Converter System
BCV200-350-8S577
Product Specification

bel POWER SOLUTIONS & PROTECTION

a bel group

URP.20038_1 15-SEP-2021

Amendment record:

Revision (Issue)	Description of Change	Author	ECO No.	Date
1	Initial issue; based on spec URP.00619_A	Martin Pietka		7-Sep-2021

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1 Scope

1.1 General

This specification defines the converter system BCV200-350-8. The use and distribution of this specification are strictly under the control of this specification is subject to change without notice.
Converter system consists of 4 subsystems:

- 15kW Bi-directional Inverter – Charger (INVCH)
- 4kW 12V_{out} Down Converter (DNC)
- 1kW 24V_{out} Fixed Voltage Down Converter (FDNC)

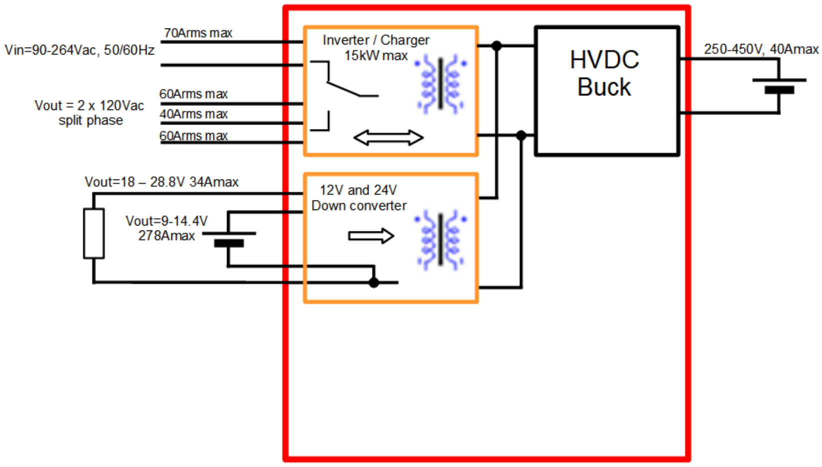


Figure 1-1:Block diagram of the converter system

1.2 Energy flow and priority

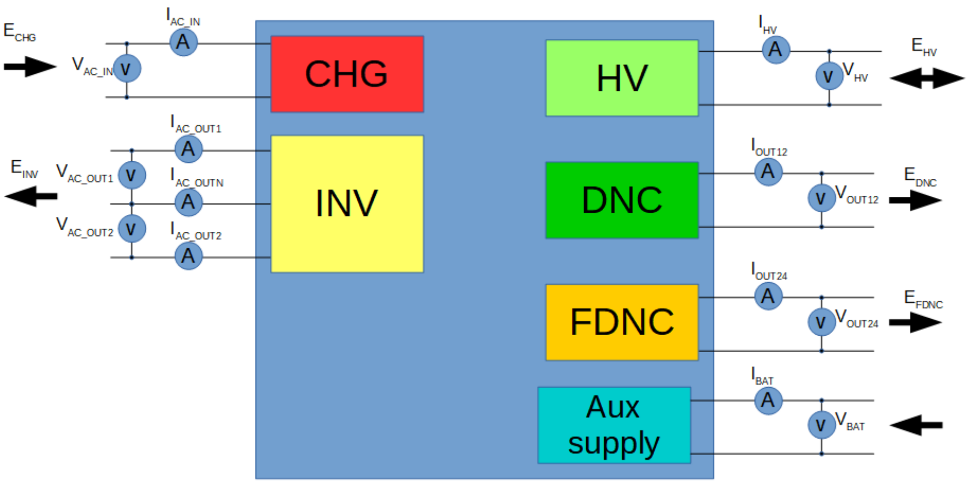


Figure 1-2: Measured values and energy flow

In general, following equation for power flow is valid, to simplify the effectiveness of the individual stages is 100%:

$P_{CHG} - P_{INV} - P_{DNC} - P_{FDNC} = P_{HV}$

Note: In each operation mode the HVDC battery needs to be connected to HV connector and HVDC buck stage needs to be active.

1.2.1 Energy source priority

Priority	Source	Max available power[kW]
1 - Hi	CHG	15
2 - Low	HV	15

1.2.2 Energy consumption priority

Priority	Source	Max available power[kW]
1 - Hi	FDNC	1
2	DNC	4
3	INV	15
4 - Low	HV	15

1.2.3 Energy flow example

Example 1

CHG: enabled, V_{AC_IN} = 200V, Control Pilot duty = 88%
INV: disabled (only one from INV-CHG can be enabled)
FDNC: enabled, V_{OUT24} = 24V, I_{OUT24} = 41.7A, P_{FDNC} = 1kW
DNC: enabled, V_{OUT12} = 12V, I_{SET12} = 200A
HV: V_{HV} = 300V, I_{HVSET} = 38A.Control system requested charging current is 38A, but only I_{HV_AVAIL} = 24.9A is available, because based on energy flow priority only 24.9A is available for HV output.

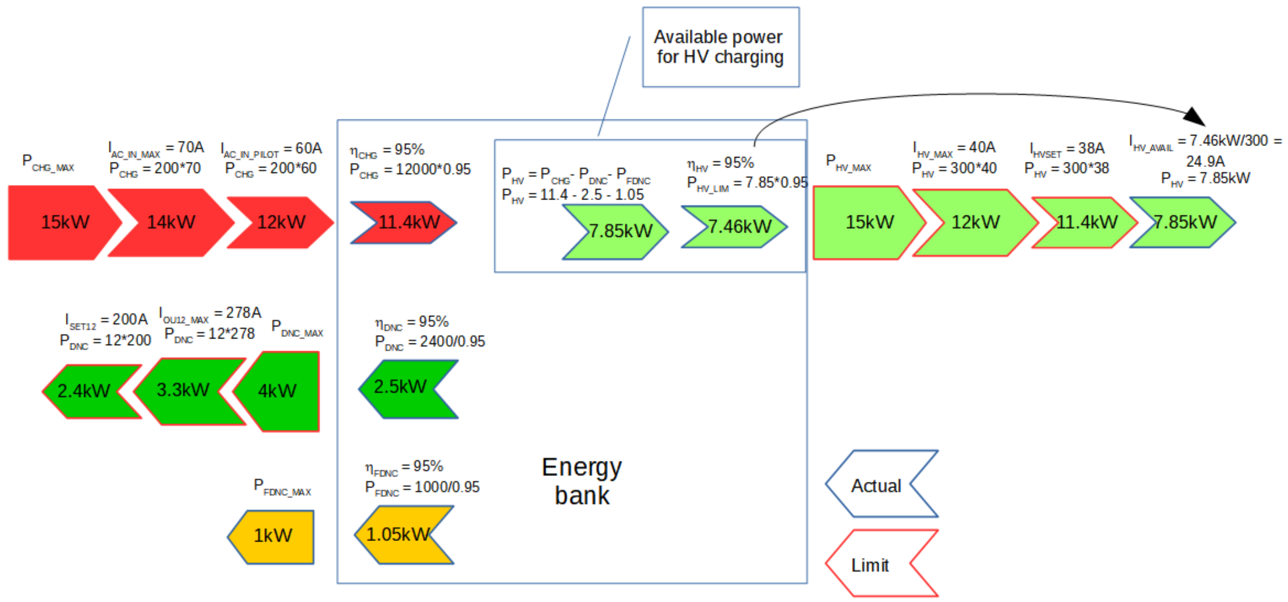


Figure 1-3: Example 1 - Energy flow and power limitation on output

Example 2

CHG: disabled
INV: enabled, P_{INV} = 7kW, invertor power limit is 7.85kW
FDNC: enabled, V_{OUT24} = 24V, I_{OUT24} = 41.7A, PFDNC = 1kW
DNC: enabled, V_{OUT12} = 12V, I_{SET12} = 200A
HV: V_{HV} = 300V, I_{HV_MAX} = 40A, available power from HV is 11.4kW; real consumption is 11kW

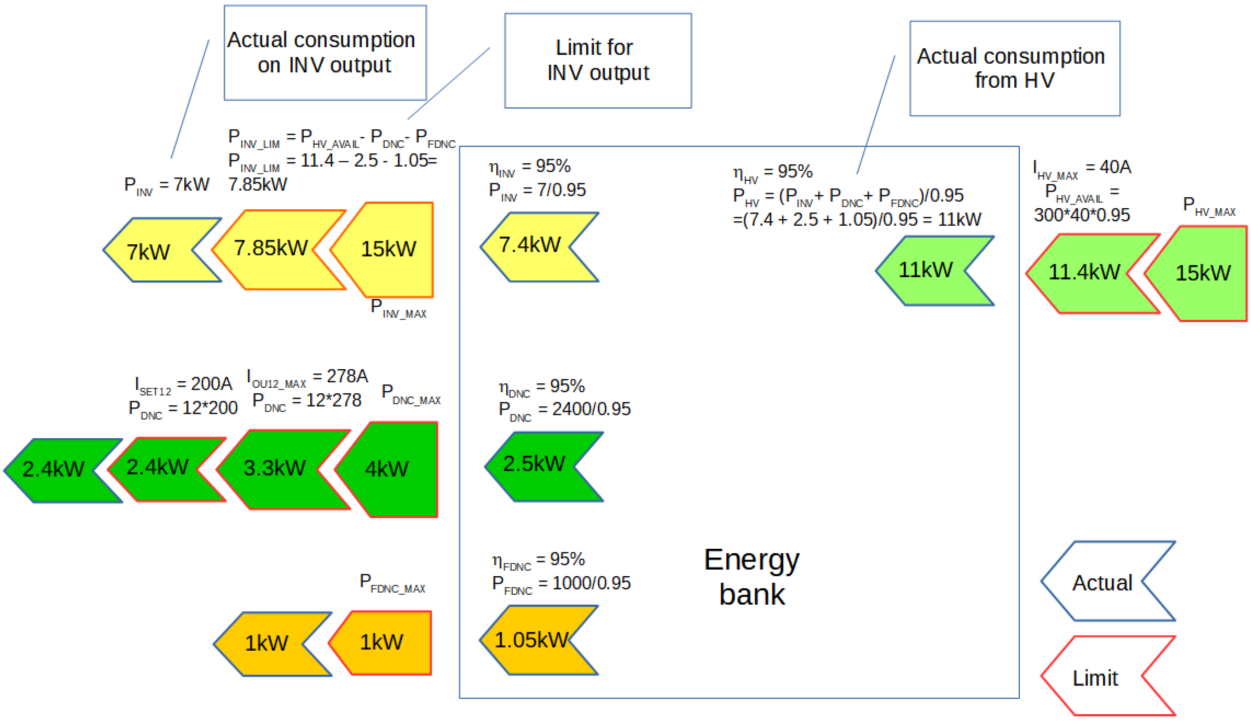


Figure 1-4: Example 2 - Energy flow and power limitation on output

1.3 Isolation Scheme

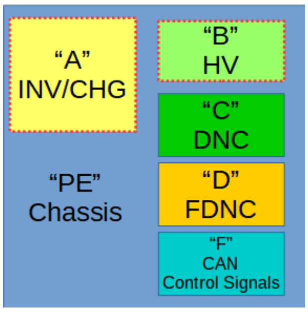


Figure 1-5: Isolation schematic

Following table covers insulation requirements for inverter-charger subcircuits.

	A -AC side	B – HVDC	C - Vout12	D - Vout24	F -CAN, signals	Chassis
A -AC side	x	Designed for 4242Vdc; Production test: 2500Vdc	Designed for 4242Vdc; Production test: 2500Vdc	Designed for 4242Vdc; Production test: 2500Vdc	Designed for 4242Vdc; Production test: 2500Vdc	Designed for 2500Vdc; Production test: 2500Vdc
B - HVDC		x	Designed for 4242Vdc; Production test: 2500Vdc	Designed for 4242Vdc; Production test: 2500Vdc	Designed for 4242Vdc; Production test: 2500Vdc	Designed for 2500Vdc; Production test: 2500Vdc
C - Vout12			x	Power return connected to chassis PE	Power return connected to chassis PE	Power return connected to chassis PE
D - Vout24				x	Power return connected to chassis PE	Power return connected to chassis PE
F -CAN, signals					x	Power return connected to chassis PE
Chassis						x

Note: Insulations barriers designed for 4242Vdc meets requirements for reinforced insulation.

2 Electrical Requirements – Inverter-Charger Subsystem

2.1 Spec for AC Side of the Inverter-Charger Subsystem

2.1.1 Operating Voltage Range

Charge mode:
AC grid is single phase, two wire plus ground, L, N, PE, (see wiring diagram 2.1.1 below)

Parameter	Min	Typ	Max	Unit
V_{AC_IN} Input voltage	90	100-240	264	V_{RMS}
f_{AC_IN} Input voltage frequency	47	50/60	63	Hz

Export mode:
Off-grid operation, 2 phases 120V_{RMS} (L1, L2) with 180° phase (split-phase), L1, L2, N, (see wiring diagram 2.1.1 below)

Parameter	Min	Typ	Max	Unit
V_{AC_OUT1} Output voltage, phase L1	108	120	128	V_{RMS}
V_{AC_OUT2} Output voltage, phase L2	108	120	128	V_{RMS}
f_{AC_OUT50} Output voltage frequency @ 50Hz	49.9	50	50.1	Hz
f_{AC_OUT60} Output voltage frequency @ 60Hz	59.9	60	60.1	Hz
THD			3	%

Tolerances of Vac are valid for loads up to nominal output currents 60Arms (line) / 40Arms (Neutral)
During overload conditions the Vac output voltage can go lower than minimal value specified above.
Note: THD value is related only to symmetrical load

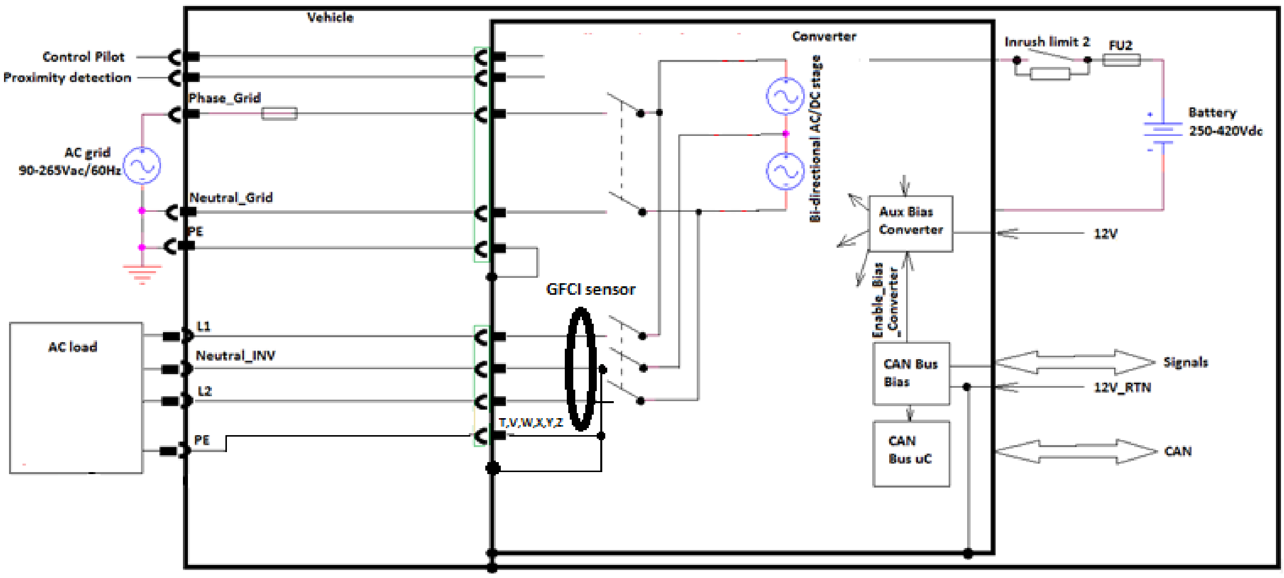


Figure 2-1: Invertor-charger wiring diagram

2.1.2 AC side current

Charge mode:

Parameter	Min	Typ	Max	Unit
I_{AC_IN} Charger input AC current @ V_{AC_IN}=195-264V			70	A_{RMS}
I_{AC_IN} Charger input AC current @ V_{AC_IN}=90-195V			30	A_{RMS}

Note: +/-1.5Arms tolerance of typical value due to limited accuracy of current sensing and rms calculation inside Inverter-Charger
Inverter-Charger control algorithm shall limit Inverter-Charger power in order to keep AC side current below required levels.

When input voltage is passing between given Max. current intervals, there is used following hysteresis for limiting:

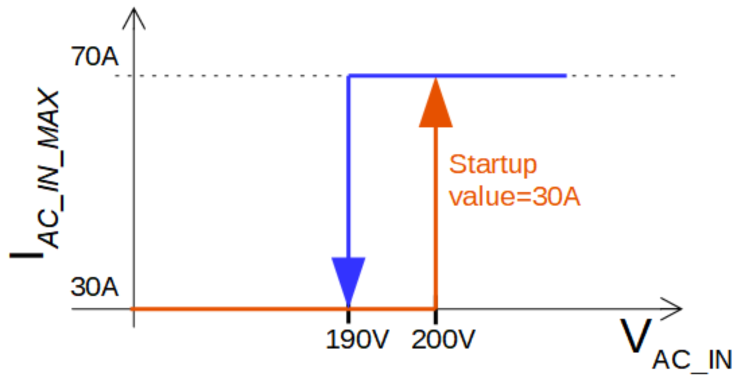


Figure 2-2 Charge mode – Max. current hysteresis

Export mode:

Parameter	Min	Typ	Max	Unit
I_{AC_OUT1} Output current, phase L1		60[1]		A_{RMS}
I_{AC_OUT2} Output current, phase L2		60[1]		A_{RMS}
I_{AC_OUTN} Output current, neutral wire		40[1]		A_{RMS}

[1] Maximum output current is variable based on available power/energy from power sources, refer to chapter 1.2

During short term overload the Line terminal output current can be up to 200% of maximal steady state value corresponding to actual HV battery voltage, actual 12V and 24V loads and actual coolant temperature.
During short term overload the Neutral terminal output current can be up to 150% of maximal steady state value corresponding to actual HV battery voltage, actual 12V and 24V loads and actual coolant temperature.

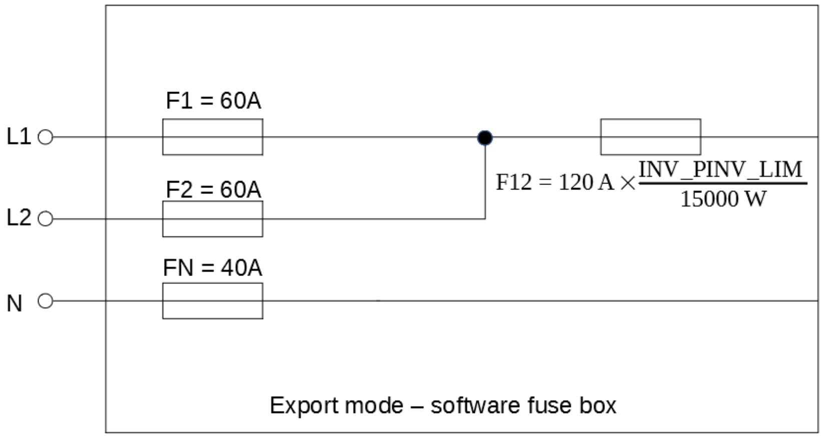


Figure 2-3 Export mode - software fuse box

Note: Inverter-Charger has special sophisticated feature implemented to prevent rapid temperature increase in case of blocked coolant. When rapid temperature increase is detected then charging AC current can be limited to 20A and maximum export mode current is limited to 30A. This state is indicated by status flag #39 bDncTempDrtngAct in CAN status message (0x00FFD4).

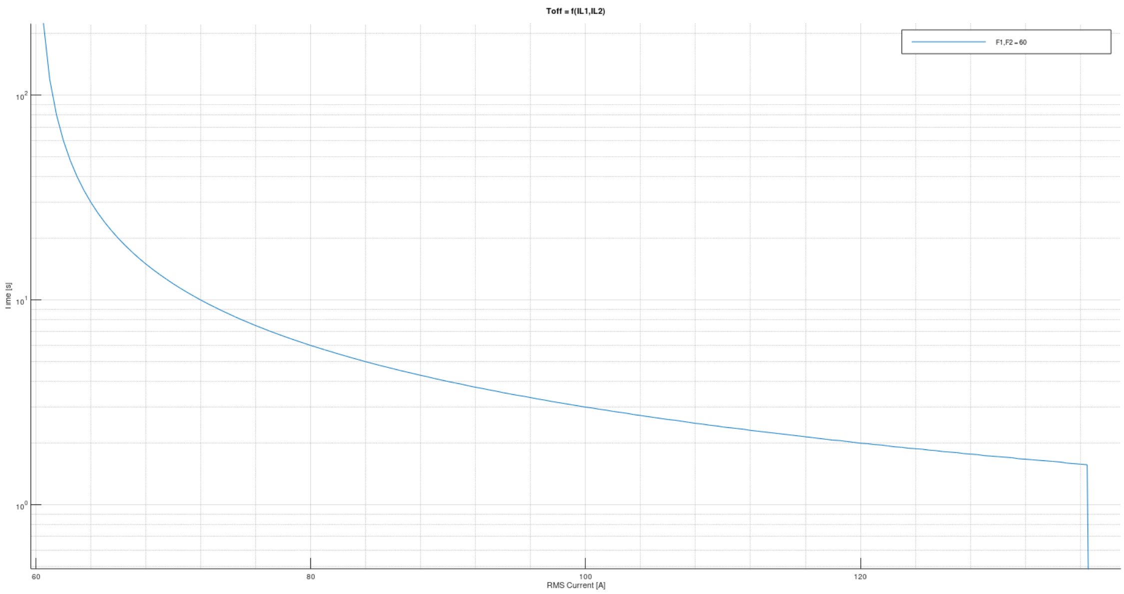


Figure 2-4: Export mode output current limit, phase L1, L2

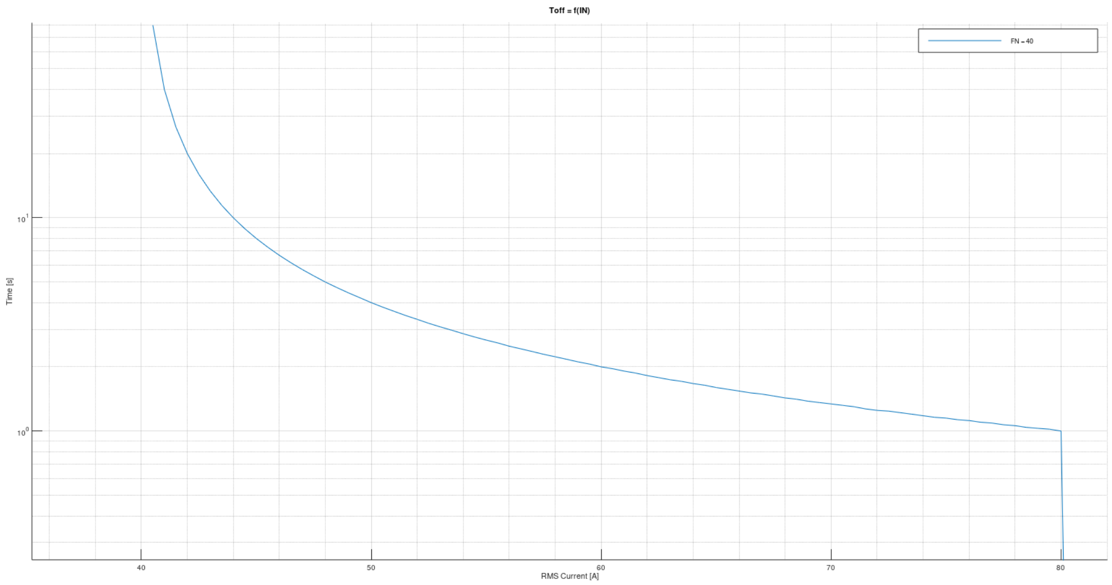


Figure 2-5: Export mode output current limit, neutral wire

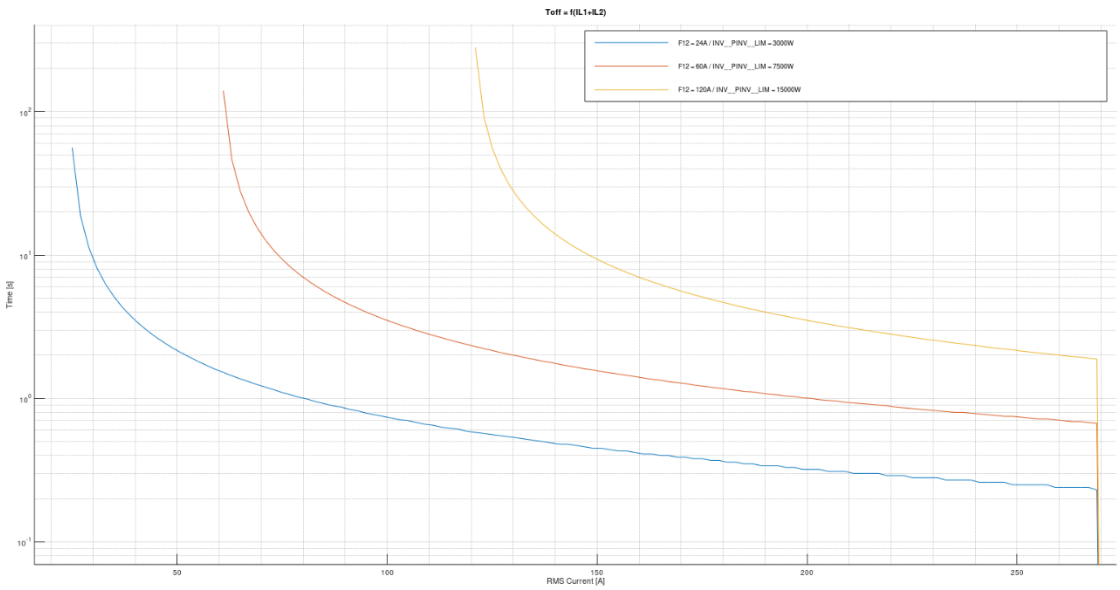


Figure 2-6 Export mode output current limit, L1+L2

2.1.3 Line Harmonic Current and Power Factor

The power supply shall have an active power factor correction and be fully compliant with the requirements of EN61000-3-12 (this standard is relevant for appliances with current >16Arms; current emission limits for equipment other than balanced three-phase equipment; Minimal Rsce 33) at 120Vac and 240Vac. P_{HV} = 250Vdc * 40Adc and P_{HV} = 435Vdc * 34Adc.
This requirement also includes even harmonics.

PF shall be higher than 0.95 at V_{AC_IN}=240V_{RMS}, P_{HV}=250Vdc*40Adc and 435Vdc*34Adc

2.1.4 Inrush Current

Customer shall use an external pre-charging circuit when connecting HV battery to the Inverter-Charger.
For information, the pre-charging shall takes less than approx.1 sec. (Tested battery system has pre-charge resistance 25R and overall charged capacity of the DC link is approximately 1000uF (traction

inverter + bi-directional Inverter-Charger +…)

Pre-charging of AC side bus capacitors shall be done by pumping energy from HV terminals.

Value of AC side capacitance of the Inverter-Charger shall be kept low - approximately 70uF.
Value of DC side capacitance of the Inverter-Charger shall be kept low - approximately 55uF.

2.1.5 Efficiency

Charge mode:
The efficiency of the Inverter-Charger (charge mode) shall be:
≥ 88% at V_{AC_IN}=240V_{RMS}, V_{HV}=375Vdc (Nominal), I_{HV}=40Adc, Tcoolant = 20°C
≥ 85% at V_{AC_IN}=240V_{RMS}, V_{HV}=250Vdc (Minimum), I_{HV}=40Adc, Tcoolant = 20°C

Export mode:
The efficiency of the Inverter-Charger (export mode) shall be:
≥ 88% at V_{HV}=375Vdc (Nominal), 435Vdc (Maximum), I_{AC_OUT1}=I_{AC_OUT2}=55Aac, Tcoolant = 20°C
≥ 85% at V_{HV}=250Vdc (Minimum), I_{AC_OUT1}=I_{AC_OUT2}=35Aac, Tcoolant = 20°C

2.1.6 AC Input Voltage Sags

EN61000-4-11, tested at V_{AC_IN}=120Vac and 230Vac, charge mode

Performance criterion	Dip	Duration
C	30%	100ms
C	30%	200ms
C	60%	20ms
C	60%	100ms
C	95%	20ms
C	95%	100ms

2.1.7 AC Leakage Current

Leakage current shall be less than 10mA measured at 264Vac, 63Hz.

2.1.8 Turn On/Off Delay

Export mode:
The turn-on delay of AC outputs after application of HV within the operating range and sending of export mode enable commands/signals shall be < 3s.
The turn off delay of AC outputs after sending of export mode disable commands/signals shall be less < 1s.
The voltage across AC side terminals shall fall below 60V in time shorter than 30s after Inverter-Charger turn off.

2.1.9 PARD (Periodic and Random Deviation)

Export power mode:
The maximum switching ripple excluding nominal 50 Hz / 60 Hz AC frequency ripple shall be within the limits specified below.

Output	Nominal Voltage	Condition	Limit

V_{AC_OUT1}	$120V_{RMS}$	Differential Mode 20MHz	+/-3.5Vpk*

* With external foil X2 capacitors 1uF connected to measuring point

2.1.10 Load Step Response

Export power mode:
The load step response due to dynamic load step at a rate of 1A/µsec is characterized in the table below.
Delta V is measured from the final steady value. The response time is measured from the application of the load step to the point where the output settles to within 1% of its final steady value.

Output	Voltage	Load Step 1 Iph1=Iph2	Load Step 2 Iph1=Iph2	Voltage Over/Undershoot	Response Time (<msec)
V_{AC_OUT1}	$120V_{RMS}$	$6A_{RMS}$ to $30A_{RMS}$ and back	$30A_{RMS}$ to $60A_{RMS}$ and back	± 30% of peak output AC voltage	4

2.1.11 Turn-On Overshoot

Export mode:
The turn-on overshoot due to any power up or power down operation of input or CAN shall be <15Vac of the nominal output voltage and it should take less than 8.33ms (half wave)

2.1.12 DC Input current Ripple Cancelation (DIRC)

Unit shall implement functionality to synchronize phase of output voltage in the export mode with second unit. Phases shall be shifted by 90°. This phase shift on the AC output will create phase shift 180° on the input (HV side). This can be useful, for example, when small battery is connected to the HV side and high current ripple can cause overheating of the cells. Units shall be interconnected with the SYNC signal. One unit shall be in the Master mode – MASTER/SLAVE signal shall be floating (not connected), and second unit shall be in the Slave mode – MASTER/SLAVE signal shall be connected to signal ground (Vout24-).

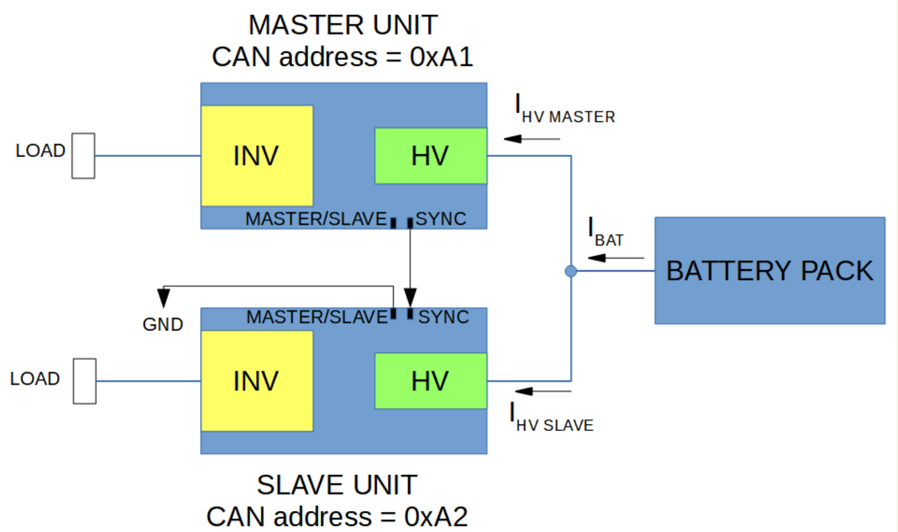


Figure 2-3 Block diagram of DIRC functionality

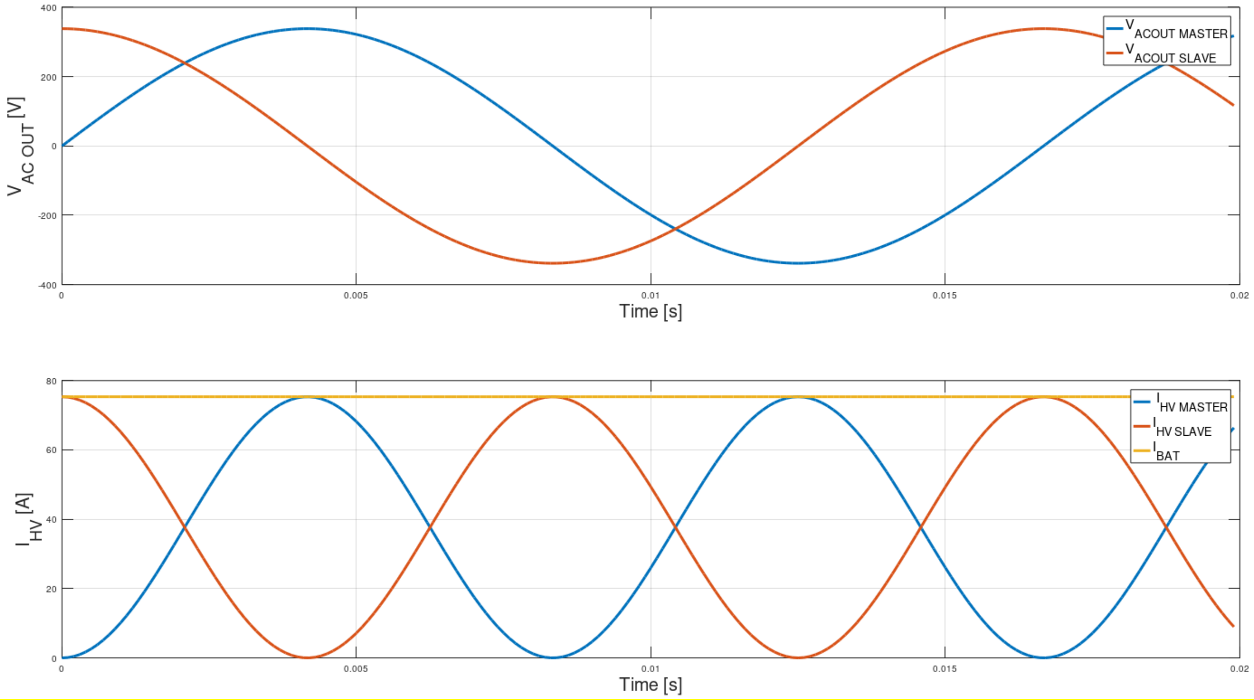


Figure 2-4 Plot of AC Output voltage and HV input current of two units with DIRC function

2.2 Spec for HV Side of the Inverter-Charger Subsystem

2.2.1 Rating

Charge/Export mode:

Parameter	Min	Typ	Max	Unit
I_{HV} HV dc current	0		40	$A_{DC(AVG)}$
P_{HV_MAX} HV side power	0		15	kW
V_{HV} HV voltage	250	375	435	V_{DC}

RMS value of the HV side current can be up to 52Arms. That means the current contain 100/120Hz sinewave component, ripple 0A to approx. 80Apk

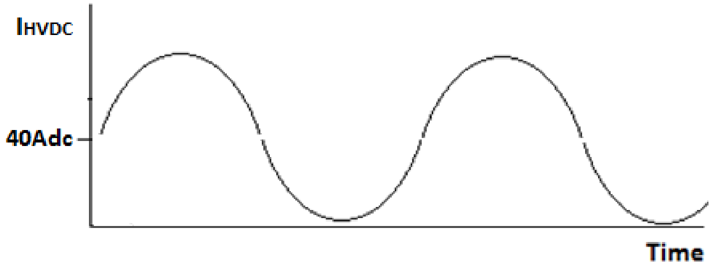


Figure 2-5: Typical waveform of I_{HV} to (from) battery

2.2.1.1 Power derating at high temperature

Output power of Inverter-Charger shall have power derating feature to limit output power at high temperature to protect Inverter-Charger from over-temperature condition or component overstress. Inverter-Charger shall provide nominal power up to +50°C coolant temperature.
Over the +50°C the output power/current can be reduced to 90% of nominal power/current to prevent overheating of internal components. Power/current derating curve shown on figure below is valid for all ambient temperature operating range up to +50°C.

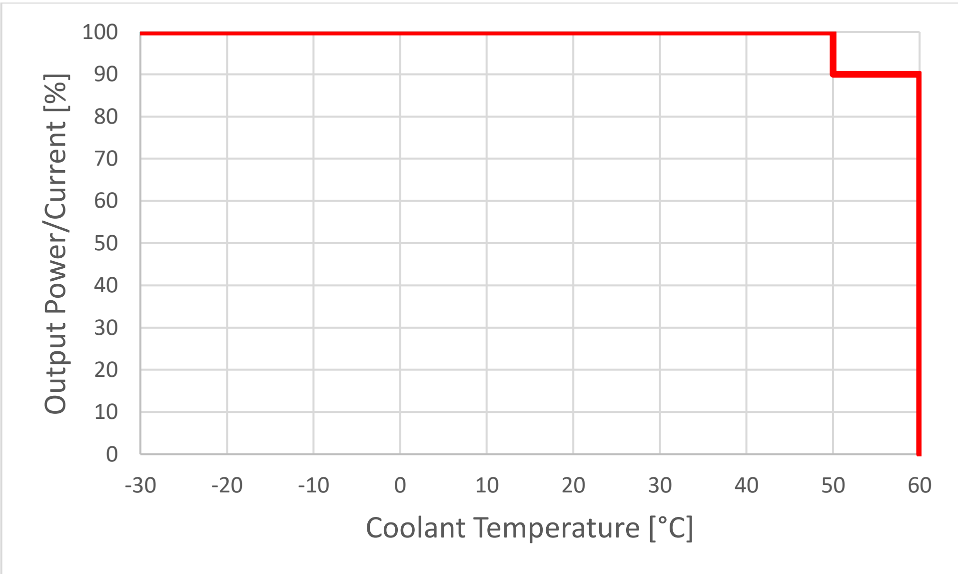


Figure 2-6: Power derating curve

2.2.2 Static Regulation

Charge mode:
Not applicable – Inverter-Charger operates as current source

2.2.3 Redundant Parallel Operation

Not applicable.

2.2.4 Remote Sense

Not applicable.

2.3 Inverter-Charger Protections

2.3.1 HV Over-Current Protection

In charge mode the HV side shall be protected from over-current and short-circuit due to natural functionality of current source output. Output current is adjustable over CAN bus and cannot be set over 40A.

Output HV current shall be further reduced by internal maximum power limit, input voltage derating and temperature derating feature to keep charger operating conditions within specification.

2.3.2 AC Over-Current Protection

In export mode the AC side shall be protected from over-current and short-circuit.
It is not an overload condition if phase current exceeds nominal $60A_{RMS}$ and nominal neutral wire current $40A_{RMS}$ in case that phase current does not exceed $120A_{RMS}$ per phase and neutral wire current $60A_{RMS}$ and the duration of this condition takes less than 2sec.
If this condition takes longer than 2s or currents exceeds $120A_{RMS}$ (phase) or $60A_{RMS}$ (neutral) the AC outputs can go into cycle by cycle current limit mode or hiccup mode. Refer to the During short term overload the Line terminal output current can be up to 200% of maximal steady state value corresponding to actual HV battery voltage, actual 12V and 24V loads and actual coolant temperature.
During short term overload the Neutral terminal output current can be up to 150% of maximal steady state value corresponding to actual HV battery voltage, actual 12V and 24V loads and actual coolant temperature.

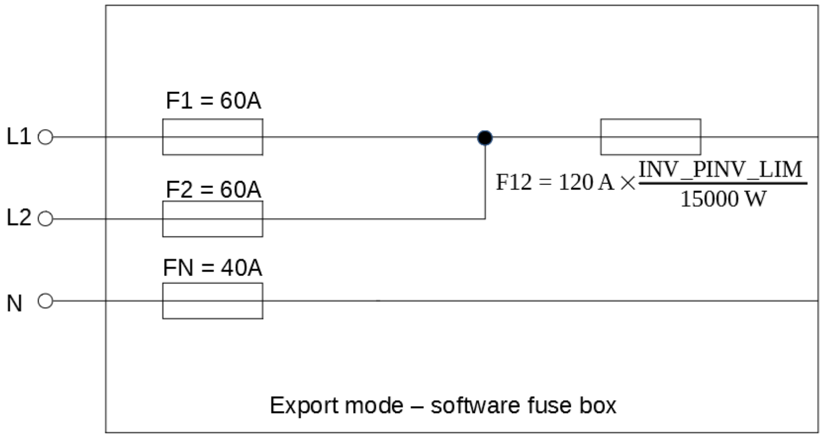


Figure 2-3 Export mode - software fuse box

Note: Inverter-Charger has special sophisticated feature implemented to prevent rapid temperature increase in case of blocked coolant. When rapid temperature increase is detected then charging AC current can be limited to 20A and maximum export mode current is limited to 30A. This state is indicated by status flag #39 bDncTempDrtngAct in CAN status message (0x00FFD4).

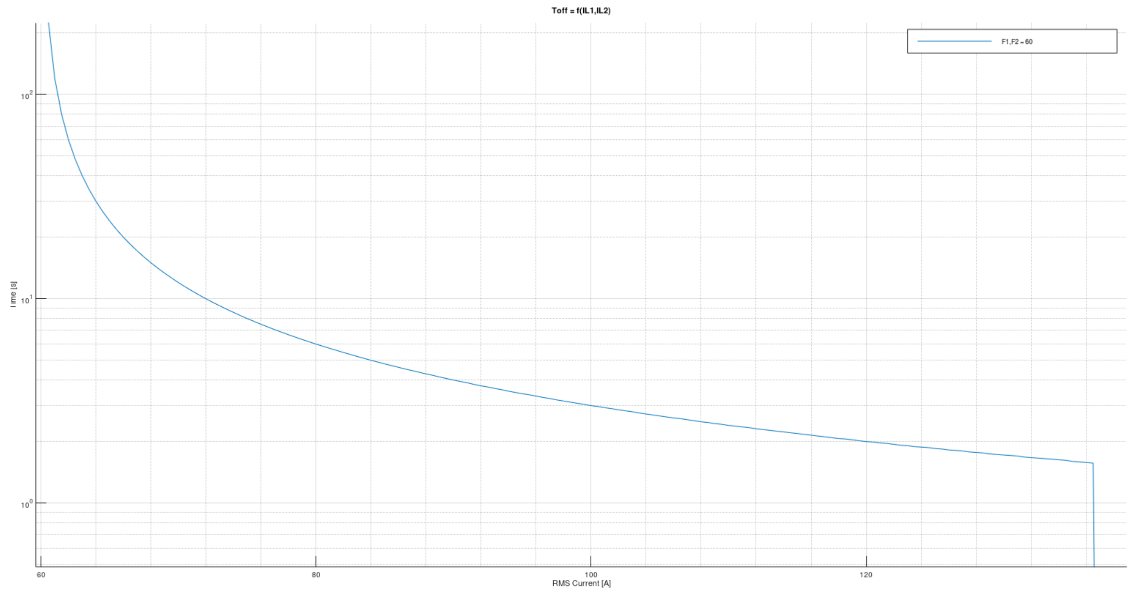


Figure 2-4: Export mode output current limit, phase L1, L2

2.3.3 HV Over-Voltage Protection

Over-Voltage protection (OVP) shall be provided for the HV terminals as specified below. The OVP shall be latch-type which shall disable the converter system. Converter system shall recover by CAN bus command.

Terminals	Voltage	OVP Trip Range	Maximum OV Duration
HV	*250-435Vdc*	440V default value Levels will be CAN adjustable. Range 240-440Vdc. Accuracy +/-10Vdc	1ms

Hysteresis typical 10Vdc to clear HV OPV flag is added to prevent oscillation.

2.3.4 HV Under-Voltage Protection

Under-Voltage protection (UVP) shall be provided for the HV terminals. The UVP disable the converter system. Once the cause of the fault is removed, unit need to be commanded to turn on. Under-Voltage flag is cleared when HV voltage increases above UVP set point plus 10Vdc providing hysteresis.

Terminals	Voltage	UVP Trip Range	Maximum UV Duration
HV	Decreasing Increasing	220Vdc 240Vdc Accuracy +/-10Vdc	1s

2.3.5 Reverse Polarity Protection

No electronic reverse polarity protection shall be provided for HVDC output. Input connector shall be equipped by key feature preventing reversed plug in.

2.3.6 Over-Temperature Protection

The Inverter-Charger shall incorporate thermal protection feature to prevent damage or degradation due to overheating.
The Inverter-Charger shall turn off if there is an over temperature condition. Once the temperature of the Inverter-Charger is reduced within the normal limit, the Inverter-Charger need to be commanded to start.

2.3.7 Input and Output Fuse Protection

- AC input fuse: shall be provided by EVSE (Electric Vehicle Supply Equipment) circuit breaker, maximum allowed circuit breaker rating is 100A Type D
- AC output fuse: NA – Inverter-Charger shall have electronic output overcurrent protection.
- DC line fuse: shall be HINODE ELECTRIC Co., Ltd. p/n 660GH-80UL
- Aux_Supply_12V fuse: all 12V inputs (Vbat and Key_Switch) shall be fused by external Automotive (Car) fuse 7.5A, Joule integral of the fuse must be less than $70A^2s$ (e.g.: LITTELFUSE 028707.5PXCN)
- For fusing of down converters see specific section in this specification below

2.3.8 ALCI (Appliance Leakage Current Interrupter)

Inverter-Charger shall be equipped with differential current sense transformer at AC side output. Differential current trip range shall be within 20 to 30mA. In case of higher differential current than trip level the inverter shut down and disconnect AC side relays. Maximum turn off delay from ALCI trip point shall be 30ms.

2.3.9 AC side Over-Voltage Protection

Over-Voltage protection (OVP) shall be provided. The OVP disable the inverter- charger input stage. Once the cause of the fault is removed, unit need to be commanded to turn on.

Side	Voltage	OVP Trip Range	Max
AC	$264V_{RMS}$	Turn off Typ. 270Vrms Turn on Typ. 265Vrms	(Max $275V_{RMS}$) (Min $260V_{RMS}$)

AC side will be equipped with properly rated varistors (surge protection) to survive surge test.

2.3.10 AC side Under-Voltage Protection

Under-Voltage protection (UVP) shall be provided. The UVP disable the charger/inverter input stage. Once the cause of the fault is removed, unit need to be commanded to turn on DC output.

Output	Voltage	UVP Trip Range	Max
V_{AC_IN}	$90V_{RMS}$	Turn off Typ. $83V_{RMS}$ Turn on Typ. $88V_{RMS}$	(Max $85V_{RMS}$) (Max $90V_{RMS}$)

2.4 Inverter-Charger Control Signals

These are Control signals which are directly connected from the vehicle system to the Inverter-Charger. Although these signals are input to the Inverter-Charger the noise requirements must be met as the control signal may be shared with other system components.

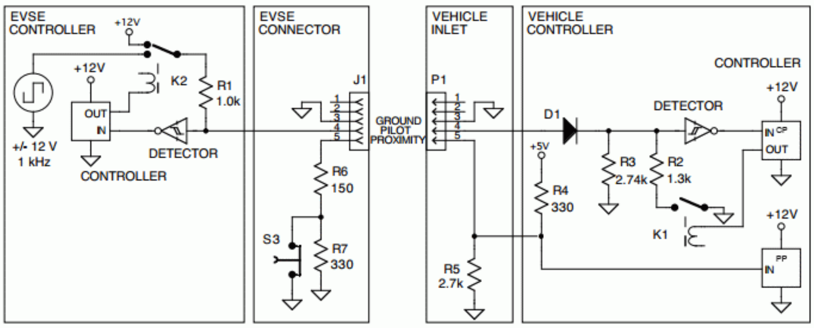


Figure 2-7: J1772 signaling circuit. For details see SAE J1772

Note: Circuit example picture form [Wikipedia]

2.4.1 Control Pilot

SAE J1772 compatible.
Duty cycle accuracy +/-2% in range 20 – 96%.
Duty cycle accuracy -2/+5% in range 10 – 20%.

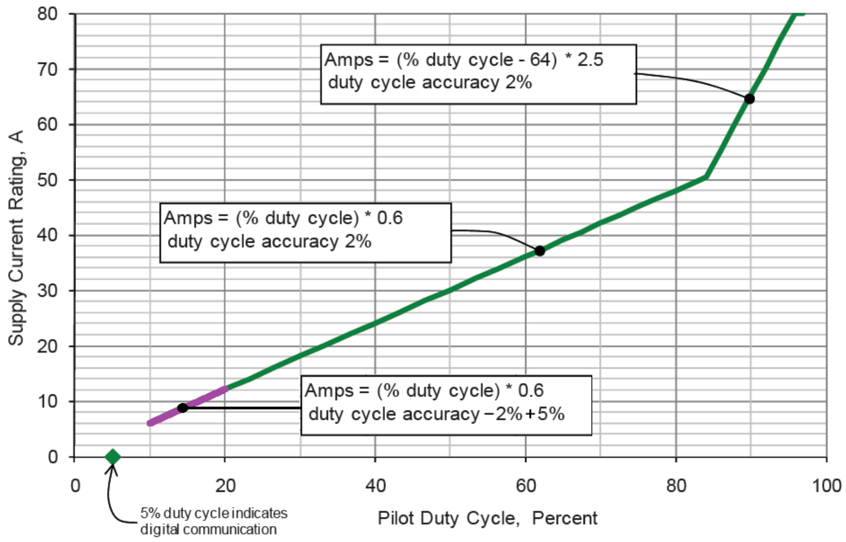


Figure 2-8: Supply current versus Control pilot

5% Duty cycle indicates connected DC fast charger.
Control Pilot signal needs series impedance before it is connected to internal control circuits of AC on board charger. This impedance prevents unwanted loading of HF signals of PLC communication. Unfiltered Control Pilot signal is copied to pin 3 of signal connector.

2.4.2 Proximity Detection

Function and levels according SAE J1772

3 Electrical Requirements – 12V Down Converter

3.1 DC Output

3.1.1 Rating

The Down Converter shall be designed, labeled and Safety approved to the maximum continuous rating. Maximum continuous output power rating 4000 W.

Parameter	Min	Typ	Max	Unit
V_{OUT12} Output voltage, adjustable by CAN	9	14.4	14.4	V
P_{12} Continuous power	0		4000	W
I_{OUT12} Output current, adjustable by CAN	0		278	A
η_{12} Efficiency of 12Vout buck stage @ V_{OUT12}= 14.4V, VHV = 350V, I_{OUT12} = 278A	92			%

3.1.2 Static regulation of V_{OUT12}

Parameter	Conditions	Minimum	Typical	Maximum	Unit / Note
Line regulation	Vin min - Vin max, at 139A, Tamb= 45°C	-0.1		+0.1	VDC
Load Regulation	Vo droop between 27 A and 278 A load, Tamb= 45 °C	~~0.1~~		0.2	VDC
Vo Set Point	At 139 A, Tamb= 45 °C	14.35	14.4	14.45	VDC
Output voltage range	Adjustable via CAN BUS	9.0		14.4	VDC
Thermal Drift	After 15 min warm up period	-0.05		+0.05	%/°C

3.1.3 PARD (Periodic and Random Deviation) of Vout12

The maximum PARD at 25°C shall be within the limits specified below.

Output	Nominal Voltage	Conditions	Limit
V_{out12}	+14.4 V	Differential Mode 20 MHz	288 mVpkpk*

* With external capacitors 47 uF (Electrolytic cap) & 1 uF (X7R Ceramic cap) connected to measuring point

3.1.4 Redundant Parallel Operation

Not Applicable

3.1.5 Remote Sense

The Vou12 output shall incorporate remote sense and shall compensate for specified load cable drop. In the event of loss of remote sense, output shall revert to internal sense so as to limit the outputs to less than 105 % of nominal. Outputs shall be protected against reversal of sense leads.

Output	Voltage	Cable Drop @ Maximum Load
V_{out12}	+14.4 V	0.5 V

3.1.6 Turn on Delay

The turn-on delay after application of HV within the operating range, after setting of proper signals and after sending of relevant CAN commands shall be as defined in the following tables.

The output rise times shall be measured from 10 % of the nominal output to the 90 % of the nominal output. Monotonic is defined as having no negative inflections in the output voltage due to system loads.

Output	Min	Max	Notes
V_{out12} Rise time		300 ms	Cext = 0 uF
V_{out12} Power-on-delay		2 s	From applying of HV voltage + CAN and signal enables to Vo=90%

3.2 Protection

3.2.1 Vout12 Output Over-Current Protection

Vout12 shall be protected from over-current and short-circuit.

If load causes that output current should exceed nominal level (corresponding to set Vout12 voltage level) the converter starts to limit its output. (converter acts as current source).

If output runs in current limitation and its voltage drops below approximately 8 VDC for more than 1 s, the output can shut down and latch off. Error condition must be reported over CAN J1939 interface as a high priority.

3.2.1.1 Vout12 Short Circuit Survival

The Vout24 DC-DC converter is required to protect itself and not sustain any permanent damage.

3.2.2 Vout12 Output Over-Voltage Protection

Over-Voltage protection (OVP) shall be provided for the Vout12 output. The OVP shall be latch-type which shall disable the output. Once the cause of the fault is removed, the converter shall recover by CAN command.

Output	Voltage	OVP	OVP Trip Range	Maximum OV Duration
V_{out12}	+14.4 V	>17 V	17.0 V – 18.0 V	1 ms

For single output only: Converter output needs to be rated to be able to handle Jump Start according SAE J1455 (32V, 5minutes)

3.2.3 Vout12 Output Under-Voltage Protection

Under-Voltage protection (UVP) shall be provided for the Vout12 output. Error condition must be reported over CAN J1939 interface as a high priority.

Output		Voltage	UVP	UVP Trip Range	Maximum UV Duration
V_{out12}		+14.4 V	<8 V	6.0 V – 8.0 V	1 s

3.2.4 Vout12 Reverse Polarity Protection

The converter is required to protect itself against reverse polarity on output according SAE J1455 and not sustain any permanent damage (test -12 V, 5 minutes). Once the cause of reverse polarity on output terminals is removed, the converter shall recover automatically.

3.2.5 Vout12 Fuse Protection

There is no internal fuse on Vout12 output.
No external fuse is required if there is no other power source connected in parallel with Vout12.
In case the hi-power source like battery is connected to Vout12 it is recommended to add fuse between Vout12 output and battery to protect wiring and connectors from catastrophic failure caused by short circuit.
Fuse example: LITTELFUSE p/n: 153.5395.6401 - automotive 32V/400A.

3.3 Ground scheme

V_{out12} return has the same potential as V_{out12} return and is connected to chassis PE.

4 Electrical Requirements – 24V Down Converter Section

4.1 DC Output

4.1.1 Operating Voltage Range

Parameter	Min	Typ	Max	Unit
V_{OUT24} Output voltage, adjustable by CAN	18	28.8	28.8	V
P_{24} Continuous power	0		1000	W
I_{OUT24} Output current, adjustable by CAN	0		34.7	A
η_{12} Efficiency of 24Vout buck stage @ V_{OUT24}= 28.8V, VHV = 350V, I_{OUT24} = 15A	92			%

* Vout24 - There can be battery connected on the 24V output.

4.1.2 Vout24 Static regulation

Parameter	Conditions	Minimum	Typical	Maximum	Unit / Note
Line regulation	Vin min - Vin max, at 17A, Tamb= 45°C	-0.2		+0.2	VDC
Load Regulation	Vo droop between 4 A and 34 A load, Tamb= 45 °C			0.4	VDC
Vo Set Point	At 17 A, Tamb= 45 °C	28.6	28.8	29.0	VDC
Thermal Drift	After 15 min warm up period	-0.05		+0.05	%/°C

4.1.3 PARD (Periodic and Random Deviation)

The maximum PARD shall be within the limits specified below.

Output	Nominal Voltage	Conditions	Limit
V_{out24}	+28.8 V	Differential Mode 20 MHz	600 mVpkpk*

* With external capacitors 47 uF (Electrolytic cap) & 1 uF (X7R Ceramic cap) connected to measuring point

4.1.4 Vout24 Load Step Response

The load step response due to dynamic load step at a minimum rate of 2A/µsec is characterized in the table below. The performance shall be met at any load from minimum to 100% of the rated load.

Delta V is measured from the final steady value. The response time is measured from the application of the load step to the point where the output settles to within 1% of its final steady value.

Output	Voltage	Load Step 1	Load Step 2	Voltage Over/Undershoot	Response Time (< µsec)
V_{out24}	+28.8V	10 to 50 % and back	50 to 100 % and back	± 3500 mV	1000

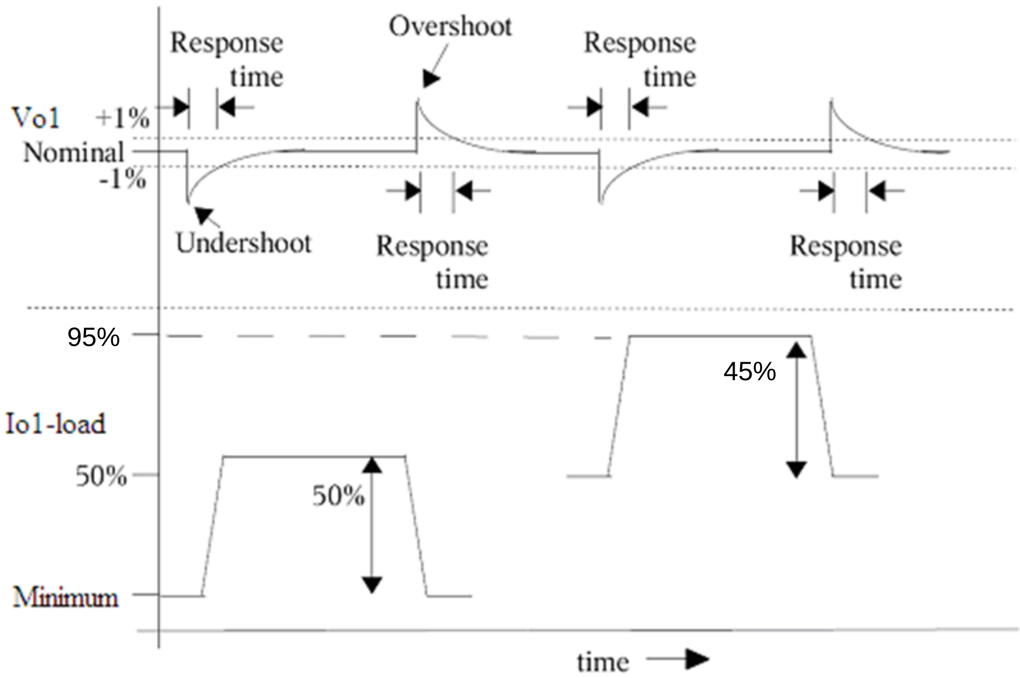


Figure 4-1: Load step response

4.1.5 Vout24 Turn-On Overshoot

The turn-on overshoot due to any power up or power down operation of input or Enable shall be < 5 % of the nominal output voltage and it should take less than 100 ms for any application of input voltage or load within the specified range.

4.1.6 Vout24 Redundant Parallel Operation

Not Applicable

4.1.7 Vout24 Remote Sense

Not applicable.

4.1.8 Vout24 Turn on Delay

The turn-on delay after application of input within the operating range shall be as defined in the following tables.

The output rise times shall be measured from 10 % of the nominal output to the 90 % of the nominal output. Monotonic is defined as having no negative inflections in the output voltage due to system loads.

Power on delay, rise time signaling

Parameter	Min	Max	Notes
V_{out24} Rise time		300 ms	Cext = 0 uF
V_{out24} Power-on-delay		2 s	From applying of HV input voltage to Vo=90%
~~**V_{out24} Power-on-time from CAN command**~~		~~100 ms~~	~~From CAN command ON to V_{out24}=90% of nom (HV input ON, VBAT ON)~~

4.1.9 Vout24 Capacitive Loading

The DC-DC converter shall be able to power up and operate normally with the following capacitance on the DC outputs. Any ultra-low ESR type capacitors are present on the system planes are noted in the last column.

Output	Voltage	Nominal Capacitive Load	Maximum Capacitive Load	Very low ESR Capacitors
V_{out24}	+24 V	0 uF	1,000 uF	

4.2 Vout24 Protection

4.2.1 Vout24 Output Over-Current Protection

Output shall be protected from over-current and short-circuit.

If load causes that output current should exceed nominal level 34.7A the converter starts to limit its output. (converter acts as current source)

If output runs in current limitation and its voltage drops below approximately 16VDC for more than 1 s, the output can shut down and latch off. Error condition must be reported over CAN J1939 interface as a high priority.

4.2.1.1 Vout24 Short Circuit Survival

The Vout24 DC-DC converter is required to protect itself and not sustain any permanent damage.

4.2.2 Vout24 Output Over-Voltage Protection

Over-Voltage protection (OVP) shall be provided for the output specified below. The OVP shall be latch-type which shall disable the output. Once the cause of the fault is removed, the converter shall recover by CAN command.

Output	Voltage	OVP	OVP Trip Range	Maximum OV Duration
V_{out24}	+24 V	>29 V	29 V – 32.0 V	1 ms

4.2.3 Vout24 Output Under-Voltage Protection

Under-Voltage protection (UVP) shall be provided. Error condition must be reported over CAN J1939 interface as a high priority.

Output	Voltage	UVP	UVP Trip Range	Maximum UV Duration
V_{out24}	+24 V	<16 V	13 V – 16 V	1 s

4.2.4 Vout24 Output Reverse Polarity Protection

The converter is required to protect itself against reverse polarity on output according SAE J1455 and not sustain any permanent damage (test -30 V, 5 minutes). Once the cause of reverse polarity on output terminals is removed, the converter shall recover automatically.

4.2.5 Vout24 Fuse Protection

There is no internal fuse on Vout12 output.
No external fuse is required if there is no other power source connected in parallel with Vout24.
In case the hi-power source like battery is connected to Vout12 it is recommended to add fuse between Vout24 output and battery to protect wiring and connectors from catastrophic failure caused by short circuit.

Fuse example: LITTELFUSE p/n: 0299050.TXN - automotive 32V/50A.

4.3 Ground scheme

V_{out24} return has the same potential as V_{out12} return and is connected to chassis PE.

5 N/A

6 Converter Control Signals

These are Control signals which are directly connected from the vehicle system to the DC-DC converter. Although these signals are input to the converter the noise requirements must be met as the control signal may be shared with other system components.

6.1.1 EVSE_WAKE_OUT

Energy taken from VBAT.
High side switch to wake VCU (Vehicle Control Unit) and other vehicle control modules. Output is protected by resettable PTC fuse (TDK B59707A0120A062).

Parameter	Min	Typ	Max	Unit
V_{WAKE} Output voltage	9	12.5	16	V
$R_{DS(ON)}$ On state resistance		125		Ω
I_{WAKE} Nominal output current		10		mA

6.1.2 IGN (Key_Switch signal)

Thisw signal enables internal aux converter and is one of wake-up source.
Level High = Enable
It is referenced against 12V_RTN

Parameter	Min	Typ	Max	Unit
V_{IGN_ABS} Absolut maximum rating	-0.2		16	V
V_{IGN_HI} High level	8	12.5	16	V
V_{IGN_LOW} Low level	0	0	2	V
I_{IGN_IN} Input current @14.4V	0.3	0.6	1	mA

6.1.3 VBAT

12V battery voltage input. Used to supply internal aux converter. Input shall be protected against reverse connected battery by anti-parallel diode. (Serial diode would have too much dissipations because the Vbat input current is around 3A)

Parameter	Min	Typ	Max	Unit
V_{BAT_ABS} Absolut maximum rating	0		16	V
V_{BAT} Recommended Operating Conditions	9	12.5	16	V
V_{BAT} Under-voltage protection		8.5		V
V_{BAT} Over-voltage protection (duration >500ms)		16.5		V
I_{BAT_OP} Input current @ 12.5V, normal operation		4.5	6	A
I_{BAT_STB} Input current @ 12.5V, stand-by mode		1.2	1.5	A
I_{BAT_SLEEP} Input current @ 12.5V, sleep mode (Key Switch enabled; microcontroller in sleep mode)		100	150	mA
$I_{BAT\_KEYSW\text{-}OFF}$ Input current @ 12.5V, sleep mode when key switch is off		0.2	3	mA

6.1.4 Wake up and Sleep mode

When unit is in Sleep mode, current consumption from VBAT shall be less than 3mA@14.4Vdc. Unit shall be able to wake up using two wake up sources: Control Pilot signal and IGN signal. Unit shall asleep when Go to sleep command is received or if unit does not receive RUN signal during 5 sec after wakeup (wakeup timeout) or during normal operation (watch dog timeout).
RUN signal goes high when some message with unit address is received by unit.
RUN signal goes low when during 100ms there was no message received by unit.
Several scenarios can occur:

6.1.4.1 Scenarios 1,5 – IGN/CONTROL PILOT Wake up and wake up timer

In time t_0 IGN signal goes high and in time t_1 unit start sending CAN broadcast messages and start countdown wakeup timer. After t_{WAKE}, in time t_3 there is still no RUN signal and unit goes to the Sleep mode.

6.1.4.2 Scenarios 2,6 – IGN/CONTROL PILOT Wake up and watch dog timer

Unit is running, but in time t_4 RUN signal goes low. Unit start count down watch dog timer and after $t_{WDT}=t_{WAKE}$, in time t_5 unit goes to the Sleep mode.

6.1.4.3 Scenario 3 and 4 – IGN Wake up and Sleep command

When VCU want to command unit to Sleep mode, VCU shall set Sleep = 1 command to unit. In t_6 unit stop all CAN communication and goes to sleep mode after Sleep = 1 and IGN wake up source is low. When Sleep is set and IGN = 1 unit stop operation (DNC, FNDC, INVCH stages goes OFF) but CAN is still on. Sleep can be set again to low and unit can continue with normal operation. In t_8 Sleep = 1 and IGN goes to low, unit goes to the sleep mode.

6.1.4.1 Scenario 7 and 8 – CONTROL PILOT Wake up and Sleep command

When VCU want to command unit to Sleep mode, VCU shall set Sleep = 1 command to unit. In t_6 unit stop all CAN communication and goes to sleep mode after Sleep = 1. When Sleep is set and CONTROL PILOT is active, unit goes to the sleep mode and PILOT signal is blocked as a wake-up source. This is useful when unit(vehicle) is connected to the charging station and battery is fully charged – unit can go to sleep mode even if PILOT is active. Unit can be wake up again only when PILOT signal goes low for minimum t_{PILOT_OFF} time. This will reset blocking of PILOT signal as a wake-up source.

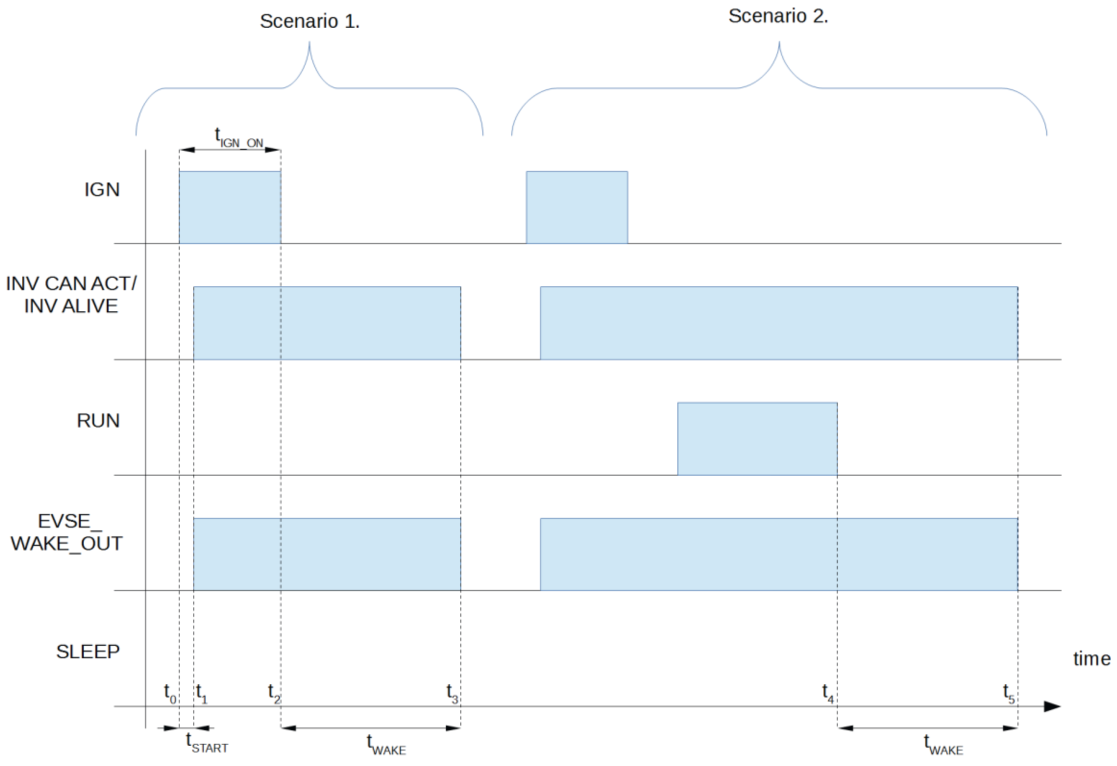


Figure 6-1: IGN Wake up - Scenarios 1,2

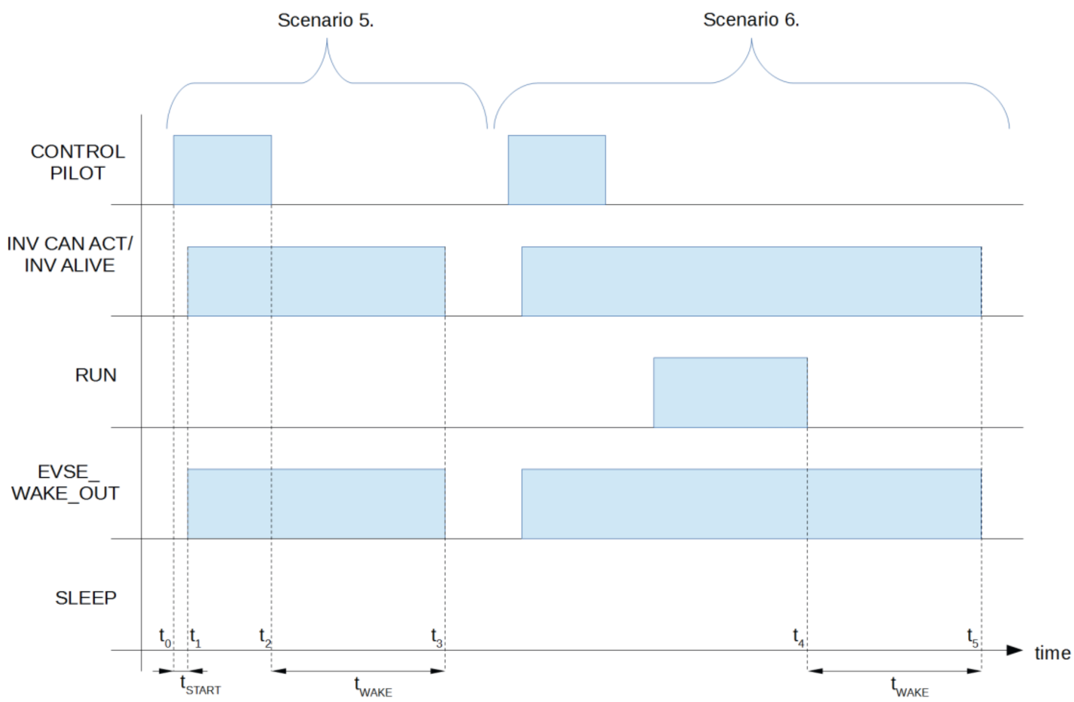


Figure 6-2: CONTROL PILOT Wake up - Scenarios 5,6

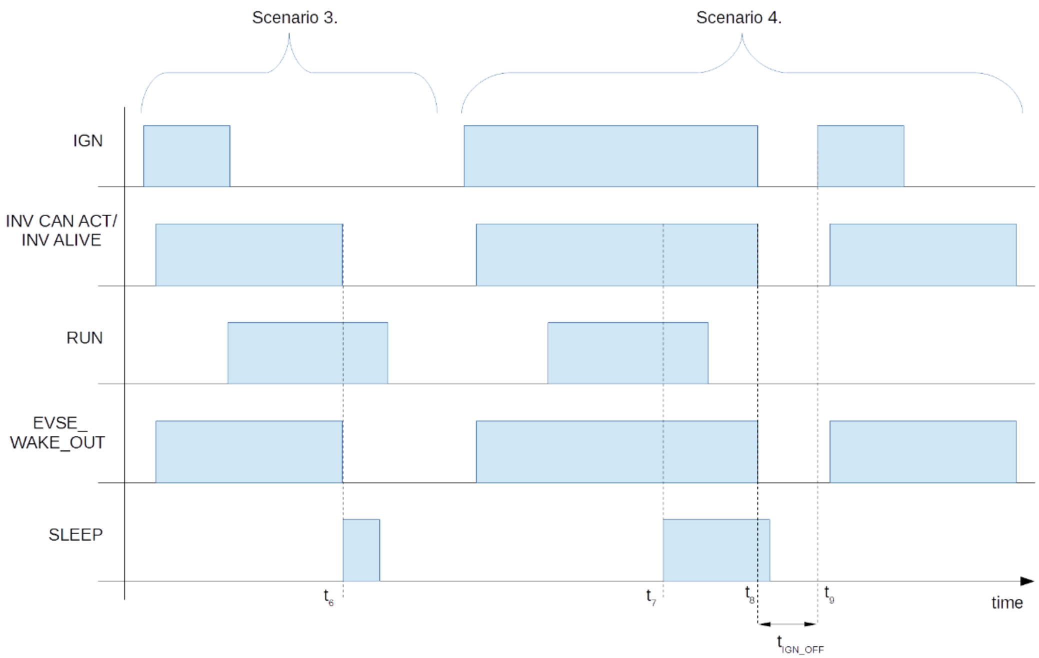


Figure 6-3: IGN Wake up - Scenario 3,4

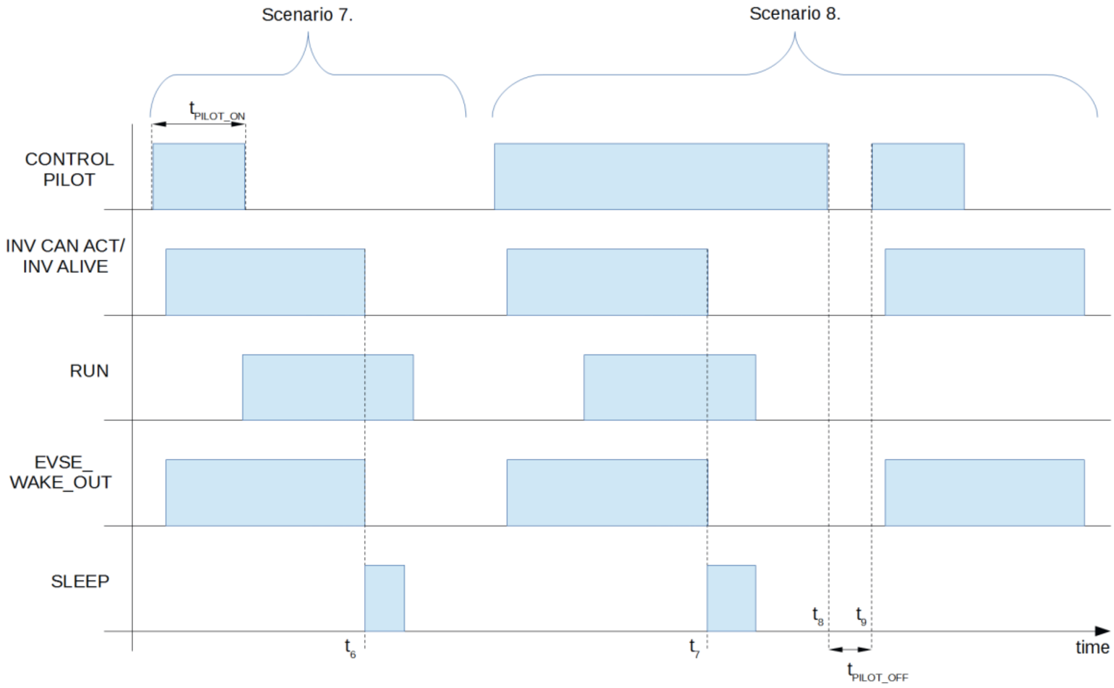


Figure 6-4: CONTROL PILOT Wake up - Scenario 7,8

Parameter	Min	Typ	Max	Unit
t_{WAKE} Wake up timeout	4.8	5	5.2	sec
t_{START} Start up time of CAN communication	0	0.5	1	sec
t_{IGN_ON} IGN signal pulse length	0.5			sec
t_{PILOT_OFF}	1			sec
t_{IGN_OFF}	1			sec

6.1.5 MASTER/SLAVE

When DIRC functionality is used, MASTER/SLAVE input pin is used to select MASTER or SLAVE mode.
It is referenced against 12V_RTN

Settings:
MASTER – signal not connected / left floating (Note: Master's CAN address will be automatically changed to the 0xA1)
SLAVE – signal grounded; connected to 12V_RTN. (Note: Slave's CAN address will be automatically changed to the 0xA2)

MASTER/SLAVE mode is detected only at start up when 12V voltage is applied.
It is not possible to change MASTER/SLAVE mode after start up - during normal operation.

Parameter	Min	Typ.	Max	Unit
$V_{MASTER/SLAVE}$ Absolut maximum rating	-0.2		16	V
$V_{MASTER/SLAVE}$ High level	8	12.5	16	V
$V_{MASTER/SLAVE}$ Low level	0	0	2	V
$I_{MASTER/SLAVE}$ Input current @14.4V	0.5	1	2	mA

6.1.6 SYNC

Synchronization signal used to synchronize two units (Master and Slave) during DIRC functionality. Master and Slave SYNC signals shall be connected together. The SYNC signal shall only be connected to another SYNC signal!

Parameter	Min	Typ.	Max	Unit
V_{SYNC} High level	2.4	5	5	V
V_{SYNC} Low level	0	0	1.8	V

6.1.7 HVIL_IN and HVIL_OUT

Signals used for HVIL (high-voltage interlock loop). Interlock is current and/or voltage loop mechanism used to detect tampering or opening of the high-voltage equipment.
It is referenced against 12V_RTN.
State of HVIL is reported on CAN (UNIT_Status_Message(0x18FFD4A0)- SIG_bHvilOk).
Signal SIG_bHvilOk = 1 when both HVIL_IN and HVIL_OUT are high.
Signal SIG_bHvilOk = 0 when one from HVIL_IN, HVIL_OUT is low.

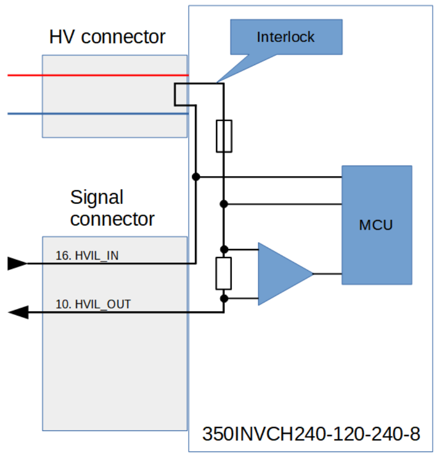


Figure 6-5: HVIL schematic

Parameter	Min	Typ	Max	Unit
V_{HVIL} Absolut maximum rating	-0.2		16	V
V_{HVIL} High level*	7.5		16	V
V_{HVIL} Low level*	0		5.5	V
I_{HVIL} Input leakage current @14.4V		4	6	mA
I_{HVIL} Measurement range*	-150		150	mA
I_{HVIL} Maximum continuous current	-300		300	mA
R_{HVIL} Series resistance (Shunt + Fuse) @ 100mA	1.15		2	Ω
Fuse type: PTC, PN: Littelfuse 1812L050/30				

*Current and voltage levels are not reported to the CAN bus, only logic state is reported.

6.2 System Management bus

6.2.1 CAN BUS SAE J1939 interface

CAN-bus communication allows complete integration of converter in the electrical system of trucks. CAN bus interface is described in separate communication manual BCA.20014:

6.2.2 CAN bus measured parameters and readback accuracy

CAN bus readbacks shall be measured with following accuracy:

Measured parameter	**Readback accuracy**	**Comments**
V_{AC_OUT1}	+/- 2 V_{RMS} OR +/- 4%	In range 90-130Vac
V_{AC_OUT2}	+/- 2 V_{RMS} OR +/- 4%	In range 90-130Vac
I_{AC_OUT1}	+/- 3 A_{RMS} OR +/- 4%	In range 6 – 120 Arms
I_{AC_OUT2}	+/- 3 A_{RMS} OR +/- 4%	In range 6 – 120 Arms
I_{AC_OUTN}	+/- 3 A_{RMS} OR +/- 4%	In range 6 – 60 Arms
I_{HV}	+/- 3 A_{DC} OR +/- 4%	
V_{HV}	+/- 2 V_{DC} OR +/- 4%	
V_{AC_IN}	+/- 5 V_{RMS} OR +/- 4%	In range 90-264Vac
I_{AC_IN}	+/- 6 A_{RMS} OR +/- 4%	
I_{OUT12}	+/- 2 A_{DC} OR +/- 4%	
V_{OUT12}	+/- 0.1 V_{DC} OR +/- 2%	
I_{OUT24}	+/- 2 A_{DC} OR +/- 4%	
V_{OUT24}	+/- 0.1 V_{DC} OR +/- 4%	
V_{BAT}	+/- 0.1 V_{DC} OR +/- 4%	In range 9-16Vdc

7 Substances of Concern/Environmental Impact

7.1 Hazardous and Toxic Materials

Components and or manufacturing processes containing the following substances shall be avoided and are prohibited from purchase:

- Beryllium Oxide
- Cadmium
- Capacitors containing Polychlorinated Napthalenes (PCN)
- Chlorinated Paraffin
- Hexavalent Chromium
- Lead
- Mercury
- Polybrominated Biphenyl's Ethers / Oxides (PBBE / PBBO)
- Polybrominated Diphenyl Ethers (PBDE).
- Bis(2-ethylhexyl) phthalate (DEHP)
- Butyl benzyl phthalate (BBP)
- Dibutyl phthalate (DBP)
- Diisobutyl phthalate (DIBP)
- Polychlorinated Biphenyl's (PCB)
- Polychlorinated Terphenyls (PCT)
- Asbestos
- Azo colorants
- Radioactive substances

The following substances may not be used in the manufacturing process:

- Chlorofluorocarbons (CFC)
- Class I Ozone Depleting Substances (Annex A and Annex B of the Montreal Protocol).

7.2 EU Reduction of Hazardous Substances (RoHS)

The material set and qualifications shall conform in all respects to the provisions for Restriction of Hazardous Substances (RoHS 2) EU Directive 2011/65/EU and any future amendments, addendum and decisions.

This Inverter-Charger shall be RoHS-6 compliant and will be lead free soldered.

8 Environmental Requirements

The Inverter-Charger shall meet all the requirements of this document when tested to confirm compliance to the following environmental requirements according SAE J1455 from JAN 2011.
The Inverter-Charger shall meet IP67 and IP6k9k protection.

8.1 Temperature

Operating inlet coolant and ambient temperature is Tmin = -30°C to Tmax = 50°C at full load. Coolant temperature can be up to Tmax = 60°C with power derating according chapter 2.2.1.1.
Non-operating ambient air temperature range is -40°C to +85°C.
Validation testing per SAE J1455 JAN2011.

8.1.1 Temperature Cycle Test

Operating: Inverter-Charger shall be designed to operate with no degradation of performance Temperature cycle profiles are shown below. For exterior environment these limits are specified (refer to SAE J1455): min. temp.: -30°C; max. +50°C coolant and ambient.
The Inverter-Charger shall be tested 3 x 8 hours cycle and 1 x 24 hours cycle.

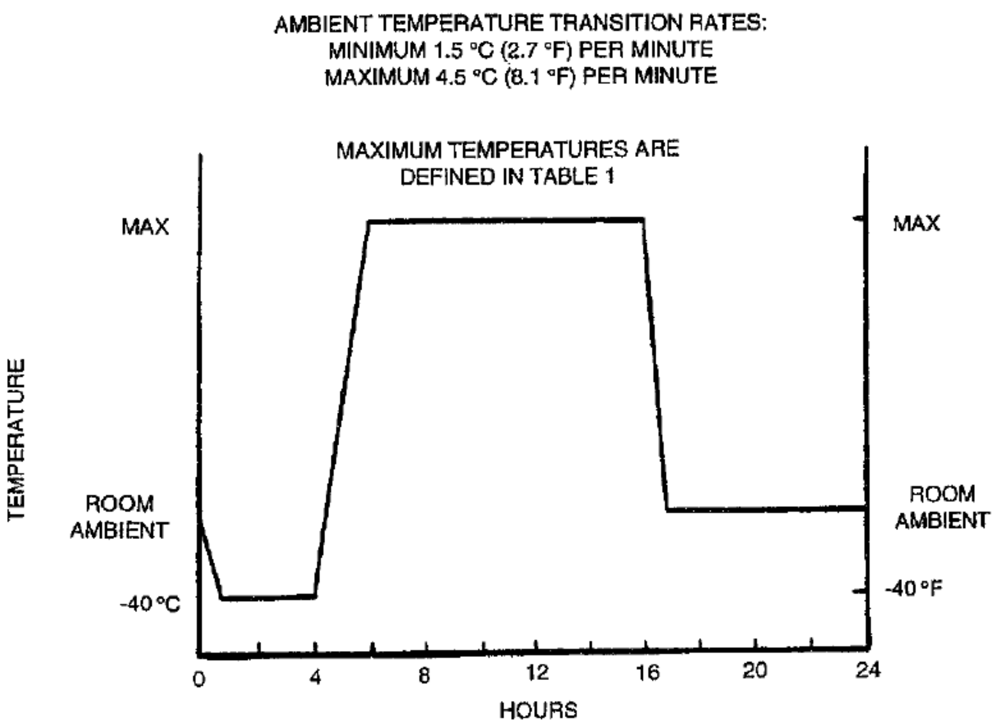


FIGURE 2A - 24 HOUR THERMAL CYCLE

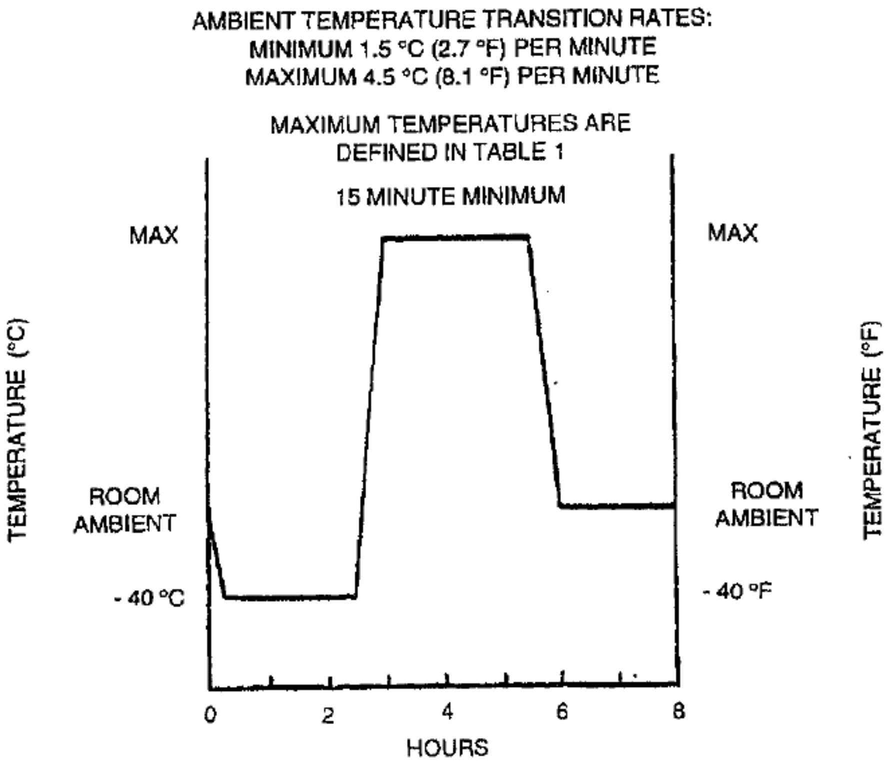


FIGURE 2B - SHORT (8 HOUR) THERMAL CYCLE

A coolant loop cycle shall be added to the cycle shown above that tracks along with the ambient temperature within 5°C up to the maximum stated coolant loop temperature of 50°C

8.1.2 Thermal Shock Test

Non-operating: Inverter-Charger shall be designed to operate with no degradation of performance Thermal shock cycle profiles are shown below. For exterior environment these limits are specified (refer to SAE J1455): min. temp.: -40°C; max. +85°C ambient (no coolant cycling)

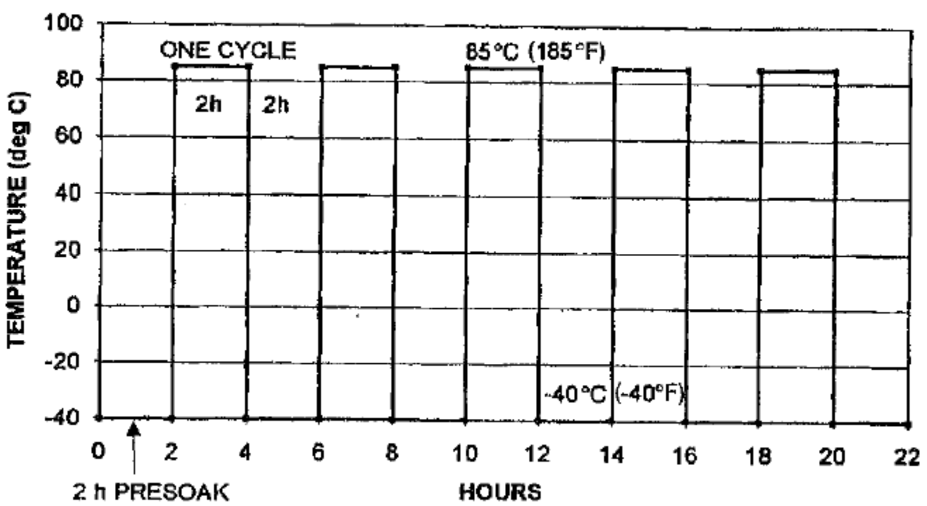


FIGURE 2C - THERMAL SHOCK

8.2 Humidity

Operating: Inverter-Charger shall be designed to operate with no degradation of performance Validation testing per SAE J1455.

a.) 8hours active temp. humidity cycling under accelerated conditions (figure below)

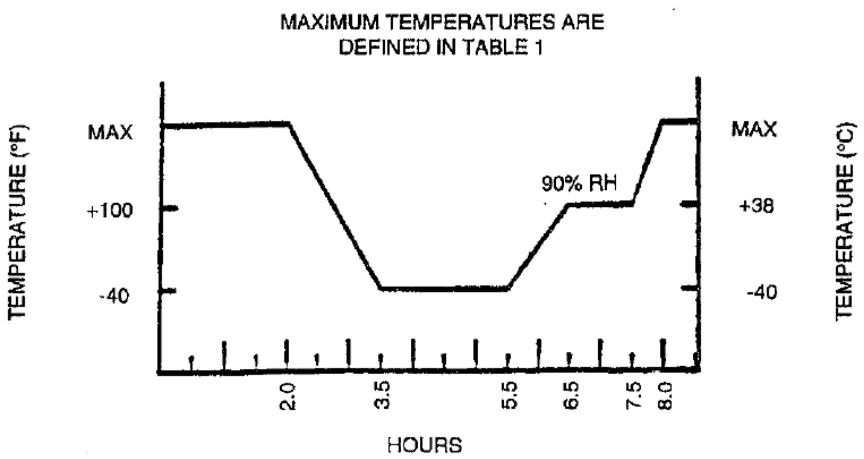
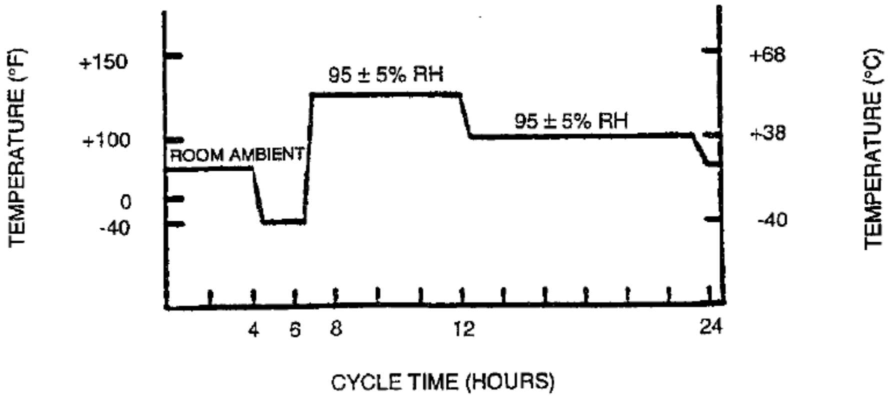


FIGURE 4a—8 h HUMIDITY CYCLE

b.) 8 to 24hours exposure at 103.4kPa gage pressure in a presser vessel (figure below)



Electrical performance shall be continuously monitored during these tests and Inverter-Charger shall be able to withstand.
A coolant loop cycle shall be added to the cycle shown above that tracks along with the ambient temperature within 5°C up to the maximum stated coolant loop temperature of 60°C

8.3 Altitude

Non-Operating: Inverter-Charger shall be designed to not be damaged by non-operating up to 12200m (18.6kPa absolute pressure)
Operating: Inverter-Charger shall be designed to-operate up to 4000m.

Validation testing per SAE J1455.

8.4 Gravel Bombardment

Non-Operating: Inverter-Charger shall be designed to operate with no degradation of performance. Some superficial or cosmetic damage is acceptable if functional and packaging integrity is not affected

Validation testing per SAE J400.

8.5 Dust and Sand

Non-operating: Inverter-Charger shall be designed to operate with no degradation of performance. Functional test should be performed prior to and after testing.

Exposed mechanical elements:
Dust mixture shall be used
a.) SAE J726 coarse or equivalent 70%
b.) 120 grift aluminum oxide 30%

Inverter-Charger should be placed in dust chamber with sufficient dry air movement to maintain a concentration of 0.88 g/m^3 for a period of 24h.
An alternate method is to place Inverter-Charger sample about 15cm from one wall in 91.3cm cubical box. The box should contain 4.54kg of fine powdered cement in accordance with ASTM C150-56. At intervals of 15min, the dust must be agitated by compressed air or fan blower. Blasts of air for a 2s period in a downward direction assure that the dust is completely and uniformly diffused throughout the entire cube. The dust is then allowed to settle. The cycle is repeated for 5h.

8.6 Fungus

Non-operating: Inverter-Charger shall be designed to operate with no degradation of performance

An effect of fungal growth on Inverter-Charger during 30days is determined (for details refer to SAE J1455 JAN2011)

8.7 Other Environmental Test

- Exposure to chemicals and oils
- Steam cleaning and pressure washing - Level 1 (Standard Test)

For all refer to SAE J1455 JAN2011.

- Salt spray atmosphere

GMW-3172, non-operating unit during test, Climatic code J

8.8 Mechanical Shock

Non-Operating: Inverter-Charger shall be able to withstand following shocks without degradation of performance or mechanical damage to components.

Validation testing per SAE J1455

- shipping and handling shocks
- installation harness shock
- operational shock
- crash shock

8.8.1 Transit Drop Test

Shall comply with ASTM D 5276 and D 880.
Non- Operating: Drop packed Inverter-Charger to surface with flat, firm, non-yielding base such as steel, concrete, etc. For details refer to SAE J1455 4.11.3.2 Transit drop test.

Inverter-Charger shall be able to withstand following shocks without degradation of performance or mechanical damage to components.

8.8.2 Operational Shock

According GMW-3172

8.8.3 Crash Shock Test

Non-operating: Inverter-Charger shall be able to withstand following shocks without degradation of performance or mechanical damage to components.

Validation testing per SAE J1455 4.11.3.5 crash shock test

Shock profile (as a representative profile for 48km/h vehicle speed)

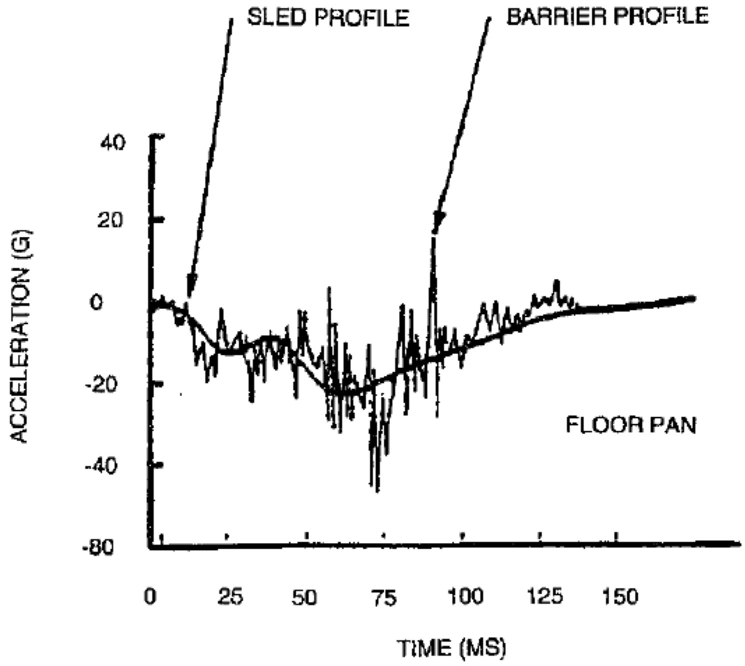


FIGURE 13 - 48 km/h (30 mph) BARRIER AND SLED SHOCK PROFILES

8.8.4 Bulk Packaging Drop Test

Non-operating: Inverter-Charger shall be able to withstand following drop test without degradation of performance or mechanical damage to components.

Table 17 (6.3.2) Transit Shock Test Summary

	Level 1	Level 2	Level 3	Level 4
Test Basis	Application Specific	DUT 0 – 23 kg	DUT 23 kg – 45 kg	DUT over 45 kg (Pallets or Totes)
DUT Surfaces	(User Defined)	As described in Additional Notes following Table 17		
Drop Height		1200 mm (± 50 mm)	500 mm (± 50 mm)	1 m (± 50 mm)
Drop Surface		Concrete		
Number of Drops		10	10	1
DUT Connections		No connections		
DUT Operation		Non-operating during application		
Pass-Fail Criteria		No visual damage to DUT; must operate after test.		

Figure 8-1 Table from spec JDQ 53.3

Test conditions in column "Level 4" - see Fig.1.
Pass-Fail Criteria – The shipping container is allowed to show damage but must still adequately protect the DUT.

Before Bulk package drop test shall be perform visual inspection all packages filled by samples - any deformation of cardboard is not allowed.
After Bulk package drop test shall be perform this:
1. Visual inspection all packages and samples.
2. Functional testing of UUT on ATE.

8.9 Vibration

8.9.1 Swept sine vibration tests

8.9.1.1 Test condition (5g peak)

The specimens, while deenergized or operating under the load conditions specified, shall be subjected to the vibration amplitude, frequency range, and duration specified in 8.9.1.2, 8.9.1.3, and 8.9.1.4, respectively.

8.9.1.2 Amplitude

The specimens shall be subjected to a simple harmonic motion having an amplitude of either 0.06-inch double amplitude (maximum total excursion) or 5 gravity units (g peak), whichever is less. The tolerance on vibration amplitude shall be ±10 percent.

8.9.1.3 Frequency range

The vibration frequency shall be varied logarithmically between the approximate limits of 10 and 500 Hz, except that the procedure of method 201 of standard MIL-STD-202G may be applied during the 10 to 55 Hz band of the vibration frequency range.

8.9.1.4 Sweep time and duration

The entire frequency range of 10 to 500 Hz and return to 10 Hz shall be traversed in 15 minutes. This cycle shall be performed 12 times in each of three mutually perpendicular directions (total of 36 times), so that the motion shall be applied for a total period of approximately 9 hours. Interruptions are permitted provided the requirements for rate of change and test duration are met. Completion of cycling within any separate band is permissible before going to the next band. When the procedure of method 201 of standard MIL-STD-202H is used for the 10 to 55 Hz band, the duration of this portion shall be the same as the duration for this band using logarithmic cycling (approximately 1-1/3 hours in each of three mutually perpendicular directions).

8.9.2 Random vibration testing (standard MIL-STD-202G)

Random vibration tests according MIL-STD-202G, method 214D, test condition I, letter A, test duration 8hrs:

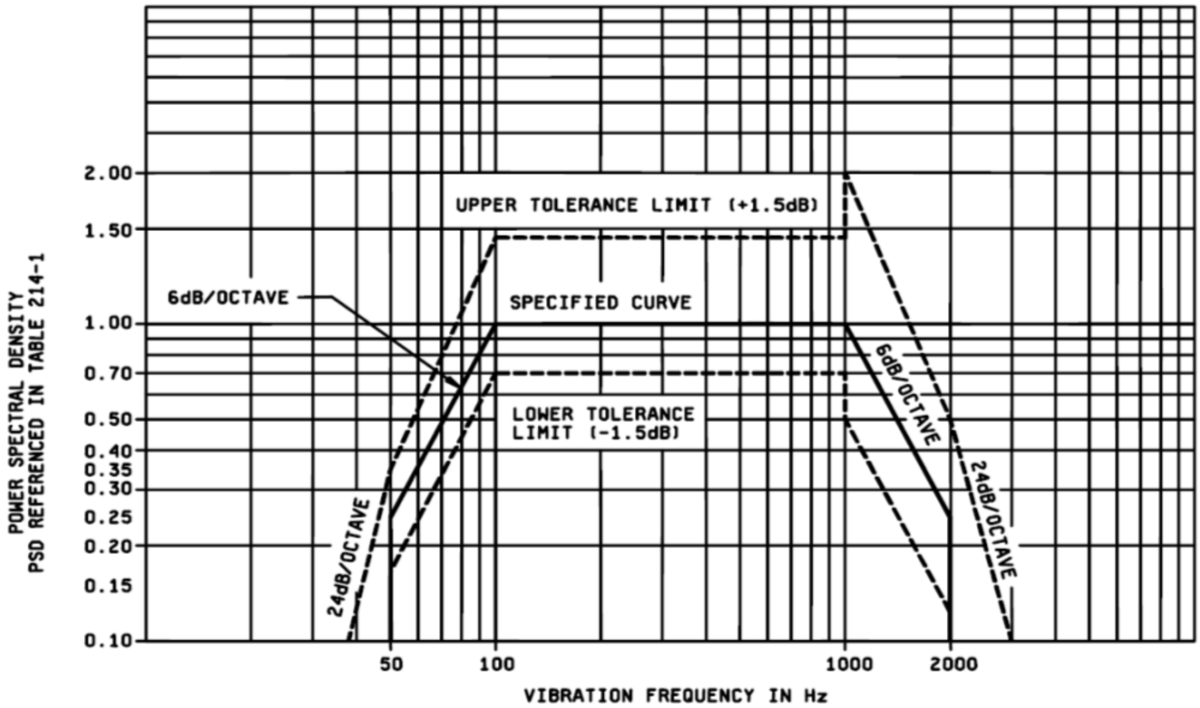


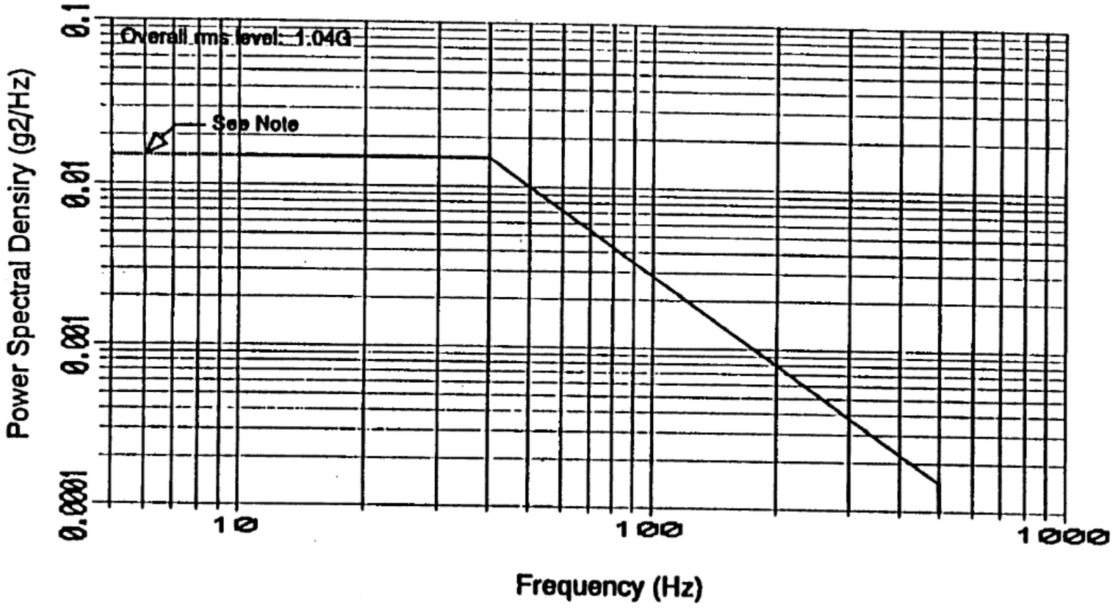
Figure 8-2 Random vibration test-curve envelope (see standard MIL-STD-202G, test method 214A, page 3, figure 214-1)

Characteristics		
Test condition letter	Power spectral density	Overall rms G
A	.02	5.35

Figure 8-3 Values for test-conditions I. (see standard MIL-STD-202G, test method 214A, page 3, table 214-I.)

8.9.3 Random vibration testing (standard SAE J1455)

Random vibration tests according SAE J1455, chapter 4.10, test duration 3hrs:



NOTE: If it is known that excitation is expected below 10 Hz, the curve shall be extended and shaped to comply with the available data.

Figure 8-4 Random vibration test-curve (see standard SAE J1455, page 22, figure 6)

8.10 Cooling

The following describes the Converter system cooling requirements:

The Converter system shall have liquid cooling.
Inlet Coolant Temperature: -30°C/ +60°C (90% derating above +50°C)
Coolant Medium/Mixture: 50/50 Ethylene glycol/Distilled Water with proper corrosion inhibitor to prevent cooling system from corrosion.
Following materials are used in the cooling system of the converter system unit:
AlSi10Mg, AISI 304, FKM.
Coolant Flow: 7 - 10LPM, for short-term operation, 20% duty cycle, 15LPM can be used
Max. coolant gauge pressure: 26 psi (1.8 bar)

Inlet/Outlet Coolant Connection:
Cooling ports – suitable for ½ inch hose.

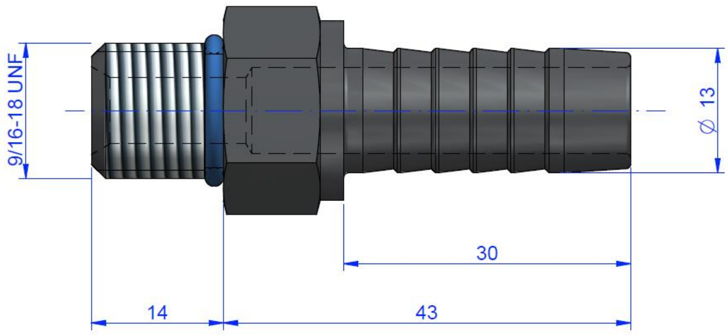


Figure 8-5: Coolant connector

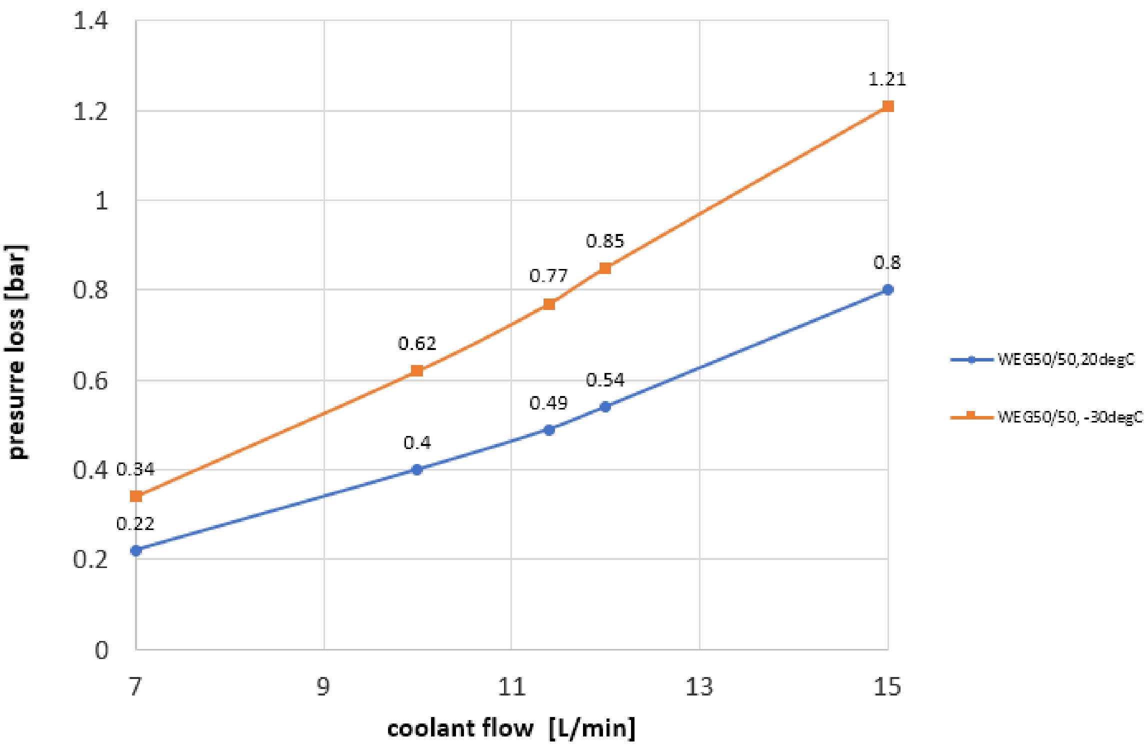


Figure 8-6: Pressure loss versus coolant flow dependency

9 Electromagnetic Compatibility

Evidence shall be provided that the Converter System meets following requirements.

9.1 Emissions Requirements

9.1.1 Radiated Emissions (FCC15 Class A)

When installed in a configuration emulating application the Inverter-Charger shall comply with the FCC15 Class A limits for radiated emissions.
The testing must be performed in a 10m chamber or an open-air test site with ground plane.

Verification:
Unit tested in Charge mode: V_{AC_IN}=230Vac, I_{AC_IN}=60-70Arms, V_{HC} approximately 375Vdc, V_{out12}=13.8Vdc, I_{out12}=250A, V_{out24}=24Vdc, I_{out24}=37A, V_{in48}=48Vdc, I_{in48}=80A

9.1.2 Conducted Emissions (FCC15, CISPR 22, Class A)

When installed in a configuration emulating application the Inverter-Charger shall comply with the FCC15, CISPR 22 Class A limits for conducted emissions.

Verification:
Unit tested in Charge mode: Vin=230Vac, Iac=60-70Arms, Vdc approximately 375Vdc, Vo12=13.8Vdc, Io12=250A, Vo24=24Vdc, Io24=40A, Vin48=48Vdc, Iin48=80A

9.2 Immunity Requirements

When installed in a configuration emulating application, the Inverter-Charger shall meet the following immunity requirements when tested using the appropriate IEC 61000-4 test method. Unless otherwise stated no performance degradation shall occur during the test.

9.2.1 Electrostatic Discharge (IEC 61000-4-2)

Converter System meets IEC 61000-4-2 criterion C.

Contact Discharge

Contact discharge 8kV for metallic surfaces including connector bodies. 10 discharges per test point. 5 positive polarity and 5 negative polarity.

Air Discharge

Air discharge in 5kV increments to 15kV for seams and non-metallic user accessible surfaces. 10 discharges per test point; 5 positive polarity and 5 negative polarity.

9.2.2 Radiated Electromagnetic Field (IEC 61000-4-3, SAE J1113/21)

A) IEC 61000-4-3
The Converter shall be immune to an Electromagnetic Field Strength of 10 V/m with both an 80% Amplitude Modulation (AM) at 1kHz for the RF frequency band of 80 to 1000MHz. Unit needs to meet performance criterion C.

B) SAE J1113/21
The Inverter-Charger shall be immune to an Electromagnetic Field Strength according to A) SAE J1113/21 class B status 3.

Functionality Class according SAE J1113/21:
Class A: any function that provides a convenience (i.e. entertainment or comfort)
Class B: any function that enhances but is not essential to the operation or control of the vehicle (i.e. tachometer)
Class C: any function that is essential to the operation of the vehicle (i.e. brake or engine control system)

Performance will be judged based on the following status definitions and test severity levels.
Status 1: The function operates as designed during and after exposure to a disturbance.

Status 2: The function may deviate from designed performance during exposure to a disturbance and revert to a fail-safe mode of operation, but must return to normal operation, without operator assistance, after the disturbance is removed.

Status 3: The function may deviate from designed performance during exposure to a disturbance. Operator action is permitted to return the function to normal operation after the disturbance is removed.

Performance of the module must conform to the following matrix:

<table>
<tr><th></th><th>Class A</th><th>Class B</th><th>Class C</th></tr>
<tr><td>Level 3 (100 V/m)</td><td>Status 3</td><td rowspan="2">Status 2</td><td rowspan="3">Status 1</td></tr>
<tr><td>Level 2 (80 V/m)</td><td>Status 2</td></tr>
<tr><td>Level 1 (50 V/m)</td><td>Status 1</td><td>Status 1</td></tr>
</table>

Test Procedure shall meet SAE J1113/21 (Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber-Lined Chamber).
Square wave modulation of 1kHz at 100% for those frequencies greater than or equal to 200MHz and a sine wave modulation of 1kHz at 100% for those frequencies below 200MHz.

9.2.3 Electrical Fast Transient (EFT)/Burst (IEC 61000-4-4)

Level 2, Performance criterion C, +/-5kHz (latest revision of IEC) (direct and capacitive coupling – at DC and AC side)

9.2.4 Surge Immunity (IEC61000-4-5)

The equipment shall be immune to the Level 3 surge (+/-1kV DM and +/-2kV CM). Performance criterion C.

9.2.5 RF Conducted Immunity (IEC61000-4-6)

The Inverter-Charger shall be immune to a RF Conducted Immunity level 3. 10V, 0.15…80MHz, AM 80%, 1KHz. Performance criterion C.

9.2.6 BCI (Bulk Current Injection) ISO 11452-4

The Inverter-Charger shall be immune to BCI (Bulk Current Injection) according ISO 11452-4, 1-400MHz, 60mA, Class A

9.2.7 CCC (Capacitive Coupling Clamp) ISO 7637-3

The Inverter-Charger shall be immune to CCC (Capacitive Coupling Clamp) ISO 7637-3
-60V, +40V, Class A

9.2.8 Flicker Tests (IEC 61000-3-11)

The power supply shall comply with EN 61000-3-11:2017.

10 Additional Regulatory Certification

NA

11 Reliability

11.1 MTBF (Demonstrated – Reliability Hypothesis test)

40 kHours, confidence level 50%, operating temperature Tcoolant=50°C.

11.2 MTBF (Stress Calculation Method)

Reliability prediction by stress method shall be performed in accordance with Telcordia (Bellcore) SR-332, Ground Benign, 25°C.
The calculated MTBF shall be equal to or greater than specified in 10.1.

11.3 Strife Test

The Inverter-Charger shall be subjected to a strife test per document C05-ENG-003-2 as part of the Design Verification Testing.

11.4 Accelerated Life Test (ALT)

Not applicable.

11.5 Component Derating

The component derating shall follow document IPC9592:
It is not intended that this *Guideline* result in *illogical* design decisions. Where component availability, special circuit conditions, environmental, cost or other considerations necessitate deviation from these guidelines, trade-off analysis shall be presented to the cognizant engineer in writing for review. Such analysis shall include impact on cost, reliability and smoke prevention requirements.

12 Identification Markings

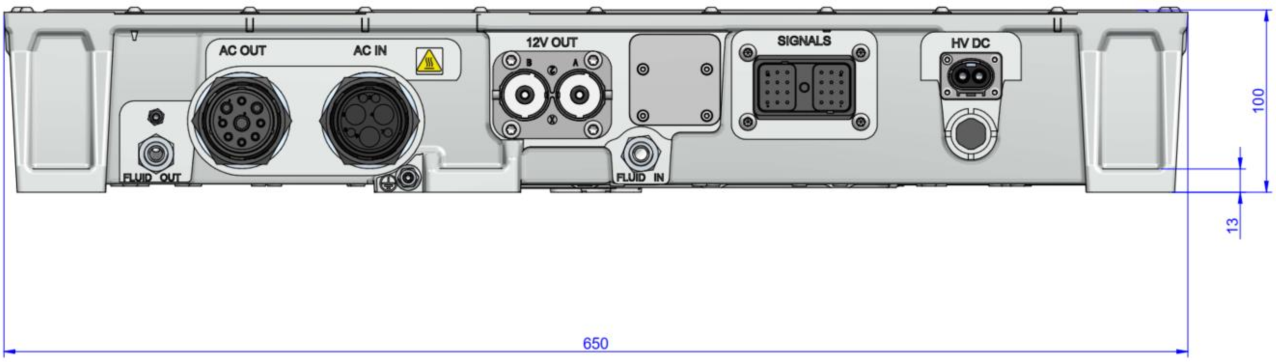
The Inverter-Charger markings shall include:

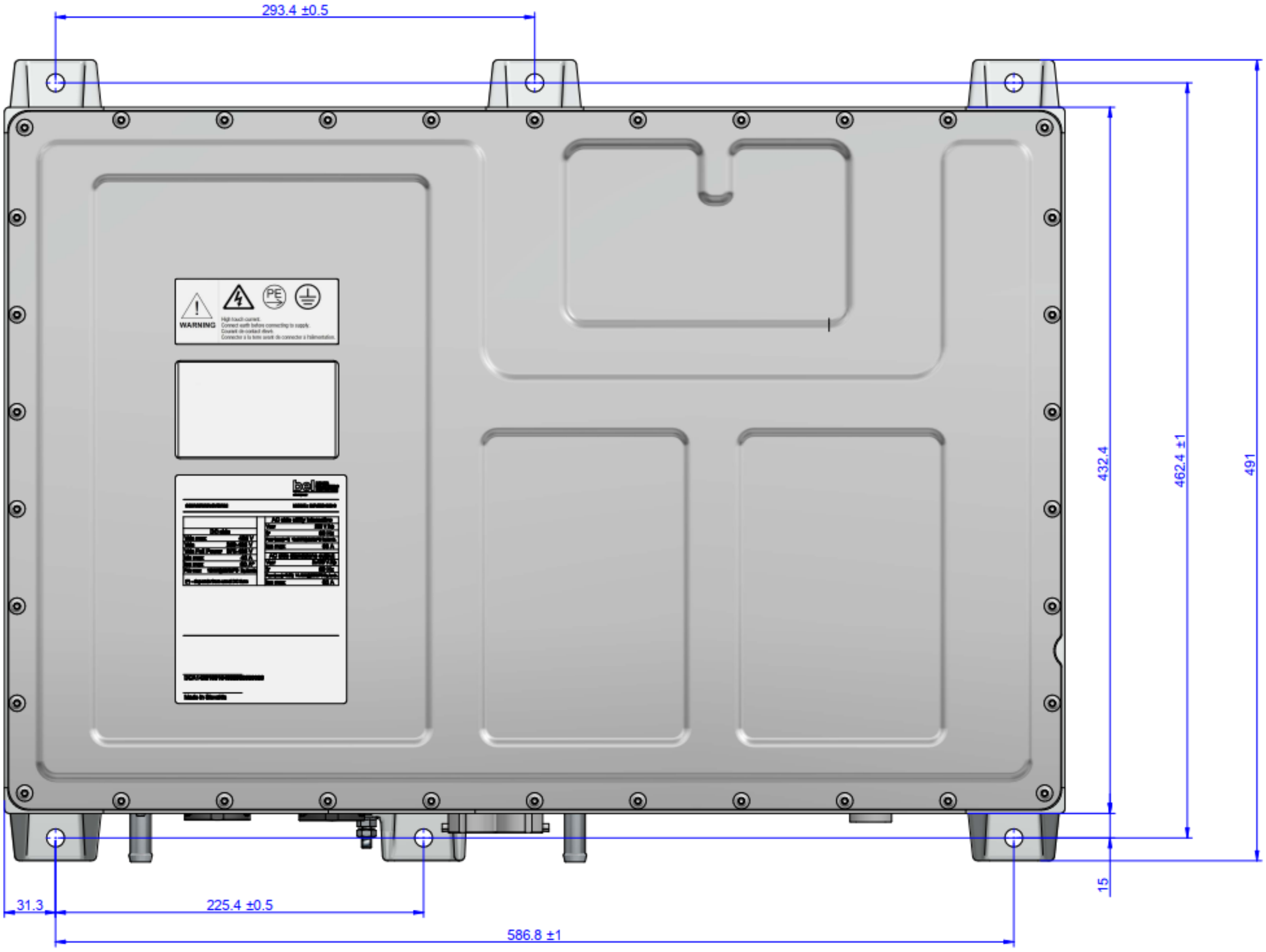
1. Part Number
2. Serial Number and revision (this must change to reflect any build changes including in development)
3. Bar Code Label,
4. Voltage and current ratings
5. Date Code. (The date code shall be the industry standard 4-digit year/week combination.)
6. Required Regulatory Markings as defined in sections 5 Safety and 9 Additional Regulatory Certification
7. Country of Origin
8. HIGH VOLTAGE WARNING LABEL
9. HIGH LEAKAGE CURRENT WARNING LABEL
10. HOT SURFACE WARNING LABEL

13 Mechanical Requirements

13.1 Outline Drawings

The Converter System should have following dimensions.
See BCV200-350-8.FD drawing for details.



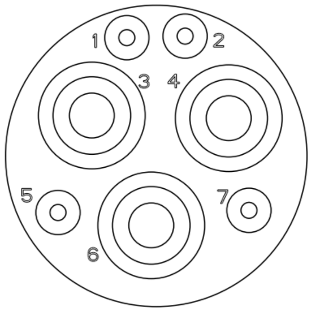


13.2 Connectors

13.2.1 AC Side Power Connectors

AC side charge connector will be DEUTSCH, MPN: HDP24-24-7PN-C038
Matting part DEUTSCH, MPN: HDP26-24-7SN-C038
Connector will contain two signal pins for Control Pilot and proximity signals.

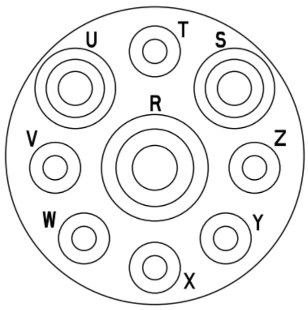
PIN	FUNCTION
1	Control Pilot*
2	Proximity*
3	L2 or N - Input
4	L1 – Input
5	Not Used
6	PE
7	Not Used



* Function and levels according SAE J1772;
Insulated from AC side;
Referenced to V_{out12} RTN = PE

AC side export connector will be DEUTSCH, MPN: HDP24-24-9SE
Mating part: DEUTSCH, MPN: HDP26-24-9PE-L015

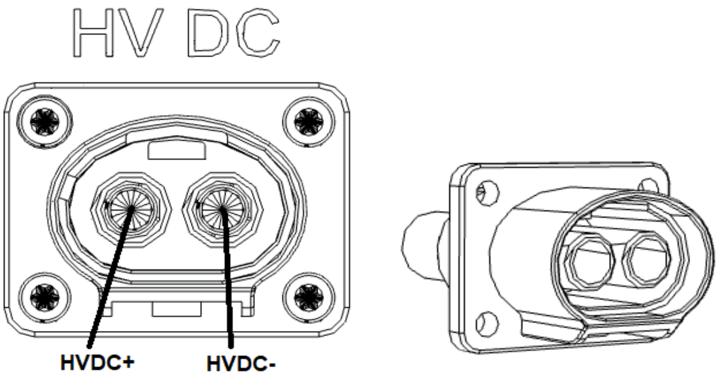
PIN	FUNCTION
R	N - Output
S	L1 - Output
T	PE*
U	L2 - Output
V	PE*
W	PE*
X	PE*
Y	PE*
Z	PE*



* All PE terminals (T, V, W, X, Y, Z) shall be connected together to keep safety rating requirements.

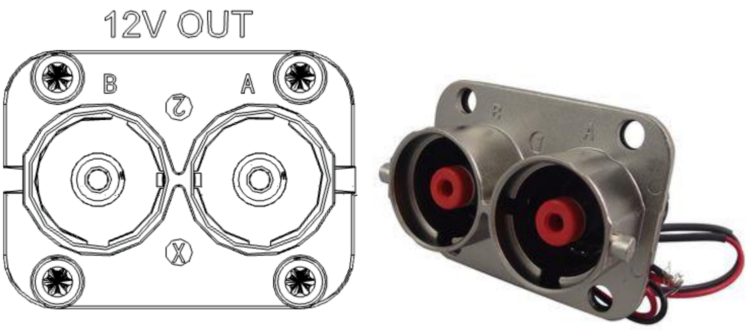
13.2.2 HV Power Connector

HV connector with HVIL pass-through to signal connector will be Amphenol PL082X-61-6
Mating part: Amphenol PL182X-61-6

HVDC+ – high voltage positive HVDC– – high voltage negative	

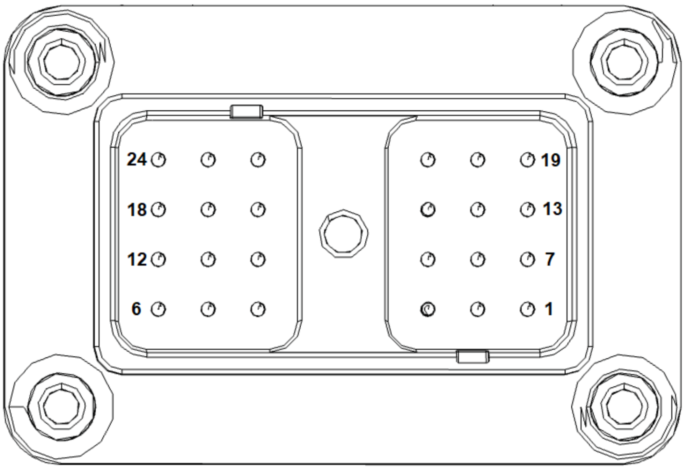
13.2.3 Vout12 Power Connector

<u>Unit (panel mounted):</u>
Amphenol, PL082X-300-10M8
Mating Part: PL182X-300-70

Terminal A – Vout12+ Terminal B – Vout12– (Return)	

13.2.4 Signal Connector:

Unit (panel mounted):
Deutsch DRC13-24PA
Mating Part: DRC16-24SA
Mating Insert Socket: 1062-16-0122 (18 – 14 AWG [0.75 – 2mm^2]
Recommended current rating: 10A per pin with wire 16 AWG.



PIN	SIGNAL NAME	SIGNAL DESCRIPTION
1	Vout24+	+24V output
2	Vout24+	+24V output
3	Control Pilot output	Copy of Control Pilot from AC charge connector
4	+SENSE V_{out12}	Remote sense for V_{out12}
5	Sync	Synchronization for DIRC
6	CAN_L_int	Internal can - for production purpose, DO NOT CONNECT
7	Vout24+	+24V output
8	Vout24+	+24V output
9	VBAT	12V supply of internal Bias
10	HVIL_OUT	HVIL loop OUT
11	IGN	(Key Switch) Supply of CAN and Bias convertor enable.
12	CAN_H_int	Internal can - for production purpose, DO NOT CONNECT
13	Vout24-	+24V output RTN
14	Vout24-	+24V output RTN
15	VBAT	12V supply of internal bias
16	HVIL_IN	HVIL loop IN
17	Master/Slave	DIRC mode selection: Master = floating(not connected); Slave = GND
18	CAN_H	CAN Bus H
19	Vout24-	+24V output RTN
20	Vout24-	+24V output RTN
21	Reserve	NA
22	-SENSE V_{out12}	Remote sense for V_{out12}
23	EVSE_WAKE_OUT	Signal to wake up Vehicle Control Unit (VCU module)
24	CAN_L	CAN Bus L

All signals are referenced to V_{out12} RTN

13.3 Inverter-Charger Handle

Not applicable.

13.4 Inverter-Charger Weight

The converter weight shall be around 35kg.

13.5 Mechanical Fixation to Frame

The Inverter-Charger shall be fixed by 6pcs of self-locking screws of size M10 x 50mm tightened by torque 20Nm.

14 Appendices

14.1 Appendix A - Ripple & Noise Measurement

Standard test conditions for noise and ripple measurements using the method below.
For guidance only.

Figure 14-1 Setup for noise measurement

Set-up:

1. Terminate scope to 50R or use external BNC 50R termination
2. Keep all leads as short as possible
3. Measurements at 20MHz bandwidth to be shown using envelope or infinite persistence mode.
4. Set time base to 10ms and AC coupling
5. For final noise measurements on power rails add the Nominal output capacitance of to each rail