

# 350INV60-1 20-240-9G

6000 W DC-AC Inverter

The Bel Power Solutions 350INV60-120-240-9G is a highly efficient DC-AC inverter that converts high-voltage DC power into split phase AC power 120/240 VAC required to drive AC accessory loads directly from the High Voltage DC Drive or Battery Bus.

Liquid cooled DC-AC inverter operates at input voltages from 240 to 430 VDC and power range up to 6000 W. The DC-AC inverter utilizes CAN communication to the vehicle controller which allows selection of operational modes and frequency selection.

The DC-AC inverter is built in a sealed aluminum enclosure, ready to be mounted to the vehicle chassis and is a commercial-off the-shelf solution for electric vehicle manufacturers and developers.



## FEATURES

- 92 % typical efficiency
- Input voltage range: 240 – 430 VDC
- Power rating of 1 module 6 kW, possible parallel synchronized operation up to 6 modules with total power up to 32 or 36 kW
- Full galvanic insulation between input and output
- CAN bus serial interface
- Over temperature, output over voltage and over current protection
- Protection degree IP65 and IP67
- Liquid cooled
- Vibration immunity meets military level
- Three phase function: outputs of 3 modules can create 3 phase system 3 x 400 VAC or 3 x 208 VAC
- E-MARK E13\*10R00-10R05\*13865

## APPLICATIONS

- Hybrid and Electric Vehicles
- Medium through heavy duty, on and off highway vehicles

## 1. MODEL SELECTION

| MODEL               | DESCRIPTION                                                                                                                |
|---------------------|----------------------------------------------------------------------------------------------------------------------------|
| 350INV60-120-240-9G |                                                                                                                            |
| 350INV60-CON-KIT-8G | Kit that includes mating input connector with assembled 3 m of HV DC cable, output and signal connector with terminal pins |
| 350INV60-CON-KIT-9G | Kit that includes input, output and signal connectors with terminal pins                                                   |

## 2. INPUT SPECIFICATIONS

| PARAMETER               | DESCRIPTION / CONDITION                                                       | MIN  | NOM | MAX | UNIT      |
|-------------------------|-------------------------------------------------------------------------------|------|-----|-----|-----------|
| Input Voltage           |                                                                               | 240  | 350 | 430 | VDC       |
| Max. Input Current      | at nominal Power 6000 W, $V_{in} = 240 V_{mean}$                              |      | 28  | 34  | ADC       |
|                         | at peak Power 8000 W $V_{in} = 240 V_{mean}$                                  |      |     | 37  | ADC       |
| Typical Efficiency      | Maximum @ $V_{in} = 350 VDC$ , $P_{out} = 4 kW$ , $T_{coolant} = 40^{\circ}C$ |      | 92  |     | %         |
| Internal Power Loss     | at $V_{in} = 350 VDC$ , $P_{out} = 6 kW$ , $T_{coolant} = 40^{\circ}C$        |      | 430 |     | W         |
|                         | at $V_{in} = 350 VDC$ , $P_{out} = 0 kW$ , $T_{coolant} = 40^{\circ}C$        |      | 110 |     | W         |
| Input Line Interruption | Inverter shutdown                                                             |      |     | 240 | VDC       |
| Input Capacitance       |                                                                               |      |     | 54  | $\mu F$   |
| Insulation              | Input-to-Chassis: Basic                                                       | 3000 |     |     | VDC       |
|                         | Input-to-Output: Reinforced                                                   | 3000 |     |     | VDC       |
| Insulation Resistance   | Input to Chassis (ground)                                                     | 10   |     |     | $M\Omega$ |
|                         | Input to Output                                                               | 10   |     |     | $M\Omega$ |
| Input Current Waveform  | Remaining amplitude part of 50 / 60 Hz component                              |      |     | 10  | %         |
| Inrush Current          | External pre-charging circuit required                                        |      |     |     |           |

## 3. OUTPUT SPECIFICATIONS

| PARAMETER                     | DESCRIPTION / CONDITION                                                                                                                                      | MIN    | NOM     | MAX    | UNIT |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|---------|--------|------|
| Output Voltage                | L1 to N, L2 to N                                                                                                                                             |        | 120     |        | VAC  |
|                               | L1 to L2                                                                                                                                                     |        | 240     |        | VAC  |
| Phase shift                   | L1 to L2                                                                                                                                                     |        | 180     |        | Deg  |
| Output Current                | at 6 kW                                                                                                                                                      |        | 25      |        | A    |
| Output Power                  | Continuous                                                                                                                                                   |        |         | 6      | kVA  |
|                               | Output overload, (max. 10 sec)                                                                                                                               |        |         | 8      | kVA  |
|                               | Overload for motor load spin-up (max 3 sec)                                                                                                                  | 8      |         |        |      |
| Static Regulation             | $L1 = L2 = 120 VAC$ at load 0 to 25 A                                                                                                                        | -12    |         | + 12   | VAC  |
| In-factory Output Calibration | $L1$ to $L2 = 240 VAC$ at load 25 A, $T_{coolant} = 30^{\circ}C$                                                                                             | 237.75 |         | 237.85 | VAC  |
| Frequency                     |                                                                                                                                                              |        | 50 / 60 |        | Hz   |
| Periodic & Random Deviation   | at 120 VAC / Nominal load                                                                                                                                    |        |         |        |      |
|                               | - Differential Mode 20 MHz of $V_{o\_max}$                                                                                                                   |        | 4       |        | %    |
|                               | - Differential Mode 20 MHz                                                                                                                                   |        | 7       |        | Vp-p |
| Load Crest Factor             | $V_{in} = 240 - 430 V_{mean}$ , $So1 = So2 = 3 kVA$ , $I_{pk1} = I_{pk2} = 70 A$ , $T_{ambient} = 85^{\circ}C$ , $T_{coolant} = 70^{\circ}C$                 |        |         | 2.5    |      |
| Total Harmonic Distortion     | $V_{in} = 240 - 430 V_{mean}$ , $So1 = So2 = (0.01 kVA, 1 kVA, 3 kVA)$ , $\cos(\phi) = (0.5, 1)$ , $T_{ambient} = 25^{\circ}C$ , $T_{coolant} = 50^{\circ}C$ |        |         |        |      |
|                               | 0.1 – 1 kVA linear load                                                                                                                                      |        |         | 4      | %    |
|                               | 1 – 3 kVA linear load                                                                                                                                        |        |         | 10     | %    |
| Turn-On Delay                 | After application of DC input or cycling enable signal                                                                                                       |        |         | 5000   | ms   |
| Load Power Factor             | The output voltage of the inverter kept within the limits.                                                                                                   | 0.3    |         | 1      |      |

## 4. PROTECTION SPECIFICATIONS

| PARAMETER                                     | DESCRIPTION / CONDITION                                                                                                                                                                                                                                                                                                  | MIN        | NOM        | MAX           | UNIT             |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------|---------------|------------------|
| Output Over-Current Protection shut-down time | V <sub>in</sub> = 240 - 430 V <sub>mean</sub> , T <sub>ambient</sub> = 85°C, T <sub>coolant</sub> = 70°C,<br>I <sub>o1</sub> = I <sub>o2</sub> = step from 25 Arms to 27.5 Arms<br>I <sub>o1</sub> = I <sub>o2</sub> = step from 25 Arms to 33 Arms<br>I <sub>o1</sub> = I <sub>o2</sub> = step from 25 Arms to >33 Arms |            |            | 65<br>12<br>8 | s                |
| Short Circuit Survival shut-down time         | V <sub>in</sub> = 350 V <sub>mean</sub> , T <sub>ambient</sub> = 85°C, T <sub>coolant</sub> = 70°C,<br>I <sub>o1</sub> = I <sub>o2</sub> = from 25 Arms/cos(Φ) = 1 to short cut                                                                                                                                          | 60         |            |               | ms               |
| Output Over-Voltage Protection                | Latch type                                                                                                                                                                                                                                                                                                               | 200        |            | 210           | V <sub>pk</sub>  |
| Output Under-Voltage Protection               | UV duration 60 ms                                                                                                                                                                                                                                                                                                        | 95         |            | 100           | V <sub>rms</sub> |
| Over-Temperature Protection                   | Converter shutdown at T <sub>coolant</sub> higher than                                                                                                                                                                                                                                                                   | 70         |            |               | °C               |
| Input Fuse Protection                         | DC Input: Single on positive pole                                                                                                                                                                                                                                                                                        |            | 50         |               | A                |
| Input Low Line Protection                     | Turn ON threshold<br>Turn OFF threshold                                                                                                                                                                                                                                                                                  | 250<br>235 | 255<br>240 | 260<br>245    | VDC              |
| Input Overvoltage protection                  | Recovery: V <sub>in</sub> re-cycling or ENABLE                                                                                                                                                                                                                                                                           | 435        |            | 450           | VDC              |

## 5. MONITORING AND CONTROL SIGNALS

| PARAMETER                   | DESCRIPTION / CONDITION                                                                                                                                                                                                                                                         |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CAN BUS SAE J1939 Interface | 250 kBit/s                                                                                                                                                                                                                                                                      |
| ENABLE                      | Inverter turned ON signal is pulled-up by 100 kOhm to 5 V internally by default (after U <sub>in</sub> is connected, unit will start with outputs enabled).<br>Inverter turned OFF pulled down to 0.6 V or 100 Ohm to signal GND (pin 7) - by external components, e.g. switch. |
| FREQ_SELECT                 | Output frequency selected to 60 Hz signal is pulled up 100k Ohm to 5 V internally<br>Output frequency selected to 50 Hz signal is pulled down to 0.6 V or 100 Ohm or less to signal GND (pin 7)                                                                                 |
| SYNC                        | Operation of multiple inverter modules in parallel mode.<br>SYNC signals of individual modules have to be connected together and twisted with signal ground (pin 7)                                                                                                             |
| HVIL function               | Internal short is provided on HVIL pins.                                                                                                                                                                                                                                        |

## 6. READBACK ACCURACY ON CAN

| PARAMETER                        | DESCRIPTION / CONDITION                                                                                                                                                                                                                                                                                                 |
|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Output current readback accuracy | Under all conditions for currents below 4.0 Arms read back is not working, i.e. read back value is not accurate / representing actual output current value.<br>For current higher than 4.0 A this read back is valid:<br>In case of crest factor 1 : ± 2.0 Arms<br>In case of crest factor higher than 2.5 : ± 3.0 Arms |
| Input voltage readback accuracy  | ± 2.0 VDC                                                                                                                                                                                                                                                                                                               |
| Output voltage readback accuracy | ± 2.0 V <sub>rms</sub>                                                                                                                                                                                                                                                                                                  |

## 7. ENVIRONMENTAL SPECIFICATIONS

| PARAMETER             | DESCRIPTION / CONDITION                                                                                          | MIN        | NOM | MAX           | UNIT |
|-----------------------|------------------------------------------------------------------------------------------------------------------|------------|-----|---------------|------|
| Altitude              | Operating: 62 kPa absolute pressure<br>Non-Operating: 18.6 kPa absolute pressure                                 |            |     | 3600<br>12200 | m    |
| Operating Temperature | Liquid cooled:<br>T <sub>coolant</sub> with no derating<br>T <sub>amb</sub> at full load, with no power derating | -40<br>-40 |     | +70<br>+85    | °C   |
| Storage Temperature   |                                                                                                                  | -40        |     | +95           | °C   |
| Humidity              | SAE J1455 JAN 2011                                                                                               |            |     |               |      |
| Shock                 | SAE J1455                                                                                                        |            |     |               |      |
| Vibration             | SAE J1455, MIL-STD-202G                                                                                          |            |     |               |      |

## 8. SAFETY, REGULATORY & EMI SPECIFICATIONS

| PARAMETER                              | DESCRIPTION / CONDITION                                   | CRITERION                                    |
|----------------------------------------|-----------------------------------------------------------|----------------------------------------------|
| Insulation                             | Basic<br>Reinforced                                       | Input-to-Protective Earth<br>Input-to-Output |
| Radiated Emission                      | CISPR22, EN 55022                                         | Class A                                      |
| Conducted Emission                     | CISPR22, EN 55022                                         | Class A                                      |
| Electrostatic Discharge                | IEC 61000-4-2 (10 V/m)                                    | Performance Criterion B                      |
| Radiated Electromagnetic Field         | IEC 61000-4-3, SAE J1113/21                               | Performance Criterion B                      |
| Electrical Fast Transient (EFT) /Burst | IEC 61000-4-4, ISO 7637-2; Level 2 ( $\pm 2$ kV, 2.5 kHz) | Performance Criterion B                      |
| RF Conducted Immunity                  | Level 3 (10 V, 0.15 - 80 MHz, AM 80%, 1 kHz)              | Performance Criterion A                      |
| RF Disturbances Immunity               | SAE J1113-41                                              | Class A                                      |

## 9. INVERTER MODULE CONNECTORS

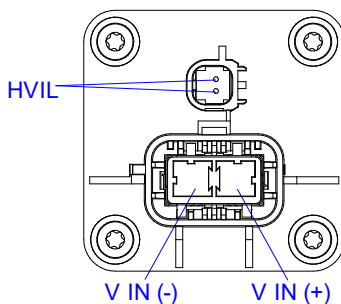
| PARAMETER                    | DESCRIPTION / CONDITION                   | MANUFACTURER | MPN        |
|------------------------------|-------------------------------------------|--------------|------------|
| Input Connector              | High voltage connector with HVIL function | Delphi HV280 | 13737767   |
| Output Connector             | High voltage unshielded connector         | Delphi       | 13879038   |
| CAN BUS and Signal Interface | Panel mounted                             | Molex MX150  | 47725-1310 |

## 10. CONNECTORS FOR MATING WIRING HARNESS

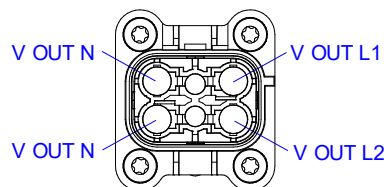
| PARAMETER                    | DESCRIPTION / CONDITION                                                  | MPN                  |
|------------------------------|--------------------------------------------------------------------------|----------------------|
| DC Input Connector           | Housing Delphi (1 pc)                                                    | 13861584             |
|                              | Female terminal (2 pcs)                                                  | 13572764             |
|                              | HVIL housing (1 pc),<br>Female terminal (2 pcs)                          | 13738743<br>13543114 |
|                              | Sealing (1pc)                                                            | 13756257             |
| AC Output Connector          | Housing Delphi (1 pc)                                                    | 13879046             |
|                              | Power terminal (4 pcs),<br>Signal terminal (2 pcs, not used for contact) | 13783301<br>13711549 |
|                              |                                                                          |                      |
| CAN BUS and Signal Interface | Housing Molex (1 pc)                                                     | 33472-1206           |
|                              | Female terminal (12 pcs, 11 pcs used for contact)                        | 0330122002           |

**Note:** Not all cavities are used for electrical function in signal and output connector. In order to maintain IP67 also non used cavities in mating connector must be assembled by dummy wires to get gasket into tightness.

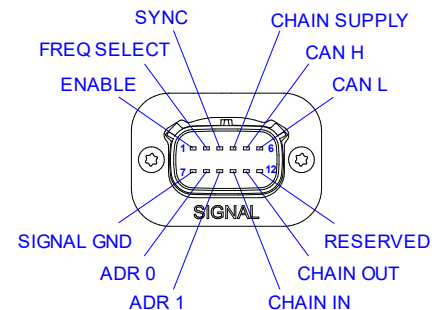
## 11. CONNECTOR PINOUTS



DC Input Connector



AC Output Connector



Signal Connector

| PIN | DESCRIPTION  | FUNCTION                       |
|-----|--------------|--------------------------------|
| 1   | ENABLE       | ENABLE                         |
| 2   | FREQ_SELECT  | Frequency select               |
| 3   | SYNC         | Multi inverter synchronization |
| 4   | CHAIN_SUPPLY | Chain protection supply        |
| 5   | CAN_H        | CAN BUS H                      |
| 6   | CAN_L        | CAN BUS L                      |
| 7   | SIGNAL_GND   | Signal return                  |
| 8   | ADR_0        | Addressing pin                 |
| 9   | ADR_1        | Addressing pin                 |
| 10  | CHAIN_IN     | Chain protection input         |
| 11  | CHAIN_OUT    | Chain protection output        |
| 12  | Reserved     | Reserved                       |

Signal Connector Pin Description

## 12. PARALLEL FUNCTION OF MULTIPLE MODULES IN SYNCHRONIZED MODE

Purpose of running multiple modules in parallel is to get higher power. The maximum number of parallel modules is 6, see wiring diagram below.

| Number of modules | Max. Power 1 [kVA]<br>Full coolant temp. range | Max. Power 2 [kVA]<br>Reduced coolant temp. range to 50°C |
|-------------------|------------------------------------------------|-----------------------------------------------------------|
| 2                 | 11.2                                           | 12                                                        |
| 3                 | 16.8                                           | 18                                                        |
| 4                 | 22.4                                           | 24                                                        |
| 5                 | 28.0                                           | 30                                                        |
| 6                 | 33.6                                           | 36                                                        |

During parallel operation load current is shared evenly between modules. However because of production tolerance on the output voltage calibration and passive current sharing between modules (droop sharing) there may be a deviation of load current - up to 6% difference module to module is possible vs. the average value. The result of this deviation may cause some modules to deliver more current than others. In the Table above, in the centre column (Max. power 1), is the available power when none of the paralleled modules override their nominal current of 25 A. The right column specifies condition for n modules - n \* 6 kVA. In the case of Max. Power 2, some of the modules may be operating over their nominal power. Functioning above the maximum power is however acceptable since the overcurrent protection only activates at an output current of ~27.5 A, however this is only possible when operating at a lower coolant temperature range, so that the over-temperature protection doesn't trip off the overloaded module.

## 13. THREE-PHASE FUNCTION

Modules connected in a 3 phase configuration, per the diagrams below are able to produce:

Case A: One load 3 x 400 VAC / 25 A

Case B: Two Loads 3 x 208 VAC / 25 A

The slaves function at 120° and 240° out of phase from the master by setting up the addressing per the table below:

| ADR_0 (PIN 8) | ADR_1 (PIN 9) | FUNCTION      |
|---------------|---------------|---------------|
| 1             | 1             | Master        |
| 0             | 1             | Slave 120 Deg |
| 1             | 0             | Slave 240 Deg |
| 0             | 0             | Reserved      |

Note: Each of the address pins are digital and have internal pull up impedances, therefore a non-connected pin will result in a logic high.

## 14. ADDITIONAL DETAILS

### MULTI-UNIT CAN ADDRESSING

After input power is connected parallel modules (or units connected in a three phase configuration, here after called “paired” units) automatically allocate their addresses on the CAN line. The design allows up to 6 paired modules, addresses are always chosen from the range of B4 to B9. Every time the input power is re-cycled there may be different addresses allocated to units in comparison to the previous state, but they will be always inside of range of B4 to B9. If the user counts active devices, within this range, you know how many modules are actively connected. In case the CAN line is not required for paired modules, then it does not need to be connected. However in the case CAN is not used the sync BUS and chain circuit still need to be co connected.

### ENABLE CONTROL

Output enable control works either through the hardware enable pin or by sending CAN message “nv\_b\_cmd\_Enable”. Hardware ENABLE PIN has higher priority than CAN Enable command, i.e. if hardware ENABLE PIN is pulled down to 0.6 V or 100 Ohm to signal GND (pin 7), unit will ignore CAN Enable command until hardware ENABLE PIN is disconnected from 0.6 V / signal GND (pin 7). Hardware ENABLE PIN is internally pulled up by 100 kOhm to 5 V by default, which means, after Uin is connected, unit will start with outputs enabled. To start unit with output disabled ENABLE PIN has to be connected to 0.6 V or 100 Ohm to signal GND (pin 7), by external components, e.g. switch.

In parallel mode, hardware enable pins are required to be wired together, this ensures the same level is sent to all modules. The requirement CAN enable message is sent out to all active units. By re-cycling the enable control (disable then re-enable) will clear an output latch condition that might have occurred because of a protection feature e.g.: output over current, over temperature, etc.

### PAIRED MODE SYNC

Modules use the “sync” signal to synchronize their outputs. This happens automatically and there is no user intervention required. After start up one of the paired units automatically establishes itself as the master, all other units in the paired configuration will default to slave operation. Slaves synchronize their outputs according to the reference waveform from master.

### READ BACK OF INPUT / OUTPUT VALUES

In paired mode each module provides its own values. However in paired mode when input and/or output voltages are tied together there could be a read back inaccuracy of up to typical  $\pm 2V$ . Regarding output current, each module will provide its own value. To get the total output current the user must summarize read backs from all active modules.

### PAIRED MODE PROTECTION FUNCTIONS

In paired mode, the signal connector wiring is continuously monitored. This monitoring serves to protect modules against losing synchronization signal during service and is established via a chain circuit starting from the first module and ending with the last. The user needs to establish the chain circuit in the external wiring harness according to diagrams below. In case the chain line is broken all units in the chain will shut down and provide active warning bit on CAN Bit 29 – Inv\_b\_ft\_SyncError. This may happen for example when signal connector of any unit is unplugged during service.

There is no redundancy provided for paired modules. This means in case a functional failure would occur in any of the paired modules, all modules would shut down. This is a requirement to protect output stages of modules against permanent damage.

### PAIRED MODE CHASSIS GROUNDING

During parallel operation it is required that the chassis of all paired modules are galvanic tied together and grounded to PE.

## 15. WIRING SETUP

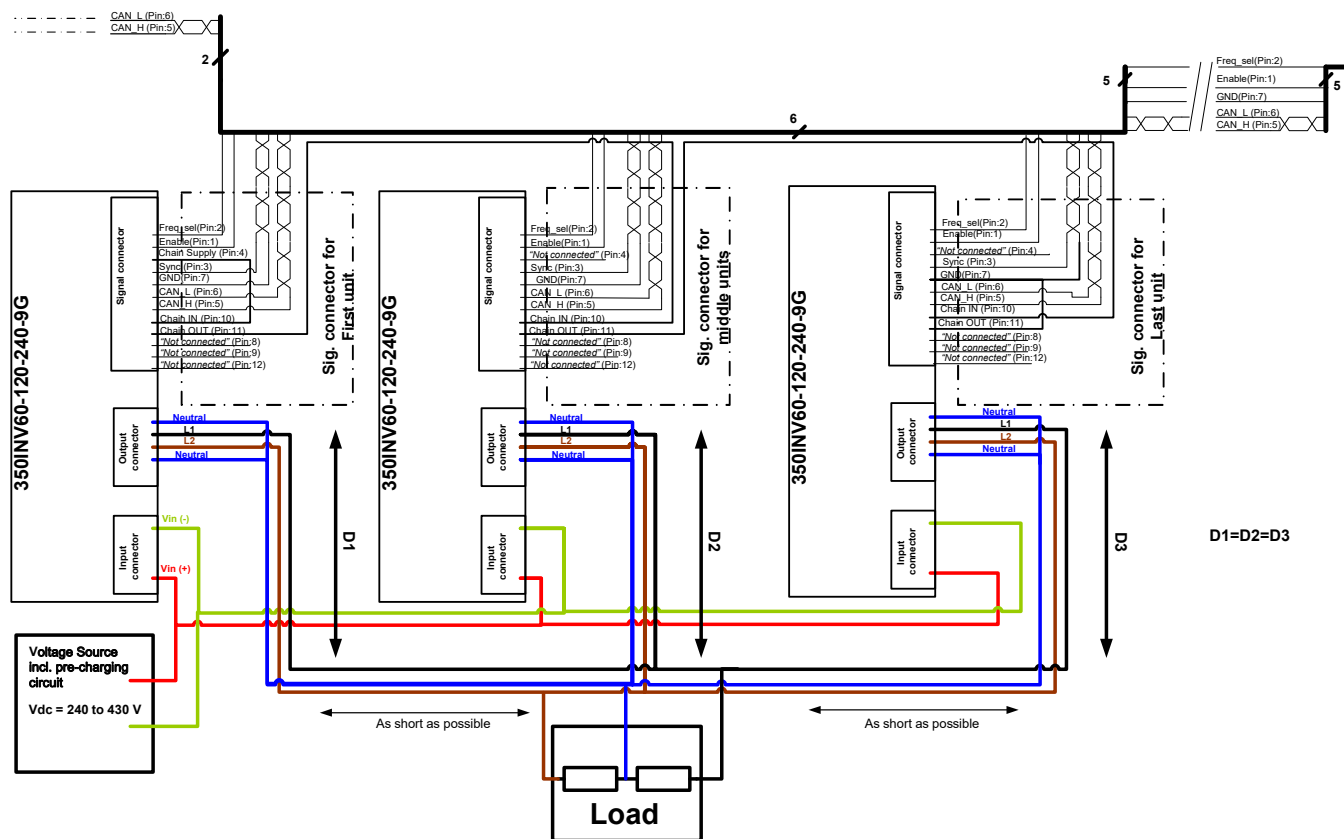


Figure 1. Wiring setup for parallel operation 350INV60-120-240-9G

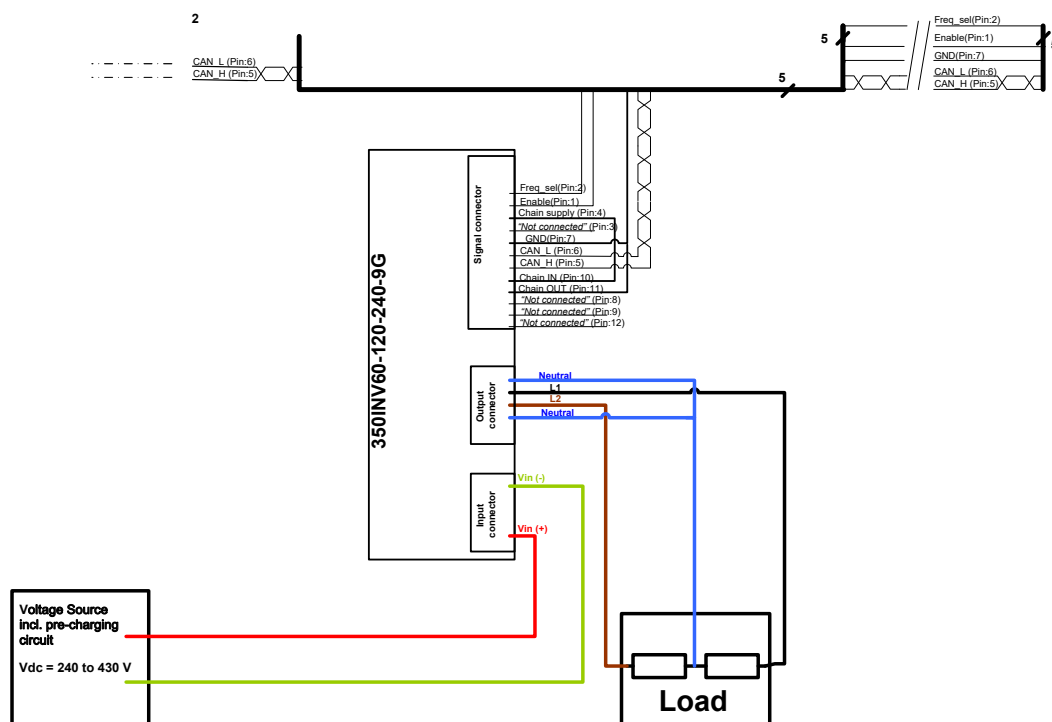
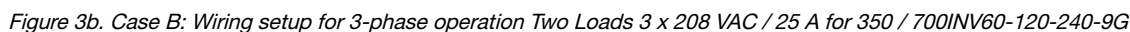


Figure 2. Wiring setup for single operation 350INV60-120-240-9G



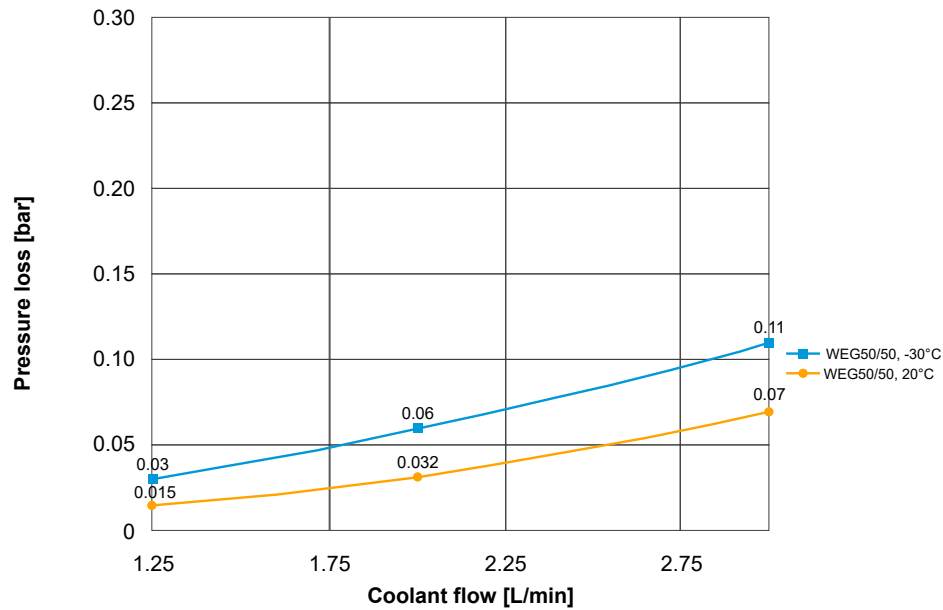


Figure 4. 350INV60-120-240-9G Pressure losses at coolant flow dependency

## 16. MECHANICAL SPECIFICATIONS

| PARAMETER                                  | DESCRIPTION / CONDITIONS                         | MIN | NOM             | MAX | UNIT |
|--------------------------------------------|--------------------------------------------------|-----|-----------------|-----|------|
| Dimensions                                 | W x H x D                                        |     | 374 x 163 x 384 |     | mm   |
| Weight                                     |                                                  |     | 20              |     | kg   |
| Enclosure                                  | IP65 and IP67                                    |     |                 |     |      |
| Maximum allowed pressure of cooling liquid | 20 PSI (1.4bar)                                  |     |                 |     |      |
| Recommended Coolant Medium/Mixture         | 50/50 Propylene or Ethylene Glycol/Water         |     |                 |     |      |
| Recommended Coolant Flow                   | 0.0208 to 0.0505 L/s (0.33 to 0.8 GPM)           |     |                 |     |      |
| Inlet/Outlet Coolant Connection            | Hose Adapter, Threaded 1-14 UNF, Stainless Steel |     |                 |     |      |

## MECHANICAL DRAWINGS

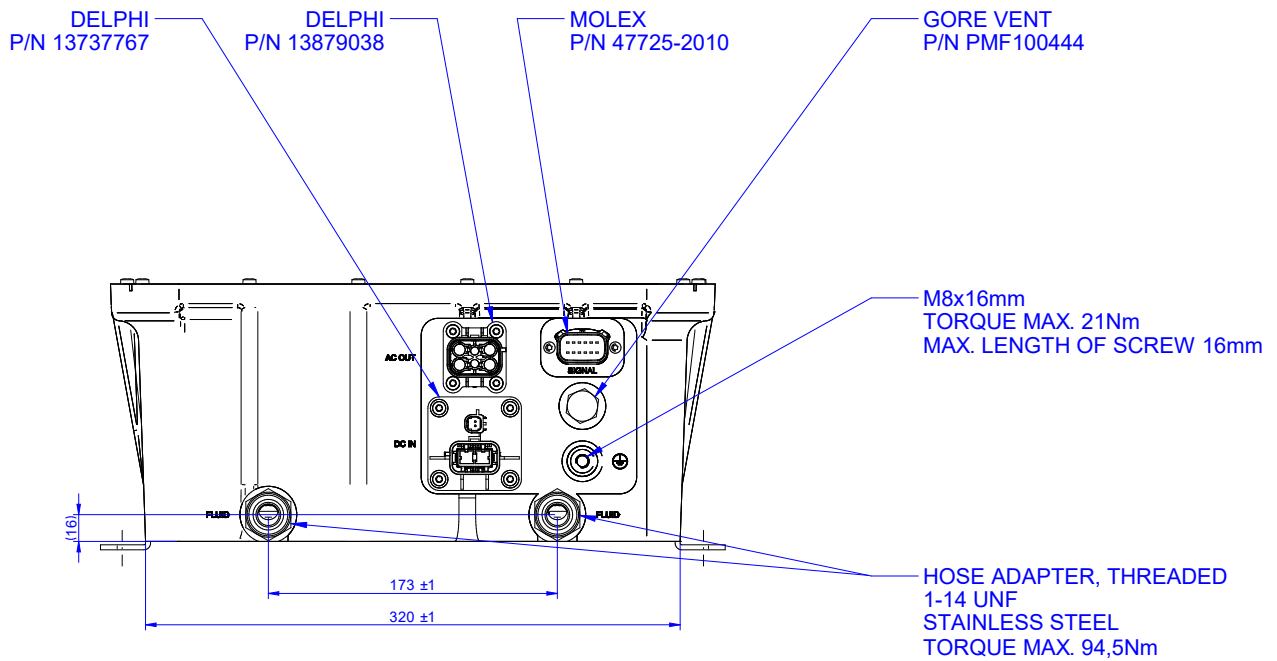


Figure 5. Front view

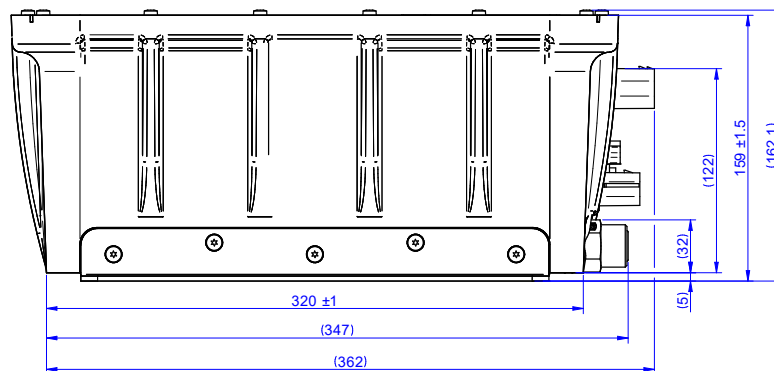


Figure 6. Side view

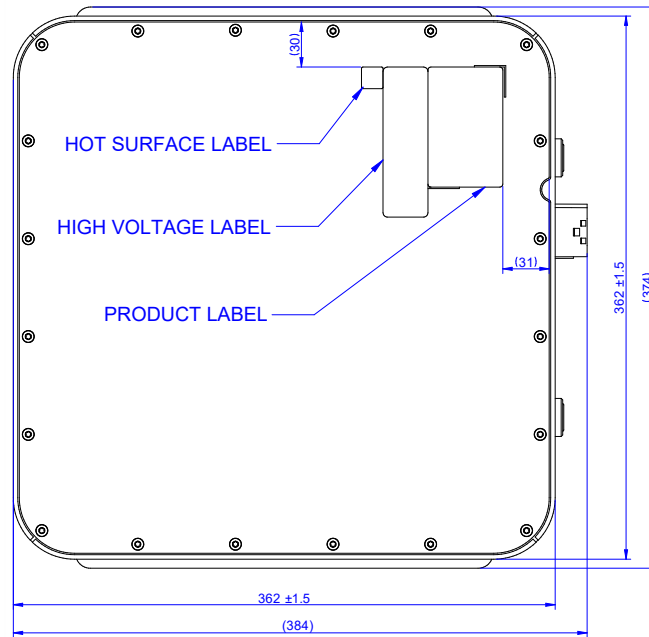


Figure 7. Top view

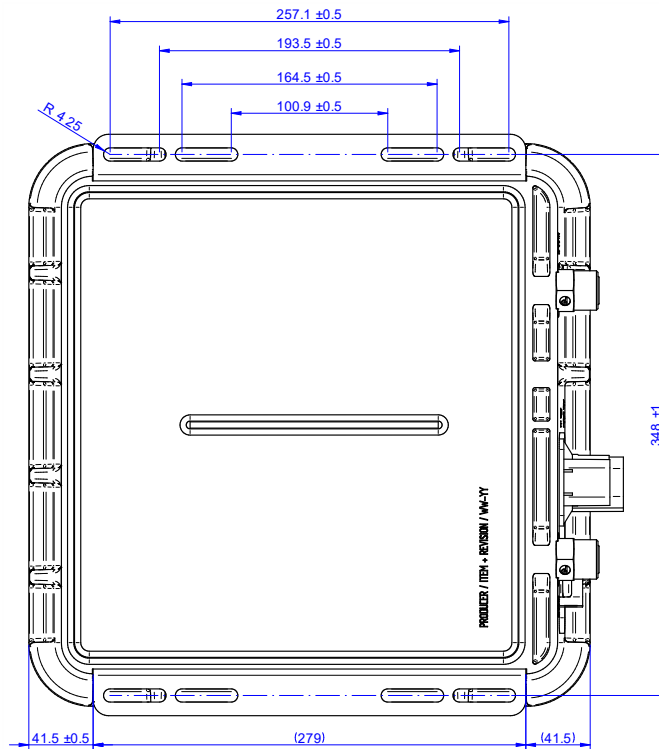


Figure 8. Bottom view

For more information on these products consult: [tech.support@psbel.com](mailto:tech.support@psbel.com)

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