

Features

- Suitable for 110 V railway batteries
- RoHS-compliant
- Class I equipment
- Compliant with EN 50155, EN 50121-3-2, EN 45545.
- Input over- and programmable undervoltage lockout with shutdown function
- Inrush current limitation
- Interruption time 10 ms
- 2 independent, isolated outputs: no load, overload, and short-circuit proof
- Adjustable output voltage
- Rectangular current limiting characteristic
- Parallel operation with active current sharing
- Very high efficiency up to 94%
- Immunity according to IEC 61000-4-2, -3, -4, -5, -6
- ALL PCB boards protected by lacquer
- Very high reliability

Safety-approved according to IEC/EN 60950-1, UL/CSA 60950-1 2nd Ed.



Description

The HR Series of DC-DC converters represents versatile power supplies ideally suitable for use in transportation and other advanced electronic systems. Features include a broad input voltage range, very high efficiency, high reliability, low output voltage noise, and excellent dynamic response to load/line changes.

The converter inputs are protected against surges and transients. An input over- and undervoltage lockout circuitry disables the outputs if the input voltage is outside of the specified range. The shutdown input allows for adjusting of the undervoltage lockout to a suitable level, thus allowing the use of an appropriate input fuse.

The converters exhibit an inrush current limiter, preventing circuit breakers and fuses from tripping at switch-on.

The outputs are open- and short-circuit proof.

Full input-to-output, input-to-case, output-to-case, and output to output isolation is provided. The converters are particularly

suitable for railway applications and can be supplied by a 110 or 120 V railway battery. All boards are coated with a protective lacquer.

The case design allows operation at nominal load up to 71 °C with natural cooling. If forced cooling is provided, the ambient temperature may exceed 71 °C, but the case temperature must remain below 95 °C.

A temperature sensor generates an inhibit signal, which disables the outputs when the case temperature T_C exceeds the limit. The outputs are automatically re-enabled when the temperature drops below the limit.

LED indicators display the status of the converter and allow for visual monitoring of the system at any time.

The converters may either be plugged into a 19" rack system according to IEC 60297-3, or be chassis mounted. Two heat sinks of different size and cooling plates for chassis mounting are available (see option B, B1).

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Model Selection

Table 1: Model Selection

Output 1		Output 2		Power $P_{o nom}$ [W]	Input voltage			η_{110} ¹		Model	Opt.
$V_{o nom}$ [V]	$I_{o nom}$ [A]	$V_{o nom}$ [V]	$I_{o nom}$ [A]		$V_{i min}^2$ [V]	$V_{i cont}$ [V]	$V_{i max}^2$ [V]	min. [%]	typ. [%]		
12	20	--	--	240	66	77 to 150	168	93	95	ER2320-9RG ³	B, B1
12	12	--	--	144	66	77 to 150	168			ERL2320-9RG ³	
12	24	--	--	288	66	77 to 150	168	93	95	ERP2320-9RG ³	
15	16	--	--	240	66	77 to 150	168			ER2540-9RG ³	
15	19.2	--	--	288	66	77 to 150	168			ERP2540-9RG ³	
48	4	--	--	192	66	77 to 150	168			ER2880-9RG ³	
48	5	--	--	240	66	77 to 150	168			ERP2880-9RG ³	
12	10	12	10	240	66	77 to 150	168	93	95	ER2320-9RG	B, B1
12	6	12	6	144	66	77 to 150	168			ERL2320-9RG	
12	12	12	12	288	66	77 to 150	168	93	95	ERP2320-9RG	
15	8	15	8	240	66	77 to 150	168			ER2540-9RG	
15	9.6	15	9.6	288	66	77 to 150	168			ERP2540-9RG	
48	2	48	2	192	66	77 to 150	168			ER2880-9RG	
48	2.5	48	2.5	240	66	77 to 150	168			ERP2880-9RG	
24	10	--	--	240	66	77 to 150	168	93	95	ER2320-9RG ⁴	B, B1
24	6	--	--	144	66	77 to 150	168			ERL2320-9RG ⁴	
24	12	--	--	288	66	77 to 150	168	93	95	ERP2320-9RG ⁴	
30	8	--	--	240	66	77 to 150	168			ER2540-9RG ⁴	
30	9.6	--	--	288	66	77 to 150	168			ERP2540-9RG ⁴	
96	2	--	--	192	66	77 to 150	168			ER2880-9RG ⁴	
96	2.5	--	--	240	66	77 to 150	168			ERP2880-9RG ⁴	

¹ Efficiency at $T_A = 25\text{ }^\circ\text{C}$, $V_i = 110\text{ V}$, $I_{o nom}$, $V_{o nom}$

² Short time; see table 2 for details

³ Both outputs connected in parallel

⁴ Both outputs connected in series

Part Number Description

	ER 2 5 40 -9 R B1 G
Operating input voltage $V_{i\text{cont}}$ (continuously): 77 – 150 VDC	ER, ERL, ERP
Number of outputs	2, 7 ²
Nominal voltage of main output $V_{o1\text{nom}}$	
12 V	3
15 V	5
24 V	6
36 V	7
48 V	8
Other voltages ¹	9
Nominal voltage of tracking output V_{o2} ³	
12 V	20
15 V	40
24 V	60
36 V	70
48 V	80
Other specifications or additional features ¹	21 – 99
Operational temperature range: T_A :	
$T_A = -40$ to 71 °C, $T_C \leq 95$ °C	-9
Other ¹	-0, -5, -6
Auxiliary functions and options:	
Output voltage control input	R
Cooling plate standard case	B, B1
Cooling plate for long case 220 mm ²	B2 ²
RoHS-compliant for all 6 substances	G ⁴

¹ Customer-specific models. No safety-relevant changes compared to the respective basic model, e.g. different mechanical details, special markings, mounted front plates, reduced output voltage, etc.

² Converters with 220 mm case (customer-specific models). Add 5000 to the model number!

³ The nominal voltages of both outputs are always equal.

⁴ G is always placed at the end of the part number.

Note: The sequence of options must follow the order above.

Example: ER2540-9RB1G: DC-DC converter, operating input voltage range 77 – 150 VDC, 2 isolated outputs, each providing 15 V, 8 A, control input R to adjust the output voltages, cooling plate B1, and RoHS-compliant for all six substances.

Product Marking

Basic type designation: applicable approval marks, CE mark, warnings, pin designation, patents and company logo, identification of LEDs.

Specific type designation: input voltage range, nominal output voltages and currents, degree of protection, batch no., serial no., and data code including production site, modification status, and date of production.

Functional Description

The input voltage is fed via an efficient filter and a diode to the bulk capacitor C_b . The inrush current is limited by the resistor R_{inr} , which is shorted by V_{inr} after the bulk capacitor was charged.

The bulk capacitor sources a single-transistor forward converter with active clamp and provides the power during the interruption time of 10 ms.

The main transformer exhibits two separate secondary windings for the two outputs. The resultant voltages are rectified by synchronous rectifiers in order to provide the best efficiency (not models with $V_o = 2 \times 48$ V). The ripple voltages are smoothed by a dual power choke and output filters. The control logic senses the main output voltage V_{o1} and generates the control signal for the forward converter, with respect to the max. output current transferred via magnetic feedback to the control circuit of the forward converter, located on the primary side.

The second output voltage is tracking the main output, but has its own current limiting circuit. If the main output voltage drops

due to current limitation, the second output voltage will drop as well and vice versa.

The output voltages can be adjusted by external means. Parallel operation of several converters is possible by interconnecting the T-pins to provide active current sharing. Both outputs can be connected in parallel or in series without any precaution. They exhibit a rectangular current limitation characteristic. Switchable preloads V_{PL} ensure good regulation even with no load at one output.

A control output (D) and two LEDs signal correct operation of the converter. In case of an output overvoltage, the converter is disabled by a latch.

Input over- and undervoltage lockout is provided. The undervoltage trigger level can be adjusted by an external resistor connected to the PUL-pin.

Temperature sensors on the primary and secondary side prevent the converter from excessive warm-up.

A cooling plate for chassis-mounting is available (opt. B, B1).

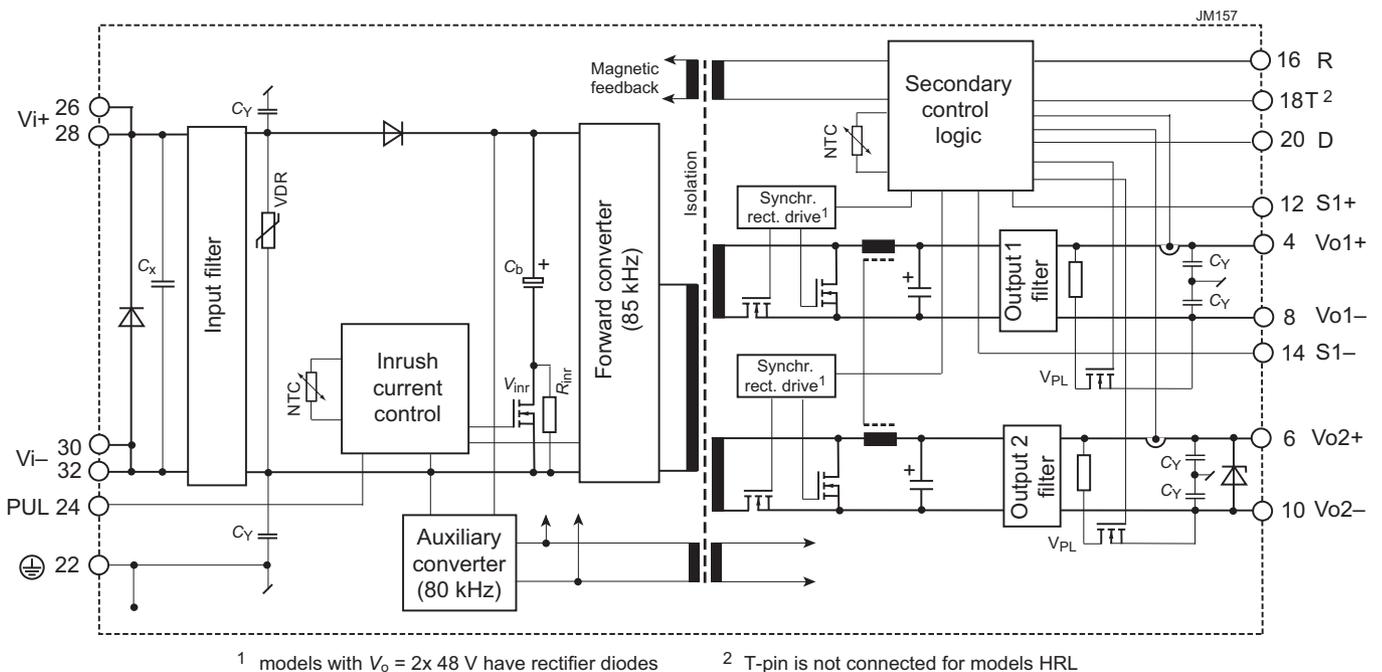


Fig. 1
 Block diagram

Electrical Input Data

General Conditions:

- $T_A = 25\text{ }^\circ\text{C}$, unless T_C is specified.
- Pin 24 (PUL), pin 16 (R), pin 18 (D) left open-circuit.

Table 2: Input data

Model			ER			ERL			ERP			Unit
Characteristics		Conditions	min	typ	max	min	typ	max	min	typ	max	
V_i	Operating input voltage	$I_o = 0 - I_o \text{ max}$ $T_C \text{ min} - T_C \text{ max}$	77		150	77		150	77		150	V
	for ≤ 2 s, without shutdown		66		168	66		168	66		168	
$V_{i \text{ nom}}$	Nom. input voltage range			110	120		110	120		110	120	
$V_{i \text{ abs}}$	Input voltage limits	3 s, without damage	0		176	0		176	0		176	
I_i	Input current: ER2320 ER2540 ER2880	$V_{i \text{ max}} \dots (110 \text{ V}) \dots V_{i \text{ min}}, I_o \text{ nom}$	1.76	(2.36)		1.03	(1.38)		2.1	(2.83)		A
			1.76	(2.36)					2.1	(2.83)		
			1.37	(1.86)					1.71	(2.33)		
P_{i0}	No-load input power	$V_{i \text{ min}} - V_{i \text{ max}}, I_o = 0$			10			10			10	W
$P_{i \text{ inh}}$	Idle input power	$V_{i \text{ min}} - V_{i \text{ max}}, V_{\text{PUL}} = 0 \text{ V}$			2.5			2.5			2.5	
C_x	Input capacitance ¹											μF
R_i	Input resistance			10			10			10		m Ω
$I_{i \text{ nr p}}$	Peak inrush current ²	$V_i = 150 \text{ V}, I_o \text{ nom}$										A
$t_{i \text{ nr r}}$	Time constant of $I_{i \text{ nr}}$											ms
$t_{d \text{ on}}$	Start-up time		$0 \rightarrow V_{i \text{ min}}, I_o \text{ nom}$		400			400			400	
t_r	Rise time after shutdown	$V_i \geq 77 \text{ V}, I_o \text{ nom}, V_{\text{PUL}} = 0 \rightarrow 5 \text{ V}$		40			40			40		

¹ At start-up (not smoothed by the inrush current limiter)

² According to ETS 300132-2

PUL Function and Fuse

This converter is designed for the input voltage range of a common 110 V railway battery. A input undervoltage lockout (PUL, pin 24) may be adjusted in order to limit the high input current at start-up; see fig 2. For stationary batteries, a higher start-up voltage might be advantageous.

Table 3 specifies the values of the resistor R_{PUL} , connected between PUL and V_i- , versus the resultant minimum input voltage and the recommended fuse.

Note: If PUL (pin 24) is connected to V_i- (pin 30/32), the converter is disabled. See also *Shutdown Function*.

Table 3: PUL specification (typ.) and recommended external fuse. A smaller fuses is possible for ERL models.

Battery	R_{PUL}	$V_{i \text{ min}}$ (on / off)	Fuse rating
110 V	5.0 k Ω	64.5 V 60.5 V	6.3 A, slow, BEL fuse MRT ²
110 V	4.0 k Ω	74.5 V 69 V	6.3 A, slow, BEL fuse MRT ²
110 V	3.0 k Ω	87.4 V 81.6 V	6.3 A, slow, BEL fuse MRT ²
110 V	2.5 k Ω	96 V 90 V	6.3 A, slow, BEL fuse MRT ²
120 V	2.2 k Ω	101.7 V 96 V	5 A, slow, BEL fuse MRT ²
--	< 100 Ω	Converter disabled	

¹ fuse size 6.3 × 32 mm ² fuse size 5 × 20 mm

No fuse is incorporated in the converter. Consequently, an external fuse or a circuit breaker must be installed at system level to protect against severe defects.

Reverse polarity protection is provided by a serial diode and an antiparallel diode across the input, causing the external input fuse or circuit breaker to trip.

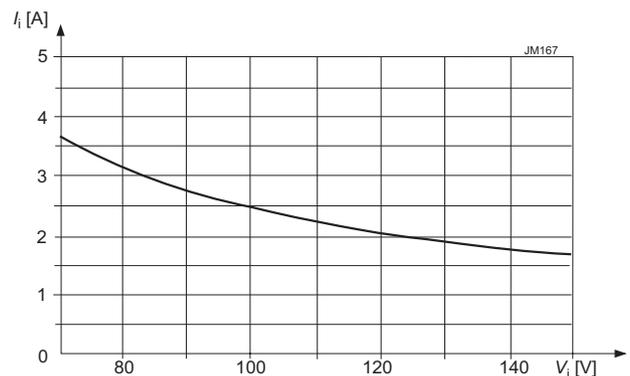


Fig. 2
Typ. input current versus input voltage at nominal load (ER2320)

Input Transient Protection

The double stage symmetrical input filter together with a VDR (voltage depending resistor) form an effective protection against high input transient voltages which typically occur in battery-driven mobile applications.

At very high input voltage, the overvoltage lockout disables the converter such protecting it from damage.

Inrush Current Limitation

The converters exhibit an electronic inrush current limiting circuit. This circuit is also functional, when the input voltage is removed and immediately reapplied.

However, several capacitors are directly connected to the input pins. Consequently, a peak current is still present when applying the input voltage.

The inrush current peak value can be determined by following calculation; see also fig. 3:

$$I_{inr p} = \frac{V_{i source}}{(R_{ext} + R_i)}$$

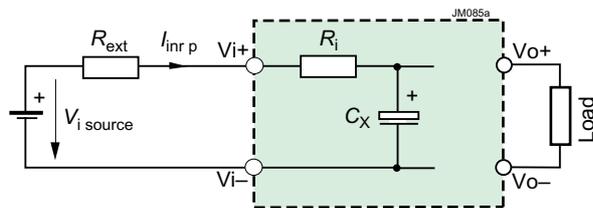


Fig. 3
Equivalent input circuit

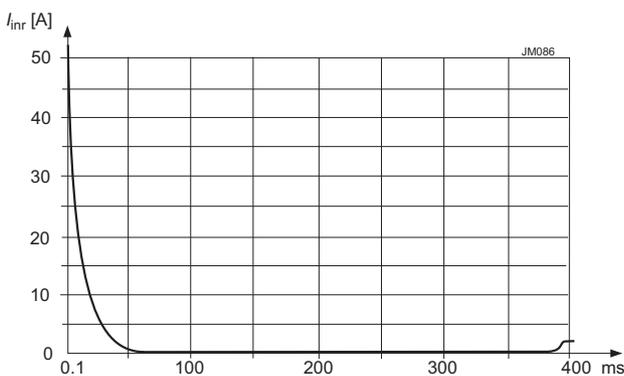


Fig. 4
Inrush current at $V_i = 150 V$, $I_o nom$ (ER2320)

Efficiency

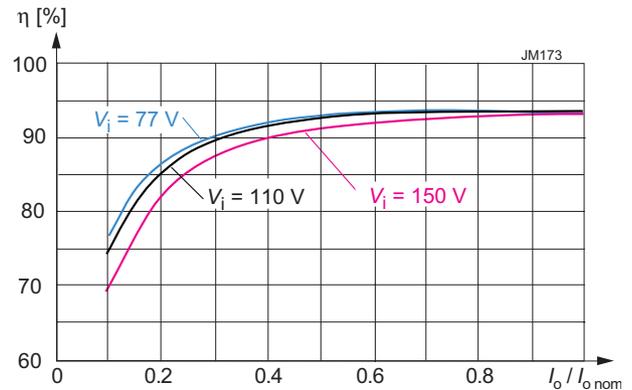


Fig. 5
Efficiency versus V_i and I_o (ER2320, both outputs connected in series)

Electrical Output Data

General Conditions: – $T_A = 25\text{ }^\circ\text{C}$, unless T_C is specified; Pin 24 (PUL) $\geq 5\text{ V}$

Table 4a: Output data of ER2320 and ERL2320

Model Nom. output voltage			ER2320 2 × 12 V						ERL2320 2 × 12 V						Unit			
Characteristics			Conditions			Output 1			Output 2			Output 1				Output 2		
						min	typ	max	min	typ	max	min	typ	max		min	typ	max
V_o	Output voltage		$V_{i\text{nom}}, 0.5 I_{o\text{nom}}$			11.93	12.0	12.07	12.0			1.93	12.0	12.07	12.0			V
$V_{o\text{BR}}$	Output protection (suppressor diode)		Output 2			--			14.4	15.9		--						
$I_{o\text{nom}}$	Output current nom.		$V_{i\text{min}} - V_{i\text{max}}$			10			10			6.0			6.0			A
I_{o1L}, I_{o2L}	Output current limit ¹		$T_{C\text{min}} - T_{C\text{max}}$			10.5			10.5			6.5			6.5			
I_{o12L}	Output current limit ^{1 2}					21 ²			--			13			--			
v_o	Output noise	Switching freq.	$V_{i\text{nom}}, I_{o\text{nom}}$			-			-			-			-			mV _{pp}
		Total incl.spikes	BW = 20 MHz			60			60									
$V_{o\text{adj}}$	Adjustment by R-input ⁴		$V_{i\text{min}} - V_{i\text{max}}$			4.8	13.8 ¹		3			4.8	13.8 ¹		3			V
$\Delta V_{o\text{u}}$	Static line/load regulation (total deviation of V_o)		$(0.1 - 1) I_{o\text{nom}}$			± 120			3			± 120			3			mV
$v_{o\text{d}}$	Dynamic load regulat.	Voltage deviation ⁵	$V_{i\text{nom}}, 0.5 I_{o2\text{nom}}$			± 200			± 200			± 150			± 150			
$t_{o\text{d}}$		Recovery time ⁵	$I_{o1\text{nom}} \leftrightarrow 0.5 I_{o1\text{nom}}$ and after turn on			1			3			1			3			ms
α_{v_o}	Temperature coefficient of output voltage		$T_{C\text{min}} - T_{C\text{max}}$			+0.01	+0.02		--			+0.01	+0.02		--			%/K

Table 4b: Output data of HRP2320 models

Model Nom. output voltage			ERP2320 2 × 12 V						Unit			
Characteristics			Conditions			Output 1				Output 2		
						min	typ	max		min	typ	max
V_o	Output voltage		$V_{i\text{nom}}, 0.5 I_{o\text{nom}}$			11.93	12.0	12.07	12.0			V
$V_{o\text{BR}}$	Output protection (suppressor diode)		Output 2			--						
$I_{o\text{nom}}$	Output current nom.		$V_{i\text{min}} - V_{i\text{max}}$			12			12			A
I_{o1L}, I_{o2L}	Output current limit ¹		$T_{C\text{min}} - T_{C\text{max}}$			12.3			12.3			
I_{o12L}	Output current limit ^{1 2}					24.6 ²			--			
v_o	Output noise	Switching freq.	$V_{i\text{nom}}, I_{o\text{nom}}$			-			-			mV _{pp}
		Total incl.spikes	BW = 20 MHz			60			60			
$V_{o\text{adj}}$	Adjustment by R-input ⁴		$V_{i\text{min}} - V_{i\text{max}}$			4.8	13.8 ¹		3			V
$\Delta V_{o\text{u}}$	Static line/load regulation (total deviation of V_o)		$(0.1 - 1) I_{o\text{nom}}$			± 120			3			mV
$v_{o\text{d}}$	Dynamic load regulat.	Voltage deviation ⁵	$V_{i\text{nom}}, 0.5 I_{o2\text{nom}}$			± 250			± 250			
$t_{o\text{d}}$		Recovery time ⁵	$I_{o1\text{nom}} \leftrightarrow 0.5 I_{o1\text{nom}}$ and after turn on			1			3			ms
α_{v_o}	Temperature coefficient of output voltage		$T_{C\text{min}} - T_{C\text{max}}$			+0.01	+0.02		--			%/K

¹ If V_o is increased above $V_{o\text{nom}}$ through R-, sense, or T-input, the output currents should be reduced so that $P_{o\text{nom}}$ is not exceeded.

² Both outputs connected in parallel

³ See Output voltage regulation

⁴ For battery charger application, a defined negative temp. coefficient can be provided by using a temp. sensor (see Accessories)

⁵ See Dynamic load regulation

⁶ Measured according to IEC/EN 61204 with a probe according to annex A

Table 4c: Output data of ER2540 and ERP2540. General conditions as per table 6a

Model			ER2540 2 x 15 V						ERP2540 2 x 15 V						Unit			
Nom. output voltage			Output 1			Output 2			Output 1			Output 2						
Characteristics			Conditions			min	typ	max	min	typ	max	min	typ	max		min	typ	max
V_o	Output voltage		$V_{i\text{nom}}, 0.5 I_{o\text{nom}}$			14.91	15.0	15.09	15.0			14.91	15.0	15.09	15.0			V
$V_{o\text{BR}}$	Output protection (suppressor diode)		Output 2			--			--									
$I_{o\text{nom}}$	Output current nom.		$V_{i\text{min}} - V_{i\text{max}}$			8			8			9.6			9.6			A
I_{o1L}, I_{o2L}	Output current limit ¹		$T_{C\text{min}} - T_{C\text{max}}$			8.4			8.4			10.1			10.1			
I_{o12L}	Output current limit ²					16.8 ²			--			19.7 ²			--			
V_o	Output noise	Switching freq.	$V_{i\text{nom}}, I_{o\text{nom}}$			-			-			-			-			mV _{pp}
		Total incl.spikes	BW = 20 MHz			60			60			60			60			
$V_{o\text{adj}}$	Adjustment by R-input ⁴		$V_{i\text{min}} - V_{i\text{max}}$			6.0	17.25 ¹		3			6.0	17.25 ¹		3			V
$\Delta V_{o\text{u}}$	Static line/load regulation (total deviation of V_o)		$(0.1 - 1) I_{o\text{nom}}$			±150			3			±150			3			mV
$V_{o\text{d}}$	Dynamic load regulat.	Voltage deviation ⁵	$V_{i\text{nom}}, 0.5 I_{o2\text{nom}}$			±250			±250			±300			±300			
$t_{o\text{d}}$		Recovery time ⁵		$I_{o1\text{nom}} \leftrightarrow 0.5 I_{o1\text{nom}}$ and after turn on			1			3			1			3		
α_{V_o}	Temperature coefficient of output voltage		$T_{C\text{min}} - T_{C\text{max}}$			+0.01	+0.02		--			+0.01	+0.02		--			%/K

¹ If the output voltages are increased above $V_{o\text{nom}}$ through R-input control, remote sensing, or option T, the output currents should be reduced accordingly so that $P_{o\text{nom}}$ is not exceeded.

² Both outputs connected in parallel

³ See *Output voltage regulation*

⁴ For battery charger applications, a defined negative temperature coefficient can be provided by using a temperature sensor (see *Accessories*)

⁵ See *Dynamic load regulation*

⁶ Measured according to IEC/EN 61204 with a probe according to annex A

Table 4d: Output data of ER2880 and ERP2880. General conditions as per table 6a

Model			ER2880						ERP2880						Unit
Nom. output voltage			2 x 48 V						2 x 48 V						
Characteristics			Output 1			Output 2			Output 1			Output 2			
Conditions			min	typ	max	min	typ	max	min	typ	max	min	typ	max	
V_o	Output voltage	$V_{i\text{nom}}, 0.5 I_{o\text{nom}}$	47.7	48.0	48.3		48.0		47.7	48.0	48.3		48.0		V
$V_{o\text{BR}}$	Output protection (suppressor diode)	Output 2	--						--						
$I_{o\text{nom}}$	Output current nom.	$V_{i\text{min}} - V_{i\text{max}}$	2.0			2.0			2.5			2.5			A
I_{o1L}, I_{o2L}	Output current limit ¹	$T_{C\text{min}} - T_{C\text{max}}$	2.1			2.1			2.625			2.625			
I_{o12L}	Output current limit ²		4.2 ²			--			5.25 ²			--			
v_o	Output noise	Switching freq. Total incl.spikes	$V_{i\text{nom}}, I_{o\text{nom}}$ BW = 20 MHz			-			-			-			mV _{pp}
$V_{o\text{adj}}$	Adjustment by R-input ⁴	$V_{i\text{min}} - V_{i\text{max}}$ $(0.1 - 1) I_{o\text{nom}}$	19.2	55.2 ¹		3		19.2	55.2 ¹		3		V		
$\Delta V_{o\text{u}}$	Static line/load regulation (total deviation of V_o)		± 0.5			3			± 0.5			3			
$v_{o\text{d}}$	Dynamic load regulat.	Voltage deviation ⁵	± 0.8			± 0.8			± 1.0			± 1.0			
$t_{o\text{d}}$		Recovery time ⁵	1			3			1			3			ms
α_{v_o}	Temperature coefficient of output voltage	$T_{C\text{min}} - T_{C\text{max}}$ $I_{o\text{nom}}$	+0.01	+0.02		--		+0.01	+0.02		--		%/K		

¹ If the output voltages are increased above $V_{o\text{nom}}$ through R-input control, remote sensing, or option T, the output currents should be reduced accordingly so that $P_{o\text{nom}}$ is not exceeded.

² Both outputs connected in parallel

³ See *Output voltage regulation*

⁴ For battery charger applications, a defined negative temperature coefficient can be provided by using a temperature sensor (see *Accessories*)

⁵ See *Dynamic load regulation*

⁶ Measured according to IEC/EN 61204 with a probe according to annex A

Thermal Considerations

If a converter is located in free, quasi-stationary air (convection cooling) at the indicated maximum ambient temperature $T_{A\max}$ (see table *Temperature specifications*) and is operated within the specified input voltage range and nominal load, the temperature measured at the *Measuring point of case temperature* T_C (see *Mechanical Data*) will approach the indicated value $T_{C\max}$ after the warm-up phase. However, the relationship between T_A and T_C depends heavily upon the conditions of operation and integration into a system. The thermal conditions are influenced by input voltage, output current, airflow, and temperature of surrounding components and surfaces. $T_{A\max}$ is therefore, contrary to $T_{C\max}$, an indicative value only.

Caution: The installer must ensure that under all operating conditions T_C remains within the limits stated in the table *Temperature specifications*.

Notes: Sufficient forced cooling or enhanced cooling with the help of cooling plates (options B, B1) allows for T_A to be higher than 71 °C (e.g. 85 °C), as long as $T_{C\max}$ is not exceeded.

Thermal Protection

Two temperature sensors generate an internal inhibit signal, which disables the converter in the case of overtemperature. The outputs automatically recover when the temperature drops below the limit.

Interruption Time

The integrated storage capacitor (C_b) is decoupled from the input by a diode. This capacitor ensures full output voltage with nominal load during an interruption time (or ride-through time) of at least 10 ms, provided that V_i was ≥ 100 V before the interruption. This complies with EN 50155 class S2.

Output Protection

The 2nd output of xx2320 models is protected by a suppressor diode against overvoltage, which could occur due to a failure of the internal control circuit. This suppressor diode was not designed to withstand externally applied overvoltages. Overload at any of the outputs will cause both outputs to shut-down.

Note: V_{OBR} of the suppressor diode is specified in *Electrical Output Data*. If this voltage is exceeded, the suppressor diode generates losses and may become a short circuit.

Note: The output voltage of the first output is monitored. If it exceeds typ. 140% of $V_{O,nom}$ for 10 ms, the converter is inhibited. To reactivate, V_i must be removed or a shutdown signal applied to PUL (pin 24).

Each output has its own current limiting circuit, providing a rectangular output characteristic and protecting against short circuit. There is no limitation for the capacitive load, and battery charging is possible as well.

Series and Parallel Connection

Both outputs of the same converter can be series-connected or parallel-connected in order to double the output current or the output voltage respectively.

Outputs of different converters may be series-connected.

In parallel connection of several converters, the T-pins should be interconnected so that all converters share the output current equally. HRL models have no T-pins and should not be operated in parallel connection.

If both outputs of each converter are connected in series, Vo1– of both converters should be connected together and the T-pins as well. See fig. 7 and 8.

Notes:

- Not more than 5 converters should be connected in parallel.
- If several outputs are connected in series, the resulting voltage may exceed the SELV level.
- The PUL-pins (pin 24) should exhibit an individual PUL resistor for each converter. If the shutdown function is used, each PUL-pin must be controlled individually.
- The R-pins should be left open-circuit. If not, the output voltages must individually be adjusted prior to paralleling within 1 to 2% or the R-pins should be connected together.
- Series connection of second outputs without involving their main outputs should be avoided, as regulation may be poor.

Output Voltage Regulation

If both outputs are connected in parallel or in series, the converter exhibits a rectangular output characteristic; see fig. 9.

The typ. dynamic load regulation illustrates fig. 10.

Output 1 is under normal conditions regulated to $V_{O,nom}$, irrespective of the output currents.

However, V_{O2} depends upon the load distribution; see fig. 11. This chart applies for ER2320. At very low loads, a switchable preload on each output improves the cross regulation.

Note: If output 2 is not used, connect it in parallel with output 1! This ensures good regulation and efficiency.

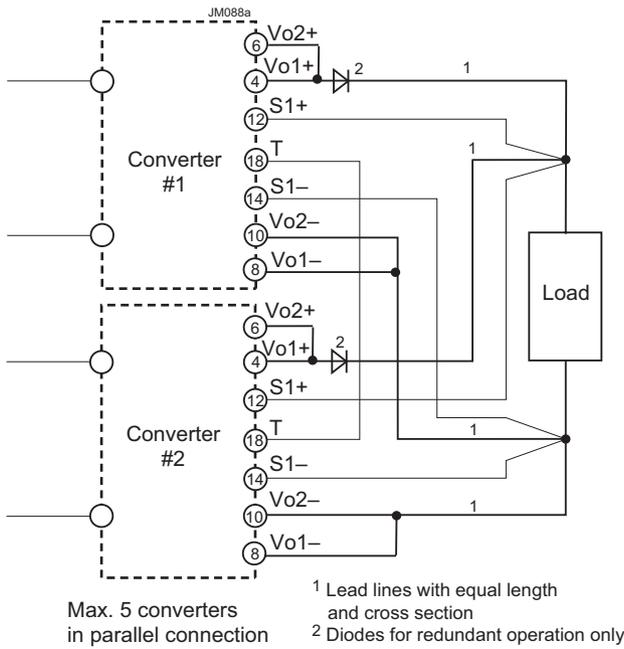


Fig. 7
Parallel connection with OR-ing diodes and sense lines connected at the load

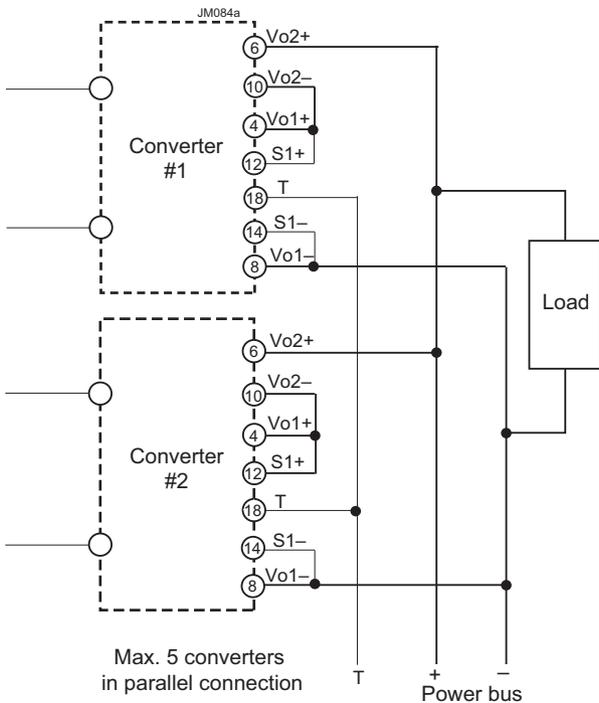


Fig. 8
Parallel connection of double-output models with the outputs of each converter connected in series, using option T. The signal at the T pins is referenced to Vo1-.

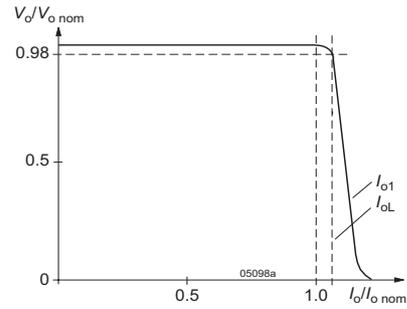


Fig. 9
Output characteristic V_o versus I_o (both outputs connected in parallel or in series)

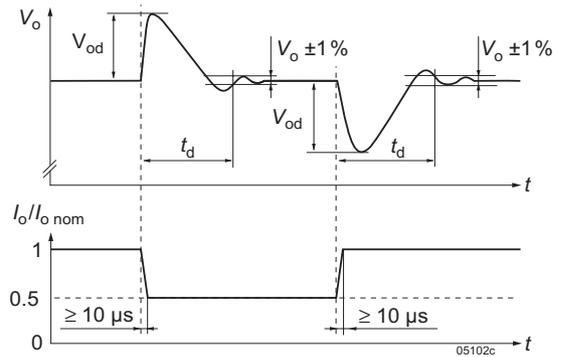


Fig. 10
Typical dynamic load regulation of V_o .

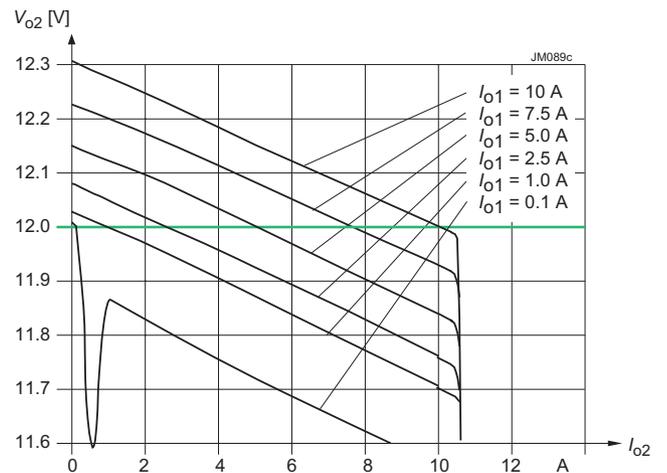


Fig. 11a
Models ER2320 (two 12 V outputs): V_{o2} versus I_{o2} with various I_{o1}

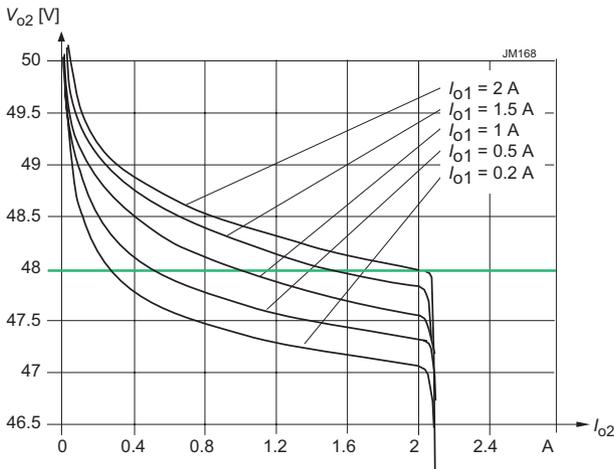


Fig. 11b
 Models ER2880 (2×12V outputs): V_{o2} versus I_{o2} with various I_{o1}

Auxiliary Functions

Shutdown Function

The PUL input (pin 24) can also be used as shutdown (for the PUL function see table 3). The response time t_r is specified in table 2.

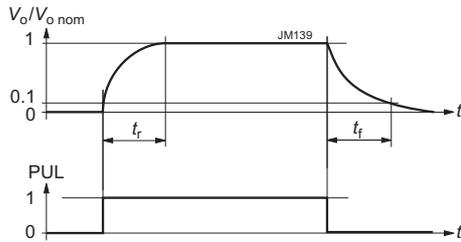


Fig. 12
 Typical output response to the PUL-signal (shutdown)

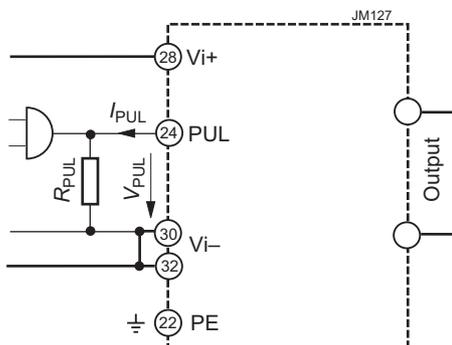


Fig. 13
 Circuit for the shutdown function

The current coming out from pin 24 (PUL) is typ. 1.5 mA (<2 mA). If pin 24 is left open-circuit, the voltage is typ. 5 V. The converter is disabled when V_{PUL} is ≤ 500 mV.

Current Share Function

If the pins 18 (T) of parallel-connected converters are linked together, the converters share the output current evenly. Refer to section *Parallel and Series Connection*. Not for HRL models.

Sense Lines

This feature allows for compensation of voltage drops across the connector contacts and if necessary, across the load lines. We recommend connecting the sense lines directly at the female connector.

To ensure correct operation, both sense lines (S1+, S1–)

Table 7: Maximum voltage compensation allowed using sense lines

Output voltage	Total voltage difference between sense lines and their respective outputs	Voltage difference between Vo1– and S1–
12 V	<1.0 V	<0.5 V
15 V	<1.25 V	<0.6 V
48 V	<2.0 V	<1.0 V

should be connected to their respective power outputs (Vo1+ and Vo1–), and the voltage difference between any sense line and its respective power output (as measured on the connector) should not exceed the values specified in table 7.

Important: Sense lines should be connected! Incorrectly connected sense lines may activate the overvoltage protection resulting in a permanent short-circuit of the output. Open sense lines are allowed, but result in inaccurate output voltages.

Output Voltage Adjust

As a standard feature, the converters offer an adjustable output voltage. The control input R (pin 16) accepts either a control voltage V_{ext} or a resistor R_{ext} to adjust the output voltage. When input R is not connected, the output voltage is set to $V_{o nom}$.

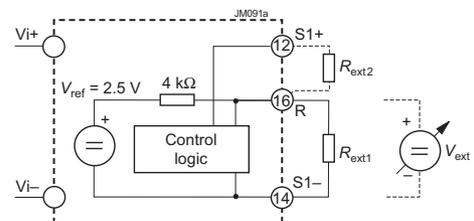


Fig. 14
 Output voltage adjustment

a) Adjustment by means of an **external control voltage** V_{ext} between pin 16 (R) and pin 14 (S1-):

The control voltage range is 1.0 – 2.875 V and allows for an adjustment in the range of approx. 40 – 115% of $V_{o\ nom}$.

$$V_{ext} \approx \frac{V_o \cdot 2.5\text{ V}}{V_{o\ nom}}$$

Caution: Applying an external control voltage >2.875 V may damage the converter.

b) Adjustment by means of an **external resistor**:

Depending on the value of the required output voltage, the resistor shall be connected

either: between pin 16 (R) and pin 14 (S1-) to adjust the output voltage in the range of approximately 40 – 100% of $V_{o\ nom}$.

$$R_{ext1} \approx 4\text{ k}\Omega \cdot \frac{V_o}{V_{o\ nom} - V_o}$$

or: between pin 16 (R) and pin 12 (S1+) to adjust the output voltage in the range of 100 – 115% of $V_{o\ nom}$.

$$R_{ext2} \approx 4\text{ k}\Omega \cdot \frac{(V_o - 2.5\text{ V})}{2.5\text{ V} \cdot (V_o/V_{o\ nom} - 1)}$$

Caution: To prevent the converter from damage, the value of R'_{ext} shall never be less than the value for increasing V_{o1} to 115% !

Notes:

- If the output voltages are increased above $V_{o\ nom}$ via R-input control, sense lines, or option T, the output currents should be reduced, so that $P_{o\ nom}$ is not exceeded.
- The second output of double-output models follows the voltage of the controlled main output.

Output Voltage Monitor

The output voltage monitor generates a logic "low" signal (NPN open-collector output) at the D-output (pin 20), when $V_{o1} \geq 0.96 V_{o\ nom}$. For converters with version V101 (or later), the voltage at S1+ (corresponding to V_{o1}) must be $\geq 0.96 V_{o\ nom}$ and $\leq 1.04 V_{o\ nom}$ (typ. values). Then, a green LED (Out OK) at the frontplate is illuminated. If the output voltage is adjusted by the R-input, the trigger levels are corrected accordingly.

At low D-output, the current is limited by a 10 Ω protective resistor; for converters with Version V102 (or later) I_D should be ≤ 100 mA. If the D-output is high (open collector), V_D should be ≤ 75 V. For previous converters: ≤ 50 mA and 50 V.

Note: Output overvoltage activates a latch; see *Output Protection*.

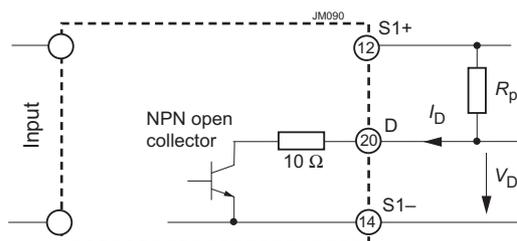


Fig. 15
Output voltage monitor

Indicators

Two green indicators are visible at the front plate:

- Out OK; see *Output Voltage Monitor*
- In OK. This signal is activated when V_i is below 158 V and greater than $V_{i\ min}$, whereas $V_{i\ min}$ is defined by the adjust resistor connected to the PUL input (pin 24).

Battery Charging / Temperature Sensor

All converters with an R-input are suitable for battery charger application. For optimal battery charging and life expectancy of the battery an external temperature sensor can be connected to the R-input. The sensor is mounted as close as possible to the battery and adjusts the output voltage according to the battery temperature.

Depending upon cell voltage and the temperature coefficient of the battery, different sensor types are available, see *Accessories*.

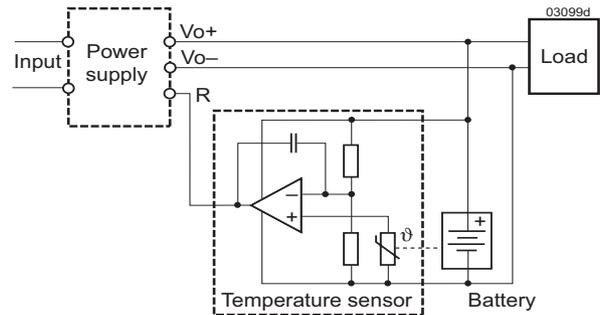


Fig. 16
Connection of a temperature sensor

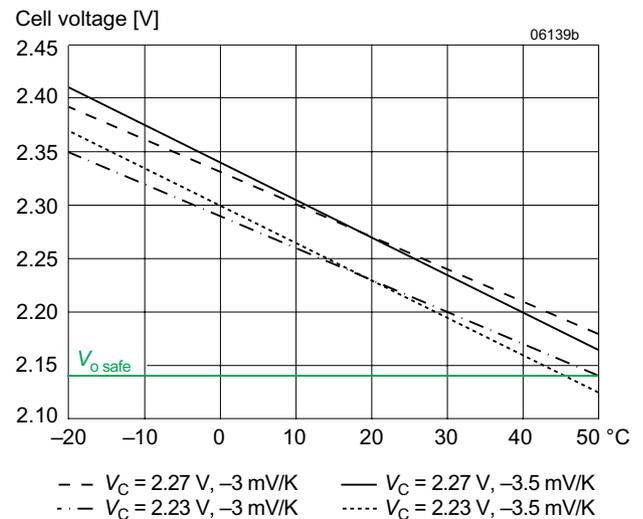


Fig. 17
Trickle charge voltage versus temperature for defined temperature coefficient. $V_{o\ nom}$ is the output voltage with open R-input.

Electromagnetic Compatibility (EMC)

A metal oxide VDR together and an efficient input filter form an effective protection against high input transient voltages,

which typically occur in most installations. The converters have been successfully tested to the following specifications:

Electromagnetic Immunity

Table 8: Electromagnetic immunity (type tests)

Phenomenon	Standard	Level	Coupling mode ¹	Value applied	Waveform	Source imped.	Test procedure	In oper.	Perf. crit. ²
Electrostatic discharge (to case)	IEC/EN 61000-4-2	4 ⁵	contact discharge	8000 V _p	1/50 ns	330 Ω	10 positive and 10 negative discharges	yes	A
			air discharge	15000 V _p					
Electromagnetic field	IEC/EN 61000-4-3	x ⁶	antenna	20 V/m	AM 80% /1 kHz	n.a.	80 – 1000 MHz	yes	A
				20 V/m			800 – 1000 MHz		
				10 V/m			1400 – 2100 MHz		
		5 V/m	2100 – 2500 MHz						
		3	antenna	10 V/m	50% duty cycle, 200 Hz rep. rate	n.a.	900 ±5 MHz	yes	A
Electrical fast transients/burst	IEC/EN 61000-4-4	3 ⁸	capacitive, o/c	±2000 V _p	bursts of 5/50 ns 2.5/5 kHz over 15 ms; burst period: 300 ms	50 Ω	60 s positive 60 s negative transients per coupling mode	yes	A
		4	i/c, +i/-i direct	±4000 V _p					
Surges	IEC/EN 61000-4-5	3 ⁹	i/c	±2000 V _p	1.2/50 μs	12 Ω	5 pos. and 5 neg. surges per coupling mode	yes	A
			+i/-i	±1000 V _p		2 Ω			
Conducted disturbances	IEC/EN 61000-4-6	3 ¹⁰	i, o, signal wires	10 VAC (140 dBμV)	AM 80% 1 kHz	150 Ω	0.15 – 80 MHz	yes	A
Power frequency magnetic field	IEC/EN 61000-4-8	3 ¹¹	--	300 A/m			60 s in all 3 axis	yes	A
Pulse magnetic field	IEC/EN 61000-4-9	-	--	±300 A/m			5 pulses per axis repetit. rate 10 s	yes	A

¹ i = input, o = output, c = case

² A = normal operation, no deviation from specs.; B = normal operation, temporary loss of function or deviation from specs possible

⁵ Exceeds EN 50121-3-2:2006 table 9.3 and EN 50121-4:2006 table 1.4.

⁶ Corresponds to EN 50121-3-2:2006 table 9.1 and exceeds EN 50121-4:2006 table 1.1.

⁷ Corresponds to EN 50121-3-2:2006 table 9.2 and EN 50121-4:2006 table 1.2 (compliance with digital mobile phones).

⁸ Corresponds to EN 50121-3-2:2006 table 7.2 and EN 50121-4:2006 table 2.2.

⁹ Covers or exceeds EN 50121-3-2:2006 table 7.3 and EN 50121-4:2006 table 2.3.

¹⁰ Corresponds to EN 50121-3-2:2006 table 7.1 and EN 50121-4:2006 table 3.1 (radio frequency common mode).

¹¹ Corresponds to EN 50121-4:2006 table 1.3.

Electromagnetic Emissions

All models comply with Class A according to EN 55011/55022 for conducted and radiated emissions.

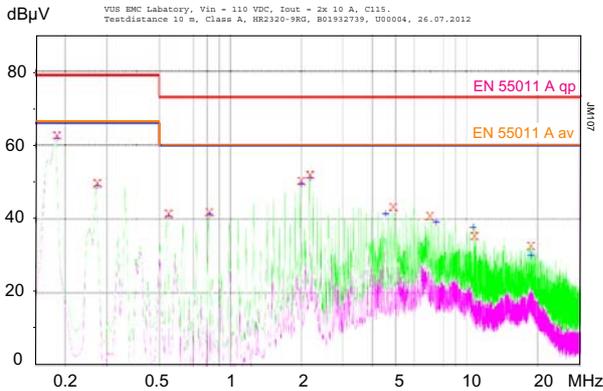


Fig. 18
Typ. conducted emissions (peak/quasipeak and average) at the input according to EN 55011/22, measured at $V_i = 110\text{ V}$ and $I_{o\text{nom}}$ (ER2320-9RG).

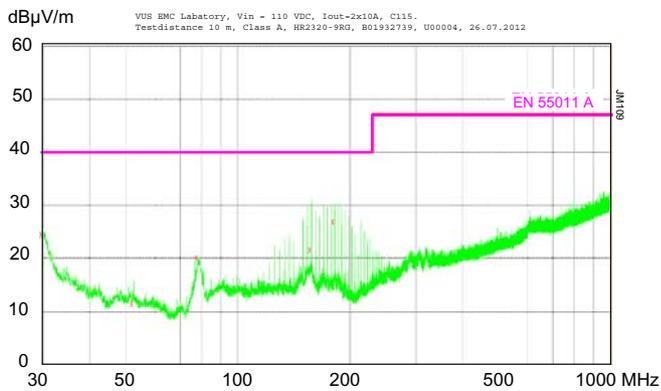


Fig. 19
Typ. radiated emissions accord. to EN 55011/22, antenna 10 m distance, measured at $V_i = 110\text{ V}$ and $I_{o\text{nom}}$ (ER2320-9RG).

Immunity to Environmental Conditions

Table 9: Mechanical and climatic stress (type tests)

Test method	Standard	Test conditions	Status
Cb Humidity	IEC/EN 60068-2-56	Temperature: 25 °C Relative humidity: 95 % Duration: 8 h	Converter operating
Cab Damp heat steady state	IEC/EN 60068-2-78 MIL-STD-810D section 507.2	Temperature: 40 ±2 °C Relative humidity: 93 +2/-3 % Duration: 56 days	Converter not operating
Db Damp heat test, cyclic	EN 50155:2007, clause 12.2.5 IEC/EN 60068-2-30	Temperature: 55 °C and 25 °C Cycles (respiration effect): 2 Duration: 2 × 24 h	Converter not operating
Bd Dry heat test steady state	EN 50155:2007, clause 12.2.4 IEC/EN 60068-2-2	Temperature: 70 °C Duration: 6 h	Converter operating
Ad Cooling test steady state	EN 50155:2007, clause 12.2.3 IEC/EN 60068-2-1	Temperature, duration: -40 °C, 2 h Performance test: +25 °C	Conv. not operating
-- Salt mist test sodium chloride (NaCl) solution	EN 50155:2007, clause 12.2.10 class ST2	Temperature: 35 ±2 °C Duration: 16 h	Converter not operating
Fc Vibration (sinusoidal)	IEC/EN 60068-2-6 MIL-STD-810D section 514.3	Acceleration amplitude: 0.35 mm (10 – 60 Hz) 5 g _n = 49 m/s ² (60 - 2000 Hz) Frequency (1 Oct/min): 10 – 2000 Hz Test duration: 7.5 h (2.5 h in each axis)	Converter operating
Fh Random vibration broad band (digital control) and guidance	IEC/EN 60068-2-64	Acceleration spectral density: 0.05 g _n ² /Hz Frequency band: 8 – 500 Hz Acceleration magnitude: 4.9 g _{n rms} Test duration: 1.5 h (0.5 h in each axis)	Converter operating
Eb Bump (half-sinusoidal)	IEC/EN 60068-2-29 MIL-STD-810D section 516.3	Acceleration amplitude: 25 g _n = 245 m/s ² Bump duration: 6 ms Number of bumps: 6000 (1000 in each direction)	Converter operating
Ea Shock (half-sinusoidal)	IEC/EN 60068-2-27 MIL-STD-810D section 516.3	Acceleration amplitude: 50 g _n = 490 m/s ² Bump duration: 11 ms Number of bumps: 18 (3 in each direction)	Converter operating
-- Shock	EN 50155:2007 clause 12.2.11, EN 61373 sect. 10, class B, body mounted ¹	Acceleration amplitude: 5.1 g _n Bump duration: 30 ms Number of bumps: 18 (3 in each direction)	Converter operating
-- Simulated long life testing at increased random vibration levels	EN 50155:2007 clause 12.2.11, EN 61373 sect. 8 and 9, class B, body mounted ¹	Acceleration spectral density: 0.02 g _n ² / Hz Frequency band: 5 – 150 Hz Acceleration magnitude: 0.8 g _{n rms} Test duration: 15 h (5 h in each axis)	Converter operating

¹ Body mounted = chassis of a railway coach

Temperatures

Table 10: Temperature specifications, valid for an air pressure of 800 - 1200 hPa (800 - 1200 mbar)

Temperature				-9			Unit
Characteristics	Conditions			min	typ	max	
T _A	Ambient temperature	Converter operating		-40		71 ¹	°C
T _C	Case temperature				-40		
T _S	Storage temperature	Non operational		-55		100	

¹ See *Thermal Considerations*.

² Overtemperature lockout at T_C > 95 °C (An NTC resistor on primary and secondary heatsink).

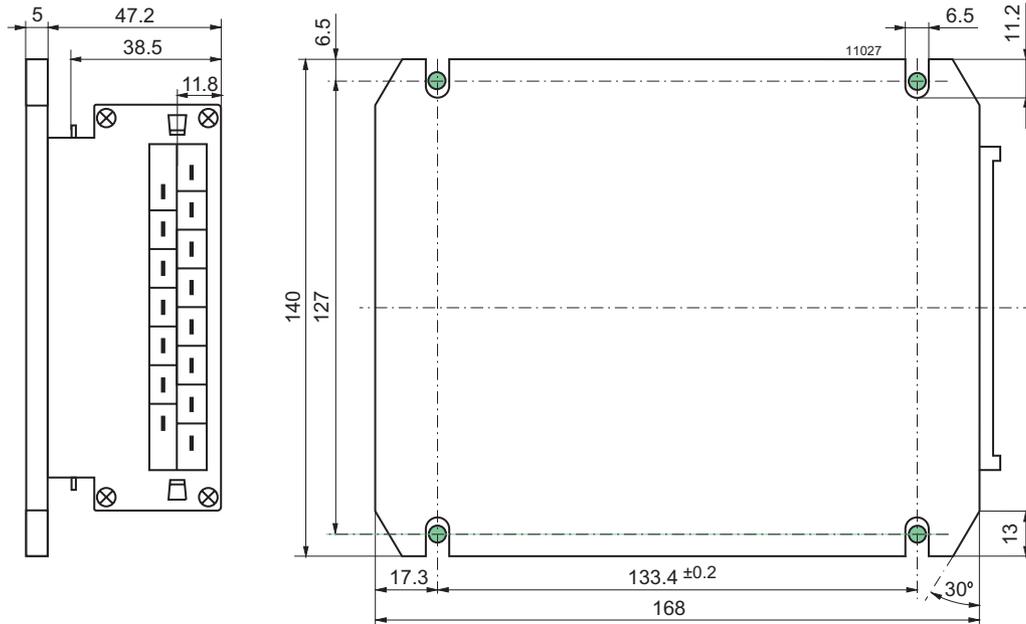


Fig. 22
Option B: Aluminum case S with large cooling plate; black finish (EP powder coated).
Suitable for front mounting.
Total weight approx. 1.5 kg



Note: Long case with option B2, elongated by 60 mm for 220 mm rack depth, is available on request. (No LEDs)

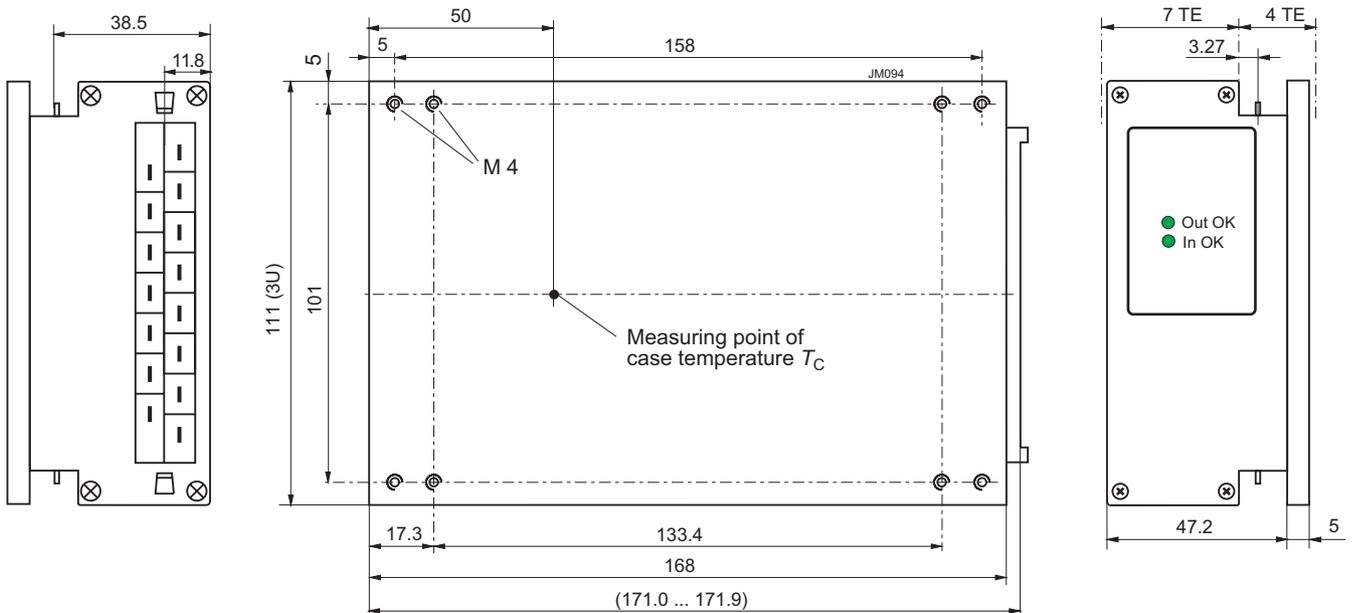


Fig. 23
Option B1: Aluminum case S with small cooling plate; black finish (EP powder coated).
Suitable for mounting with access from the backside.
Total weight approx. 1.4 kg.

Safety and Installation Instructions

Connector Pin Allocation

The connector pin allocation table defines the electrical potentials and the physical pin positions on the H15 connector. The protective earth is connected by a leading pin (no. 24), ensuring that it makes contact with the female connector first.

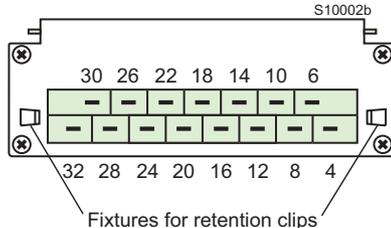


Fig. 24
View of module's male connectors

Table 12: Pin allocation

Pin no.	Name	Function
4	Vo1+	Pos. output 1
6	Vo2+	Pos. output 2
8	Vo1-	Neg. output 1
10	Vo2-	Neg. output 2
12	S1+	Pos. sense line
14	S1-	Neg. sense line
16	R	Output voltage adjust
18 ²	T	Current share
20	D	Out OK
22 ¹	PE	Protection earth ⊕
24	PUL	Programmable undervoltage lockout
26 + 28	Vi+	Pos. input
30 + 32	Vi-	Neg. input

¹ Leading pin (pre-connecting)

² Not connected for HRL models

Installation Instructions

The converters are components, intended exclusively for inclusion within other equipment by an industrial assembly operation or by professional installers. Installation must strictly follow the national safety regulations in compliance with the enclosure, mounting, creepage, clearance, casualty, markings, and segregation requirements of the end-use application.

Connection to the system shall be made via the female connector H15; see *Accessories*. Other installation methods may not meet the safety requirements.

Pin no. 22 (⊕) is connected with the case. For safety reasons it is essential to connect this pin reliably to protective earth.

Notes:

- The PUL function (pin 24) must be programmed to enable the outputs. PUL should be connected to Vi- (pins 30 + 32) by a resistor to adjust the start-up voltage; see table 3. Otherwise, the input current may become too high at low input voltage.
- Do not open the converter, or warranty will be invalidated.
- If the second output of double-output models is not used, connect it parallel with the main output.

Make sure that there is sufficient airflow available for convection cooling and verify it by measuring the case temperature T_C , when the converter is installed and operated in the end-use application; see *Thermal Considerations*.

Ensure that a converter failure (e.g. an internal short-circuit) does not result in a hazardous condition.

Standards and Approvals

The converters are safety-approved to UL/CSA 60950-1 2nd Ed. and IEC/EN 60950-1 2nd Ed.

The converters correspond to Class I equipment (with case connected to ground). They have been evaluated for:

- Building-in
- Basic insulation between input and case based on 250 VA. Double or reinforced insulation between input and outputs
- Functional insulation between outputs
- Overvoltage category II
- Pollution degree 2 environment
- Max. altitude: 2000 m
- The converters fulfill the requirements of a fire enclosure.

The output voltage is considered as SELV, except HR/HRP2880 with both outputs in series connection.

The converters are subject to manufacturing surveillance in accordance with the above mentioned standards and ISO 9001:2008. CB-scheme is available on request.

Cleaning Liquids

In order to avoid possible damage, any penetration of cleaning fluids has to be prevented, since the power supplies are not hermetically sealed.

Protection Degree

The protection degree is IP 40, provided that the female connector is fitted to the converter.

Railway Application and Fire Protection

The converters have been designed by observing the railway standards EN 50155, EN 50121-3-2, and EN 50121-4. All boards are coated with a protective lacquer.

The converters comply with NF-F16 (I2/F1). They also comply with EN 45545-1, EN 45545-2 (2013), if installed in a technical compartment or cabinet.

Table 13: Isolation

Characteristic		Input to case and output(s)	Output(s) to case	Output 1 to output 2	Unit
Electric strength test	Factory test >1 s	2.8 ¹	1.4	0.3	kVDC
	AC test voltage equivalent to factory test	2.0	1.0	0.21	kVAC
Insulation resistance at 500 VDC		>300	>300	>100 ²	MΩ
Creepage distances		≥ 3.5 ³	≥ 2.5	--	mm

¹ According to EN 50116 and IEC/EN 60950, subassemblies connecting input to output are pre-tested with 5.6 kVDC or 4 kVAC.

² Tested at 150 VDC

³ Input to outputs: 6.4 mm

Isolation and Protective Earth

The electric strength test is performed in the factory as routine test according to EN 50116 and IEC/EN 60950 and should not be repeated in the field. Power-One will not honor any warranty claims resulting from electric strength field tests. The resistance case to the earth pin (<0.1 Ω) is tested as well.

Description of Options

B, B1 Cooling Plates

Where a cooling surface is available, we recommend the use of a cooling plate instead of the standard heat sink. The mounting system should ensure that the maximum case temperature $T_{C_{max}}$ is not exceeded. The cooling capacity is calculated by (η see *Model Selection*):

$$P_{Loss} = \frac{(100\% - \eta)}{\eta} \cdot V_o \cdot I_o$$

For the dimensions of the cooling plates; see *Mechanical Data*.

Accessories

A variety of electrical and mechanical accessories are available including:

- Front panels for 19" DIN-rack: Schroff or Intermas, 12 or 16TE /3U
- Mating H15 connectors with screw, solder, faston, or press-fit terminals.
- Coding clips for connector coding HZZ00202
- Pair of connector retention clips HZZ01209-G
- Connector retention brackets HZZ01216-G (CRB-HKMS)
- Cable hood for H15 connectors:
 - HZZ00141-G (KSG-H15/H15S4), screw version
 - HZZ00142-G, use with retention brackets HZZ01218-G
 - HZZ00143-G, metallic version providing fire protection
- Cage clamp adapter HZZ00144-G; see fig. 27
- DIN-rail mounting assembly HZZ0615-G (DMB-K/S)
- Wall-mounting plate K02 (HZZ01213-G) for models with option B1
- Additional external input and output filters
- Different battery sensors S-KSMH... for using the converter as a battery charger. Different cell characteristics can be selected; see *Battery Charging/ Temperature Sensors*

For additional accessory product information, see the accessory data sheets listed with each product series or individual model at our web site:

belpowersolutions.com/power



Different front panels

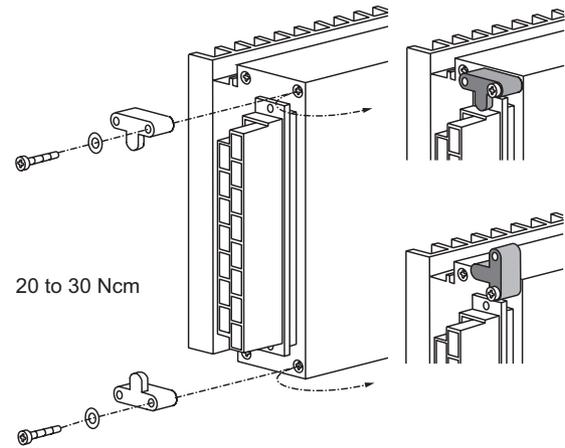


Fig. 25
Connector retention brackets HZZ01216-G (CRB-HKMS)

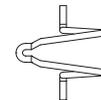


Fig. 26
Connector retention clips to fasten the H15 connector to the rear plate; see fig. 24. HZZ01209-G consists of 2 clips.

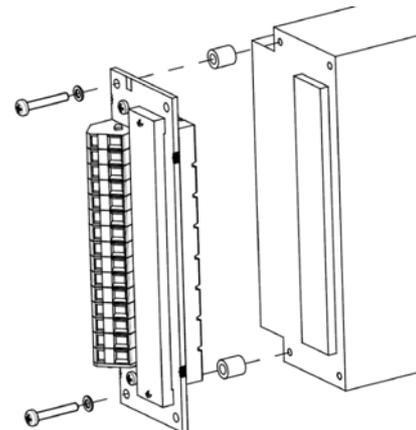


Fig. 27
Cage clamp adapter HZZ00144-G



Different cable hoods

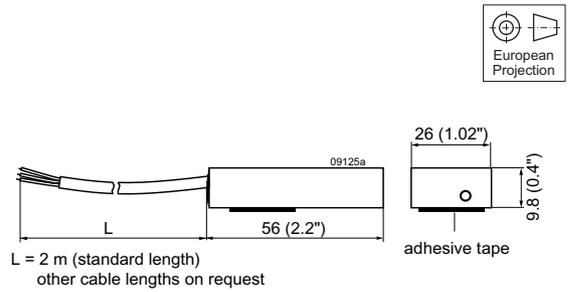


Fig. 28
Battery temperature sensor



Chassis- or wall-mounting plate
HZZ01213-G (Mounting plate K02)

Table 14: Battery temperature sensors

Battery voltage nom. [V]	Sensor type	Cell voltage [V]	Cell temp. coefficient [mV/K]	Cable length [m]
12	S-KSMH12-2.27-30-2	2.27	-3.0	2
12	S-KSMH12-2.27-35-2	2.27	-3.5	2
24	S-KSMH24-2.27-30-2	2.27	-3.0	2
24	S-KSMH24-2.27-35-2	2.27	-3.5	2
24	S-KSMH24-2.31-35-0	2.31	-3.5	4.5
24	S-KSMH24-2.31-35-2	2.31	-3.5	2
24	S-KSMH24-2.35-35-2	2.35	-3.5	2
48	S-KSMH48-2.27-30-2	2.27	-3.0	2
48	S-KSMH48-2-27-35-2	2.27	-3.5	2

Note: Other temperature coefficients and cable lengths are available on request.



DIN-rail mounting assembly
HZZ00615-G (DMB-K/S)

NUCLEAR AND MEDICAL APPLICATIONS - These products are not designed or intended for use as critical components in life support systems, equipment used in hazardous environments, or nuclear control systems.

TECHNICAL REVISIONS - The appearance of products, including safety agency certifications pictured on labels, may change depending on the date manufactured. Specifications are subject to change without notice.

Данный компонент на территории Российской Федерации

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Нашей специализацией является поставка электронной компонентной базы двойного назначения, продукции таких производителей как XILINX, Intel (ex.ALTERA), Vicor, Microchip, Texas Instruments, Analog Devices, Mini-Circuits, Amphenol, Glenair.

Сотрудничество с глобальными дистрибьюторами электронных компонентов, предоставляет возможность заказывать и получать с международных складов практически любой перечень компонентов в оптимальные для Вас сроки.

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