3	1.014	µH
Leakage Inductance		W2, W1 shorted	0.3557	µH
		W3, W1 shorted	0.3496	µH
Saturation Current W1	DC		7.9	A
Resistance W1	DC, 20 °C, 32.895 mV, 1008 mA		32.63	mΩ
	DC, 100 °C, 445.4 mV, 10504 mA		42.40	mΩ
	4 Vpp sine, AD2 Shunt = 10 Ω, W2+W3 shorted	10 kHz	140.2	mΩ
		100 kHz	145.4	mΩ
		200 kHz	552.6	mΩ
		350 kHz	1081	mΩ
		1000 kHz	14540	mΩ
Resistance W2	DC, 21 °C, 6.740 mV, 5012 mA		1.345	mΩ
	DC, 57 °C, 30.46 mV, 19990 mA		1.524	mΩ
	4 Vpp sine, AD2 Shunt = 10 Ω, W1 shorted	10 kHz	2.4	mΩ
		100 kHz	15.1	mΩ
		200 kHz	6.2	mΩ
		350 kHz	16.7	mΩ
		1000 kHz	100.8	mΩ
Resistance W3	DC, 21 °C, 5.884 mV, 5010 mA		1.174	mΩ
	DC, 66 °C 27.175 mV, 19986 mA		1.360	mΩ
	4 Vpp sine AD2 Shunt = 10 Ω, W1 shorted	10 kHz	2.4	mΩ
		100 kHz	18.3	mΩ
		200 kHz	13.7	mΩ
		350 kHz	3.5	mΩ
		1000 kHz	94.3	mΩ
Winding Capacitance	4 Vpp sine 1000 kHz, AD2 Shunt = 10 kΩ	W1 || W2	6.1	pF
		W1 || W3	5.9	pF
		W1 || W2+W3	6.9	pF
		W2 || W3	26.3	pF

Module	Parameter		Typ.	Unit
Resonant Frequ. W1	4 Vpp sine, AD2 Shunt = 100 Ω		8.0	MHz
Typ. Frequency Range	V_{in} = 200 to 600 V	P_{out} = 0 W,	95 to 200	kHz
		P_{out} = 250 W,	90 to 170	kHz
	V_{in} = 400 to 600 V	P_{out} = 750 W,	115 to 160	kHz
Resonant Half Bridge	Max. dynamic Input Voltage W1		300	V
	Typ. Output Voltage W2, W3		24.0	V
	Typ. LLC Gain		1.1 to 3.4	
Isolation	1 minute DC, no Isolation breakdown		5000	V RMS
	Isolation Resistance (DC)		≥ 200	GΩ
	1 minute AC, 50 Hz, no Isolation breakdown		3000	V RMS
Typ. Current W1	V_{in} = 200 to 600 V	P_{out} = 0 W,	1.6 to 2.8	A RMS
		P_{out} = 250 W,	2.4 to 3.6	A RMS
	V_{in} = 400 to 600 V	P_{out} = 750 W,	4.2 to 4.8	A RMS
Typ. Current W2 + W3	equal load share	P_{out} = 750 W,	31.25	A RMS
Coil Former	Material: Liqcreate Flame Retardant HDT	Temp. Rating	250	°C
		FR Level	UL94 V-0	
Prim. and Sec. Windings	Temp. Rating		155	°C
Core	Material		N27 + N97	
	Form		ETD39	
	typ. Temperature		80 to 120	°C
	Saturation Flux density at 100 °C		410	mT
	Relative Losses 100 kHz, 200 mT		0.30	W/cm^3
	Air Gap length between cores		1.000	µm
W1 Power Dissipation	Passive Convection, DC, 445.4 mV, 10504 mA Hotspot = 100 °C unlimited time, RT 21 °C		4.7	W
	Active Convection, DC, 603.9 mV, 13998 mA Fan: 0.5 W @ 3.75 V, 30 x 30 x 7 mm, 5 m^3/h, Manufacturer: UltraFan, Type: XD3007D5H, 5 V, 200 mA, Top Cooled Hotspot = 100 °C unlimited time,		8.5	W
W2 Power Dissipation	Passive Convection, DC, 30.46 mV, 19990 mA Hotspot = 57 °C, unlimited time		0.61	W
	Active Convection, DC, 28.96 mV, 19986 mA Fan: 0.5 W @ 3.75 V, 30 x 30 x 7 mm, 5 m^3/h, Manufacturer: UltraFan, Type: XD3007D5H, 5 V, 200 mA, Top Cooled Hotspot = 46 °C unlimited time		0.58	W
W3 Power Dissipation	Passive Convection, DC, 27.175 mV, 19986 mA Hotspot = 66 °C, unlimited time		0.54	W
	Active Convection, DC, 26.07 mV, 19986 mA Fan: 0.5 W @ 3.75 V, 30 x 30 x 7 mm, 5 m^3/h, Manufacturer: UltraFan, Type: XD3007D5H, 5 V, 200 mA, Top Cooled Hotspot = 53 °C unlimited time		0.52	W



Saturation current on primary Coil (W1) using a 201.2 mΩ Shunt resistor

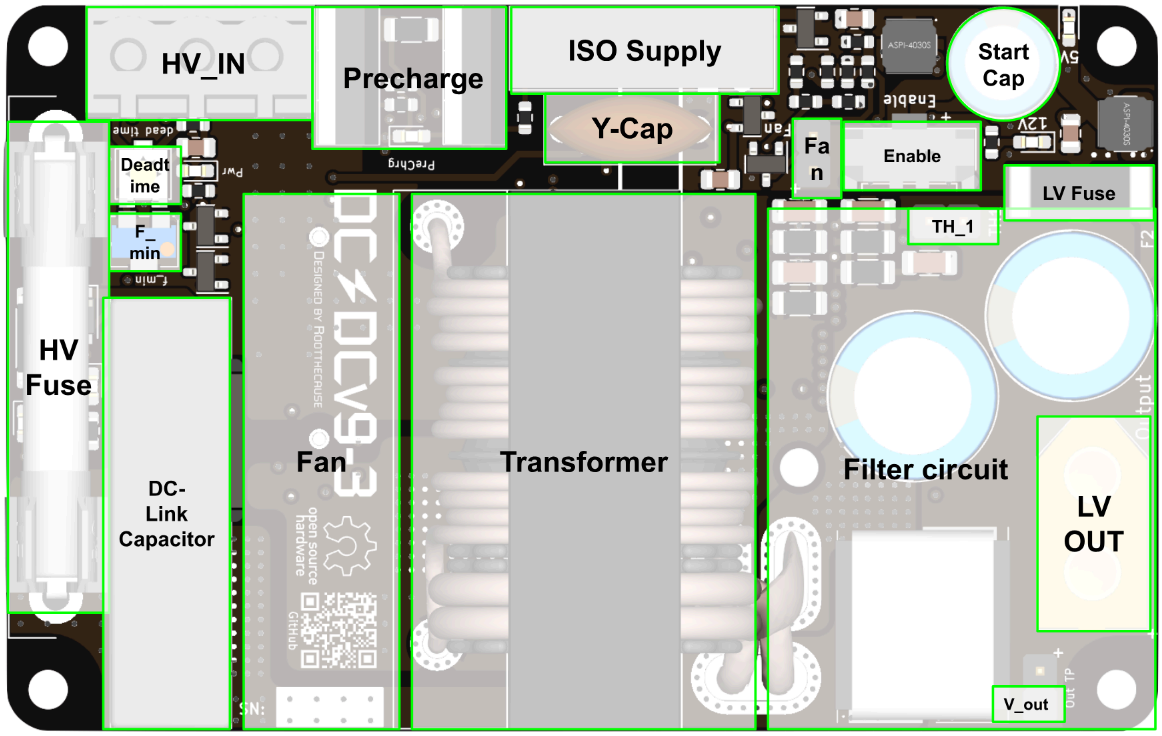
Resistance Measurement:
Blue: Primary Coil W1 Resistance vs. Frequency, secondary Coils open (inaccurate)
Green: Primary Coil W1 Resistance vs. Frequency, secondary Coil W2 shorted
Purple: Primary Coil W1 Resistance vs. Frequency, secondary Coil W3 shorted
Red: Capacitance Measurement between primary Coil W1 and secondary Coils W2+W3

Dimensions and Weight

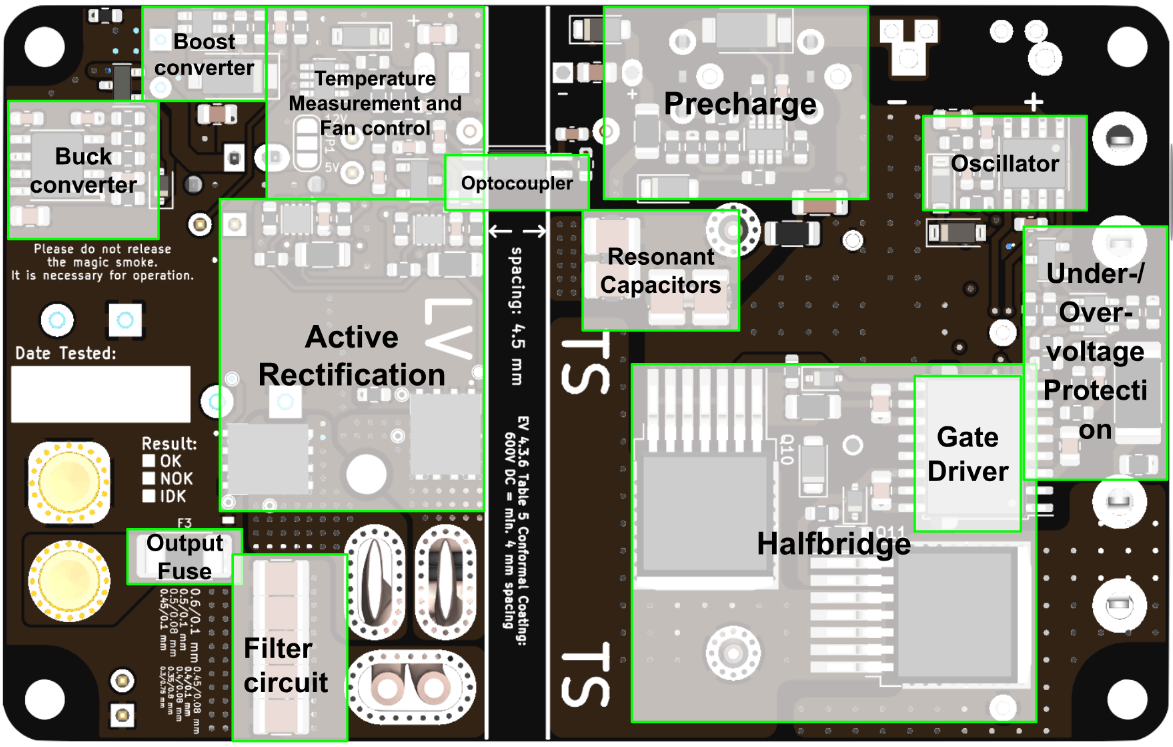
Module	Parameter		Typ.
Dimensions	L x W x H	85.6 x 54 x 48	mm
DCDCv9-3	PCB only	17.55	g
DCDCv9-3	PCBA only	20.46	g
DCDCv9-3	Weight with Fan and Fuses	167.2	g

Overview

Front

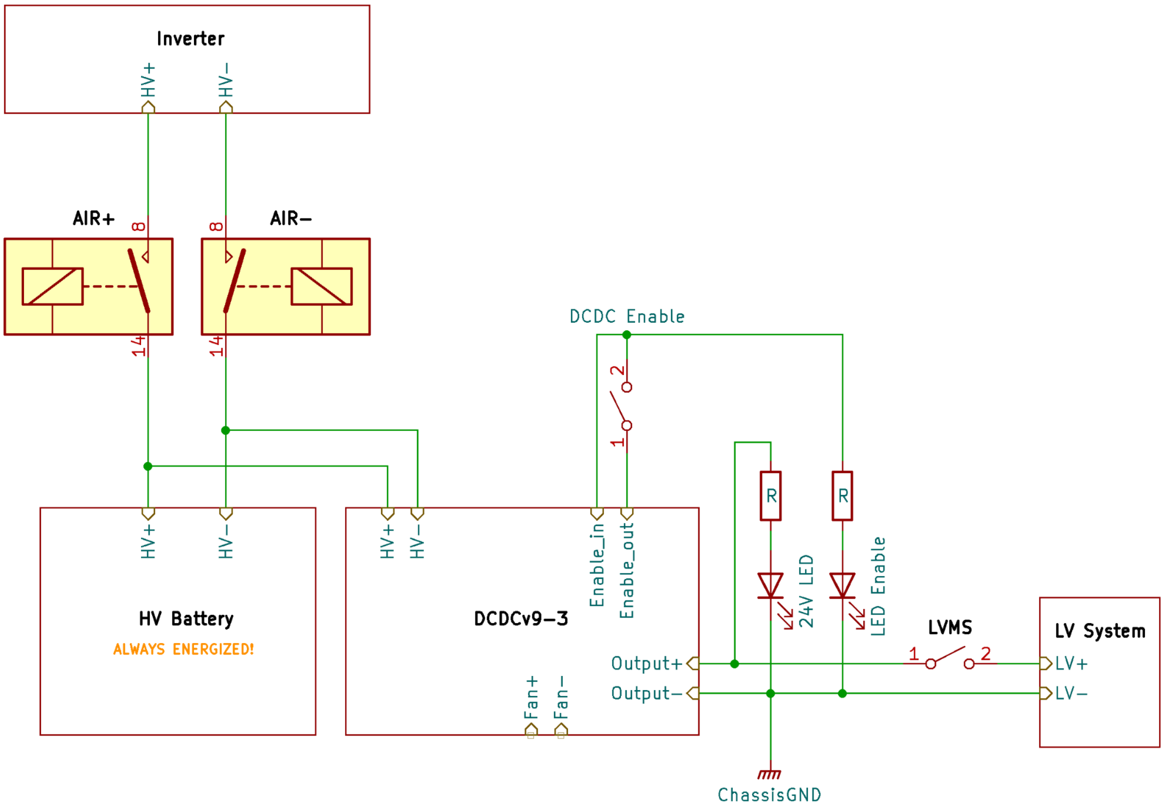


Back



Installation

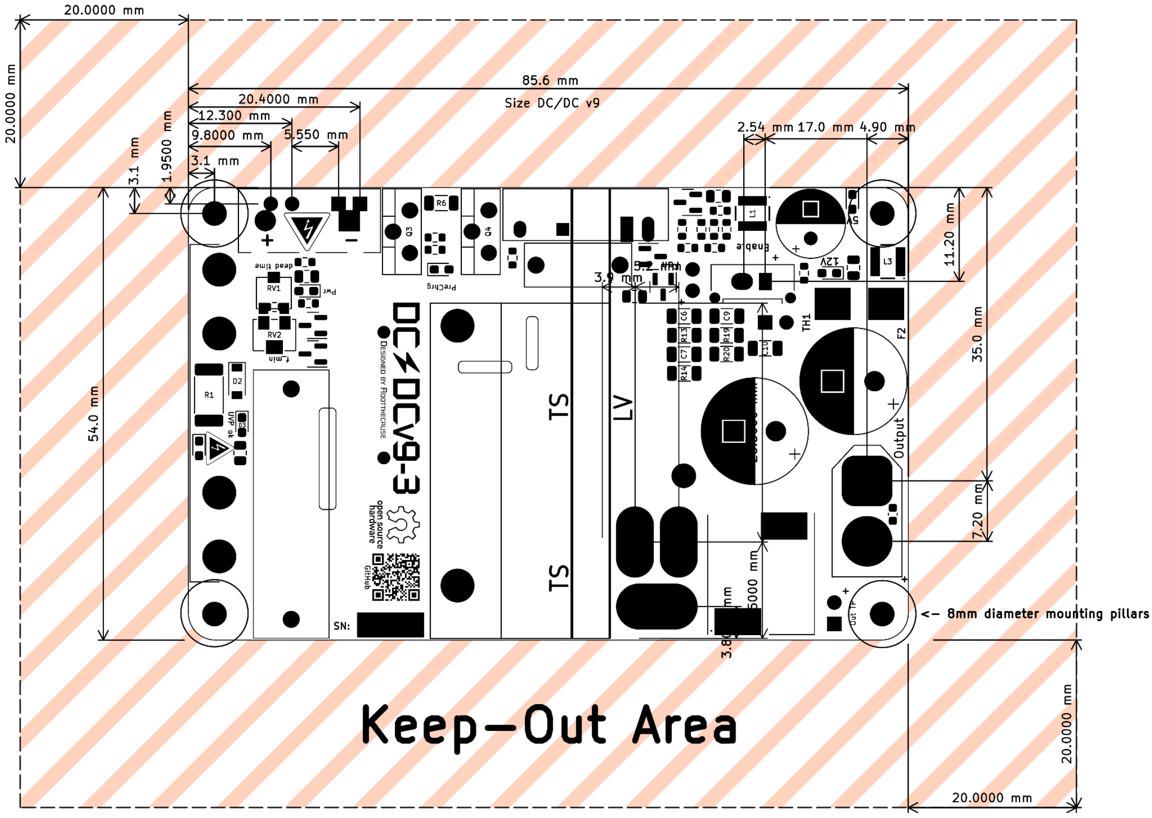
The DCDC is designed for permanent connection to a high-voltage source, such as a high-voltage battery. No pre-charge prior to the DCDC is required, as it is included. The converter can be connected while high voltage is present at the input, as long as safety measures are observed (personal protective equipment to prevent accidental contact with high-voltage).



The enable switch establishes a connection between the two enable lines. This switch must be designed as an ON/OFF switch (latching). When switched off, the supply line has a nominal voltage of 3.7 V measured against ground (between 2.5 V and 3.8 V depending on the SOC of the start capacitor) and the return line has 0 V. An LED can be connected to ground on the return line to indicate the active DCDC. The enable lines and switches should have a low resistance (< 0.5 Ω) and withstand at least 0.5 A. An LED with series resistor between 24V and ground is also recommended to indicate operational readiness at the output (and thus the permitted switch-on of the LV system).

A fan is required for continuous outputs above 300 W (if not already installed on the circuit board). This can be connected to the corresponding pin headers or soldered permanently. A solder bridge (JP1) for the fan voltage selection must be soldered at the back of the converter. This can be either 3.7 V or 12 V. The fan should not have a power consumption of more than 2 W, as otherwise the buck and boost converters will be subject to overload.

Mechanical installation

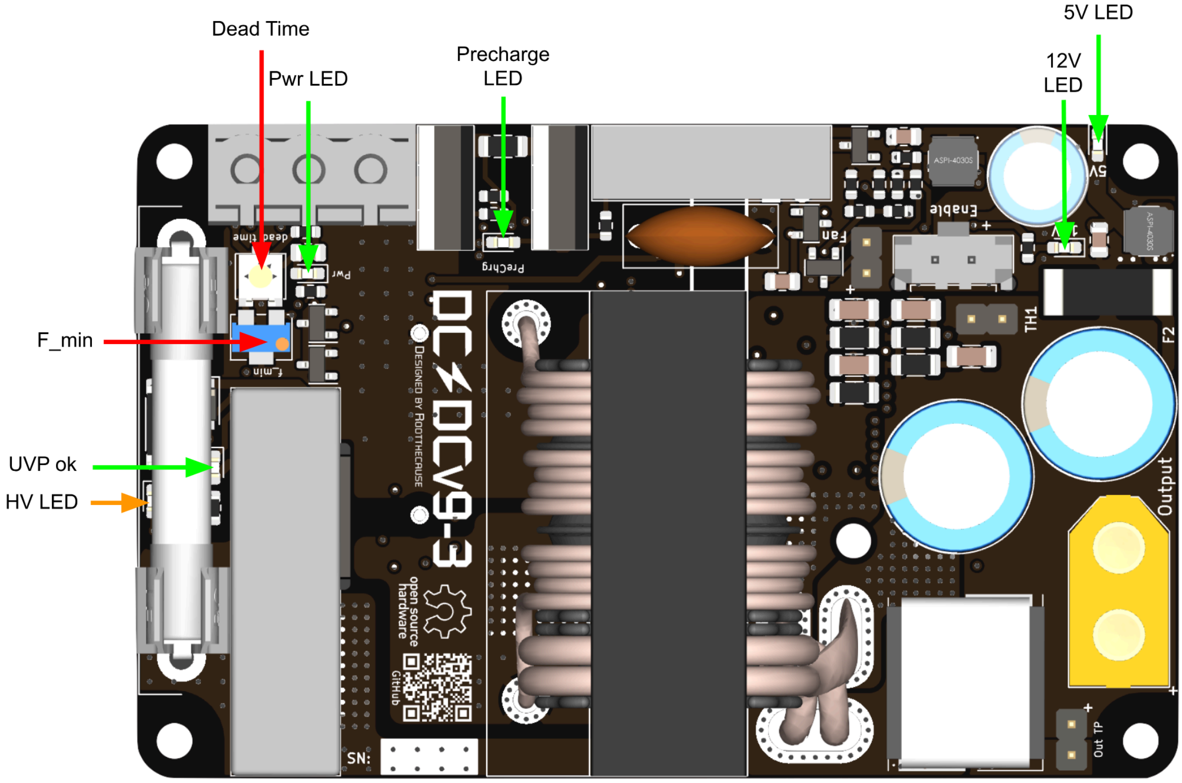


The DCDC Converter must be mounted with four M3 Nylon Screws in each corner onto an isolating Material, like nylon spacers. M3 Screws made from metal and 3D-Printed pillars (max. 8 mm diameter) which use metal inserts are allowable, if sufficient isolation (≥ 1800 V AC RMS) to Low-Voltage potential can be shown. A distance of 10 mm from the PCB backside to any material should be maintained for sufficient heat dissipation. Nearby components must not obstruct the air flow of the fan. When mounted inside an airtight enclosure, the ambient air can reach more than 60°C due to the converter's power dissipation. Long exposure to this temperature can lead to premature component failure or over temperature shutdown. Additional ventilation with cool air or usage of thermally conductive enclosures is advised.

The converter can be mounted in any position. However, an upside down mounting can affect the converter's power dissipation.

The Keep-Out Area must be maintained if no moisture resistant isolating material other than air is used to isolate the converter from Low-Voltage potential.

User Interface



LED Indicators

LED	Color	Function	Normal Operation
PreChrg	Green	active precharging, LED is off after precharging	flashing once for < 500 ms after turn-on
5V	Green	active Buck converter	ON
12V	Green	active Boost converter	ON
UVP ok	Green	Input Voltage is over UVP threshold	ON
HV LED	Orange	DC-Link Capacitor Voltage is higher than 2 V	ON

Adjustment options

Potentiometer	Location	Type	Function
Dead time	top left	1-Turn	turn CCW to increase deadtime between halfbridge FETs
F_{min}	top left	10-Turn	turn CCW to increase minimum switching frequency

Operation

Power ON

1. Ensure that an input supply is connected. Do not enable the DCDC without input supply for more than 100 seconds, to avoid completely discharging C_{start1}.
2. Turn on the converter by closing the Enable switch.
3. Connect the load after the output voltage has reached 90 % (see 24V LED indicator). As the converter has a soft start, the nominal output voltage is reached approx. 500 ms after enabling. The converter may be overloaded if it is switched on together with large loads. If the 24 V LED indicator does not light up, turn off the converter and check for faults.

Power OFF

1. Open the enable switch. It is not usually necessary to disconnect the loads prior to this.

Troubleshooting

Fault	Cause	Solution
DCDC cannot be switched on, no LEDs light up	Discharged start capacitor. Measure the voltage of the enable supply line to ground. Must be > 2.5 V. otherwise Boost converter may be broken	By applying a voltage between 5V and 24V to LV-Out, the start capacitor can be recharged via the internal buck converter. Replace boost converter IC if necessary.
DCDC cannot be switched on, 5V LED does not light up when recharging via output	Check LV fuse, possibly buck converter overloaded or broken.	Replace fuse and/or buck converter IC. Remove Fuse before continuity test!
Precharge LED continuously on	DC link is permanently drained or precharge defective. Measure the resistance of components in the DC link (e.g. half-bridge FETs). Check resistance R6 for the correct value.	Replace half-bridge FETs or precharge FETs/OPV/R6 if necessary
Orange HV LED does not light up		
Orange HV LED lights up continuously, even if DCDC = Disabled	Precharge defective.	replace Precharge FETs
PWR LED does not light up	Precharge not completed or the 12V supply after D11 is overloaded. It is also possible that the enable switch and its cables or connections to the converter have too high resistance (>0.5 Ω). Measurement required!	Replace half-bridge FETs or precharge FETs/OPV/R6 if necessary. Check for overheating components. Check and replace connectors, cables or enable switch.
D3 does not light up	HV input voltage below the UVP threshold value or HV fuse is blown due to overload. If the HV Fuse is blown, check resistance of the half-bridge FETs before replacement. They might be defective.	Increase voltage above the UVP threshold value or adjust UVP threshold value if necessary. Replace HV fuse if blown.
LEDs light up normally, but no voltage at the output	output fuse blown due to overload	Replace output fuse if blown.
Only 12V LED lights up	Overtemperature protection active	Allow to cool down for 10 seconds. If a restart is not possible, the fault lies elsewhere.

Output voltage Oscillates in the lower Hz range	Overcurrent protection active. Load may have been switched on too early.	Switch off the converter immediately and check the loads for too high currents!
No output signal on U11 or U12 while testing	If the output is fed with 24 V for testing, the control loop will shut down the U12 if it is above the set output voltage (this must happen). Due to tolerances, the setpoint value may be slightly below 24 V.	Decrease the fed voltage on the output to at least 23 V. If you're working with custom set output voltage (e.g. 12 V), stay below that.
Primary current not symmetrical and/or whining and hot SR-FETs without load or SR-FETs not switching correctly	One of the two secondary coils may be connected the wrong way around or a winding may have been accidentally short-circuited (both connections in pin 4). Check that the windings have an opposite winding direction or generate opposite voltages when seen from the centre tap (pin 4).	Swap the connections of one of the secondary windings.

Revision History

Date	Change	Page
July 18, 2025	Added maximum internal low power control signal Voltage	4
	Updated Troubleshooting from Build Guide (July 18, 2025)	14/15
May 21, 2025	Added C_{start1} storage time and voltage after this time	4
	Added Revision History	15
February 19, 2025	First Release	-