1kW 24V / 48V Wireless Charger

WPU 1000W 1AC US / WPU 1000W 1AC EU +
WSU 1000W 24V / WSU 1000W 48V

User Manual and Professional Installation Guide

Smarter. Greener. Together.

Contents

1. Safety

1.1. User Safety Guide

⚠**WARNING** - RISK OF EXPLOSIVE GASES. WORKING WITH RECHARGEABLE BATTERY(s) IS DANGEROUS. EXPLOSIVE GASES DEVELOP DURING NORMAL BATTERY OPERATION. READ THIS MANUAL EACH TIME AND MAKE CERTAIN YOU FULLY UNDERSTAND IT AND FOLLOW THE SAFETY AND OPERATING INSTRUCTIONS AT ALL TIMES.

- To reduce risk of battery explosion, follow all safety instructions below and those published by the battery manufacturer. Review cautionary markings on vehicle or equipment containing the battery.
- Use of an attachment not recommended or sold by the battery charger manufacturer may result in a risk of fire, electric shock or injury to persons.
- Do not operate this charger if it has received a sharp blow, was dropped or otherwise damaged in any manner. Refer to a qualified service agent.
- The charger contains no user serviceable parts. If it fails during its warranty period, contact your dealer for a warranty replacement.
- To reduce risk of electric shock, unplug charger from AC outlet and disconnect battery before attempting any maintenance or cleaning.
- Have your distributor, dealer or other qualified service agent, repair or replace worn or damaged parts immediately. Repairs should not be attempted by unqualified people.
- Whenever removing AC Plug from the receptacle, pull from the Plug Body; not the cord.
- Do not operate the charger if it is malfunctioning. Personal injury or property damage could result.

⚠**WARNING**: MATERIAL DAMAGE POSSBILE! If metallic objects get into the air-gap between 2 pads during operation, they may get heated and damage the plastic cover.

- Select the installation site where no metallic objects can go into the air-gap and stay on the plastic cover of the pads.
- If the users would like to place the pads horizontally, it would be the users' responsibility to make sure no metallic objects will be staying on any pads during charging.

⚠**WARNING**: USERS ARE EXPOSED TO ELECTRIC AND MAGNETIC FIELD (EMF)!

- This equipment is not suitable for use in location where children are likely to be present.
- This device complies with the FCC RF exposure limits and has been evaluated in compliance with mobile exposure conditions. The equipment must be installed and operated with minimum distance of 20 cm between the pad and the human body.
- Operators (if any) should be trained to know their exposed to EMF, and keep enough distance from the pads.
- Users with medical devices, such as metallic prostheses, cardiac pacemakers and implanted defibrillators and cochlear implants, should keep away from the pads. The distance should be > 1m.
- Warning signs should be placed clearly during installation.

- If the equipment is used in public areas, the installer is suggested to reserve a specific charging zone, for which general public are forbidden to enter.

WARNING: ELECTROMAGNETIC INTERFERENCE POSSIBILITY

- This equipment has been tested and found to comply with the limits for a Class A device, pursuant to EN 55011 Group 2, EN 55032 Group 2, as well as a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the user manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

1.2. Personal Precautions While Working with Batteries

- Have someone within range of your voice to come to your aid if needed.
- Have plenty of fresh water and soap nearby in case battery acid contacts your skin, clothing or eyes. Wear eye and clothing protection and avoid touching eyes.
- If battery acid contacts skin or clothing, wash immediately with soap and water.
- If acid enters eye, immediately flush eye with running cold water for at least 10 minutes. Get medical attention immediately.
- NEVER smoke or allow a spark or flame in vicinity of battery.
- Be extra cautious not to drop a metal tool onto battery. It might spark or short circuit battery or other electrical part that may cause an explosion.
- Remove personal metal items such as rings, necklaces, watches, etc. Batteries can produce a short-circuit current high enough to weld such items causing a severe burn.
- NEVER charge a frozen battery. Thaw it out for safer and more efficient charging.

WARNING: CHARGERS CAN IGNITE FLAMMABLE MATERIALS AND VAPORS. DO NOT USE NEAR FUELS, GRAIN DUST, SOLVENTS, OR OTHER FLAMMABLES. TO REDUCE THE RISK OF AN ELECTRIC SHOCK, CHARGER SHOULD BE KEPT DRY. DO NOT EXPOSE TO RAIN OR WATER.

1.3. Declaration of Conformity for EU

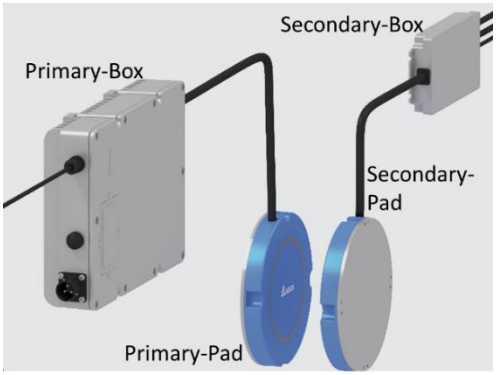
Hereby, Delta Energy Systems (Germany) GmbH declares that the radio equipment types WPU 1000W 1AC EU / WSU 1000W 24V / WSU 1000W 48V are in compliance with Directive 2014/53/EU.

The full text of the EU declaration of conformity is available at the following internet address: https://filecenter.deltaww.com/Products/Download/21/2110/1kW%20Wireless%20Charging%20System_EU%20DoC_EN_20207.pdf

2. Product Descriptions

2.1. System description

The wireless charger includes a primary side (transmitter, TX) and a secondary side (receiver, RX).

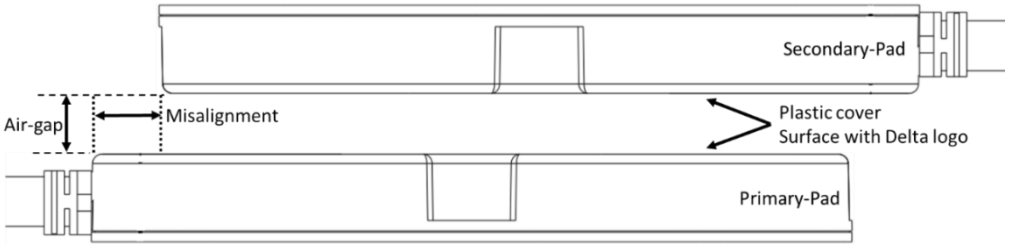


Primary side includes Primary-Box (or Wall-Box, TX-Box) and Primary-Pad (or Base-Pad, TX-Pad), and a cable between them. Normally it is installed on the infrastructure, such as wall or ground. Its function is to convert the electric power from the 1-phase AC input to the high-frequency magnetic power, and transfer out through the Primary-Pad.

Secondary side includes Secondary-Pad (or On-Board-Pad, RX-Pad) and Secondary-Box (or On-Board-Electronics, RX-Box), and a cable between them. It is installed on moving devices like AGVs. Its function is to receive the high-frequency magnetic power from the Secondary-Pad, and convert the magnetic power to the DC electric power, to charge the battery.

Corresponding to Primary-Pad's "wall-mounting" or "ground-mounting", Secondary-Pad need to be mounted at the side or bottom of the vehicle, and make sure that Primary-Pad and Secondary-Pad are face-to-face during charging.

2 important parameters for wireless charger, "air-gap" and "misalignment", are defined as following.



The operating frequency for wireless power transfer (WPT) is 160…250kHz at steady state, depending on the air-gap, misalignment and output voltage.

2.1.1. Wireless communication as a radio equipment

To fulfill the data exchange between the Primary and Secondary side, radio-frequency transceivers are used at both side, located in Primary-Box and Secondary-Box, respectively.

The used RF transceiver module is IEEE Std. 802.15.4 compliant. With an integral antenna, it has got Radio Regulation Certification for various countries and regions. With the module, the radio equipment operates at ISM Band 2.405…2.480GHz, with maximum RF transmit power as 0 dBm.

The wireless communication via the 2 RF transceivers at both sides is with a proprietary protocol, which can't be accessed by the user.

2.2. Functional description

When connected to an active AC power source, and if the Primary-Pad & Secondary-Pad are face-to-face with air-gap and misalignment within the specified range, the primary side is able to wirelessly transfer power to the secondary side, and eventually charge a battery via cables. The wireless power transfer can exist even when the air-gap or misalignment is up to 20mm. It's recommended to work at lower than 12mm air-gap to achieve optimized charging performance.

2.3. Technical Data

AC Input	
Nominal input Voltage	$100V_{AC}$ - $240V_{AC}$
Input Voltage Range	$85V_{AC}$ - $264V_{AC}$
Frequency	50Hz / 60Hz
Power Factor	≥ 0.95 at full load, EN 61000-3-2 Class A compliant

DC Output	
Nominal Output	24V / 48V
Voltage Range	$12V_{DC}$ - $30V_{DC}$ / $24V_{DC}$ - $60V_{DC}$
Efficiency	≥90% (25°C, $230V_{AC}$, nominal output voltage, 1kW, 0mm air-gap, no misalignment)
Current Demand Range	Up to 41.7A for 24V variant; Up to 20.8A for 48V variant
Ripple Current(1)	Low frequency (<300Hz): ≤$6A_{pk\ to\ pk}$ for 24V variant; ≤$4A_{pk\ to\ pk}$ for 48V variant High frequency (>1kHz): ≤$4A_{pk\ to\ pk}$ for 24V variant; ≤$3A_{pk\ to\ pk}$ for 48V variant

Note (1): test conditions - without battery, on resistive load with 100,000uF capacitor in parallel.

Protection	
Over-voltage	Protect if the charger measures excessive voltage on the output terminals. Immediate OVP threshold is approximately $33V_{DC}$ for 24V variant, and $66V_{DC}$ for 48V variant; Slow OVP threshold is (1+0.5%) * setting voltage, for over 10s.
Over-current / Short Circuit	Triggered by excessive current being drawn or a short on the output terminals. OCP threshold is nominally 46A~50A for 24V variant, 23A~25A for 48V variant; or (1+5%) * setting current, for over 10s.
Over-temperature	Triggered by internal excessive temperature.
Battery Reverse Connection	The charger will not be damaged if the battery is connected in reverse.
Input under / over voltage	Protect against input voltages out of the specified operating range.

All protection faults are indicated by the red LED on the cover of Primary-Box, and result in the charging off.

Environmental	
Air-gap(1)	0 - 20mm
Misalignment(1)(2)	0 - 20mm
Operating Temperature	-20°C - 50°C
Storage Temperature	-40°C - 85°C
Humidity (non-condensing)	0% - 95%
Operating Altitude	-100m - 3000m

Note (1): Refer to section 2.1 for the definitions.

Note (2): Defined at nominal output voltage (24V/48V).

Regulatory	
Safety	IEC 60950-1 and IEC 62368-1 CE marks, cULus/cCSAus/cMETus or equivalent marks
EMC / Stray field	EN 55011, EN 55022 & FCC, Class A Refer to ICNIRP Guidelines 2010, for Occupational exposure
Material	EU WEEE Directive 2012-19-EU, EU RoHS Directive 2011/65/EC, EU REACH Directive 1907/2006

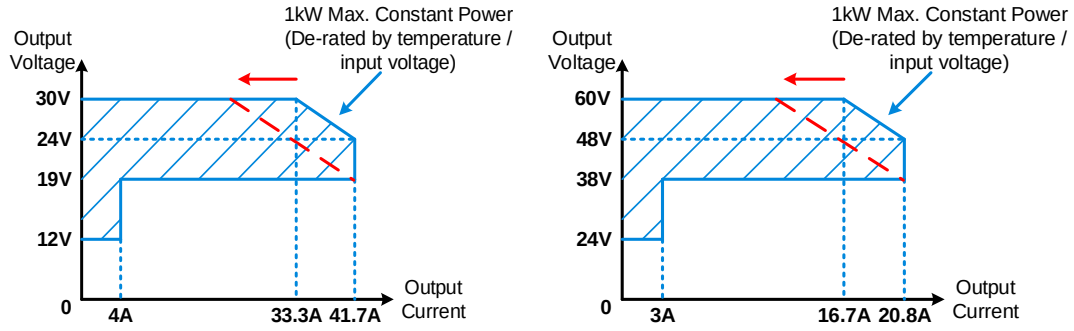
2.4. Output power and de-rating

2.4.1. Output power vs. terminal voltage

For 24V variant, charging current can be 41.7A maximum when the battery terminal voltage is at 19V ~ 24V. While at 24V ~ 30V, charging current will automatically be decreased to keep 1000W maximum output power. A maximum charging current of 4A can be delivered at 12V ~ 19V.

For 48V variant, charging current can be 20.8A maximum when the battery terminal voltage is at 38V ~ 48V. While at 48V ~ 60V, charging current will automatically be decreased to keep 1000W maximum output power. A maximum charging current of 3A can be delivered at 24V ~ 38V.

The curves are shown as following. Low input voltage and high ambient temperature would result in a de-rated output power, details as section 2.4.2 and 2.4.3.

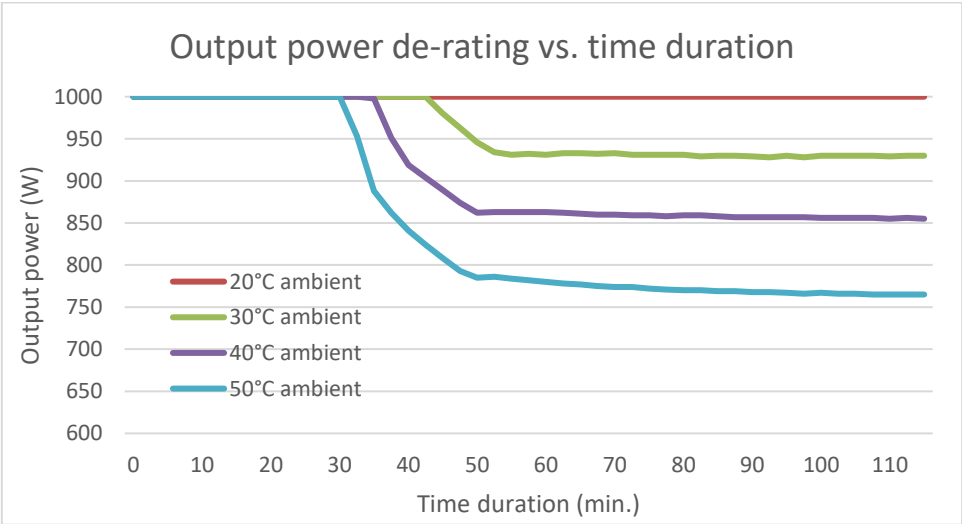


2.4.2. Power vs. input voltage

Output power will be de-rated when input voltage is < 100Vac, to keep input current ≤ 13A.

2.4.3. Power vs. ambient temperature

Due to the requirements on the chassis temperature limitation in safety standards, the output power will be automatically de-rated per different ambient temperature conditions. Typical (tested, not guaranteed) curves are shown below. Tested at 24V output, for the conditions of 20°C, 30°C, 40°C, 50°C ambient. The final output power will be 1000W, 920W, 850W, 760W, respectively.



The power de-rating situations at high ambient temperature can be improved by attaching heat-sinker to the bottom of Secondary-Box.

2.4.4. Power transfer capability at different air-gap / misalignment conditions

As stated in section 2.4.1, 1000W maximum power can be outputted only in the output voltage range of nominal ~ maximum (24V~30V, or 48V~60V). But output power will be also impacted by output voltage in different air-gap / misalignment conditions.

At nominal output (24V / 48V), power can reach 1000W at any air-gap / misalignment of 0~20mm.

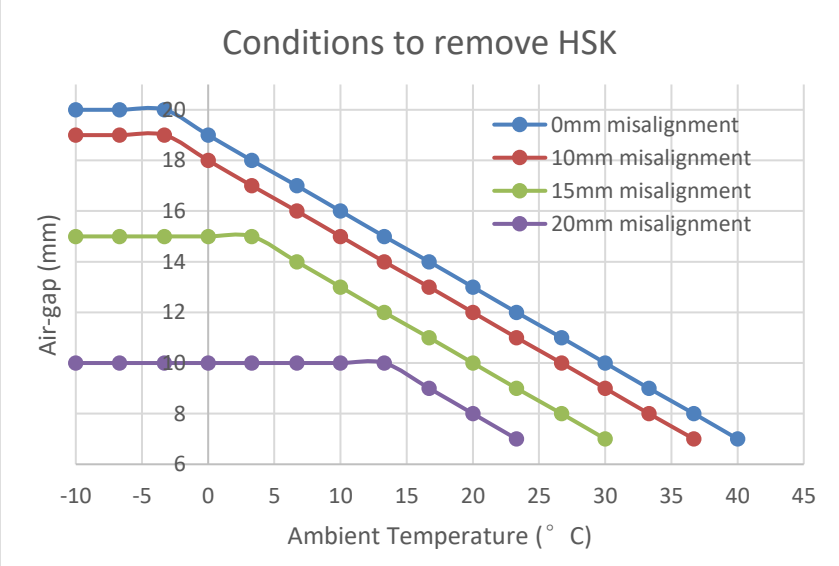
At higher voltage, the accepted air-gap / misalignment range for 1000W output will be narrower. Typical data for maximum output voltage (30V / 60V) is shown below for a reference.

Air-gap	Max. misalignment for 1000W output	Max. Power at 20mm misalignment
0~6mm	20mm	1000W
8mm	18mm	600W
10mm	17mm	450W
12mm	16mm	150W
14mm	15mm	60W
16mm	10mm	60W
18mm	5mm	NA
20mm	5mm	NA

2.5. Heat-sinker

There is already a Heat-sinker (HSK) being attached to the chassis of Primary-Pad, shown in section 2.6.1 and section 3.2.2. This HSK is to improve the thermal situation of the Primary-Pad at high ambient temperature and air-gap / misalignment, as well as to avoid the charger's shut-down due to over-temperature-protection (OTP) of the Primary-Pad in this condition.

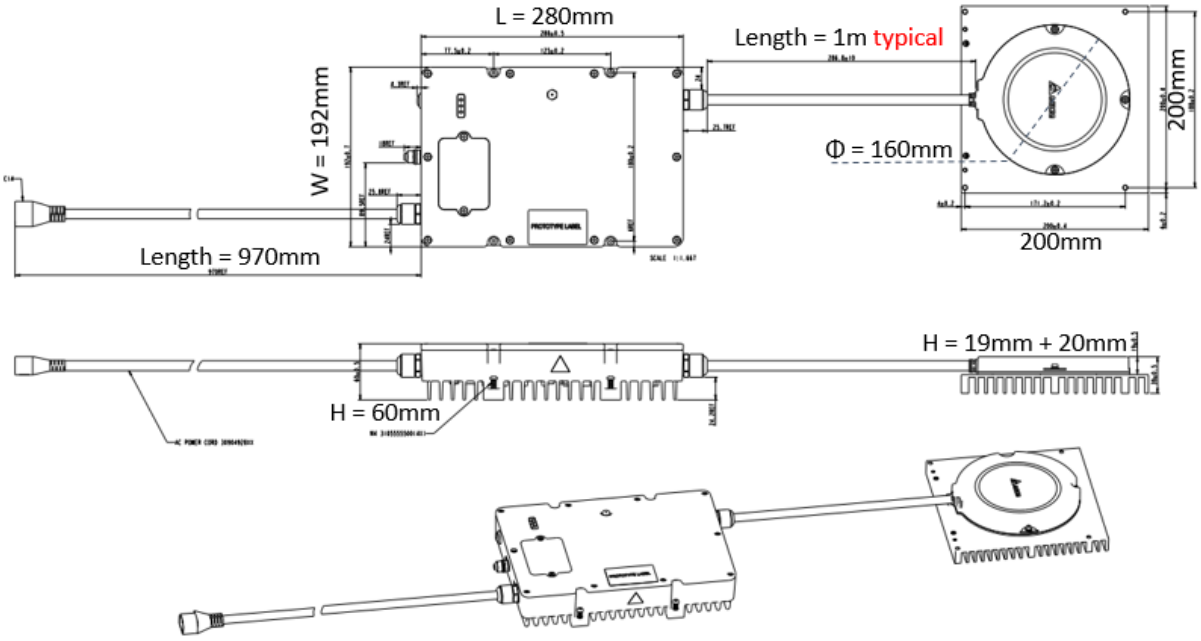
If the user can ensure the operating temperature is low, or the air-gap / misalignment can be well controlled to be low enough in the operation, the HSK can also be removed. The conditions to remove the HSK are shown in below curves.



2.6. Physical Dimensions

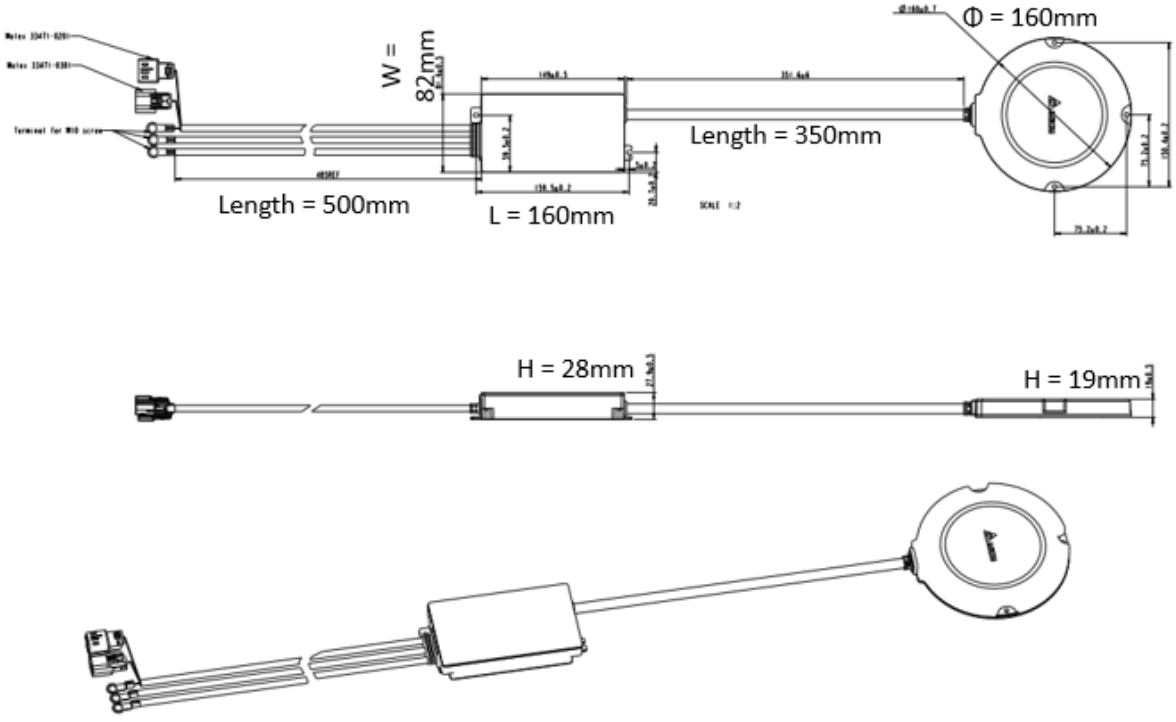
The users can ask Delta for the 3D files for the design of system installation/integration. Key data of the dimensions are shown below.

2.6.1. Primary side (transmitter)



Note: the length of the cable between Primary-Box and Primary-Pad should be 1m typical. This can be changed per customer request. Minimum 0.3m, maximum 1m.

2.6.2. Secondary side (receiver)



2.7. Included in delivery

- 1kW wireless charger primary side (transmitter).
- 1kW wireless charger secondary side (receiver) - 24V, or 1kW wireless charger secondary side (receiver) - 48V.

2.8. Dev Kits (Delta PN EOE99000823)

When requested, a set of Dev Kits can be provided to the user for easy connection to the signal connectors (refer to section 4.2) and the using of Delta's CAN-Bus GUI (refer to section 6.4). Below materials are included in the Dev Kits:

1. CAN-to-USB adapter, 1pc.
2. A cable with D-Sub connector (Delta PN 3081434602), for the connection from the adapter to the wireless charger.
3. A cable (Delta PN 3673135400) for the mating of connector C2 mentioned in section 4.2.

The detailed information of the Dev Kits is also mentioned in section 6.4.2.

Note that the Dev Kits are not included in the package mention in section 2.72.7.

3. Installation

 **WARNING**: MATERIAL DAMAGE POSSBILE! If metallic objects go into the air-gap between 2 pads during operation, they may get heated and damage the plastic cover.

- Select the installation site where no metallic objects can go into the air-gap or stay on the plastic cover of the pads.

3.1. Installation Precautions

- The charger shall be installed in an environment with ambient temperature of -20 to 50°C, and is suggested to operate in 0 to 30°C ambient temperature.
- The charger has been considered for use at an altitude between -100m and 3000m, pollution degree 2 environment and overvoltage category II application.
- Earthing connection has to be ensured, details refer to section 3.2.1 and 4.1.

3.2. Installation

The users can ask Delta to provide 3D files, to have more clear idea about the installation.

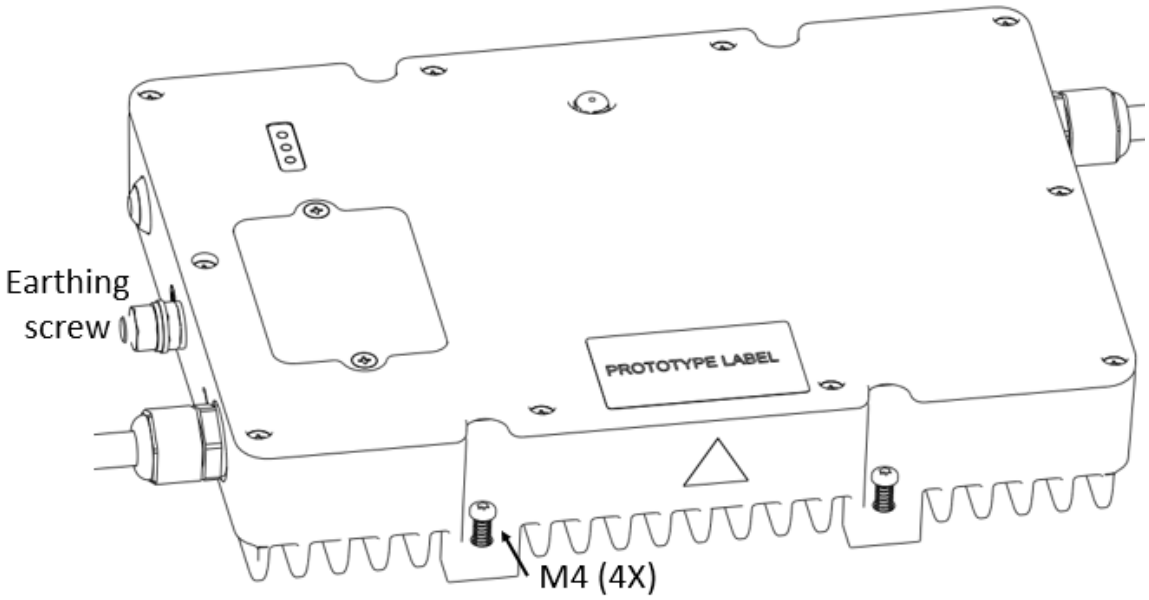
There are coils in the Primary-Pad and Secondary-Pad, to implement wireless power transfer. There are wireless communication modules in the Primary-Box and Secondary-Box, to implement wireless communication for message transfer. The installation is important to ensure stable wireless power transfer and wireless communication.

By proper installation, during charging it's better to avoid the situation that Primary-Box, 2 pads, Secondary-Box are in a straight line, and the pads are in the middle of Primary-Box / Secondary-Box.

3.2.1. Primary-Box (Wall-Box)

Use 4pcs of M4 screws.

It is strongly suggested to lock a cable from Power Earth (PE) to the Earthing screw, in order to achieve desired EMI performance. However, electronic functionally, to remove this connection won't impact the charger's working.



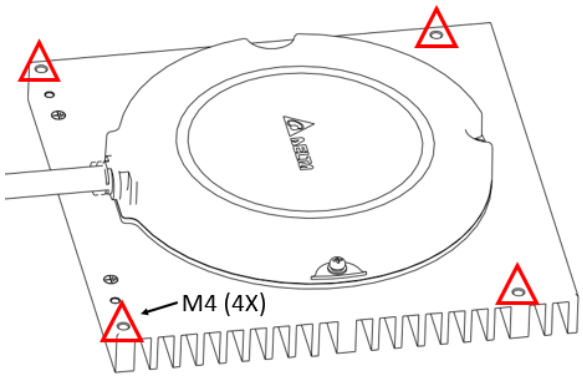
Note: there is a plastic “window” on the Primary-Box with 2 screws. Make sure no metallic object covers this window during charging, otherwise the wireless communication between Primary side and Secondary side will be impacted.

3.2.2. Primary-Pad (Base-Pad) and Secondary-Pad (On-Board-Pad)

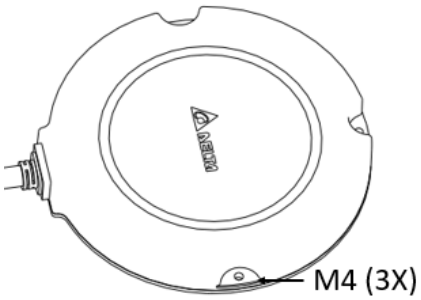
These 2 parts share the same outlines.

1. Screws

Primary-Pad is already fixed on a heat-sinker (included in the delivery) by 3pcs of M4 screws. Use 4pcs of M4 screws for mounting the heat-sinker.



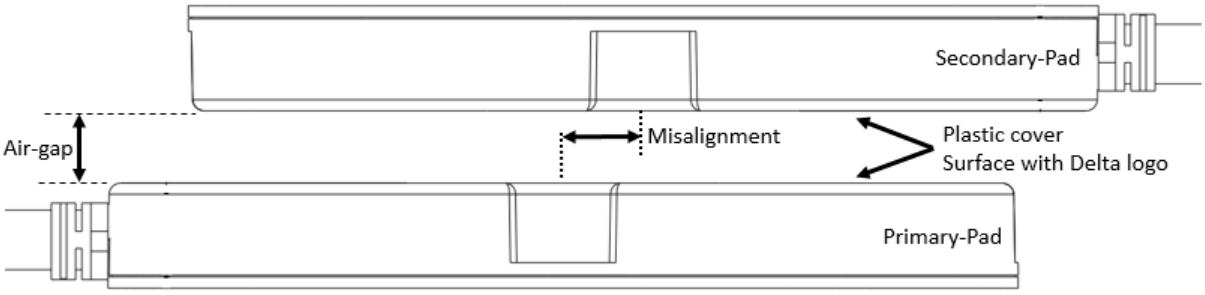
Use 3pcs of M4 screws for Secondary-Pad.



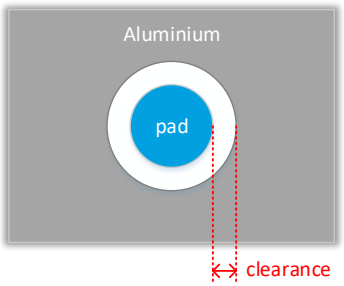
2. *Installation for effective wireless power transfer*

There 2 pads are the key components to implement wireless-power-transfer, and the installation of these 2 pads need special attentions -

- Primary-Pad and Secondary-Pad need to be face-to-face during charging. Here "face" is consider to be the surface with "Delta" logo on the plastic cover.
- Air-gap and misalignment need to be within specified ranges during charging.
- Make sure no metallic object stays between the pads during charging. (Warning: If the users would like to place the pads horizontally, it would be the users' responsibility to make sure no metallic objects will be staying on any pads during charging.)



3. *Metal around the pads*

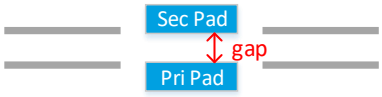


When the primary / secondary pads are installed onto infrastructure and the vehicle, respectively, it's always suggested that they are installed onto plastic parts if the mechanical strength is acceptable.

If the pads have to be installed onto metal parts, AVOID steel / iron due to the loss on steel / iron could be pretty high, which leads to an unacceptable temperature. More proper material could be aluminium.

To avoid excessive loss on the metal parts, it's strongly suggested that the metal parts are at the base of the pads (below left picture), rather than at the top (below right picture).

Metal parts at the base of pads



metal parts at the top of pads

If the aluminium parts are at the base of pads -

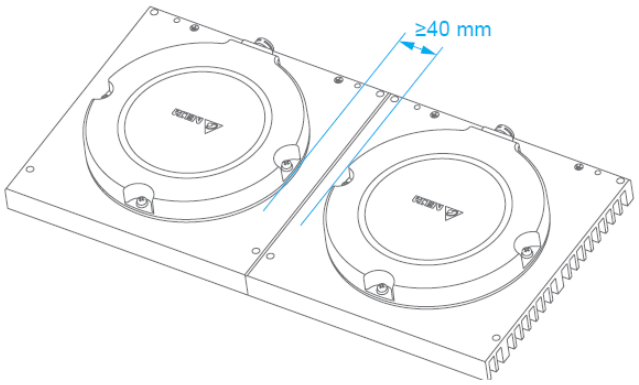
- Users don't need to pay attention to the "clearance".
- The thickness of the aluminium part should be as small as possible, if the mechanical strength is acceptable.

If the aluminium parts have to be at the top of pads -

- the "clearance" should be as large as possible. Reserve > 15mm.
- The loss on the aluminium part is not impacted by the thickness.

4. Installation for multiple pads

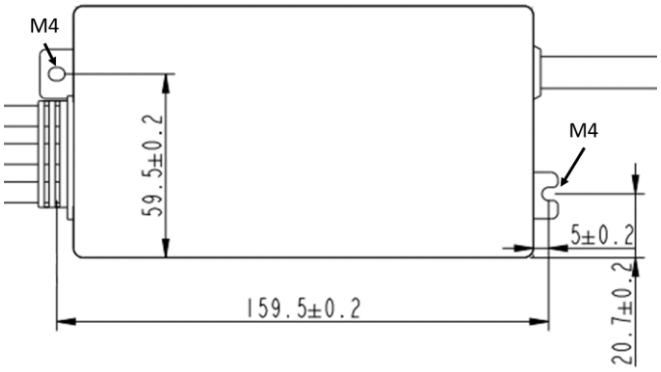
If 2 or more units are working in a close area, the adjacent Primary-Pads (with heat-sinkers) can be placed side-by-side. Without the heat-sinkers, the adjacent Primary-Pads need to be separated with a 40mm distance from the edges.



3.2.3. Secondary-Box (On-Board-Electronics)

Use 2pcs of M4 screws. If accepted, it is better to mount the Secondary-Box on a big metal plate in vehicle.

Note: Don't mount the Secondary-Box inside a vehicle with full-metal housing, otherwise the wireless communication between Primary side and Secondary side will be impacted.



3.2.4. Cables

There is a cable between Primary-Box and Primary-Pad. During installation, it should be avoided to stretch this cable to generate excessive mechanical stress. The minimum bend radius of the cable shouldn't be less than 150mm.

The situation is the same for the cable between Secondary-Pad and Secondary-Box.

3.3. User Considerations

⚠ **WARNING**: DURING CHARGING THERE WILL ELECTRIC AND MAGNETIC FIELDS BETWEEN THE PADS. DURING OPERATION, HUMAN BODIES MUST BE KEPT A DISTANCE OF >= 20cm FROM THE PADS. PLEASE NOTE AND FOLLOW THE OPERATION AND INSTALLATION INSTRUCTIONS IN SECTION 3.3 BELOW. IT IS THE RESPONSIBILTY OF THE INSTALLER TO PROVIDE SUFFICIENT WARNINGS, KEEPOUT RESTRICTIONS AND TRAINING TO ALL PERSONNEL.

Active charging will generate electric and magnetic fields between the pads. The charger has been designed to minimise stray fields and has been tested as complying with the following standards:

- EN 62311:2008
- FCC OET KDB 447498 D01
- FCC 47 CFR part 2.1093
- FCC 47 CFR part 2.1091
- ISED RSS-102 Issue 5

However, it is still necessary to take precautions to work safely with the charger.

During operation, human bodies must be > 20 cm away from the pads. Operators should be informed that they could be exposed to electromagnetic fields, and that they should keep sufficient distance from the pads. Additionally, users with medical devices, such as metallic prostheses, cardiac pacemakers, implanted defibrillators, and cochlear implants, should stay at least one meter away from the pads.

3.3.1. Critical RF Exposure Installation Requirements

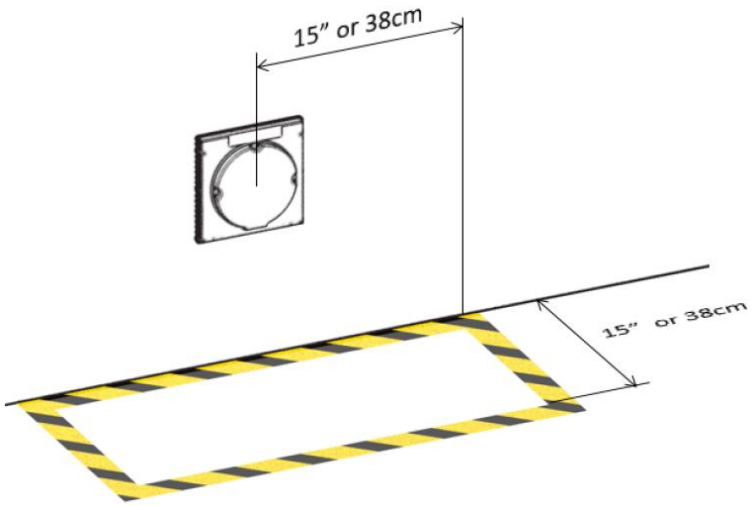
The installer of the system must provide adequate training to all operators and to place warning signs / warning lights / restrictions accordingly. A physical restriction must be in place to prevent operators or by-standers from coming closer than 20cm to the pads of wireless charger during operational charging. This barrier may be met by the physical characteristics of the placement of the wireless charger in the application. For example, a product that is large in size relative to the charger pad means that the secondary pad can be kept >= 20cm from the edges of the vehicle. In those cases, there is no possibility of a user physically being able to be within 20cm of the pads during charging due to the installation location alone.

For the charger installation area, it is suggested to mark a keep-out zone with a minimum of 15'' around the Primary-Pad as well as place warning signs saying not to enter the zone. The recommendation for keep out areas in three installation scenarios are presented in the table below,

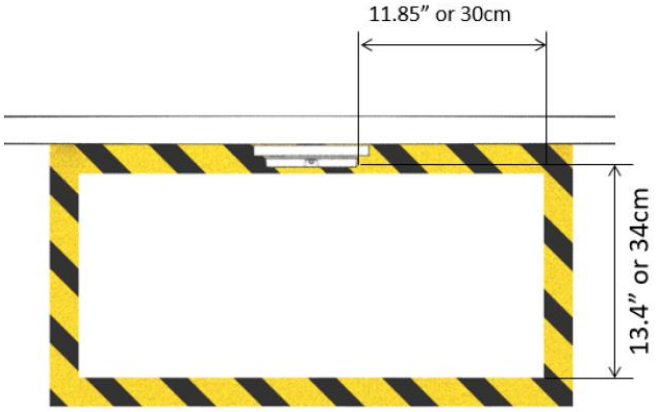
Scenario	Primary-pad mounted	Typical restriction / keep-out
1	To a wall	30cm from the edge of pad, 34cm from the surface of pad. A 76cm * 38cm rectangle against the wall.
2	On a column or post	A 76cm * 76cm square with same center as the pad.
3	On the floor	A 76cm * 76cm square with same center as the pad.

1. *Primary-Pad mounted to a wall*

Installer marks a keep-out as follows:

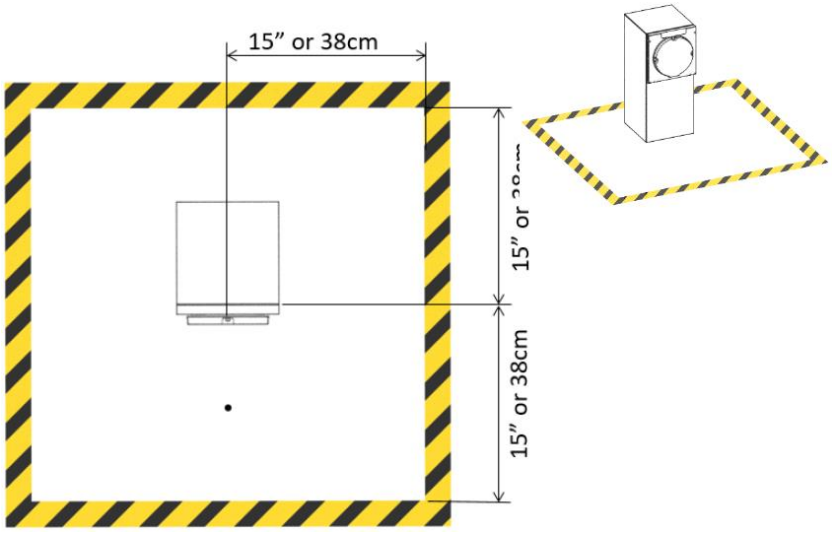


This will result in any human in the vicinity of the Primary-Pad being warned to keep at least the following distances from the plastic surfaces of the pad:

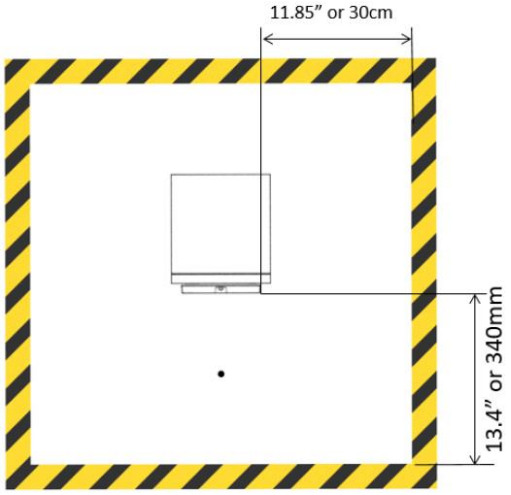


2. *Primary-Pad on a column or post*

Installer marks a keep-out as follows:

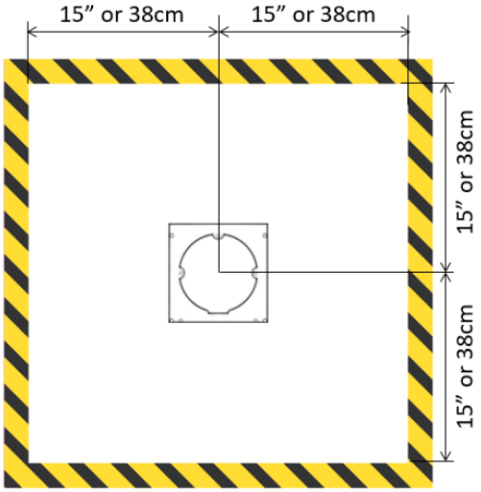


This will result in any human in the vicinity of the Primary-Pad being warned to keep at least the following distances from the plastic surfaces of the pad:

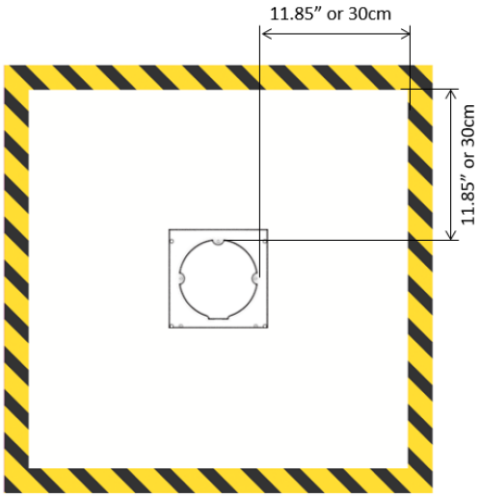


3. *Primary-Pad mounted on the floor*

Installer marks a keep-out as follows:



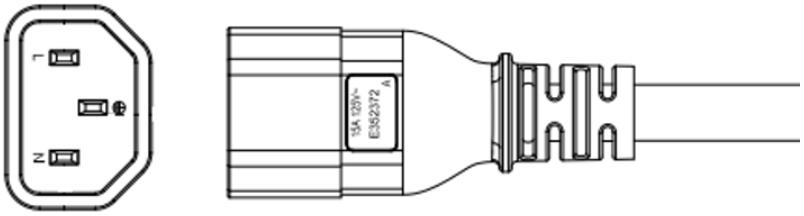
This will result in any human in the vicinity of the Primary-Pad being warned to keep at least the following distances from the plastic surfaces of the pad:



4. Connections for Input / Output

4.1. Input connector

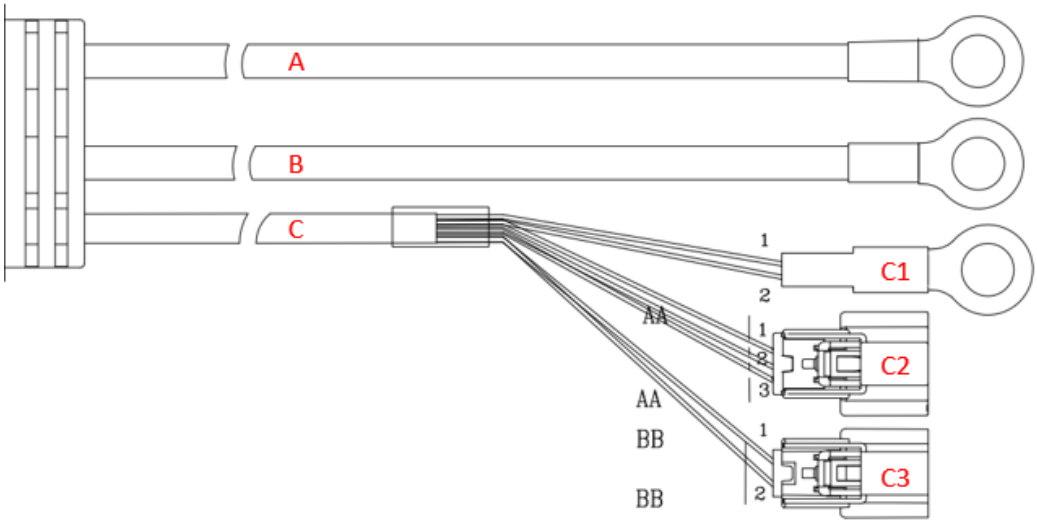
AC input connector at Primary-Box side is standard IEC C14 connector, shown as below.



A standard IEC C13 connector can be used at user side as the mating connector. **Note:** if it's planned to run the charger at 100-120Vac input with full power, the user need to ensure the cable with the mating connector is capable of supporting at least 13A current. AWG #14 or thicker wires are recommended in the cable.

The Earthing connection on the mating connector/cable has to be ensured at the user side.

4.2. DC output cables, signal cables / connectors



Signal	Cable no.	Colour	Cable thickness	Recommended screw
Output+	A	Red	AWG #8	M10
Output-	B	Black	AWG #8	M10

Cable A/B need to be fixed onto the +/- terminals of the battery, respectively.

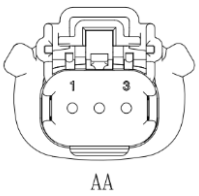
Cable C is for signals. Inside Cable C, the wires are AWG #22.

4.2.1. Cable / connector C1

This is a temperature sensor, which need to be fixed onto the negative terminal of the battery (suggested to be done by M10 screw) when the charger need to work in the “Profile Follower” mode, which is mentioned in section 5.3.2.

4.2.2. Cable / connector C2

The connector is of Molex MX150 series, sealed: 3-pin, 1 row. Molex P/N 33471-3301.
Pin no. is defined by looking from AA side. (AA is also shown in above drawing for overall A+B+C cables for power + signal).



Pin #	Assignment
1	EXT_Enable
2	Sleep
3	EXT_Signal_GND

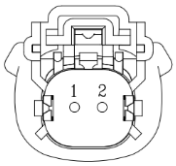
C2 is for external signals. Pin 1 (“EXT_Enable”) is for Power ON/OFF control for Profile follower mode, pin 2 (“Sleep”) is for Sleep Mode control, and pin 3 (“EXT_Signal_GND”) is the common ground / negative pin of pin 1 / 2.

Refer to section 6.5 for the details of the signals.

The signals on C2 connector is optional on vehicle. If the users find it necessary, a mating connector from Molex has to be used for the connection. (Molex P/N 33481-0301, 1pc, as the housing; Molex P/N 33000-0004, Delta P/N 3040129328, 3pcs, as the pins; or contact Molex if any special requests.)

4.2.3. Cable / connector C3 is for CAN-Bus interface.

The connector is of Molex MX150 series, sealed: 2-pin, 1 row. Molex P/N 33471-0201.
Pin no. is defined by looking from BB side. (BB is also shown in above drawing for overall A+B+C cables for power + signal).



BB

Pin #	Assignment
1	CAN_H
2	CAN_L

CAN_H and CAN_L are differential communication CAN-Bus signals. Refer to section 6.3 for the details of CAN-Bus.

A mating connector from Molex has to be used on vehicle for the connection. (Molex P/N 33481-0201, Delta P/N 3051630928, 1pc, as the housing; Molex P/N 33000-0004, Delta P/N 3040129328, 2pcs, as the pins; or contact Molex if any special requests.)

5. Operations

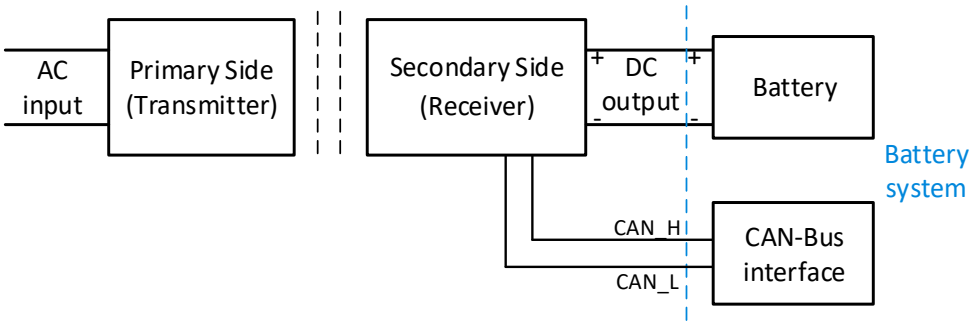
WARNING: MATERIAL DAMAGE POSSBILE! If metallic objects go into the air-gap between 2 pads during operation, they may get heated and damage the plastic cover.

5.1. Operation Precautions

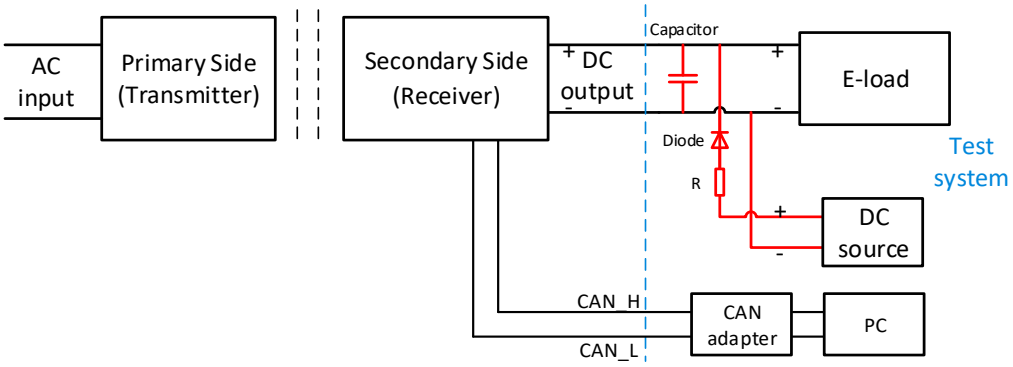
- The charger can be operated in an ambient temperature of -20 to 50°C, and is suggested to operate in an ambient temperature of 0 to 30°C.
- The charger has been considered for use at an altitude between -100m and 3000m, pollution degree 2 environment and overvoltage category II application.
- The charger shall be used to charge ~24V batteries or ~48V batteries.
- Prior to wireless charging, both primary side (transmitter) and secondary side (receiver) need to be in steady locations, and make sure the gap / misalignment value is in the specified ranges.
- Fast movement of the magnetic pads (Primary-Pad and Secondary-Pad) should be avoided during the charging process.

5.2. System configuration

After connection of AC input, DC output and CAN-Bus signal, the overall system block diagram is shown as below.



For bench test purpose, an electronics load with CV mode can be used. System block diagram in this condition is shown as below. In the test system, to simulate the battery, an 100mF capacitor need to be connected in parallel at DC output bus, and a pre-charging circuit (including DC source, diode, resistor for current limiting) is necessary to charge the capacitor to a reasonable voltage value (e.g. 24V for 24V variant, 48V for 48V variant) before turning on the wireless charger.



NOTE: the charger is designed to operate with battery only. The performance is not guaranteed for the operation with electronic load.

The charger won't have any outputs in the status of output open circuit.

5.3. Operations

5.3.1. Prepare everything

To let the wireless charger be working, the user needs to be aware of below items.

- None of the precautions mentioned in section 3.1 shall be violated.
- Pay attention to the info in section 3.2 and 4, and follow the configuration in section 5.2.
- Make sure input voltage is presented, and air-gap between the pads are within specified range.
- Make sure the charging is initiated in either working modes, see section 5.3.2 for the details.

When the user is using Delta's Dev Kits to have functional testing, the user need to make sure –

- The CAN adapter has been correctly connected. See section 6.4.2 for the details.
- The CAN adapter's driver program has been correctly installed on the PC. See section 6.4.3 for the details.
- Delta GUI software is correctly operated. See section 6.4.4 for the details.

5.3.2. Working modes

It's well known that constant-current / constant-voltage phases need to be considered in battery charging. Moreover, to better maintain the batteries and extend its life time, all the batteries should be charged according to specific charging profiles.

The charging profile data could be maintained by the BMS, or stored in the charger's internal memory. Correspondingly, the wireless charger can work in either "CAN-controlled" mode or "Profile follower" mode, whose details are shown below.

1. **"CAN-controlled" mode**

It's intended that the charger works with a vehicle / battery with a CAN-Bus interface, and the vehicle / battery can send control commands to the charger, as well as monitor its statuses via CAN-Bus communication digitally.

The vehicle / battery is supposed to send correct control commands to the charger via CAN-Bus. Accordingly, the charger will follow the commands to charge the battery.

A control command is a CAN message, including a set-point of the charging cut-off voltage, a set-point of the maximum charging current, as well as a bit for Turn-On command.

Charging process will be stopped as long as the control command is failed to be sent for a specific time duration, or the bit of Turn-On command is set to be 0.

Please refer to section 6.3 for the details of CAN-Bus.

Note: in this mode the vehicle / battery is taking over the control of charging. It is the responsibility of the user to adhere to the correct charging parameters as stated in the datasheet of the battery. The users are suggested to consult with Delta about how to set correct parameters if they are not confident.

2. **Profile follower mode**

If the vehicle / battery doesn't have a CAN-Bus interface, Delta can also provide the function of "Profile Follower", which is to charge a battery by following the specific charging profile, whose data is stored inside the charger.

"EXT_Enable" need to be activated / deactivated by the vehicle controller, to initiate / stop the charging. Refer to section 6.5.1 for the details.

When working in profile follower mode, CAN commands are bypassed, but other CAN messages are still available. That is to say, the charger's status can be still read via CAN-Bus.

As the operating temperature impacts charging profile, the temperature sensor mentioned in section 4.2 need to be fixed to the negative terminal of the battery, especially for lead-acid batteries.

Before trying to let charger work in this mode, the User shall contact Delta, and provide the tech details of the battery. Delta might need months to create the charging profile data and qualify that.

Besides CAN-controlled mode and profile follower mode for normal battery state, there is another special working mode for abnormal battery state, whose details are shown in section 5.3.3.

5.3.3. How to handle a "dead" Li-ion battery?

It's always suggested that the battery should get charged before its SOC goes to very low, otherwise the battery could be in a "dead" state with terminal voltage = 0V. And the electronics on the vehicle will lose power, so that the vehicle can't move any more, as well as can't let the charger to start charging, due to it can't have CAN-Bus communication with the charger, nor to activate "EXT_Enable" signal.

Delta provides a solution to get the "dead" Li-ion batteries back to normal state, which is a special working mode called as "Li-ion battery recovery mode".

In this case, the user need to manually move the vehicle to the charging zone, and make sure the wireless charger's secondary/primary pads are in the specified operation range.

Make sure the input voltage is presented (the 1st Green LED on the primary-box is ON, refer to section 6.2). Then press the button switch on the primary-box (refer to section 6.1), hold for at least 3 seconds, then release. The charger will then start to give a constant current (3A maximum for 24V variant, 1.5A maximum for 48V variant) to the battery, to help the battery recover. The 2nd (middle) LED on the primary-box would be blinking.

When the battery recovers to normal states, the vehicle electronics should have power again, to be able to work with the charger and let it transfer to one of the 2 working modes mentioned in section 5.3.2.

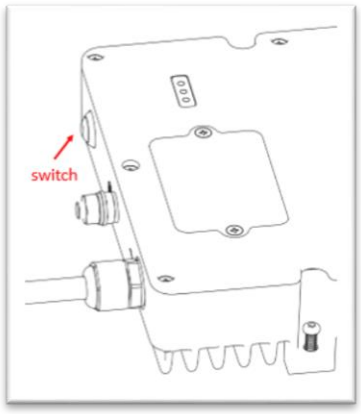
The charger will also stop working in the “battery recovery mode” as long as one of these conditions is satisfied - charger has worked in this mode for 1 hour, or the voltage has reached 24V for 24V variant, or 48V for 48V variant.

Note: This working mode is default disabled. If the users need this function, please contact Delta.

6. User Interfaces

6.1. Switch

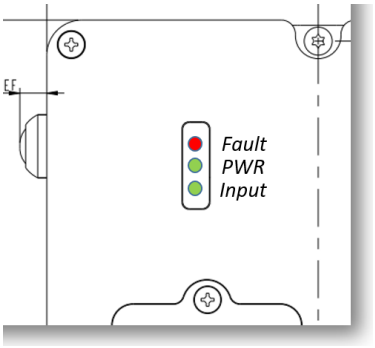
A button switch is located on the chassis of Primary-Box. A “press-and-release” operation on the button switch can reset the charging process.



Moreover, Delta provides a speical working mode as “Li-ion battery reovery mode”, which needs an operation on the switch for pressing and holding for >3s then releasing. Refer to section 5.3.3 for the details.

6.2. LED indicators

3 LEDs are located on the cover of Primary-Box:



The LEDs have different statuses at different conditions:

Condition	*1st Green LED - for input OK*	*Midde Green LED - for charging*	*Red LED - for Faults*
No input	OFF	OFF	OFF
Charging	ON	ON	OFF
Li-ion battery recovery mode	ON	1Hz flashing	OFF
Input presented, charging process OFF	ON	OFF	OFF
Fault	ON	OFF	1Hz flashing

6.3. CAN-Bus

A cable/connector at Secondary-Box (shown in section 4.2) is the CAN-Bus interface. An intelligent digital solution is provided for optimum system flexibility. Users can give the control commands to wireless charger and monitor its statuses via CAN-Bus communication digitally. A private protocol is used for CAN-Bus communication.

The CAN protocol spec can be provided as .dbc files. Before to let the vehicle / BMS communicate with the charger, please contact Delta to ask for the .dbc file, as well as a document to describe the important messages in the protocol.

It follows CAN 2.0A, with IDs as 11 bits.

A necessary command (a little part of the protocol spec) is shown as below.

Message Name	*Message ID*	*Signal name*	*Start bit*	*Length [Bit]*	*Factor*	*Unit*	*Description*
ControlModule	0x19x	Demand_V	0	20	0.001	V	The set-point of charging cut-off voltage. When the battery terminal voltage reaches this value, the charging current will reduce (eventually to 0), to keep the voltage staying at this value.
		Demand_Power Stage1	20	1	1		1 = Turn on, 0 = Turn off
		Demand_ClearFaults	21	1	1		1 = Clear Faults. Set this bit to clear faults and re-start charging when there's a fault. Note: OVP and OCP excluded, which need a "Turn off" command then a "Turn on" command.
		Demand_Power Stage10	22	1	1		1 = Turn on, 0 = Turn off, for the unit 2~10 in the parallel system. If just standalone running without any parallel units, these 9 bits can be kept as 0.
		Demand_Power Stage2	23	1	1		
		Demand_Power Stage3	24	1	1		
		Demand_Power Stage4	25	1	1		
		Demand_Power Stage5	26	1	1		
		Demand_Power Stage6	27	1	1		
		Demand_Power Stage7	28	1	1		
		Demand_Power Stage8	29	1	1		
		Demand_Power Stage9	30	1	1		
		Demand_I	32	18	0.001	A	The set-point of maximum charging current.

Notes:

One of the necessary conditions to initiate the charging process is to send a command on Message ID 0x190 from vehicle / battery.

The protocol supports parallel operation, and up to 10 wireless chargers can be connected on the same CAN-Bus. Here "x" in the signal name "Demand_PowerStagex" (bit 20, 22~30) indicates the on/off control to unit x in the parallel system. If just standalone running without any parallel units, only Demand_PowerStage1 in these 10 bits need to be set.

There is a watchdog in the CAN-Bus communications, which requires the vehicle / battery to send the command on Message ID 0x190 regularly, otherwise the charger will judge as a communication timeout, and shut-down the output. In the case that the CAN-Bus communication is failed so that the charger can't receive correct commands from vehicle / battery to stop charging, the benefits of the watchdog is to avoid the battery's being over-charged due to continuous charging. It's suggested that the 0x190 message is sent every 100ms.

Default baud rate is 1Mbps. The user can also configure baud rate to 125kbps, 250kbps, 500kbps or 800kbps via CAN-Bus protocol, please contact Delta for the details.

6.4. GUI for PC

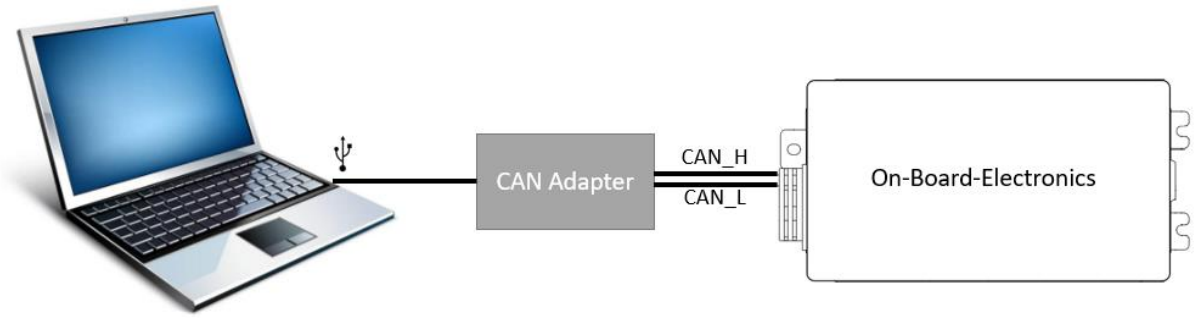
In order to increase the flexibility, A GUI (Graphical User Interface) with both hardware and software can be provided to support user's test, even when user's AGV system software for CAN-Bus communication is not ready.

6.4.1. Requirements

- A Windows PC with a USB port, and Win7 or Win10 operating system.
- A CAN-USB adapter (details mentioned in section 6.4.2)
- GUI software for PC

6.4.2. Connection for CAN adapter

The diagram for CAN adapter's connection are shown as following.

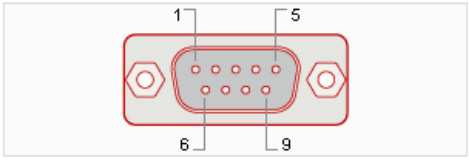


The signal cables for CAN-Bus interface (CAN_H, CAN_L) need to be connected to CAN adapter.

A CAN-to-USB adapter which can support the GUI is shown as below, called as "PCAN-USB". The adapter is included in the Wireless Charger's Dev Kits as mentioned in section 2.8.

PCAN-USB is supplied by PEAK (http://www.peak-system.com/PCAN-USB.199.0.html?L=1). The connector's pin assignment can be found in the "Technical Specification" sheet of the same URL. Pin 7 / 2 of the connector are for CAN-H / CAN-L, and need to be connected to pin 1 / 2 of signal cables C3 mentioned in section 4.2, respectively.

Pin assignment D-Sub



Pin	Pin assignment
1	Not connected / optional +5V
2	CAN-L
3	GND
4	Not connected
5	Not connected
6	GND
7	CAN-H
8	Not connected
9	Not connected / optional +5V

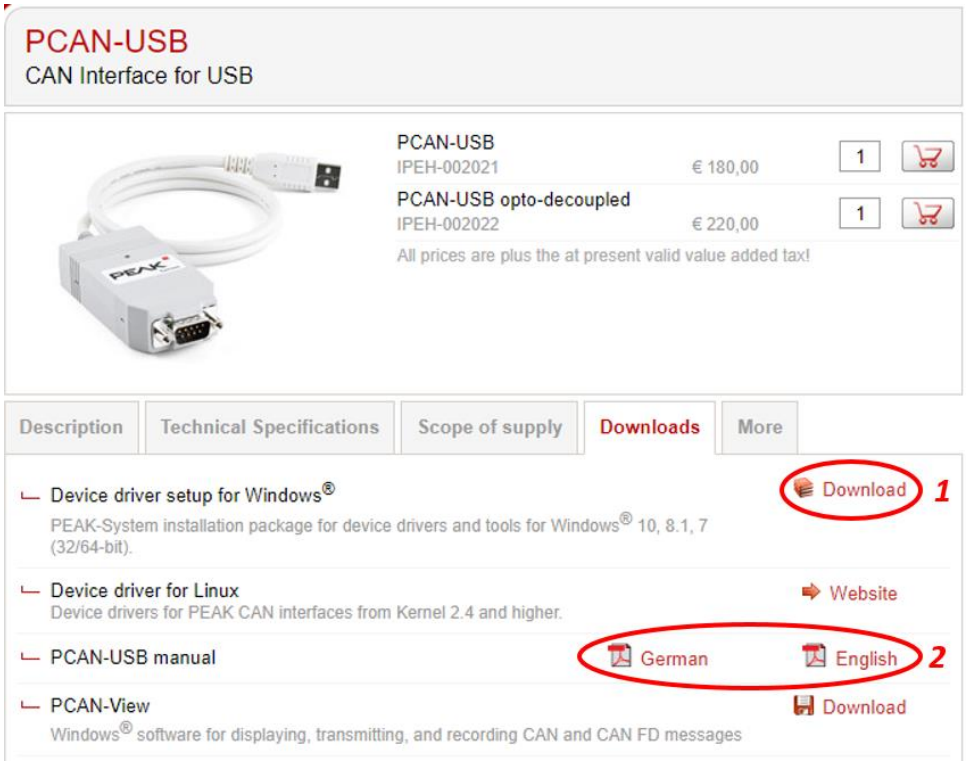
To support the users to easily fulfil the connections between the adapter's D-Sub connector and the CAN-Bus interface of the wireless charger, Delta is also providing a cable in the Dev Kits along with the CAN adapter. This "Molex-to-DSub" cable is shown as below.

A simple connection would be: Secondary-Box' 2-pin Molex connector ↔ Molex-to-DSub cable ↔ PCAN-USB adapter ↔ PC's USB port.

6.4.3. Installation of CAN adapter's driver program

Driver program of CAN adapters need to be installed on PC to work with the adapter.

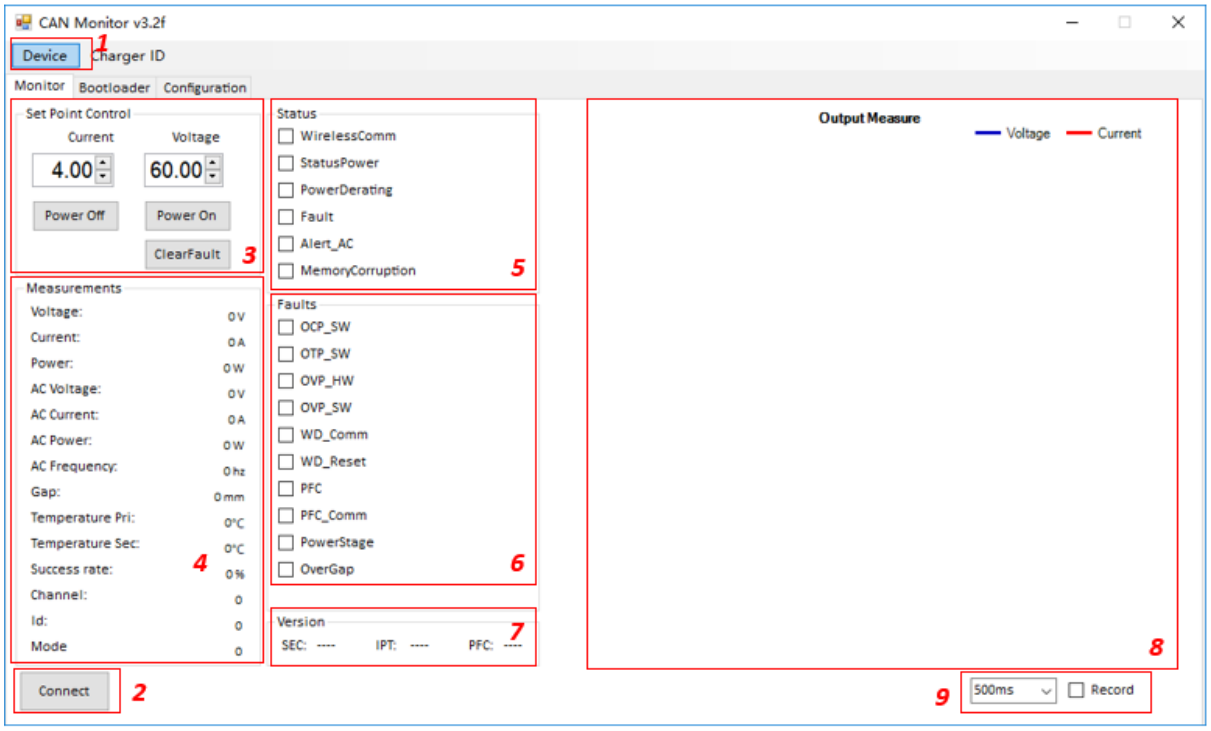
1. From http://www.peak-system.com/PCAN-USB.199.0.html?L=1 , download the driver program.
2. Find the adapter's manual in above URL, follow section 2 inside to install the driver.



6.4.4. Instructions for GUI software operation

Download the folder <<CAN GUI software>> to local PC. In the folder, the application program "CanMonitor.exe" is the GUI software.

Below is the screenshot of the interface of GUI software. There are several functional blocks.

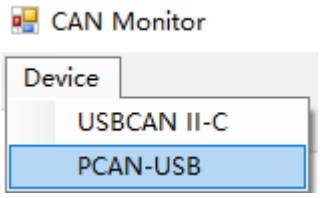


Instructions of operations:

First of all, make sure CAN adapter is well connected according to section 6.4.2, and the driver program of the corresponding CAN adapter is well installed according to section 6.4.3. And then, the operations on the GUI software would be shown below.

Select the CAN adapter

Click “Device” button in Block 1 of the GUI (Left-Upper corner), to select “PCAN-USB”.



Enter/Quit working mode

Click “Connect” button in Block 2 of the GUI (Left-Bottom corner), to enter GUI’s working mode. If CAN adapter is not connected to PC USB port, or the adapter has not been selected in last step, error information will be shown.

Data Record

If the user need the GUI Data to be recorded, Block 9 of the GUI can be operated by clicking the “Record” to be with a “√”. Users can select data refreshing cycles from the drop-down menu.

Set-point control

In GUI’s working mode, Block 3 need to be operated to give the commands to wireless charger.

“Voltage” correspond to “Demand_V” signal (Message ID 0x19x, Start bit 0) in CAN protocol, as mentioned in section 6.3. Users can input a value in the range 24~30 for 24V variant, and 48~60 for 48V variant. When the battery terminal voltage reaches this pre-set value, the charging will be in CV phase, the charging current will gradually reduce to maintain battery terminal voltage at this value.

“Current” correspond to “Demand_I” signal (Message ID 0x19x, Start bit 32) in CAN protocol, as mentioned in section 6.3. Users can input a value in the range 0~42 for 24V variant, and 0~21 for 48V variant. The charger will follow this pre-set value to control the charging current, unless (1) real-time battery terminal voltage is over 24V or 48V, the output power will be controlled not to exceed 1kW, as mentioned in section 2.4.1; or (2) any power de-rating conditions is triggered, as mentioned in section 2.4.2 / 2.4.3; or (3) battery terminal voltage reaches the set value, so the charging will be in CV phase, to maintain the voltage by reducing the current, as mentioned in last paragraph.

“Power On” and “Power Off” buttons correspond to “Demand_PowerStage1” signal (Message ID 0x19x, Start bit 20) in CAN protocol, as mentioned in section 6.3. Users can click them to turn on / off the charging process.

Values for key parameters and Status

Block 4, 5, 6, 7 of the GUI can be used to monitor the status of the wireless charger.

Block 4 shows some key working parameters’ values. Here

- “Voltage” “Current” “Power” are for the measured battery terminal voltage, charging current, output power, respectively.
- “AC Voltage” “AC Current” “AC Power” “AC Frequency” are for the parameters of AC input.
- “Gap” is for the measured air-gap value.
- “Temperature Pri” and “Temperature Sec” are for the temperature sensed by internal sensors at Primary side and Secondary side, respectively.

Block 5, 6 show the state of some Status-Bits or Faults-Bits, and a “√” indicates this bit is set.

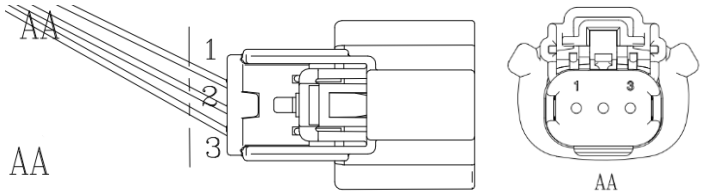
Block 7 shows the software Rev of each internal digital controllers.

Waveforms shown on GUI

Block 8 of the GUI can show the waveforms of output voltage and current.

6.5. External Signals

As mentioned in section 4.2, a 3-pin cable + connector is used for external signals from the vehicle controller.



6.5.1. EXT_Enable

When charger is working in profile follower mode, the vehicle controller’s GPIO pin need to provide a high / low voltage level to the charger’s “EXT_Enable” interface, for power ON/OFF for this mode.

A high voltage level presented between pin 1 (“EXT_Enable”) and pin 3 (“EXT_Signal_GND”) of the connector will let the charger start charging and follow the pre-set profile, while a low voltage level or NC (not-connected) will turn OFF the charging process. The high voltage level is suggested to be 3.3V or 5V, range 2.7V ~ 5.5V. The low voltage level shall be lower than 0.3V.

When working in profile follower mode, CAN-Bus control commands are bypassed.

6.5.2. Sleep Mode Control

When secondary side is in Standby Mode (connected to the battery but not working with any primary side), the secondary side will draw some current from the battery to maintain the auxiliary power of internal control circuits. Normally this power is 1W to 1.5W, depending on the battery voltage, and it won’t exceed 2W in extreme case.

The vehicle controller’s GPIO pin can provide a specific voltage level to the charger’s “Sleep Mode Control” interface, to decrease the current drawn from the battery to < 2mA. This is called as the secondary side’s Sleep Mode, due to its internal control circuits lose auxiliary power.

A high voltage level presented between pin 2 (“Sleep”) and pin 3 (“EXT_Signal_GND”) of the connector will let the charger’s secondary side enter Sleep Mode, while a low voltage level or NC (not-connected) will let it quit from Sleep Mode. The high voltage level is suggested to be 3.3V or 5V,

range 2.7V ~ 5.5V. The low voltage level shall be lower than 0.3V. A voltage level transition will be followed by a mode transition within 1s delay.

This is an optional function, and the users can choose to use this function or not by themselves. However, the user need to make sure:

1) secondary side should be controlled to quit from Sleep Mode before letting the charger start charging. And
2) Sleep Mode can be enabled only when secondary side is in Standby Mode, shouldn't be enabled during charging.

7. Failures and handling - quick reference

When the users find there's no normal charging, please follow below steps for checking.

1. If the 1st Green LED (for input, refer to section 6.2) is not lit, check input.
    - Check if input cable is connected well.
    - Check if input voltage is within the specified range.

In other cases, the red LED shall be blinking to indicate a fault, then check with below steps.

2. Check at output side.
    - Check if output power cables are connected well to the battery.
    - Check if battery voltage is within the specified range, and corresponds to the correct charger variant (24V / 48V).
    - Check if signal cables are connected well to the vehicle controller.
    - For profile follower mode, check if "EXT_Enable" signal is activated. Refer to section 6.5.1.
    - Check if "Sleep Mode" of secondary side is disabled. Refer to section 6.5.2.

3. Check air-gap and misalignment. Both need to be within the specified range.

4. For "CAN-controlled" mode, check if commands are sent to the charger correctly.
    - Check if the baud rate is correct. The default baud rate is 1Mbps, and the message 0x78x should be sent to configure the baud rate if the user is using other rates.
    - Check if message 0x19x is sent regularly (suggested to be 1 message per 100ms). If not, charging might be stopped due to communication watchdog faults. And if it's sent too frequently, the CAN-Bus might be in too heavy loading to behave correctly.
    - Check if message 0x19x is sent correctly. For instance, the voltage setting value can't be lower than the real-time battery voltage.

5. No matter for "CAN-controlled" mode or for profile follower mode, the reported status on CAN-Bus can be used to check if any faults occur.
    - The CAN messages which can be monitored are 0x31x, 0x32x, 0x3Ex, 0x5Fx, 0x77x. Ask Delta for .dbc file or protocol spec to know the details.
    - The contents of these messages can also be read via Delta GUI, refer to section 6.4.4.
    - Note that the faults bit can be cleared by set the bit of "Demand_ClearFaults" in the message 0x19x. But OVP / OCP excluded, which need a Turn-off command then a Turn-on command by two 0x19x messages.

If still no clues with above steps, the users can contact Delta for analysis. Please provide serial number of the failed units, a picture of the operation set-up, LED status, CAN data (or a GUI screenshot), etc. for faster analysis and response.