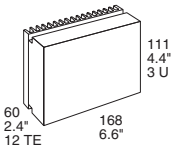
power-one®
Changing the Shape of Power



RoHS Compliant

Features

Input voltage ranges from 8 to 385 VDC and 85 to 264 VAC, 47-440 Hz
1or 2 isolated outputs up to 48 VDC
Class I equipment

- RoHS lead solder exemption compliant
- Extremely-wide input voltage range
- Input over- and undervoltage lockout
- Efficient input filter and built-in surge and transient suppression circuitry
- Outputs: SELV, no-load, and short-circuit proof
- No derating over entire operating temperature range
- PCBs coated with protective lacquer
- Very high reliability

Safety according to IEC/EN 60950 CE

TÜV c UL us

Description

The S Series AC-DC and DC-DC converters represents a broad and flexible range of power supplies for use in advanced electronic systems. Features include high efficiency, high reliability, low output voltage noise and excellent dynamic response to load/line changes. LS models can be powered by DC or AC with a wide-input frequency range (without PFC).

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. Certain types include an inrush current limiter preventing circuit breakers and fuses from tripping at switch-on.

All outputs are open- and short-circuit proof and are protected against overvoltages by means of built-in suppressor diodes. The outputs can be inhibited by a logic signal applied to pin 18 (i). If the inhibit function is not used, pin 18 must be connected with pin 14 to enable the outputs.

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

Full input-to-output, input-to-case, output-to-case and output-to-output isolation is provided. The converters are designed and built according to the international safety standards IEC/EN 60950 and EN50155. They have been approved by the safety agencies TÜV and UL (for USA and Canada).

The case design allows operation at nominal load up to 71 °C in a free-air ambient temperature. If forced cooling is provided, the ambient temperature may exceed 71 °C, but the case temperature must remain below 95 °C under all conditions.

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

Various options are available to adapt the converters to individual applications.

The converters may either be plugged into a 19" rack system according to IEC 60297-3, or be chassis mounted. They are ideally suited for Railway applications.

Important: For applications requiring compliance with IEC/EN 61000-3-2 (harmonic distortion), please use our LS4000 and LS5000 Series with incorporated power factor correction (PFC).

Table of Contents

Model Selection

Non-standard input/output configurations or special custom adaptions are available on request.

Table 1a: Model types AS

Output 1		Output 2		Input Voltage	Efficiency [1]	Options
$V_{o\ nom}$ [VDC]	$I_{o\ nom}$ [A]	$V_{o\ nom}$ [VDC]	$I_{o\ nom}$ [A]	$V_{i\ min}$ - $V_{i\ max}$ 8 to 35 VDC	η [%]	
5.1	16	-	-	AS1001-7R	76	-9
12	8	-	-	AS1301-7R	81	D
15	6.5	-	-	AS1501-7R	83	V [2]
24	4.2	-	-	AS1601-7R	84	P
12	4	12 [3]	4	AS2320-7R	79	T
15	3.2	15 [3]	3.2	AS2540-7R	80	B1, B2
24	2	24 [3]	2	AS2660-7R	80	

Table 1b: Model types BS, CS, and FS

Output 1		Output 2		Input Voltage	Eff. [1]	Input Voltage	Eff. [1]	Input Voltage	Eff. [1]	Options
$V_{o\ nom}$ [VDC]	$I_{o\ nom}$ [A]	$V_{o\ nom}$ [VDC]	$I_{o\ nom}$ [A]	$V_{i\ min}$ - $V_{i\ max}$ 14 to 70 VDC	η [%]	$V_{i\ min}$ - $V_{i\ max}$ 28 to 140 VDC	η [%]	$V_{i\ min}$ - $V_{i\ max}$ 20 to 100 VDC	η [%]	
5.1	16	-	-	BS1001-7R	77	CS1001-7R	77	FS1001-7R	77	-9
12	8	-	-	BS1301-7R	83	CS1301-7R	83	FS1301-7R	83	E [4], -9E [4]
15	6.5	-	-	BS1501-7R	85	CS1501-7R	84	FS1501-7R	84	V [2]
24	4.2	-	-	BS1601-7R	86	CS1601-7R	85	FS1601-7R	86	P
12	4	12 [3]	4	BS2320-7R	80	CS2320-7R	80	FS2320-7R	80	T
15	3.2	15 [3]	3.2	BS2540-7R	82	CS2540-7R	82	FS2540-7R	82	B1, B2
24	2	24 [3]	2	BS2660-7R	82	CS2660-7R	82	FS2660-7R	82	

Table 1c: Model types DS, ES, and LS

Output 1		Output 2		Input Voltage	Eff. [1]	Input Voltage	Eff. [1]	Input Voltage	Eff. [1]	Options
$V_{o\ nom}$ [VDC]	$I_{o\ nom}$ [A]	$V_{o\ nom}$ [VDC]	$I_{o\ nom}$ [A]	$V_{i\ min}$ - $V_{i\ max}$ 44 to 220 VDC	η [%]	$V_{i\ min}$ - $V_{i\ max}$ 67 to 385 VDC	η [%]	$V_{i\ min}$ - $V_{i\ max}$ 88 to 372 VDC 85 to 264 VAC	η [%]	
5.1	16	-	-	DS1001-7R	79	----	--	LS1001-7R	78	E [4], -9E [4]
12	8	-	-	DS1301-7R	84	ES1301-7R	83	LS1301-7R	83	D
15	6.5	-	-	DS1501-7R	86	ES1501-7R	84	LS1501-7R	84	V [2]
24	4.2	-	-	DS1601-7R	86	ES1601-7R	86	LS1601-7R	85	P
12	4	12 [3]	4	DS2320-7R	81	ES2320-7R	81	LS2320-7R	80	T
15	3.2	15 [3]	3.2	DS2540-7R	82	ES2540-7R	83	LS2540-7R	81	B1, B2
24	2	24 [3]	2	DS2660-7R	83	ES2660-7R	83	LS2660-7R	81	

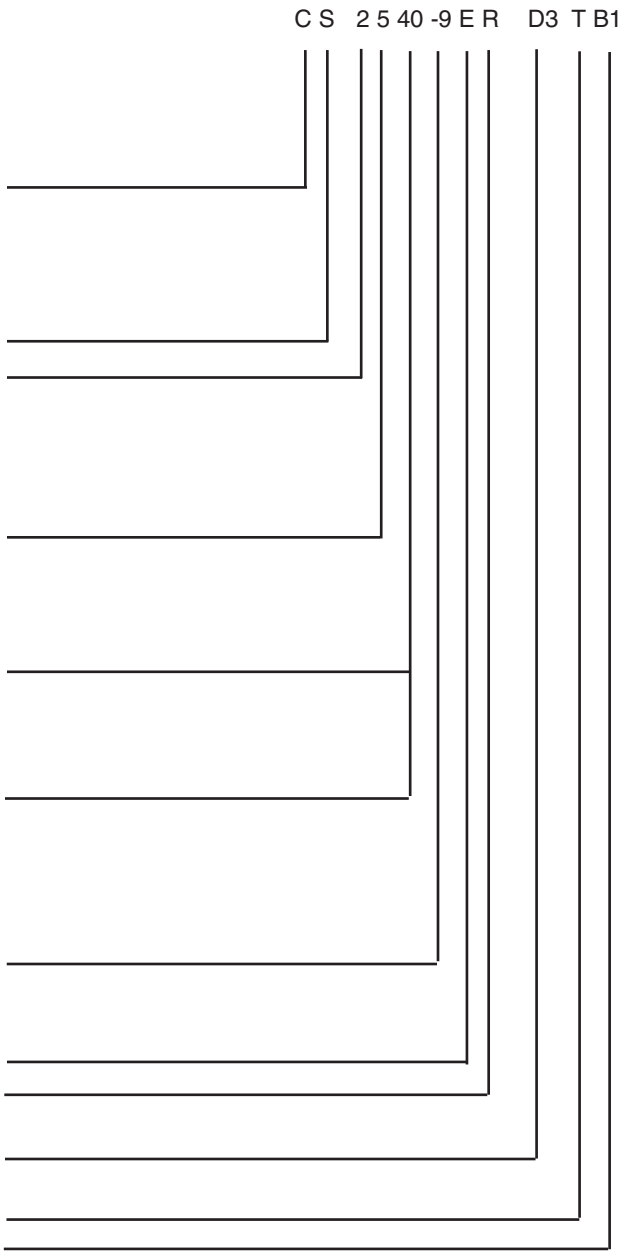
[1] Min. efficiency η at $V_{i\ nom}$, $I_{o\ nom}$, and T_A = 25 °C (DC input for LS models). Typical values are approx. 2% better.

[2] Option V for S1001 models only.

[3] Second output semi-regulated.

[4] Option E only for CS, DS, ES, FS, and LS models; mandatory for all -9 models.

Part Number Description and Product Marking



Input voltage range V_i:

8 - 35 VDC .....A
14 - 70 VDC ..... B
20 - 100 VDC ..... F
28 - 140 VDC C
44 - 220 VDC .....D
67 - 385 VDC ..... E
85 - 264 VAC or 88 - 372 VDC..... L

Series.....S

Number of outputs 1, 2

Single output models:
Nominal voltage output 1 (main output), $V_{o1\ nom}$
5.1 V 0, 1, 2
12 V 3
15 V 4, 5
24 V 6
Other voltages[1] 7, 8
Other specifications for
single output models[1] .....01 - 99

Double output models:
Nominal voltage output 1 and 2
12, 12V 20
15, 15V 40
24, 24V 60
Other specifications and additional features[1] .....70 - 99

Operational ambient temperature range T_A:
–25 to 71 °C.....-7
–40 to 71 °C.....-9
Other [1] ....-0, -5, -6

Auxiliary functions and options:
Inrush current limiter .....E [3]
Output voltage control input .....R [2]
Potentiometer (output voltage adjustment) .....P [2]
Undervoltage monitor (D0 - DD, to be specified) .....D [4]
ACFAIL signal (V0, V2, V3, to be specified) .....V [4]
Current share .....T
Cooling plate standard case B1
Cooling plate for long case (220 mm) [1] B2

[1] Customer-specific models.

[2] Feature R excludes option P and vice versa.

[3] Option E available for CS, DS, ES, FS, and LS models; mandatory for all -9 model types.

[4] Option D excludes option V and vice versa; option V available for S1001 models only.

Example: CS2540-9ERD3TB1: DC-DC converter, input voltage range 28 - 140 V, double output, each providing 15 V/3.2 A, equipped with inrush current limiter, R input (voltage adjust), undervoltage monitor D3, current share, and a cooling plate B1. Ambient temperature –40 to 71 °C.

Product Marking

Basic type designation, applicable approval marks, CE mark, warnings, pin allocation, Power-One patents, and company logo.

Identification of LEDs, test sockets, and potentiometer.

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 input fuse, an input filter, a bridge rectifier (LS), and an inrush current limiter to the input capacitor. This capacitor sources a single transistor forward converter. Each output is powered by a separate secondary winding of the main transformer. The resultant voltages are rectified and their ripple smoothed by a power choke and output filter. The control logic senses the main output voltage V_{o1} and generates, with respect to the maximum admissible output currents, the control signal for the primary switching transistor.

The second output of double-output models is controlled by the main output but has independent current limiting. If the main output is driven into current limitation, the second output voltage will fall as well and vice versa.

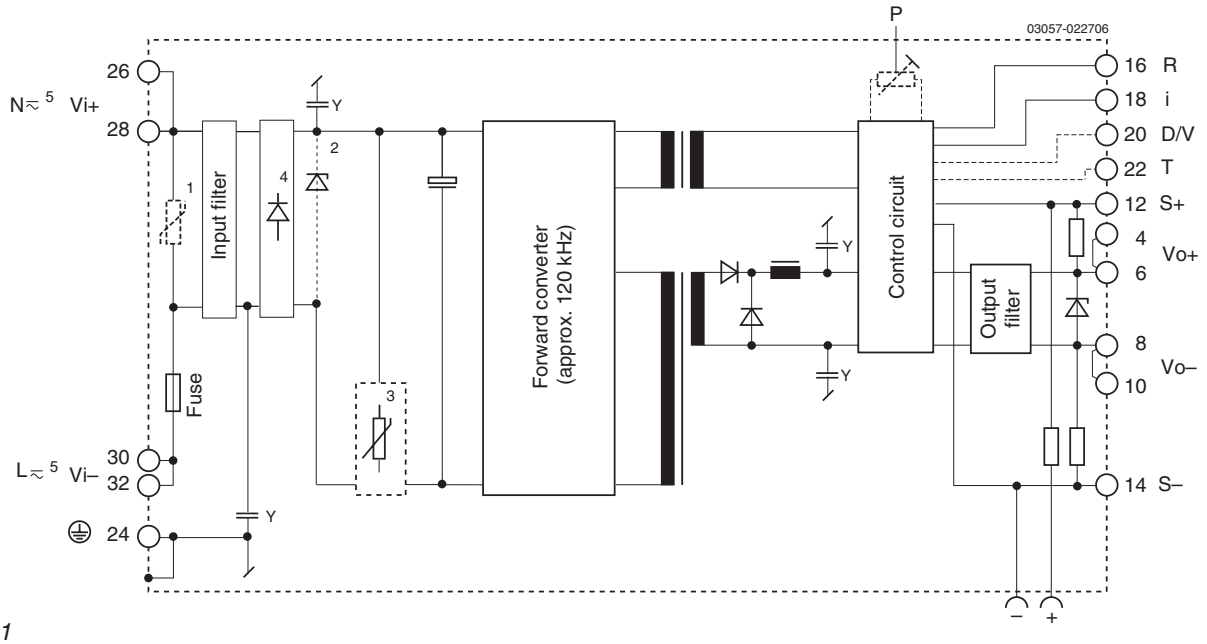


Fig. 1
Block diagram of single output converters AS - LS1000

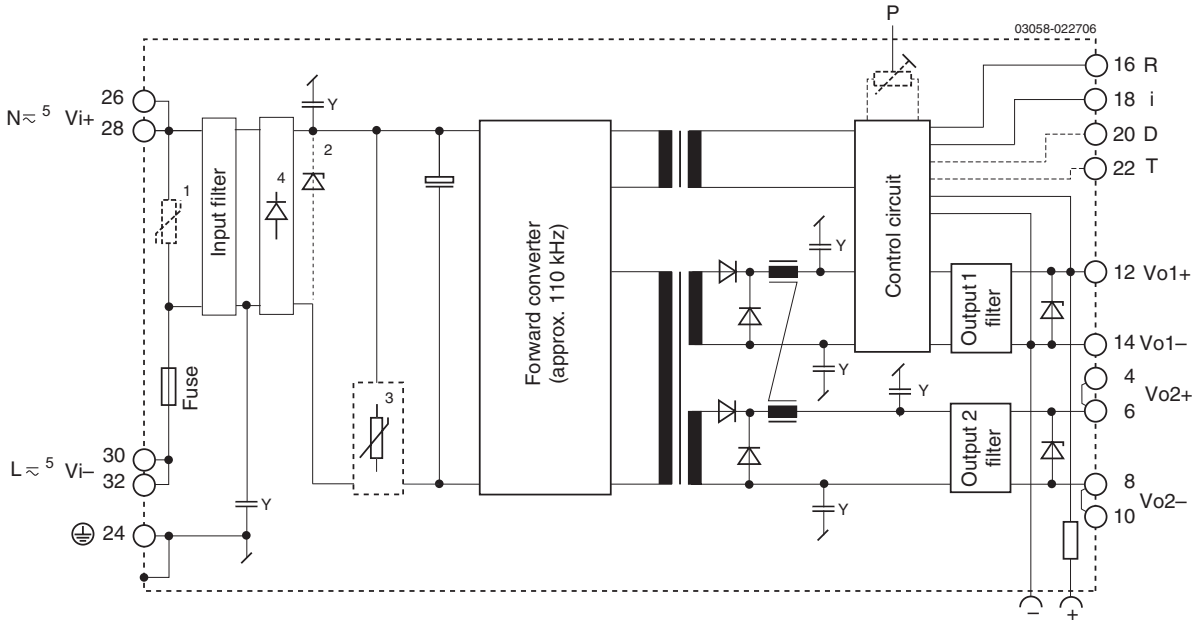


Fig. 2
Block diagram of symmetrical double output converters AS - LS2000

[1] Transient suppressor (VDR) in CS, DS, ES, FS, LS models

[2] Suppressor diode in AS, BS, CS, FS models

[3] Inrush current limiter in CS, DS, ES, LS (NTC resistor or option E circuit)

[4] Bridge rectifier (LS only)

[5] LS models

Electrical Input Data

General Conditions
– T_A = 25 °C, unless T_C is specified.
– Pin 18 connected to pin 14, R input not connected, V_o adjusted to $V_{o\ nom}$ (option P)
– Sense line pins S+ and S– connected to Vo+ and Vo–, respectively.

Table 2a: Input data

Input			AS			BS			FS			
Characteristics		**Conditions**	**min**	**typ**	**max**	**min**	**typ**	**max**	**min**	**typ**	**max**	**Unit**
V_i	Operating input voltage	I_o = 0 - $I_{o\ nom}$ $T_{C\ min}$ - $T_{C\ max}$	8		35	14		70	20		100	VDC
$V_{i\ nom}$	Nominal input voltage			15			30			50		
I_i	Input current	$V_{i\ nom}$, $I_{o\ nom}$ [1]		7.5			4.3			2.6		A
P_{i0}	No-load input power	$V_{i\ min}$ - $V_{i\ max}$			2.5			2.5			2.5	W
$P_{i\ inh}$	Idle input power	converter inhibited			1.5			1.5			1.5	
R_i	Input resistance		65			100			70			mΩ
C_i	Input capacitance			1040			370			1500		µF
$V_{i\ RFI}$	Conducted input RFI	EN 55022 $V_{i\ nom}$, $I_{o\ nom}$		A			B			B		
	Radiated input RFI			A			A			B		
$V_{i\ abs}$	Input voltage limits without damage		0		40	0		80	0		100	VDC

Table 2b: Input data

Input			CS			DS			ES			LS			
Characteristics		**Conditions**	**min**	**typ**	**max**	**min**	**typ**	**max**	**min**	**typ**	**max**	**min**	**typ**	**max**	**Unit**
V_i	Operating input voltage	I_o = 0 - $I_{o\ nom}$ $T_{C\ min}$ - $T_{C\ max}$	28		140	44		220	67		385	88		372	VDC
												85 [4]		264 [4]	VAC
$V_{i\ nom}$	Nominal input voltage			60			110			220			310		VDC
I_i	Input current	$V_{i\ nom}$, $I_{o\ nom}$ [1]		2.1			1.1			0.55			0.4		A
P_{i0}	No-load input power	$V_{i\ min}$ - $V_{i\ max}$			2.5			2.5			2.5			2.5	W
$P_{i\ inh}$	Idle input power	converter inhibited			1.5			1.5			1.5			4.5	
R_i	Input resistance		150			170			180			480			mΩ
R_{NTC}	NTC resistance [2]			1			2			4			4		Ω
C_i	Input capacitance			830			330			270			270		µF
$V_{i\ RFI}$	Conducted input RFI	EN 55022 $V_{i\ nom}$, $I_{o\ nom}$		B			B			B			B		
	Radiated input RFI			B			B			B			A		
$V_{i\ abs}$	Input voltage limits without damage		0		154	0		400 [3]	0		400	-400		400	VDC

[1] For double output models both outputs loaded with $I_{o\ nom}$.

[2] Valid for -7 versions without option E. This is the nominal value at 25 °C and applies to cold models at initial switch-on cycle. Subsequent switch-on/off cycles increase the inrush current peak value.

[3] For 1 s max.

[4] AC operating frequency range is 47 to 440 Hz (440 Hz for 115 V mains). For frequencies ≥ 63 Hz refer to *Safety and Installation Instructions*.

Input Transient Protection

A suppressor diode and/or a VDR (depending on input voltage range) together with the input fuse and a symmetrical input filter form an effective protection against high input transient voltages which typically occur in most installations, but especially in battery-driven mobile applications.

Nominal battery voltages in use are: 12, 24, 36, 48, 60, 72, 110, and 220 V. In most cases each nominal value is specified in a tolerance of –30% to 25%.

In certain applications, surges according to RIA 12 are specified in addition to those defined in IEC 60571-1. The power supply must not switch off during these surges and since their energy can practically not be absorbed an extremely wide input range is required. The ES input range for 110 V batteries has been designed and tested to meet this requirement.

Input Fuse

A fuse mounted inside the converter protects the module against severe defects. This fuse may not fully protect the module when the input voltage exceeds 200 VDC! In applications where the converters operate at source voltages above 200 VDC an external fuse or a circuit breaker at system level should be installed!

Table 3: Fuse Specification

Model	Fuse type	Reference	Rating
AS [1]	fast-blow	Little fuse 314	30.0 A, 125 V
BS [1]	fast-blow	Little fuse 314	25.0 A, 125 V
CS [2]	slow-blow	SPT	12.5 A, 250 V
DS [2]	slow-blow	SPT	8 A, 250 V
ES [2]	slow-blow	SPT	4 A, 250 V
FS [2]	slow-blow	SPT	16 A, 250 V
LS [2]	slow-blow	SPT	4 A, 250 V

[1] Fuse size 6.3 x 32 mm [2] Fuse size 5 x 20 mm

Inrush Current

The CS, DS, ES, and LS models (not -9, not option E) incorporate an NTC resistor in the input circuitry, which at initial turn-on reduces the peak inrush current value by a factor of 5 to 10. Subsequent switch-on cycles within short periods increase the inrush current due to the hotter NTC resistor.

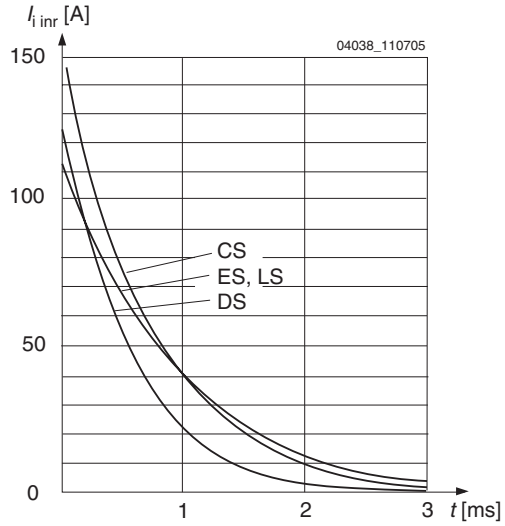


Fig. 3
Typical inrush current versus time at $V_{i\ max}$, R_{ext} = 0.
For AS, BS, and FS as well as for application-related values use the formula given in this section *to get realistic results.*

The inrush current peak value (initial switch-on cycle) can be determined by following calculation:

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

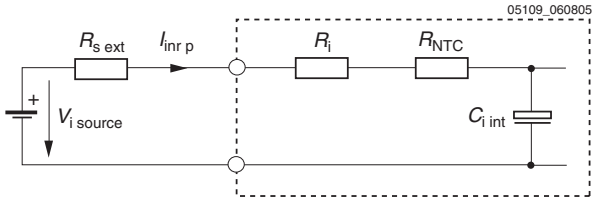


Fig. 4
Equivalent circuit for input impedance

Static Input Current Characteristic

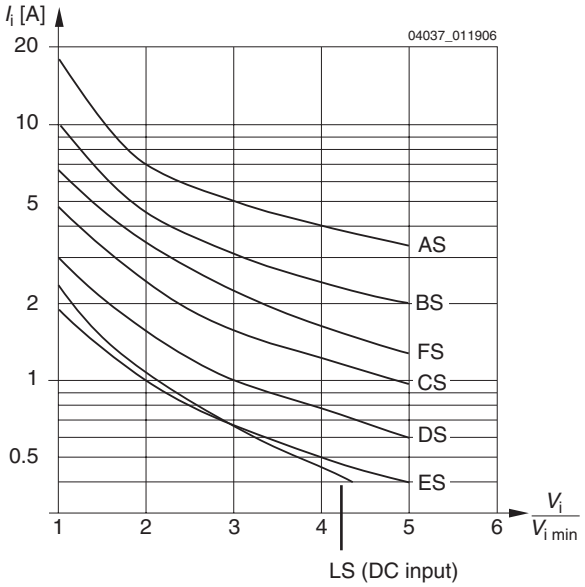


Fig. 5
Typical input current versus relative input voltage

Reverse Polarity

The converters (except LS) are not protected against reverse polarity at the input, but in general, only the input fuse will trip. LS models are fully protected due to the built-in bridge rectifier.

Input Under-/Overvoltage Lockout

If the input voltage remains below approx. 0.8 $V_{i\ min}$ or exceeds approx. 1.1 $V_{i\ max}$, an internally generated inhibit signal disables the output(s). When checking this function the absolute maximum input voltage rating $V_{i\ abs}$ should be considered! Between $V_{i\ min}$ and the undervoltage lockout level the output voltage may be below the value defined in table: *Electrical Output Data*.

Hold-up Time Versus Relative Input Voltage

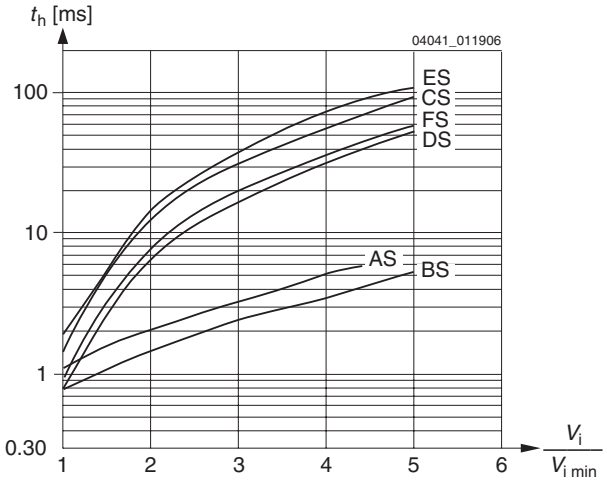


Fig. 6a
Typical hold-up time t_h versus relative input voltage $V_i/V_{i\ min}$. The DC-DC converters require an external series diode in the input path if other loads are connected to the same input supply lines.

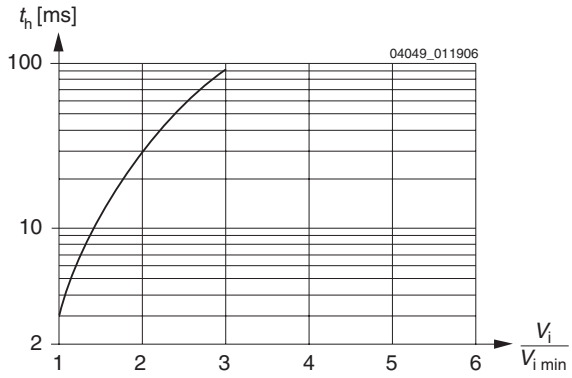


Fig. 6b
Typical hold-up time t_h versus relative AC input voltage (LS models)

Electrical Output Data

General Conditions
– T_A = 25 °C, unless T_C is specified.
– Pin 18 (i) connected to pin 14 (S–/Vo1–), V_o adjusted to $V_{o\ nom}$ (option P), R input not connected.
– Sense line pins 12 (S+) and 14 (S–) connected to Vo1+ and Vo1–, respectively.

Table 4a: Output data: single output models

Output $V_{o\ nom}$				**AS-LS1001 5.1 V**			**AS-LS1301 12 V**			**AS-LS1501 15 V**			**AS-LS1601 24 V**			
Characteristics			**Conditions**	**min**	**typ**	**max**	**min**	**typ**	**max**	**min**	**typ**	**max**	**min**	**typ**	**max**	**Unit**
V_o	Output voltage		$V_{i\ nom}$, $I_{o\ nom}$	5.05		5.15	11.88		12.12	14.85		15.15	23.76		24.24	V
$V_{o\ P}$	Overvoltage protection (suppressor diode)				7.6			21			26.5			43.5		
$I_{o\ nom}$	Output current nom [1]		$V_{i\ min}$ - $V_{i\ max}$ $T_{C\ min}$ - $T_{C\ max}$		16			8			6.5			4.2		A
$I_{o\ L}$	Output current limit [2]		$V_{i\ min}$ - $V_{i\ max}$	16.2			8.2			6.7			4.4			
v_o	Output noise [5]	Switching freq.	$V_{i\ nom}$, $I_{o\ nom}$		10 [6]			5 [6]			5 [6]			5 [6]		mV_{pp}
		Total incl. spikes	BW = 20 MHz		50			50			60			90		
$\Delta V_{o\ u}$	Static line regulation with respect to $V_{i\ nom}$		$V_{i\ min}$ - $V_{i\ max}$ $I_{o\ nom}$			±15			±20			±25			±30	mV
$\Delta V_{o\ l}$	Static load regulation		$V_{i\ nom}$, (0.1 - 1) $I_{o\ nom}$			-20			-25			-30			-40	
$v_{o\ d}$	Dynamic load regulation [5]	Voltage deviation [3]	$V_{i\ nom}$, $I_{o\ nom} \leftrightarrow 0.5 I_{o\ nom}$		±100			±100			±100			±100		
t_d		Recovery time [3]			0.4			0.5			0.5			0.5		ms
α_{vo}	Temperature coefficient of output voltage [4]		$T_{C\ min}$ - $T_{C\ max}$, $I_{o\ nom}$		±0.02			±0.02			±0.02			±0.02		%/K

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

[2] See: *Output Voltage Regulation*.

[3] See: *Dynamic Load Regulation.*

[4] For battery chargers a defined negative temperature coefficient can be provided, see *Accessories*.

[5] Measured according to IEC/EN 61204.

[6] LS models have an additional low-frequency ripple at twice the input frequency (< $5mV_{pp}$).

Table 4b: Output data: double output models

Output $V_{o\ nom}$				AS-LS2320 12 V/12 V				AS-LS2540 15 V/15 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		$V_{i\ nom}$, $I_{o\ nom}$ [1]	11.88	12.12	11.76	12.24	14.85	15.15	14.70	15.30	V
$V_{o\ P}$	Overvoltage protection (suppressor diode)			19		19		24		24		
$I_{o\ nom}$	Output current nom [2]		$V_{i\ min}$ - $V_{i\ max}$ $T_{C\ min}$ - $T_{C\ max}$	4		4		3.2		3.2		A
$I_{o\ L}$	Output current limit [6]		$V_{i\ min}$ - $V_{i\ max}$	4.2		4.2		3.4		3.4		
v_o	Output noise [3]	Switching freq.	$V_{i\ nom}$, $I_{o\ nom}$	5 [7]		5 [7]		5 [7]		5 [7]		mV_{pp}
		Total including spikes	BW = 20 MHz	40		40		50		50		
$\Delta V_{o\ u}$	Static line regulation with respect to $V_{i\ nom}$		$V_{i\ min}$ - $V_{i\ max}$ $I_{o1\ nom}$, $I_{o2\ nom}$		±20		[6]		±25		[6]	mV
$\Delta V_{o\ l}$	Static load regulation		$V_{i\ nom}$, $I_{o2\ nom}$, (0.1 - 1) $I_{o1\ nom}$		-40		[6]		-50		[6]	
$v_{o\ d}$	Dynamic load regulation [3]	Voltage deviation [4]	$V_{i\ nom}$, $I_{o1\ nom} \leftrightarrow 0.5 I_{o1\ nom}$,	±100		±150		±100		±150		
t_d		Recovery time [4]	$0.5 I_{o2\ nom}$	0.2				0.2				ms
α_{vo}	Temperature coefficient of output voltage [5]		$T_{C\ min}$ - $T_{C\ max}$ $I_{o1\ nom}$, $I_{o2\ nom}$	±0.02				±0.02				%/K

Table 4c: Output data: double output models

Output $V_{o\ nom}$				AS-LS2660 24 V/24 V				Unit
Characteristics			Conditions	Output 1		Output 2		
				min typ max		min typ max		
V_o	Output voltage		$V_{i\ nom}$, $I_{o\ nom}$ [1]	23.76	24.24	23.52	24.48	V
$V_{o\ P}$	Overvoltage protection (suppressor diode)			37		37		
$I_{o\ nom}$	Output current nom [2]		$V_{i\ min}$ - $V_{i\ max}$ $T_{C\ min}$ - $T_{C\ max}$	2		2		A
$I_{o\ L}$	Output current limit [6]		$V_{i\ min}$ - $V_{i\ max}$	2.2		2.2		
v_o	Output noise [3]	Switching freq.	$V_{i\ nom}$, $I_{o\ nom}$	5 [7]		5 [7]		mV_{pp}
		Total including spikes	BW = 20 MHz	50		50		
$\Delta V_{o\ u}$	Static line regulation with respect to $V_{i\ nom}$		$V_{i\ min}$ - $V_{i\ max}$ $I_{o1\ nom}$, $I_{o2\ nom}$		±30		[6]	mV
$\Delta V_{o\ l}$	Static load regulation		$V_{i\ nom}$, $I_{o2\ nom}$, (0.1 - 1) $I_{o1\ nom}$		-60		[6]	
$V_{o\ d}$	Dynamic load regulation [3]	Voltage deviation [4]	$V_{i\ nom}$, $I_{o1\ nom} \leftrightarrow 0.5 I_{o1\ nom}$,	±100		±150		
t_d		Recovery time [4]	$0.5 I_{o2\ nom}$	0.2				ms
α_{vo}	Temperature coefficient of output voltage [5]		$T_{C\ min}$ - $T_{C\ max}$ $I_{o1\ nom}$, $I_{o2\ nom}$	±0.02				%/K

[1] Same conditions for both outputs.

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

[3] Measured according to IEC/EN 61204.

[4] See: *Dynamic Load Regulation.*

[5] For battery chargers a defined negative temperature coefficient can be provided, see *Accessories*.

[6] See: *Output Voltage Regulation of Double Output Models.*

[7] LS models have an additional low-frequency ripple at twice the input frequency (< 5 mV_{pp}).

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 at its nominal input voltage and output power, 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 on 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 an additional heat sink allows T_A to be higher than 71 °C (e.g., 85 °C) if $T_{C\ max}$ is not exceeded.

For -7 or -9 models at ambient temperature T_A = 85 °C with only convection cooling, and the maximum permissible current for each output is approx. 40% of its nominal value as per the figure below.

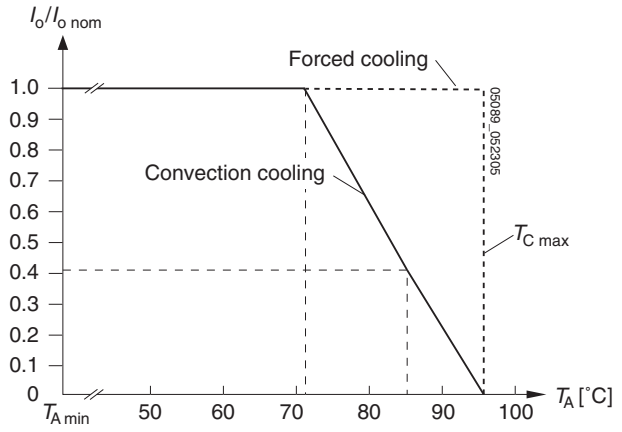


Fig. 7
Output current derating versus temperature for -7 and -9 models.

Thermal Protection

A temperature sensor generates an internal inhibit signal which disables the outputs if the case temperature exceeds $T_{C\ max}$. The outputs are automatically re-enabled when the temperature drops below this limit.

Continuous operation under simultaneous worst-case conditions of the following three parameters should be avoided: minimum input voltage, maximum output power, and maximum temperature.

Output Protection

Each output is protected against overvoltages which could occur due to a failure of the internal control circuit. Voltage suppressor diodes (which under worst case condition may become a short circuit) provide the required protection. The suppressor diodes are not designed to withstand externally applied overvoltages. Overload at any of the outputs will cause a shut-down of all outputs. A red LED indicates the overload condition.

Parallel or Series Connection

Single or double-output models with equal nominal output voltage can be connected in parallel without any precautions using Option T (current sharing).

Single output models and/or main and second outputs of double-output models can be connected in series with any other (similar) output.

Notes:

- Parallel connection of double output models should include both, main and second output to maintain good regulation of both outputs.
- Not more than 5 models should be connected in parallel.
- Series connection of second outputs without involving their main outputs should be avoided as regulation may be poor.
- Rated output voltages above 36 V need additional measures in order to comply with the safety requirements for SELV (Safe Extra Low Voltage)
- The maximum output current is limited by the output with the lowest current limitation if several outputs are connected in series.

Output Voltage Regulation

The following figures apply to single-output or double-output models with parallel-connected outputs.

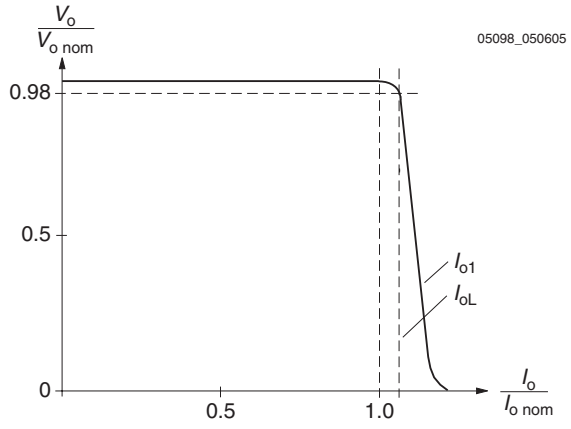


Fig. 8
Output characteristic V_{o1} vs. I_{o1} (typ.)

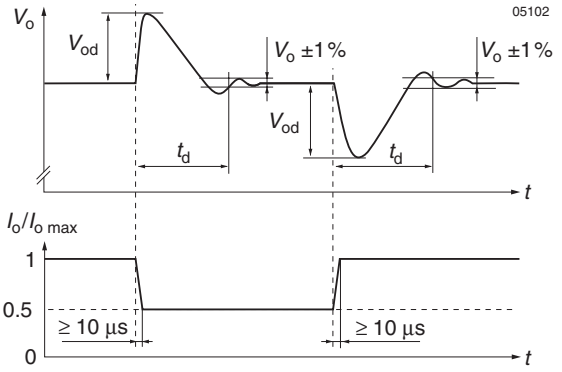


Fig. 9
Typical dynamic load regulation of V_o

Output Voltage Regulation of Double Output Models

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

Output 1 is under normal conditions regulated to $V_{o1\ nom}$, independent of output currents. V_{o2} depends upon the load distribution. If both outputs are loaded with more than 10% of $I_{o\ nom}$, the deviation of V_{o2} remains within ±5% of the value of V_{o1}. The following 3 figures show the regulation with varying load distribution.

Two outputs of an S2000 model connected in parallel will behave like the output of an S1000 model.

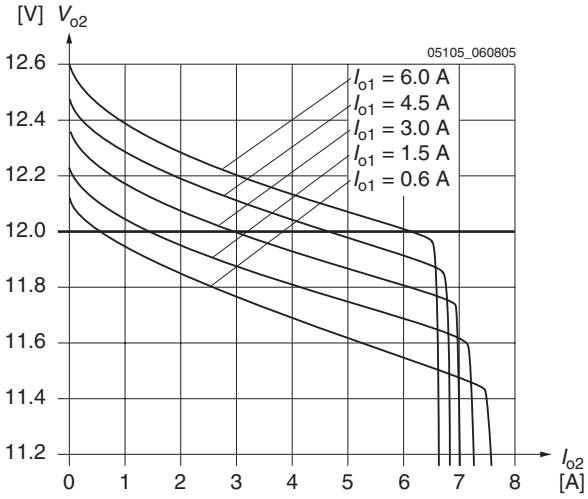


Fig. 10
AS - LS2320: ΔV_{o2} (typ.) vs. I_{o2} with different I_{01}

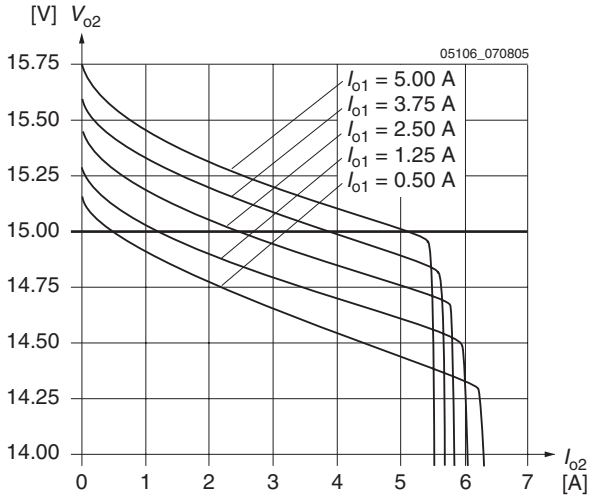


Fig. 11
AS - LS2540: ΔV_{o2} (typ.) vs. I_{o2} with different I_{01}

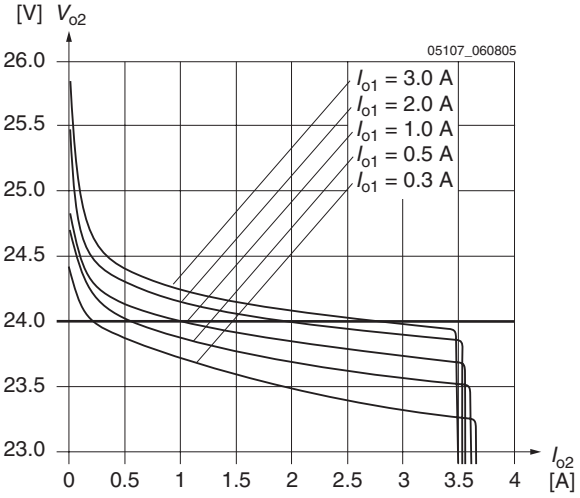


Fig. 12
AS - LS2660: ΔV_{o2} (typ.) vs. I_{o2} with different I_{01}

Auxiliary Functions

i Inhibit for Remote On and Off

Note: With open i input the output is disabled.

The outputs may be enabled or disabled by means of a logic signal (TTL, CMOS, etc.) applied between the inhibit input i and the negative pin of output 1 (Vo1–). In systems with several converters, this feature can be used to control the activation sequence of the converters. If the inhibit function is not required, connect the inhibit pin 18 to pin 14 to enable the outputs (active low logic, fail safe).

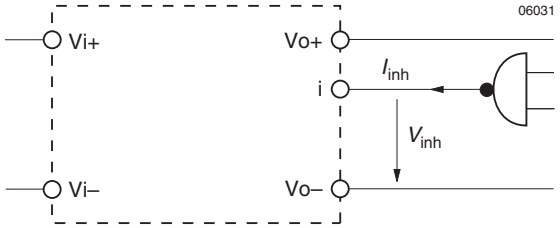


Fig. 13
Definition of V_{inh} and I_{inh}.

Table 5: Inhibit characteristics

Characteristic			Conditions	min	typ	max	Unit
V_{inh}	Inhibit voltage	V_o = on	$V_{i\,min}$ - $V_{i\,max}$	–50		0.8	V
		V_o = off		2.4		50	
I_{inh}	Inhibit current		V_{inh} = 0			–400	µA
t_r	Rise time				30		ms
t_f	Fall time		depending on I_o				

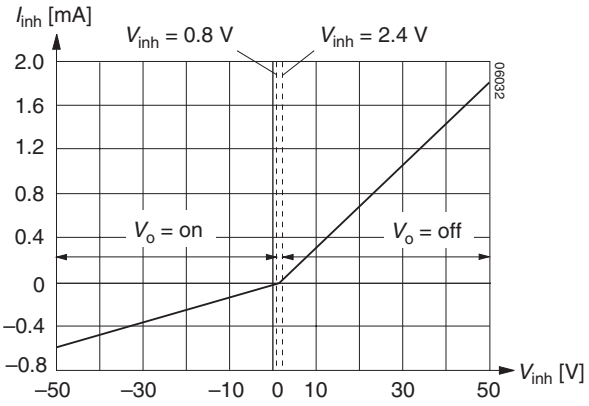


Fig. 14
Typical inhibit current I_{inh} versus inhibit voltage V_{inh}

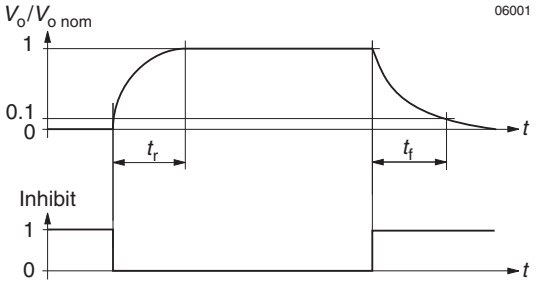


Fig. 15
Typical output response as a function of inhibit control

Sense Lines

(Only single output models)

Important: Sense lines must always be connected! Incorrectly connected sense lines may activate the overvoltage limitation, resulting in a permanent short-circuit of the output.

This feature allows for compensation of voltage drops across the connector contacts and if necessary, across the load lines. If the sense lines are connected at the load rather than directly at the connector, the user should ensure that the voltage differences specified in the table below are not exceeded. We recommend connecting the sense lines directly at the female connector.

To ensure correct operation, both sense lines (S+ and S–) should be connected to their respective power outputs (Vo1+ and Vo1–) and the voltage difference between any sense line and its respective power output pin (as measured on the connector) should not exceed the following values:

Table 6: Maximum voltage compensation allowed using sense lines

Output voltage	Total voltage difference between sense lines and their respective outputs	Voltage difference between Vo– and S–
5.1 V	< 0.5 V	< 0.25 V
12, 15, 24 V	< 1.0 V	< 0.25 V

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

Programmable Output Voltage (R-Function)

As a standard feature, the converters offer an adjustable output voltage, identified by letter R in the type designation. The control input R (pin 16) accepts either a control voltage V_{ext} or a resistor R_{ext} to adjust the desired output voltage. When not connected, the control input automatically sets the output voltage to $V_{o\ nom}$.

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

The control voltage range is 0 - 2.75 VDC and allows an output voltage adjustment in the range of approximately 0 - 110% $V_{o\ nom}$.

$$V_{ext} = \frac{V_o}{V_{o\ nom}} \bullet 2.5\ V \text{ (approximate formula)}$$

b) Adjustment by means of an external resistor:

Depending upon the value of the required output voltage the resistor shall be connected

Either: Between pin 16 and pin 14 ($V_o < V_{o\ nom}$) to achieve an output voltage adjustment range of approximately 0 - 100% $V_{o\ nom}$

or: Between pin 16 and pin 12 ($V_o > V_{o\ nom}$) to achieve an output voltage adjustment range of approximately 100 - 110% $V_{o\ nom}$.

Warning:

- V_{ext} shall never exceed 2.75 VDC.
- The value of R'_{ext} shall never be less than the lowest value as indicated in table R'_{ext} for ($V_o > V_{o\ nom}$)

Notes:

- The R-Function excludes option P (output voltage adjustment by potentiometer).
- If the output voltages are increased above $V_{o\ nom}$ via R-input control, option P setting, remote sensing or option T, the output current(s) should be reduced accordingly so that $P_{o\ nom}$ is not exceeded.
- With double-output models the second output follows the value of the controlled main output.
- In case of parallel connection the output voltages should be individually set within a tolerance of 1 - 2%.

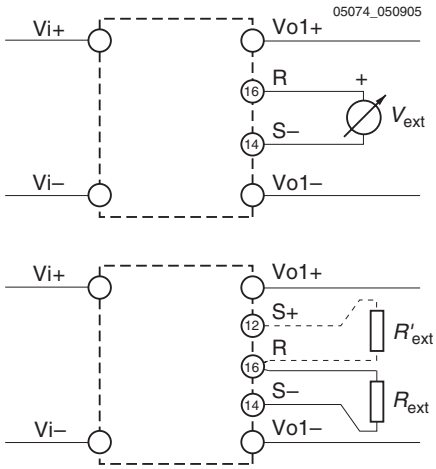


Fig. 16
Output voltage control for single-output models AS - LS1000.

Table 7a: R_{ext} for $V_o < V_{o\ nom}$; approximative values ($V_{i\ nom}$, $I_{o\ nom}$, series E 96 resistors); R'_{ext} = not fitted

$V_{o\ nom}$ = 5.1 V		$V_{o\ nom}$ = 12 V			$V_{o\ nom}$ = 15 V			$V_{o\ nom}$ = 24 V		
V_o [V]	R_{ext} [kΩ]	V_o [V] [1]		R_{ext} [kΩ]	V_o [V] [1]		R_{ext} [kΩ]	V_o [V] [1]		R_{ext} [kΩ]
0.5	0.432	2	4	0.806	2	4	0.619	4	8	0.806
1.0	0.976	3	6	1.33	4	8	1.47	6	12	1.33
1.5	1.65	4	8	2	6	12	2.67	8	16	2
2.0	2.61	5	10	2.87	8	16	4.53	10	20	2.87
2.5	3.83	6	12	4.02	9	18	6.04	12	24	4.02
3.0	5.76	7	14	5.62	10	20	8.06	14	28	5.62
3.5	8.66	8	16	8.06	11	22	11	16	32	8.06
4.0	14.7	9	18	12.1	12	24	16.2	18	36	12.1
4.5	30.1	10	20	20	13	26	26.1	20	40	20
5.0	200	11	22	42.2	14	28	56.2	22	44	44.2

[1] First column: V_o or V_{o1}, second column: outputs of double-output models in series connection

Table 7b: R'_{ext} for $V_o > V_{o\ nom}$; approximative values ($V_{i\ nom}$, $I_{o\ nom}$, series E 96 resistors); R_{ext} = not fitted

$V_{o\ nom}$ = 5.1 V		$V_{o\ nom}$ = 12 V			$V_{o\ nom}$ = 15 V			$V_{o\ nom}$ = 24 V		
V_o [V]	R'_{ext} [kΩ]	V_o [V] [1]		R'_{ext} [kΩ]	V_o [V] [1]		R'_{ext} [kΩ]	V_o [V] [1]		R'_{ext} [kΩ]
5.15	432	12.1	24.2	1820	15.2	30.4	1500	24.25	48.5	3320
5.2	215	12.2	24.4	931	15.4	30.8	768	24.5	49.0	1690
5.25	147	12.3	24.6	619	15.6	31.2	523	24.75	49.5	1130
5.3	110	12.4	24.8	475	15.8	31.6	392	25.0	50.0	845
5.35	88.7	12.5	25.0	383	16.0	32.0	316	25.25	50.5	698
5.4	75	12.6	25.2	316	16.2	32.4	267	25.5	51.0	590
5.45	64.9	12.7	25.4	274	16.4	32.8	232	25.75	51.5	511
5.5	57.6	12.8	25.6	243	16.5	33.0	221	26.0	52.0	442
		13.0	26.0	196				26.25	52.5	402
		13.2	26.4	169				26.4	52.8	383

[1] First column: V_o or V_{o1}, second column: outputs of double-output models in series connection

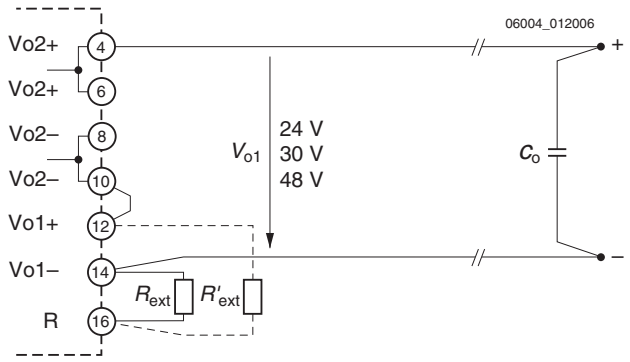


Fig. 17
Wiring for output voltage 24 V, 30 V, or 48 V (double-output models) with both outputs connected in series. A ceramic capacitor (C_o) across the load reduces ripple and spikes.

Test Jacks

Test jacks for measuring the output voltage V_o or V_{o1} are located at the front of the converter. The positive test jack is protected by a series resistor (see: *Functional Description, block diagrams*). The voltage measured at the test jacks is slightly lower than the value at the output terminals.

Display Status of LEDs

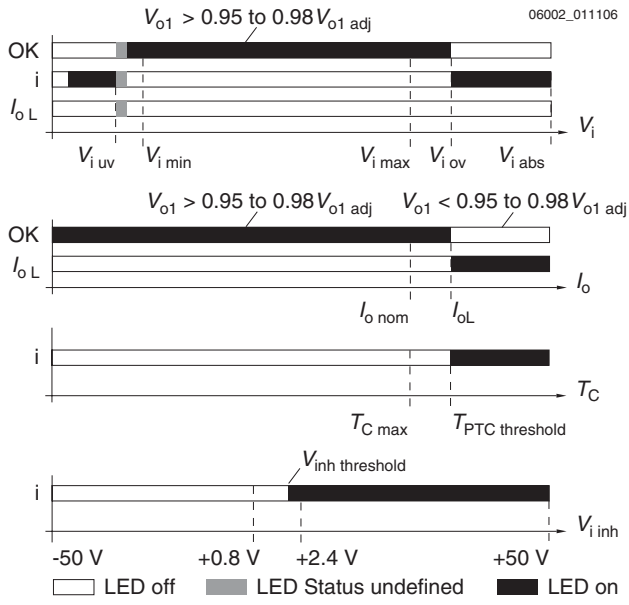


Fig. 18
LEDs "OK", "i" and "$I_{o\ L}$" status versus input voltage
Conditions: $I_o \le I_{o\ nom}$, $T_C \le T_{C\ max}$, $V_{inh} \le 0.8$ V
$V_{i\ uv}$ = undervoltage lockout, $V_{i\ ov}$ = overvoltage lockout

LEDs "OK" and "$I_{o\ L}$" status versus output current
Conditions: $V_{i\ min}$ - $V_{i\ max}$, $T_C \le T_{C\ max}$, $V_{inh} \le 0.8$ V

LED "i" versus case temperature
Conditions: $V_{i\ min}$ - $V_{i\ max}$, $I_o \le I_{o\ nom}$, $V_{inh} \le 0.8$ V

LED "i" versus V_{inh}
Conditions: $V_{i\ min}$ - $V_{i\ max}$, $I_o \le I_{o\ nom}$, $T_C \le T_{C\ max}$

Electromagnetic Compatibility (EMC)

A suppressor diode and/or a metal oxide VDR (depending upon type) together with an input fuse and an input filter form an effective protection against high input transient voltages which typically occur in most installations; especially in battery-driven mobile applications.

Electromagnetic Immunity

Table 8: Immunity type tests

Phenomenon	Standard	Surge/ Level	Coupling mode [1]	Value applied	Waveform	Source imped.	Test procedure	In oper.	Per-form. [2]
Supply related surge	RIA 12 (covers also IEC60571-1 and EN50155:1995)	A [3]	+i/–i	3.5 V_{batt}	2/20/2 ms	0.2 Ω	1 positive surge	yes	A
		B		1.5 V_{batt}	0.1/1/0.1 s				
Direct transient		C	+i/c, –i/c	960 V_p	10/100 µs	5 Ω	5 pos. and 5 neg. impulses	yes	B
		D [4]		1800 V_p	5/50 µs				
		E		3600 V_p	0.5/5 µs	100 Ω			
		F		4800 V_p	0.1/1 µs				
		G [5]		8400 V_p	0.05/0.1 µs				
Indirect coupled transient		H	+o/c, –o/c,	1800 V_p	5/50 µs				
		J		3600 V_p	0.5/5 µs				
		K		4800 V_p	0.1/1 µs				
		L		8400 V_p	0.05/0.1 µs				
Electrostatic discharge (to case)	IEC/EN 61000-4-2	4 [6]	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	3 [7]	antenna	20 V/m	AM 80% 1 kHz	n.a.	80 - 1000 MHz	yes	A
		3	antenna	10 V/m	50% duty cycle, 200 Hz repetition frequency	n.a.	900 ±5 MHz	yes	A
Fast transients/burst	IEC/EN 61000-4-4	4 [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
			i/c, +i/–i direct	4000 V_p					
Surges	IEC/EN 61000-4-5	3	i/c	2000 V_p	1.2/50 µs	12 Ω	5 pos. and 5 neg. surges per coupling mode	yes	A
		3	+i/–i	2000 V_p	1.2/50 µs	2 Ω			
RF conducted immunity	IEC/EN 61000-4-6	3 [9]	i, o, signal wires	10 VAC (140 dBµV)	AM 80% 1 kHz	150 Ω	0.15 - 80 MHz	yes	A

[1] i = input, o = output, c = case.

[2] A = Normal operation, no deviation from specifications, B = Normal operation, temporary deviation from specs possible.

[3] Only met with customer-specific models, CS (48 V battery) and ES (110 V battery) designed for an extended V_i range. Standard DS models (110 V battery) will not be damaged, but overvoltage lockout will occur during the surge.

[4] Corresponds to EN 50155:2001, waveform A, and EN 50121-3-2:2000, table 7.2.

[5] Corresponds to EN 50155:2001, waveform B.

[6] Corresponds to EN 50121-3-2:2000, table 9.2.

[7] Corresponds to EN 50121-3-2:2000, table 9.1.

[8] Corresponds to EN 50121-3-2:2000, table 7.1.

[9] Corresponds to EN 50121-3-2:2000, table 7.4.

Electromagnetic Emission

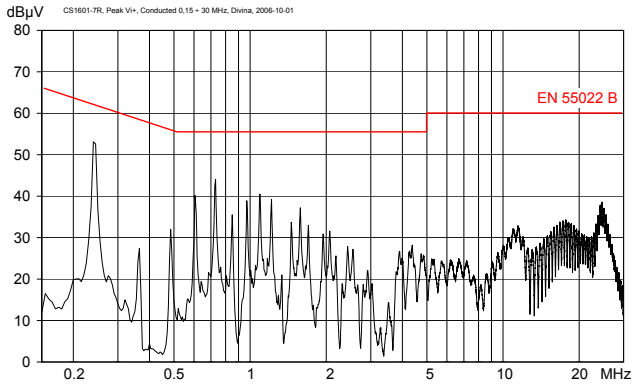


Fig. 19a
Typical disturbance voltage (peak) at the input according to EN 55011/22, measured at $V_{i\ nom}$ and $I_{o\ nom}$ (DK1301-7R).

Note: The Railway Standard, EN50121-3-2:2000 table 3, imposes much higher limits, which are by far fulfilled.

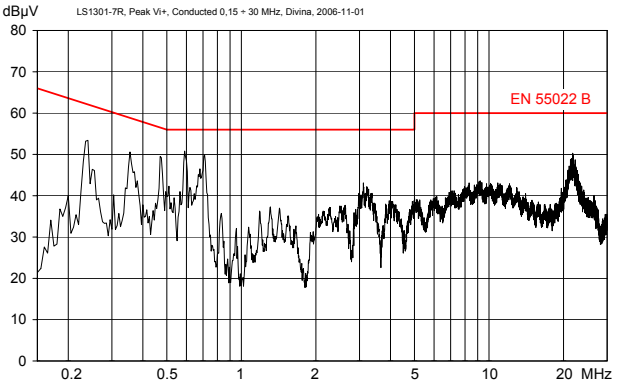


Fig. 19b
Typical disturbance voltage (peak) at the input according to EN 55011/22, measured at V_i = 230 VAC and $I_{o\ nom}$, (LK1001-7RD9B1).

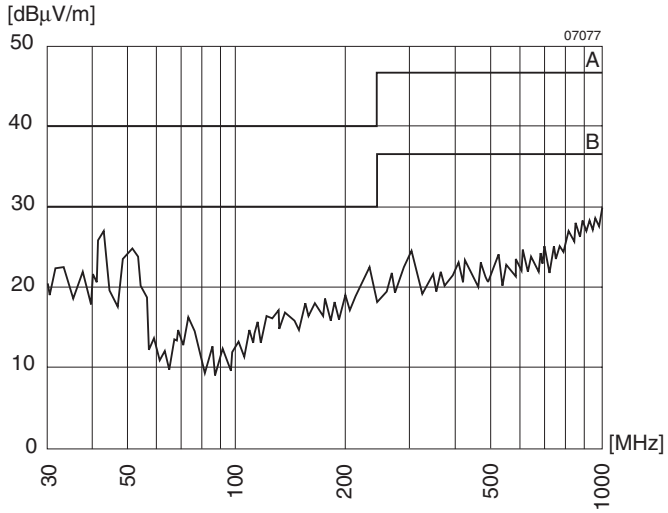


Fig. 19c
Typical radiated electromagnetic field strength (quasi-peak) according to EN 55011/22, normalized to a distance of 10 m, measured at $V_{i\ nom}$ and $I_{o\ nom}$.

Immunity to Environmental Conditions

Table 9: Mechanical and climatic stress

Test method		Standard	Test conditions		Status
Ca	Damp heat steady state	IEC/EN 60068-2-78 MIL-STD-810D sect. 507.2	Temperature: Relative humidity: Duration:	40 $^{\pm 2}$ °C 93 $^{+2/-3}$ % 56 days	Converter not operating
Ea	Shock (half-sinusoidal)	IEC/EN 60068-2-27 [1] MIL-STD-810D sect. 516.3	Acceleration amplitude: Bump duration: Number of bumps:	100 g_n = 981 m/s^2 6 ms 18 (3 each direction)	Converter operating
Eb	Bump (half-sinusoidal)	IEC/EN 60068-2-29 MIL-STD-810D sect. 516.3	Acceleration amplitude: Bump duration: Number of bumps:	40 g_n = 392 m/s^2 6 ms 6000 (1000 each direction)	Converter operating
Fc	Vibration (sinusoidal)	IEC/EN 60068-2-6 MIL-STD-810D sect. 514.3	Acceleration amplitude: Frequency (1 Oct/min): Test duration:	0.35 mm (10 - 60 Hz) 5 g_n = 49 m/s^2 (60 - 2000 Hz) 10 - 2000 Hz 7.5 h (2.5 h each axis)	Converter operating
Fn	Vibration broad band random (digital control)	IEC/EN 60068-2-64	Acceleration spectral density: Frequency band: Acceleration magnitude: Test duration:	0.05 g_n^{2}/Hz 5 - 500 Hz 4.97 g_n rms 3 h (1 h each axis)	Converter operating
Kb	Salt mist, cyclic (sodium chloride NaCl solution)	IEC/EN 60068-2-52	Concentration: Duration: Storage: Storage duration: Number of cycles:	5% (30 °C) 2 h per cycle 40 °C, 93% rel. humidity 22 h per cycle 3	Converter not operating

[1] Covers also EN50155/EN61373 (Category 1, body mounted Class B).

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

Temperature			Standard -7		Option -9		
Characteristics		Conditions	min	max	min	max	Unit
T_A	Ambient temperature	Converter Operating	–25	71	–40	71	°C
T_C	Case temperature[1]		–25	95	–40	95	
T_S	Storage temperature	Non-operational	–40	100	–55	100	

[1] Overtemperature lockout at T_C > 95 °C

Failure Rates

Table 11: MTBF

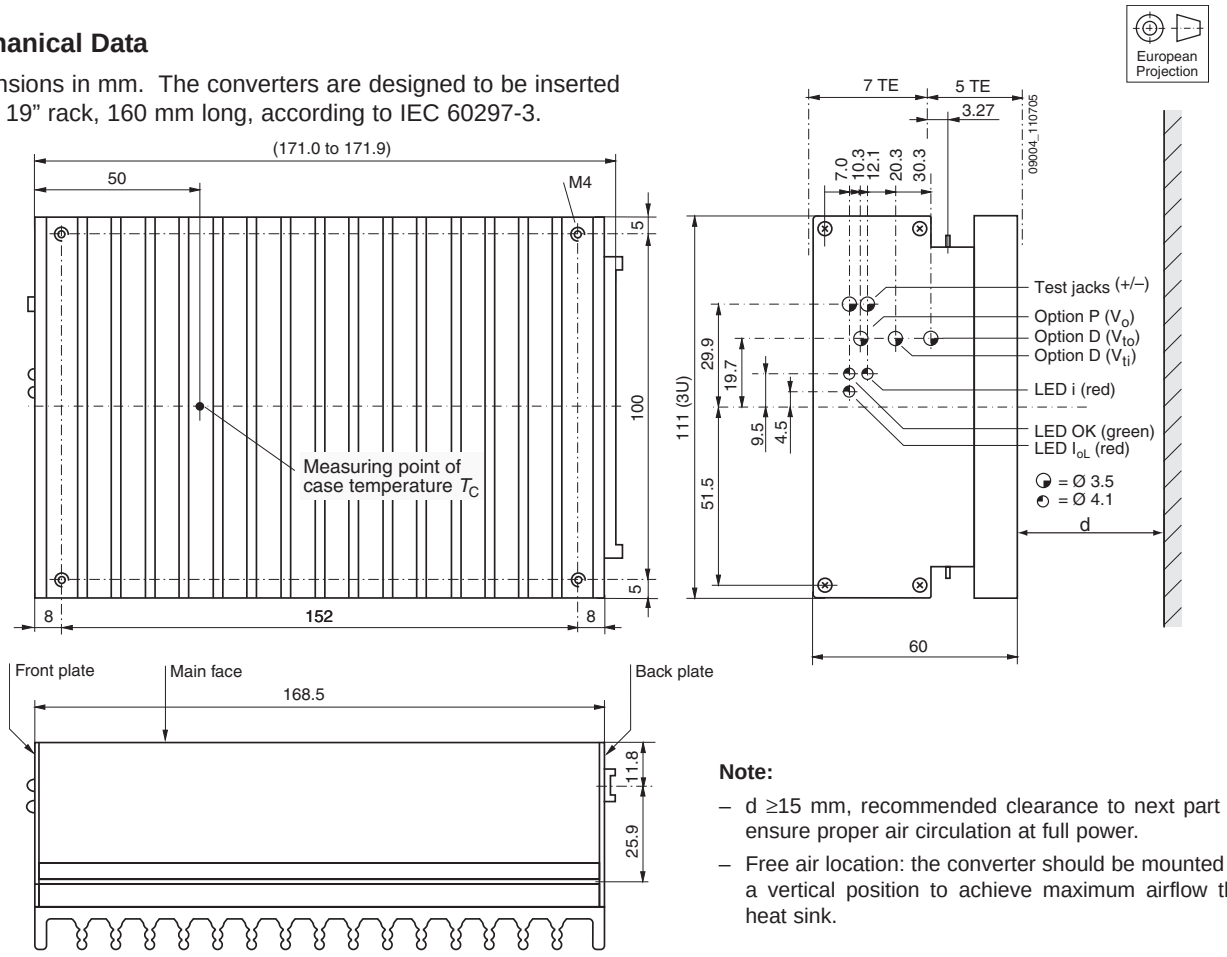
Values at specified case temperature	Model types	Ground benign 40 °C	Ground fixed 40 °C	Ground fixed 70 °C	Ground mobile 50 °C	Unit
MTBF [1]	AS - LS	500 000	150 000	80 000	50 000	h
Device hours [2]		500 000				

[1] Calculated in accordance with MIL-HDBK-217F.

[2] Statistical values, based on an average of 4300 working hours per year and over 3 years in general field use.

Mechanical Data

Dimensions in mm. The converters are designed to be inserted into a 19" rack, 160 mm long, according to IEC 60297-3.

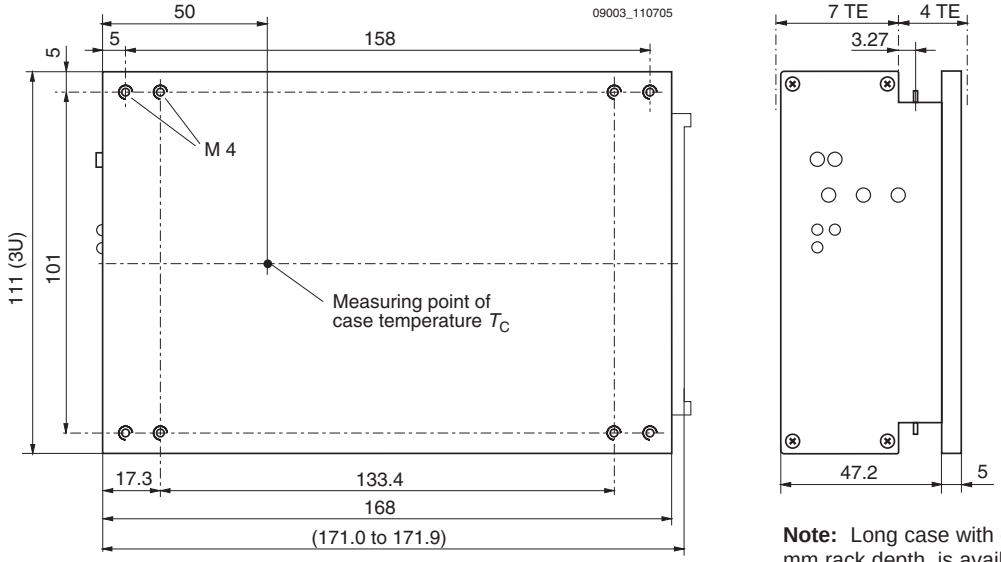


Note:

– d ≥15 mm, recommended clearance to next part in order to ensure proper air circulation at full power.

– Free air location: the converter should be mounted with fins in a vertical position to achieve maximum airflow through the heat sink.

Fig. 20
Aluminum case S02 with heat sink, black finish and self-cooling, weight: Approx. 1.25 kg



Note: Long case with option B2, elongated by 60 mm for 220 mm rack depth, is available on request with a customer-specific part number (no LEDs and no test jacks).

Fig. 21
Aluminum case S02 with option B1 (cooling plate), black finish and self-cooling, weight: Approx. 1.15 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/H15 S4 connector. Pin no. 24 (protective earth) is a leading pin, ensuring that it makes contact first.

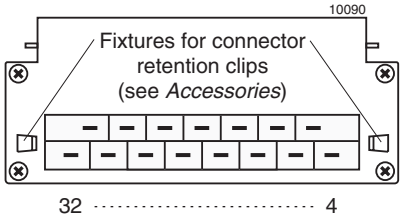


Fig. 22
View of converter's male connector

Table 12: H15 connector pin allocation

Pin No.	Connector type H15			
	AS to LS1000		AS to LS2000	
4	Vo1+	Pos. output 1	Vo2+	Pos. output 2
6	Vo1+		Vo2+	
8	Vo1–	Neg. output 1	Vo2–	Neg. output 2
10	Vo1–		Vo2–	
12	S+	Sense	Vo1+	Pos. output 1
14	S–	Sense	Vo1–	Neg. output 1
16	R [1]	Control of V_o	R [1]	Control of V_{o1}
18	i	Inhibit	i	Inhibit
20	D [3]	Save data	D [3]	Safe data
	V [3]	ACFAIL		
22	T [5]	Current share	T [5]	Current share
24 [2]	⏚	Protective earth	⏚	Protective earth
26	Vi+ N ≂ [4]	Pos. input	Vi+ N ≂ [4]	Pos. input
28		Neutral line [4]		Neutral line [4]
30	Vi– L ≂ [4]	Neg. input	Vi– L ≂ [4]	Neg. input
32		Phase line [4]		Phase line [4]

[1] Not connected, if option P is fitted.

[2] Leading pin (pre-connecting).

[3] Option D excludes option V and vice versa. Pin not connected unless option D or V is fitted.

[4] LS models.

[5] Not connected, unless option T is fitted.

Installation Instructions

The S Series 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.

The converters are provided with pin 24 (⏚), which is reliably connected with the case. For safety reasons it is essential to connect this pin to protective earth. See: *Safety of Operator Accessible Output Circuit*.

Input pins 30 and 32 are internally fused. Since this fuse is designed to protect the converter in case of an overcurrent and does not necessarily cover all customer needs, an external fuse suitable for the application and in compliance with the local requirements might be necessary in the wiring to one or both input potentials, pins 26 and 28, and/or 30 and 32.

Important: When the inhibit function is not in use, pin no. 18 (i) should be connected to pin no. 14 (S–/Vo1–) to enable the output(s). Do not open the converters, or guarantee will be invalidated.

Due to high current values, some models provide two internally parallel connected contacts for certain paths (pins 4/6, 8/10, 26/28 and 30/32). It is recommended to connect load and supply to both female connector pins of each path in order to keep the voltage drop across the connector pins at an absolute minimum and to avoid overstress of the connector contacts with currents higher than 8 A.

Make sure that there is sufficient airflow possible for convection cooling. This should be verified by measuring the case temperature when the converter is installed and operated in the end-use application. The maximum specified case temperature T_{Cmax} shall not be exceeded. See also *Thermal Consid-erations.*

If the end-product is to be UL certified, the temperature of the main isolation transformer should be evaluated as part of the end-product investigation.

Check for hazardous voltages before altering any connections.

Ensure that a converter failure (e.g., by an internal short-circuit) does not result in a hazardous condition. See also: *Safety of Operator-Accessible Output Circuits.*

LS-models Operated at Greater than 63 Hz

Above 63 Hz the earth leakage current may exceed 3.5 mA, the maximum specified in IEC/EN 60950. The built-in Y-caps are only approved for ≤ 100 Hz. Frequencies greater than 350 Hz are only permitted for V_i ≤ 200 VAC.

Isolation

The electric strength test is performed in the factory as routine test in accordance with EN 50116, IEC/EN 60950 and UL 1950 and should not be repeated in the field. Power-One will not honor any guarantee claims resulting from electric strength field tests.

Standards and Approvals

The converters are UL recognized according to UL 1950, CAN/CSA C22.2 No. 950-95, and TÜV approved to IEC/EN 60950 standards.

The converters correspond to Class I equipment and have been evaluated for:

- Building in,
- Basic insulation between input and case based on 250 V and double or reinforced insulation or an earthed part between input and output.
- The use in a pollution degree 2 environment,
- Connecting the input to a primary or secondary circuit which is subject to a maximum transient rating of 2500 V.

The converters are subject to manufacturing surveillance in accordance with the above mentioned UL and ISO 9001:2000 standards.

Railway Applications

The S Series converters have been designed according to the Railway Standards EN50155 and EN50121. All boards and components are coated with a protective lacquer.

Cleaning Agents

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

Protection Degree

Condition: Female connector fitted to the converter.

IP 30: All models except those with option P and option D,
or V with potentiometer.

IP 20: All models exhibiting a potentiometer.

Table 13: Leakage Currents for LS-models

Characteristic		Class I LS1000, LS2000	Unit
Maximum earth leakage current	Permissible according to IEC/EN 60950	3.5	mA
	Specified value at 264 V, 50 Hz	1.43	

Table 14: Isolation

Characteristic		Input to case + output(s)	Output to case	Output to output	Unit
Electric strength test voltage	Factory test >1 s	2.8 [1]	1.4	0.14	kVDC
	AC test voltage equivalent to factory test	2.0	1.0	0.1	kVAC
Insulation resistance at 500 VDC		300 [2]	300 [2]	100	MΩ

[1] In accordance with EN 50116 and IEC/EN 60950 subassemblies are pretested with 5.6 kVDC.

[2] Tested at 500 VDC.

Safety of Operator-Accessible Output Circuits

If the output circuit of a DC-DC converter is operator-accessible, it shall be a SELV circuit according to safety standard IEC/EN 60950.

The following table shows some possible installation configurations, compliance with which causes the output circuit of a DC-DC converter to be a SELV circuit according to IEC/EN 60950 up to a configured output voltage (sum of nominal voltages if in series or +/– configuration) of 36 V.

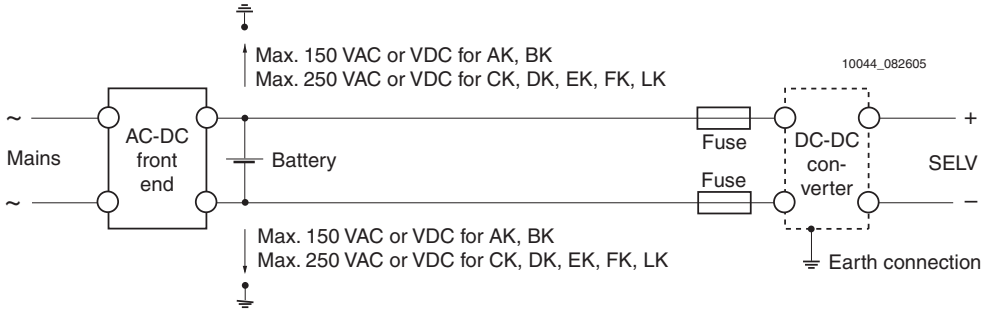


Fig. 23
Schematic safety concept.
Use earth connection as per the table below.

Table 15: Safety concept leading to a SELV output circuit

Conditions	Front end		Result	DC-DC converter		Result
Nominal supply voltage	Minimum required grade of insulation, to be provided by the AC-DC front end, including mains supplied battery charger	DC output voltage from the front end	Minimum required safety status of the front end output circuit	Types	Measures to achieve the specified safety status of the output circuit	Safety status of the DC-DC converter output circuit
Mains ≤150 VAC	Functional (no electrical insulation between the mains supply voltage and the DC-DC converter input)	≤100 V. The nominal voltage between any output pin and earth is ≤150 V (AC or DC)	Primary circuit	AS BS	a) Double or reinforced insulation based on the mains voltage (provided by the DC-DC converter) AND b) earthed case [3]	SELV circuit
Mains ≤250 VAC		≤250 V The nominal voltage between any output pin and earth is ≤250 V (AC or DC)		CS DS ES FS		
	Basic	≤250 V	Unearthed hazardous voltage secondary circuit	AS BS CS DS ES FS	a) Supplementary insulation, based on 250 VAC AND b) double or reinforced insulation [2] (provided by DC-DC converter) AND c) earthed case [3]	
			Earthed hazardous voltage secondary circuit		a) Double or reinforced insulation [2] (provided by the DC-DC converter) AND b) earthed case [3]	
	Double or reinforced	≤60 V	SELV circuit		[4]	
		≤120 V	TNV-3 circuit		Basic insulation (provided by the DC-DC converter) [4]	

[1] The front end output voltage should match the specified input voltage range of the DC-DC converter.

[2] Based on the maximum nominal output voltage from the front end.

[3] The earth connection has to be provided by the installer according to the relevant safety standards, e.g. IEC/EN 60950.

[4] Earthing of the case is recommended, but not mandatory.

If the output circuit of a AC-DC converter is operator-accessible, it shall be a SELV circuit according to the related IEC/EN 60950 safety standards.

The following table shows a possible installation configuration, compliance with which causes the output circuit of an LS Series AC-DC converter to be a SELV circuit according to IEC/EN 60950 up to a configured output voltage (sum of nominal voltages if in series or +/– configuration) of 36 V.

If the LS converters are used as DC-DC converters, please refer to the previous section.

Table 16: Safety concept leading to a SELV output circuit

Conditions	AC-DC converter	Installation	Result
Nominal voltage	Grade of insulation between input and output provided by the AC-DC converter	Measures to achieve the resulting safety status of the output circuit	Safety status of the AC-DC converter output circuit
Mains ≤250 VAC	Double or reinforced	Earthed case [1] and installation according to the applicable standards	SELV circuit

[1] The earth connection has to be provided by the installer according to the relevant safety standards, e.g. IEC/EN 60950.

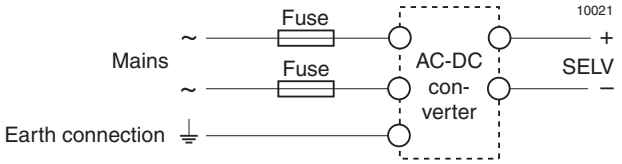


Fig. 24
Schematic safety concept. Use fuses and earth connection as per: Installation Instructions and table: Safety concept leading to a SELV output circuit.

Description of Options

Table 17: Survey of options

-9	Extended operational ambient temperature range	T_A = –40 to 71 °C
E	Electronic inrush current limitation circuitry	Active inrush current limitation for CK, DK, EK
P	Potentiometer for fine adjustment of output voltage	Adjustment range +10/–60% of $V_{o\ nom}$ (R input not connected)
D [1]	Input and/or output undervoltage monitoring circuitry	Safe data signal output (versions D0 - DD)
V [1, 2]	Input (and output) undervoltage monitoring circuitry	ACFAIL signal according to VME specs (versions V0, V2, V3)
T	Current sharing	Interconnect T-pins if paralleling outputs (5 converters max.)
B1/B2	Cooling plate	Replaces standard heat sink, allowing direct chassis-mounting

[1] Option D excludes Option V and vice versa.

[2] Only available for V_o = 5.1 V.

Option -9: Extended Temperature Range

Option -9 extends the operational ambient temperature range from –25 to 71 °C to –40 to 71 °C. The power supplies provide full nominal output power with convection cooling. Option -9 excludes inrush current limitation by NTC.

Option E: Inrush Current Limiter

CS/DS/ES/FS/LS types may be supplemented by an electronic circuit (option E, replacing the standard built-in NTC) to achieve an enhanced inrush current limiting function. Option E is mandatory for -9 models.

CS models fitted with option E and option D6 (input voltage monitoring) meet the standard ETS 300132-2 for 48 VDC supply voltage. Option D6 (externally adjustable via potentiometer from 36.0 to 40.5 V) is necessary to disable the converter at low input voltages, avoiding an excessive input current. Option D6 threshold level should be adjusted to 44.0 - 50.0 V for 60 V nominal supply systems (refer to the description of option D). The D output can be connected directly to the inhibit input.

Table 18: Inrush current characteristics with option E (DC-DC converters)

Characteristics		CS	DS	ES	FS	Unit
$V_{i\ nom}$, $I_{o\ nom}$	Input voltage	60	110	220	48	V
$I_{inr\ p}$	Peak inrush current	6.8	7.4	14.6	4.5	A
t_{inr}	Inrush current duration	18	14	16	22	ms
$V_{i\ max}$, $I_{o\ nom}$	Input voltage	140	220	380	100	V
$I_{inr\ p}$	Peak inrush current	9.3	14.5	25.3	7.5	A
t_{inr}	Inrush current duration	20	14	12	23	ms

Note: Subsequent switch-on cycles at startup are limited to max. 10 cycles during the first 20 seconds (cold model) and then to max. 1 cycle every 8 seconds.

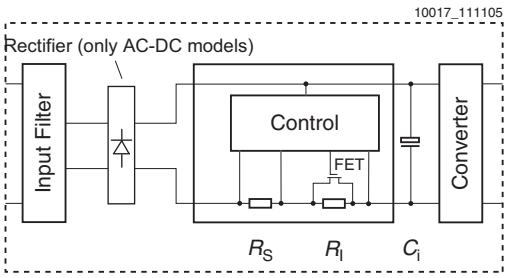


Fig. 25
Option E block diagram

Current limiting resistance = R_S + R_I = 15 Ω (all models)

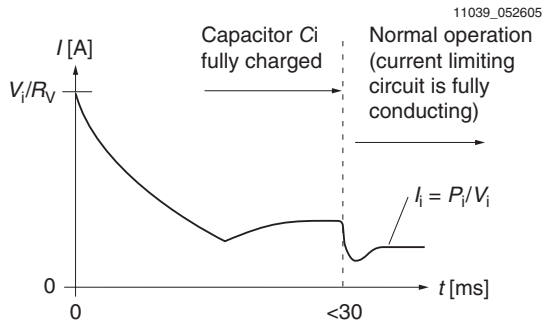


Fig. 26
Inrush current with option E (DC-DC converters)

Table 19: Inrush current characteristics with option E (AC-DC converters)

Characteristics V = 230 VAC		**LS** min	typ	max	**Unit**
$I_{inr\ p}$	Peak inrush current	–	–	25.3	A
t_{inr}	Inrush current duration	–	35	50	ms

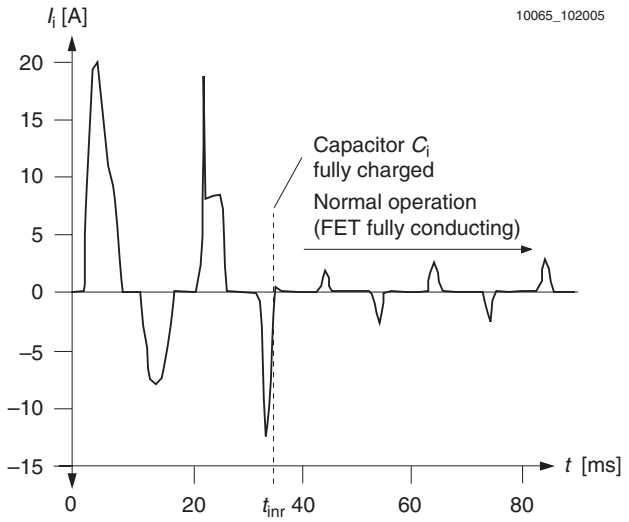


Fig. 27
Inrush current with option E
(LS models, Vi = 230 VAC, f_i = 50 Hz, $P_o = P_{o\ nom}$)

Option P: Potentiometer

The potentiometer allows for an output voltage adjustment in the range of +10/–60% of $V_{o\ nom}$. It is accessible through a hole in the front cover. This feature enables compensation of voltage drops across the connector and wiring. Option P is not recommended if models are connected in parallel.

In double-output models both outputs are influenced by the potentiometer setting. If option P is fitted, the R-pin 16 is not connected.

Note: If the output voltage is increased above $V_{o\ nom}$ via the R-input control, option P setting, remote sensing, or option T, the output current(s) should be reduced accordingly so that $P_{o\ nom}$ is not exceeded.

Option T: Current Sharing

This option ensures that the output currents are approximately shared between all paralleled converters, hence increasing system reliability. To use this facility, simply interconnect the T pins of all converters and make sure that the reference pins for the T-pin (S- for the S1000 or V_{o1}– for S2000) are also connected together. The load lines should have equal length and cross section to ensure equal voltage drops. Not more than 5 converters should be connected in parallel. The R-pins should be left in an open-circuit condition. If not, prior to paralleling the V_{o1} outputs should be individually adjusted within 1 to 2%. Parallel connection of converters with option P is not recommended.

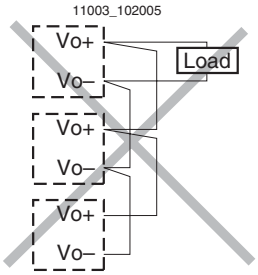
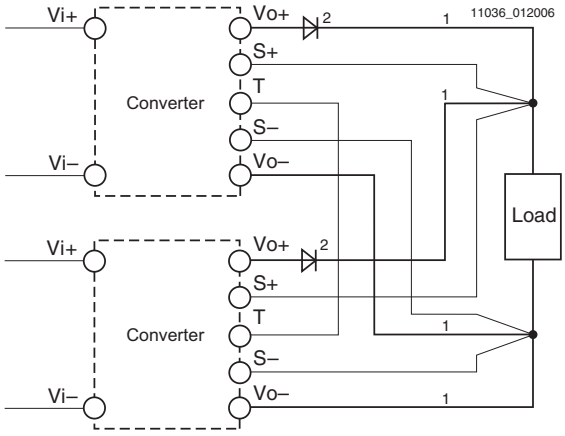


Fig. 28
An example of poor wiring for connections in parallel (unequal length of load lines)



[1] Leads should have equal length and cross sections and should run in the same cable loom.
[2] Diodes for redundant operation.

Fig. 29
Paralleling of single-output models using option T with the sense lines connected at the load

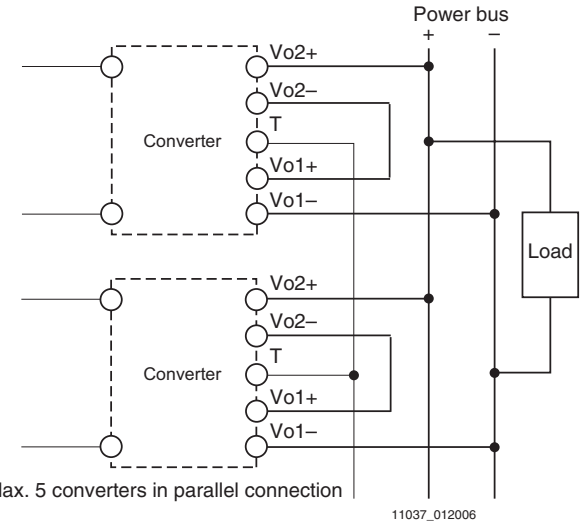


Fig. 30
Paralleling of double output models with the outputs connected in series, and using option T in an application with a power bus. Note that the signal at the T-pins is referenced to Vo1-.

Option D: Undervoltage Monitor

The input and/or output undervoltage monitoring circuit operates independently of the built-in input undervoltage lockout circuit. A logic "low" (JFET output) or "high" signal (NPN output) is generated at pin 20 as soon as one of the monitored voltages drops below the preselected threshold level V_t. The return for this signal is Vo1–. The D output recovers when the monitored voltage(s) exceed(s) $V_t + V_h$. The threshold levels V_{ti} and V_{to} are either adjustable by a potentiometer, accessible through a hole in the front cover, or factory adjusted to a fixed value specified by the customer.

Option D exists in various versions D0 - DD as shown in the following table.

Table 20: Undervoltage monitor functions

Output type		Monitoring		Minimum adjustment range of threshold level V_t		Typical hysteresis V_h [% of V_t] for $V_{t\,min}$ - $V_{t\,max}$	
JFET	NPN	V_i	V_{o1}	V_{ti}	V_{to}	V_{hi}	V_{ho}
D1	D5	no	yes	-	3.5 - 40 V [1]	-	2.5 - 0.6
D2	D6	yes	no	$V_{i\,min}$ - $V_{i\,max}$ [1]	-	3.4 - 0.4	-
D3	D7	yes	yes	$V_{i\,min}$ - $V_{i\,max}$ [1]	(0.95 - 0.985 V_{o1}) [2]	3.4 - 0.4	"0"
D4	D8	no	yes	-	(0.95 - 0.985 V_{o1}) [2]	-	"0"
D0	D9	no	yes	-	3.5 - 40 V [3]	-	2.5 - 0.6
		yes	no	$V_{i\,min}$ - $V_{i\,max}$ [3, 4]	- 3.4 - 0.4	-	
		yes	yes	$V_{i\,min}$ - $V_{i\,max}$ [3, 4]	3.5 - 40 V [3]	3.4 - 0.4	2.5 - 0.6
		yes	yes	$V_{i\,min}$ - $V_{i\,max}$ [3, 4]	(0.95 - 0.985 V_{o1}) [2]	3.4 - 0.4	"0"
-	DD	yes	yes	$V_{i\,min}$ - $V_{i\,max}$ [1]	3.5 - 40 V [1]	3.4 - 0.4	2.5 - 0.6

[1] Threshold level adjustable by potentiometer

[2] Fixed value tracking if V_{o1} is adjusted via R-input, option P or sense lines.

[3] The threshold level is permanently adjusted according to customer specification ±2% at 25 °C. Any value within the specified range is possible, but causes a new customer-specific type designation.

[4] Adjusted at $I_{o\,nom}$

JFET output (D0 - D4):

Pin 20 (D) is internally connected via the drain-source path of a JFET (self-conducting type) to Vo1+ or Vo+. $V_D \leq 0.4$ V (logic low) corresponds to a monitored voltage level (V_i and/or V_{o1}) $< V_t$. The current I_D through the JFET should not exceed 2.5 mA. The JFET is protected by a 0.5 W Zener diode of 8.2 V against external overvoltages.

V_i, V_{o1} status	D output, V_D
V_i or $V_{o1} < V_t$	low, L, $V_D \leq 0.4$ V at $I_D = 2.5$ mA
V_i and $V_{o1} > V_t + V_h$	high, H, $I_D \leq 25$ µA at $V_D = 5.25$ V

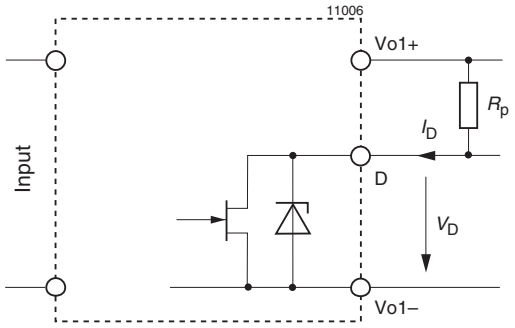


Fig. 31
Option D1 - D0: JFET output, $I_D \leq 2.5$ mA

NPN output (D5 - DD):

Pin 20 (D) is internally connected via the collector-emitter path of an NPN transistor to Vo1+ or Vo+. $V_D < 0.4$ V (logic low) corresponds to a monitored voltage level (V_i and/or V_{o1}) $> V_t + V_h$. The current I_D through pin 20 should not exceed 20 mA. This output is not protected against external overvoltages. V_D should not exceed 40 V.

V_i, V_{o1} status	D output, V_D
V_i or $V_{o1} < V_t$	high, H, $I_D \leq 25$ µA at $V_D = 40$ V
V_i and $V_{o1} > V_t + V_h$	low, L, $V_D \leq 0.4$ V at $I_D = 20$ mA

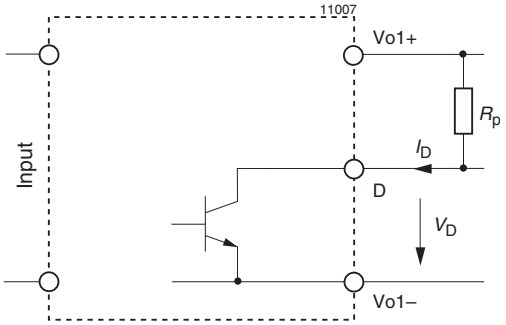


Fig. 32
Option D5 - DD: NPN output, $V_{o1} \leq 40$ V, $I_D \leq 20$ mA

Table 21: D-output logic signals

Version of D	$V_i < V_t$ resp. $V_o < V_t$	$V_i > V_t + V_h$ resp. $V_o > V_t$	Configuration
D1, D2, D3, D4, D0	low	high	JFET
D5, D6, D7, D8, D9, DD	high	low	NPN

Threshold tolerances and hysteresis:

If V_i is monitored, the internal input voltage after the input filter is measured. Consequently, this voltage differs from the voltage at the connector pins by the voltage drop ΔV_{ti} across the input filter. The threshold levels of the D0 and D9 options are factory-adjusted at nominal output current $I_{o\,nom}$ and at $T_A = 25$ °C. The value of ΔV_{ti} depends upon the input voltage range (CS, DS, ..), threshold level V_t, temperature and input current. The input current is a function of the input voltage and the output power.

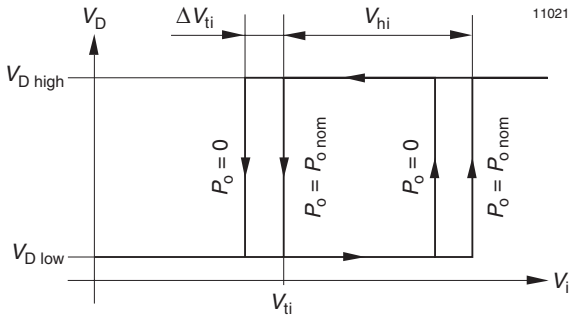


Fig. 33
Definition of V_{ti}, $\Delta V_{t\,i}$ and ΔV_{hi} (JFET output)

D-signal with respect to input and output voltage versus time:

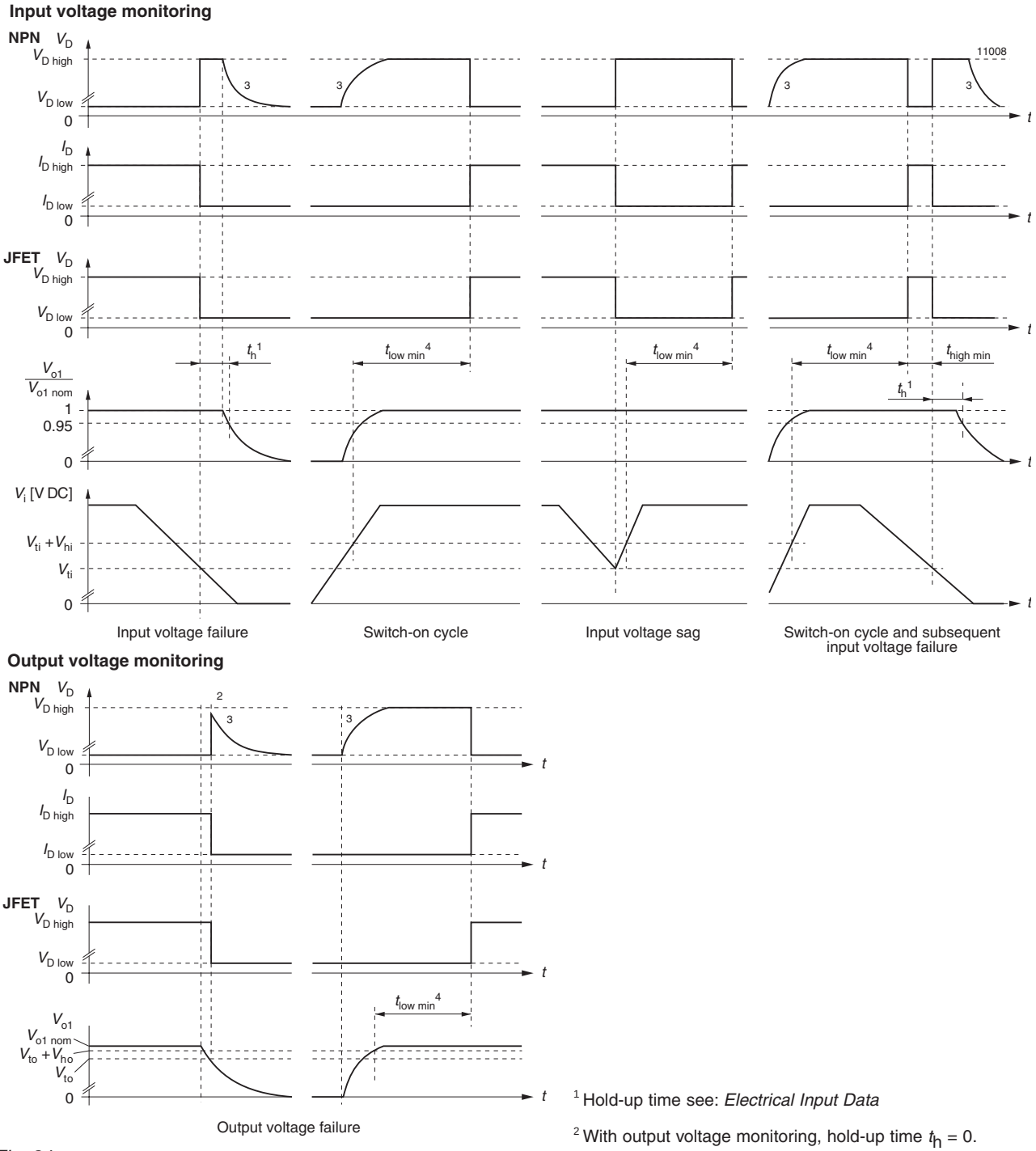


Fig. 34
Relationship between V_i, V_{o1}, V_D, $V_{o1}/V_{o\ nom}$ versus time

[1] Hold-up time see: *Electrical Input Data*

[2] With output voltage monitoring, hold-up time $t_h = 0$.

[3] The signal will remain high if the D output is connected to an external source.

[4] $t_{low\ min}$ = typically 130 ms.

Option V: ACFAIL Signal (VME)

Available only for models with V_o = 5.1 V.

This option defines an undervoltage monitoring circuit for the input and main output voltage. It generates an ACFAIL signal (V signal) which conforms to the VME standard.

The low state level of the ACFAIL signal is specified at a sink current of $I_V \leq 48$ mA to $V_V \leq 0.6$ V (open-collector output of an NPN transistor). The pull-up resistor feeding the open-collector output should be placed on the VME backplane.

After the ACFAIL signal has gone low, the VME standard requires a hold-up time (t_h) of at least 4 ms before the 5.1 V output drops to 4.875 V when the output is fully loaded. The hold-up time is provided by the internal input capacitance. Consequently, the working input voltage and the threshold level (V_{ti}) should be adequately above the minimum input voltage ($V_{i\ min}$) of the converter so that enough energy is remaining in the input capacitance. If the input voltage is below the required level, an external hold-up capacitor ($C_{i\ ext}$) should be added.

Formula for threshold level for desired value of t_h:

$$V_{ti} = \sqrt{\frac{2 \bullet P_o \bullet (t_h + 0.3\ ms) \bullet 100}{C_{i\ min} \bullet \eta} + V_{i\ min}^2}$$

Formula for the external input capacitor:

$$C_{i\ ext} = \frac{2 \bullet P_o \bullet (t_h + 0.3\ ms) \bullet 100}{\eta \bullet (V_{ti}^2 - V_{i\ min}^2)} - C_{i\ min}$$

where as:

$C_{i\ min}$ = internal input capacitance [mF]
$C_{i\ ext}$ = external input capacitance [mF]
P_o = output power [W]
η = efficiency [%]
t_h = hold-up time [ms]
$V_{i\ min}$ = minimum input voltage [V] [1]
V_{ti} = threshold level [V]

[1] Min. input voltage according to *Electrical Input Data*. For output voltages $V_o > V_{o\ nom}$, the minimum input voltage increases proportionally to $V_o/V_{o\ nom}$.

Remarks:

Option V2 and V3 can be adjusted by potentiometer to a threshold level between $V_{i\ min}$ and $V_{i\ max}$. A decoupling diode should be connected in series with the input of AS - FS converters to avoid the input capacitance discharging through other loads connected to the same source voltage.

Table 22: Available internal input capacitance and factory potentiometer setting of V_{ti} with resulting hold-up time

Types	AS	BS	FS	CS	DS	ES	LS	Unit
$C_{i\ min}$	0.83	0.3	1.2	0.66	0.26	0.21	0.21	mF
$V_{t\ i}$	9.5	19.5	39	39	61	97	120	VDC
t_h	0.1	0.1	5.3	1.9	1.8	4.3	6.4	ms

Option V operates independently of the built-in input undervoltage lockout circuit. A logic "low" signal is generated at pin 20 as soon as one of the monitored voltages drops below the preselected threshold level V_t. The return for this signal is Vo1–. The V output recovers when the monitored voltage(s) exceed(s) $V_t + V_h$. The threshold level V_{ti} is either adjustable by potentiometer, accessible through a hole in the front cover, or adjusted during manufacture to a determined customer specified value.

Versions V0, V2, and V3 are available as shown below.

Table 23: Undervoltage monitor functions

V output (VME compatible)	Monitoring		Minimum adjustment range of threshold level V_t		Typical hysteresis V_h [% of V_t] for $V_{t\ min}$ - $V_{t\ max}$	
	V_i	V_{o1}	V_{ti}	V_{to}	V_{hi}	V_{ho}
V2	yes	no	$V_{i\ min}$ - $V_{i\ max}$ [1]	–	3.4 - 0.4	–
V3	yes	yes	$V_{i\ min}$ - $V_{i\ max}$ [1]	0.95 - 0.985 V_{o1} [2]	3.4 - 0.4	"0"
V0	yes	no	$V_{i\ min}$ - $V_{i\ max}$ [3, 4]	–	3.4 - 0.4	–
	yes	yes	$V_{i\ min}$ - $V_{i\ max}$ [3, 4]	0.95 - 0.985 V_{o1} [2]	3.4 - 0.4	"0"

[1] Threshold level adjustable by potentiometer.

[2] Fixed value between 95% and 98.5% of V_{o1} (tracking).

[3] Adjusted at $I_{o\ nom}$.

[4] Fixed value, resistor-adjusted (±2% at 25 °C) acc. to customer's specifications; individual type number is determined by Power-One.

V output (V0, V2, V3):

Connector pin V is internally connected to the open collector of an NPN transistor. The emitter is connected to Vo1- or Vo-. $V_V \leq 0.6$ V (logic low) corresponds to a monitored voltage level (V_i and/or V_{o1}) $<V_t$. The current I_V through the open collector should not exceed 50 mA. The NPN output is not protected against external overvoltages. V_V should not exceed 60 V.

V_i, V_{o1} status	V output, V_V
V_i or $V_{o1} < V_t$	low, L, $V_V \leq 0.6$ V at $I_V = 50$ mA
V_i and $V_{o1} > V_t + V_h$	high, H, $I_V \leq 25$ µA at $V_V = 5.1$ V

Threshold tolerances and hysteresis:

If V_i is monitored, the internal input voltage is measured after the input filter. Consequently, this voltage differs from the voltage at the connector pins by the voltage drop DV_{ti} across the input filter. The threshold level of option V0 is adjusted during manufacture at $I_{o\ nom}$ and T_A = 25 °C. The value of ΔV_{ti} depends upon the input voltage range (AS, BS, etc.), threshold level V_t, temperature and input current. The input current is a function of input voltage and output power.

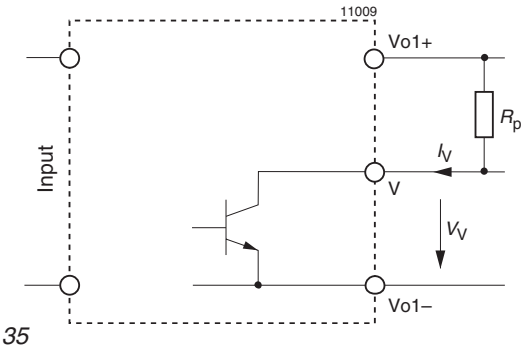


Fig. 35
Output configuration of options V0, V2, and V3

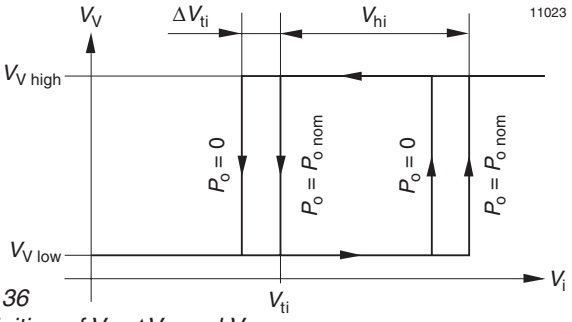
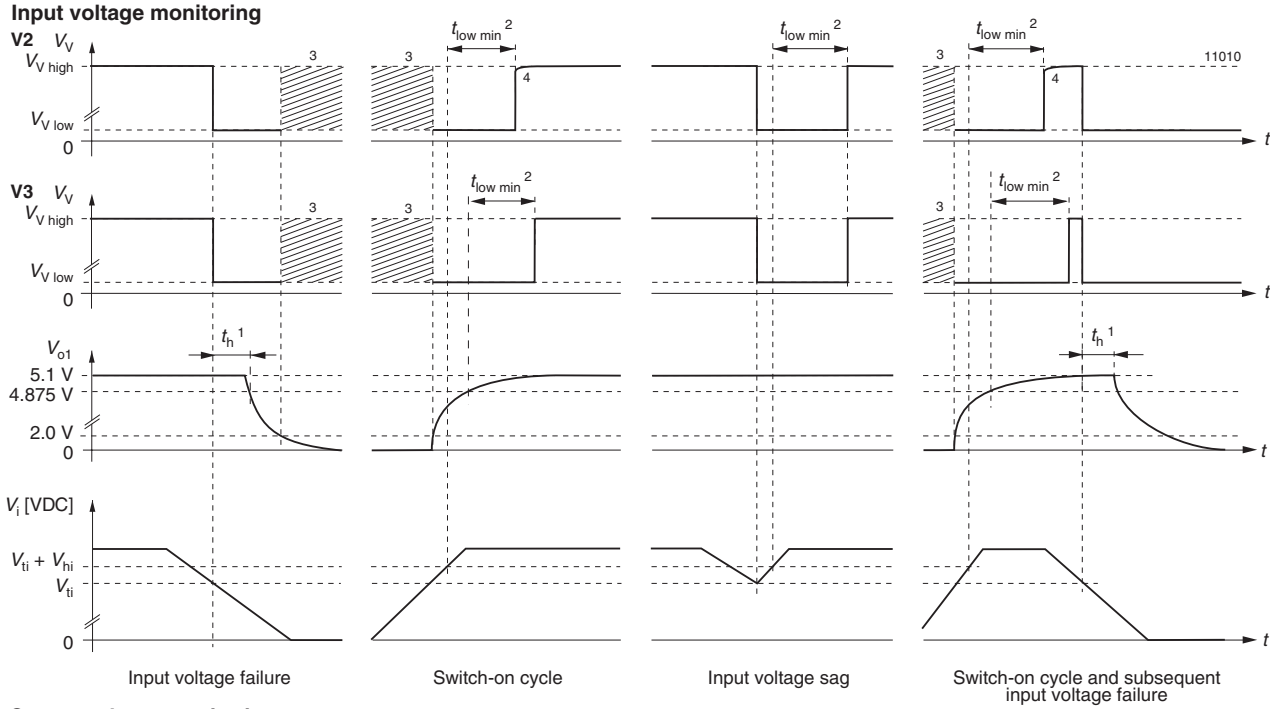


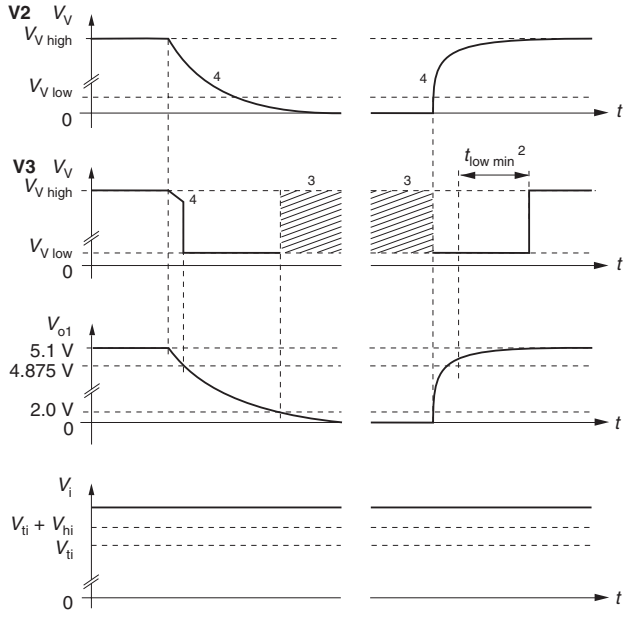
Fig. 36
Definition of V_{ti}, ΔV_{ti} and V_{hi}

Input voltage monitoring



Input voltage failure | Switch-on cycle | Input voltage sag | Switch-on cycle and subsequent input voltage failure

Output voltage monitoring



Output voltage failure

[1] VME request: minimum 4 ms

[2] $t_{low\,min}$ = 40 - 200 ms, typically 80 ms

[3] V_V level not defined at $V_{o1} < 2.0$ V

[4] The V signal drops simultaneously with the output voltage. If the pull-up resistor R_P is connected to Vo1+. The V signal remains high if R_P is connected to an external source.

Fig. 37
Relationship between V_i, V_{o1}, V_V, I_V and $V_{o1}/V_{o\,nom}$ versus time.

Options B1/B2: Cooling Plate

Where a cooling surface is available, we recommend the use of a cooling plate (option B1) instead of the standard heat sink. The mounting system should ensure sufficient cooling capacity to guarantee that the maximum case temperature $T_{C\,max}$ is not exceeded. The cooling capacity is calculated by:

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

Efficiency η see: *Model Selection*

Elongated case for 220 mm rack depth: Option B2

Dimensions see *Mechanical Data*

Accessories

A variety of electrical and mechanical accessories are available including:

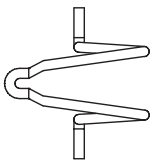
– Front panels for 19" DIN-rack: Schroff 16 TE /3U, [HZZ00831] and 16 TE /6U [HZZ00832], or Intermas 16 TE /3U [HZZ00731].
– Mating H15/H15 S4 connectors with screw, solder, fast-on or press-fit terminals.
– Cable connector housing: Screw version [HZZ00141] or retention clip version [HZZ00142].
– Connector retention clips (2x) [HZZ01209].
– Connector retention brackets CRB [HZZ01216].
– Coding clips for connector coding [HZZ00202].
– Chassis mounting plate CMB-S [HZZ00616] for fastening to a chassis with only front access.
– DIN-rail mounting assembly DMB-K/S [HZZ00615].
– Wall-mounting plate K02 [HZZ01213] for models with option B1.
– Additional external input or output filters.
– Battery temperature sensor [S-KSMH...] for use of the converter as a battery charger. Different battery characteristics can be selected.

For additional accessory product information, see the accessory data sheets listed with each product series or individually at *www.power-one.com* through the following menus: "Select Products", "Download Data Sheets & Applications Notes", or with each model in the product overviews.

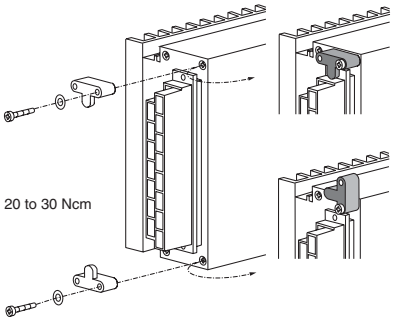
Chassis mounting brackets CMB-S

DIN mounting assembly DMB-K/S

H15 female connector, code key system



Connector retention clip



Connector retention bracket CRB

Front panels

NUCLEAR AND MEDICAL APPLICATIONS - Power-One products are not designed, intended for use in, or authorized for use as critical components in life support systems, equipment used in hazardous environments, or nuclear control systems without the express written consent of the respective divisional president of Power-One, Inc.

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.

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EC Declaration of Conformity

We

Power-One AG
Ackerstrasse 56, CH-8610 Uster

declare under our sole responsibility that K and S Series AC-DC and DC-DC converters carrying the CE-mark are in conformity with the provisions of the Low Voltage Directive (LVD) 73/23/EEC of the European Communities.

Conformity with the directive is presumed by conformity wih the following harmonized standards:

- EN 61204:1995 (= IEC 61204:1993, modified)
  Low-voltage power supply devices, DC output - Perfomance characteristics and safety requirements

- EN 60950:2000 (= IEC 60950:2000)
  Safety of information technology equipment

The installation instructions given in the data sheet describe correct installation leading to the presumption of conformity of the end product with the LVD. All K and S Series AC-DC and DC-DC converters are components, intended exclusively for inclusion within other equipment by an industrial assembly operation or by professional installers. They must not be operated as stand alone products.

Hence conformity with the Electromagnetic Compatibility Directive 89/336/EEC (EMC Directive) needs not to be declared. Nevertheless, guidance is provided in most product application notes on how conformity of the end product with the indicated EMC standards under the responsibility of the installer can be achieved, from which conformity with the EMC directive can be presumed.

Uster, 24 May 2005 Power-One AG

Rolf Baldauf
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