# 120 A 10 V
# 4-Quadrant Power Supply

CAENels
Gear for Science

MAGNET POWER SUPPLY SYSTEMS

# 4Q10120PS
# User's Manual



Rev. 15 – February 2025

This product is compliant with:

**CAEN ELS s.r.l.**
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# User Manual – Models – Options – Custom Models

*This manual covers the following Power Supplies models:*

- **4Q10120PS, Ordering Code: WAMI1201006B**

*For technical assistance please refer to the following contact:*

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# Table Of Contents

# Document Revisions

| Revision | Date | Comment |
|---|---|---|
| 0 | September 26th 2022 | Preliminary Release |
| 1 | December 1st 2022 | Added remote configuration section |
| 2 | January 10th 2023 | Added IOEN and IPOL in remote configuration section. Updated DIP switch configuration. Updated weight. Updated pictures. |
| 3 | August 11th 2023 | Corrected input voltage range and maximum ambient temperature |
| 4 | August 29th 2023 | Added derating curve |
| 5 | December 1st 2023 | Added derating curve with thermal isolation |
| 6 | February 15th 2024 | Added 80% indication on derating curve |
| 7 | April 19th 2024 | Corrected Max Input Current and added Max Input Power specification |
| 8 | May 10th 2024 | Added some technical specifications and warnings/caution for UL certification |
| 9 | June 13th 2024 | Added ENAD, HELP, INFO, INH, MRDC, MRDT, REBOOT, TO commands in remote configuration section |
| 10 | June 21st 2024 | Changed maximum allowed voltage on pin status for both DCCT and INTERLOCK&STATUS connectors |
| 11 | July 5th 2024 | Model has been changed from C-AMI-12010 to 4Q10120PS |
| 12 | September 10th 2024 | Corrected Output Overpower intervention time |
| 13 | September 17th 2024 | Removed factory address |
| 14 | January 15th 2025 | Corrected description of the Low Range in Table 2 |
| 15 | February 7th 2025 | Updated Cooling and ventilation (sec.1.3.5) Command table (sec.3.2) and added commands sec. 3.3.2, 3.3.9, 3.3.10, 3.3.12, 3.3.15 |

# Safety Information (English)

The following table shows the general environmental requirements for a correct operation of instruments referred in this User's Manual:

| Environmental Conditions | Requirements |
|---|---|
| Environment | Indoor use |
| Operating Temperature | 5°C to 50°C |
| Operating Humidity | 20% to 80% RH (non-condensing) |
| Altitude | Up to 2000 m |
| Pollution degree | 2 |
| Overvoltage Category | II |
| EMC Class Device | A |
| Storage Temperature | -10°C to 60°C |
| Storage Humidity | 5% to 90% RH (non-condensing) |

The following symbols are used within this manual or are reported in the box and along this manual:

-  **CAUTION Risk of Electrical Shock**
-  Caution: Documentation must be consulted in all cases where this symbol is marked
-  Caution: Hot surface
-  Indicates ground terminal
-  Protective Ground Conductor Terminal
-  Off (Power)
-  On (Power)

- **WARNING** The WARNING sign denotes a hazard. An attention to a procedure is called. Not following the procedure correctly could result in personal injury. A WARNING sign should not be skipped and all indicated conditions must be fully understood and met.

- **CAUTION** The CAUTION sign denotes a hazard. An attention to a procedure is called. Not following procedure correctly could result in damage to the equipment. Do not proceed beyond a CAUTION sign until all indicated conditions are fully understood and met.

CAEN ELS s.r.l. will repair or replace any product within the guarantee period if the Guarantor declares that the product is defective due to workmanship or materials and has not been caused by mishandling, negligence on behalf of the User, accident or any abnormal conditions or operations.

**Please read carefully the manual before operating any part of the instrument**

**WARNING**

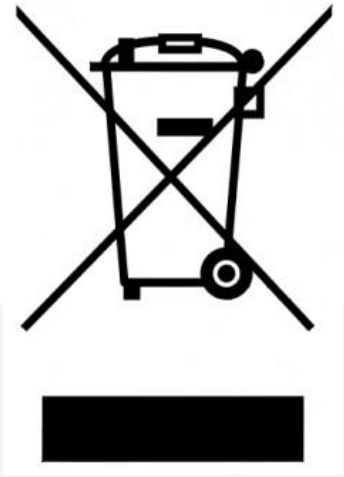
**DO NOT OPEN THE BOX TOP COVER**

**CAEN ELS s.r.l. declines all responsibility for damages or injuries caused by an improper use of the Modules due to negligence on behalf of the User. It is strongly recommended to read thoroughly this User's Manual before any kind of operation.**

CAEN ELS s.r.l. reserves the right to change partially or entirely the contents of this Manual at any time and without giving any notice.

## Disposal of the Product

The product must never be dumped in the Municipal Waste. Please check your local regulations for disposal of electronics products.



**WARNING**

- Do not use this product in any manner not specified by the manufacturer. The protective features of this product may be impaired when used in improper manner.
- Do not use the device if damaged. Before each use, inspect the device for possible cracks or breaks.
- Do not operate the device around explosives gas, vapor or dust.
- Always use the device with the provided cables.
- Ensure the presence of Protective Earth (PE) on the grid to which the device is connected.
- Turn-off the device before establishing any connection.
- Do not operate the device with the cover removed or loosened.
- Do not install substitute parts or perform any unauthorized modification to the product.
- Return the product to the manufacturer for service and repair to ensure that safety features are maintained.

**CAUTION**

- Always arrange the device such that AC-input plug and inhibit button are easily achievable by the operator.
- Ensure not to obstruct the ventilation grids (both inlet and exhaust) on the chassis of the device.
- This is a Class A product. On a domestic environment, this product may cause radio-interference in which case user may be required to take adequate measures.

# Informations de Sécurité (Français)

Le tableau suivant présente les exigences environnementales générales pour un fonctionnement correct des instruments mentionnés dans ce manuel d'utilisation:

| Conditions environnementales | Exigences |
|---|---|
| Environment | Utilisation intérieure |
| Température de fonctionnement | 5°C à 50°C |
| humidité d'exploitation | 20% à 80% RH (sans condensating) |
| Altitude | Jusqu'à 2000 m |
| Degré de pollution | 2 |
| Catégorie de surtension | II |
| Appareil de classe EMC | A |
| Température de stockage | -10°C à 60°C |
| Humidité de stockage | 5% à 90% RH (sans condensating) |

Les symboles suivants sont utilisés dans ce manuel ou sont signalés dans l'encadré et dans ce manuel :

-  **ATTENTION Risque de choc électrique**
-  Attention: La documentation doit être consultée dans tous les cas où ce symbole est marqué
-  Attention surface chaude
-  Indicates ground terminal
-  Borne de conducteur de terre de protection
-  E'teint (alimentation)
-  Allumé (alimentation)

- **WARNING** Le signe WARNING indique un danger. L'attention sur une procédure est appelée. Ne pas suivre correctement la procédure pourrait entraîner des blessures. Un panneau WARNING ne doit pas être ignoré et toutes les conditions indiquées doivent être entièrement comprises et respectées.

- **CAUTION** Le signe CAUTION indique un danger. Une attention à une procédure est appelée. Ne pas suivre correctement la procédure pourrait entraîner des dommages à l'équipement. N'allez pas au-delà du panneau CAUTION tant que toutes les conditions indiquées ne sont pas entièrement comprises et remplies.

CAEN ELS s.r.l. réparera ou remplacera tout produit pendant la période de garantie si le garant déclare que le produit est défectueux en raison de la fabrication ou des matériaux et n'a pas été causé par une mauvaise manipulation, une négligence de la part de l'utilisateur, un accident ou des conditions ou opérations anormales.

**Veuillez lire attentivement le manuel avant d'utiliser une partie de l'instrument.**

**WARNING**

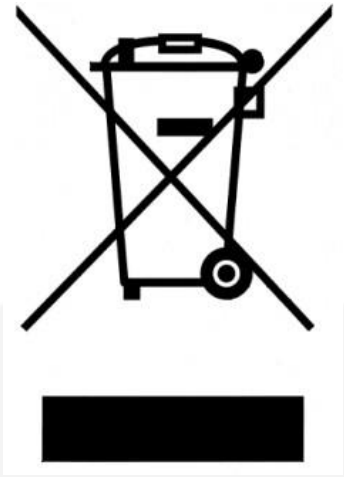
**NE PAS OUVRIR LE COUVERCLE SUPÉRIEUR DE LA BOÎTE**

**CAEN ELS s.r.l. décline toute responsabilité pour les dommages ou blessures causés par une mauvaise utilisation des Modules dus à une négligence de la part de l'Utilisateur. Il est fortement recommandé de lire attentivement ce manuel d'utilisation avant tout type d'opération.**

CAEN ELS s.r.l. se réserve le droit de modifier partiellement ou entièrement le contenu de ce manuel à tout moment et sans préavis.

**Mise au rebut du produi**

Le produit ne doit jamais être jeté avec les déchets municipaux. Veuillez vérifier vos réglementations locales pour l'élimination des produits électroniques.



## WARNING

- N'utilisez pas ce produit d'une manière non spécifiée par le fabricant. Les fonctions de protection de ce produit peuvent être altérées en cas d'utilisation inappropriée.
- N'utilisez pas l'appareil s'il est endommagé. Avant chaque utilisation, inspectez l'appareil pour déceler d'éventuelles fissures ou cassures.
- N'utilisez pas l'appareil à proximité de gaz, de vapeurs ou de poussières explosifs.
- Utilisez toujours l'appareil avec les câbles fournis.
- S'assurer de la présence d'une terre de protection (PE) sur le réseau auquel l'appareil est connecté.
- Éteignez l'appareil avant d'établir une connexion.
- N'utilisez pas l'appareil avec le couvercle retiré ou desserré.
- N'installez pas de pièces de rechange et n'effectuez aucune modification non autorisée sur le produit.
- Renvoyez le produit au fabricant pour entretien et réparation afin de garantir que les caractéristiques de sécurité sont maintenues.

## CAUTION

- Disposez toujours l'appareil de manière à ce que la prise d'entrée AC et le bouton d'inhibition soient facilement accessibles par l'opérateur.
- Assurez-vous de ne pas obstruer les grilles de ventilation (entrée et sortie) sur le châssis de l'appareil.
- Il s'agit d'un produit de classe A. Dans un environnement domestique, ce produit peut provoquer des interférences radio, auquel cas l'utilisateur peut être amené à prendre des mesures adéquates.

# Introduction

This chapter describes the general characteristics and main features of the 4Q10120PS 4-Quadrants power supply.

## 1.1 4Q10120PS Overview

The 4Q10120PS is a 4-Quadrant switching-mode amplifier, highly efficient, voltage-controlled, specifically designed for supplying superconducting magnets. Output ratings are:

| *Model Name* | Current | Voltage | Max Sink/Source power |
|---|---|---|---|
| *4Q10120PS* | **±120 A** | **±10 V** | **620 W** |

**Table 1:** *4Q10120PS output ratings.*

Lower output voltage (down to 5 V) ratings are available by configuring the dedicated DIP-Switch present on the rear side.

Furthermore, to improve the regulation across the 0 V output, the power supply can be configured to limit the voltage output range to only ± 2 V.

Control of the amplifier is made by simple dry-contacts and an Analog Voltage input reference with values to ± 10 V.

The module integrates a dissipation unit, i.e. an embedded power resistor coming into operation whenever the working point will require to dissipate the energy coming from the load.

Concerning the output current sensing, the amplifier integrates a high precision DCCT model CT-200 (from CAEN ELS) featuring 1:1000 current ratio. The secondary current is a 1000-times-scaled copy of the amplifier output current and it is available for monitoring on the back DCCT-SUB-D connector.

The local display helps the user in checking settings and working point, providing the set range, the instantaneous output current and voltage readings. Tri-color LEDs on the front panel provide some visual basic information of the 4Q10120PS status, i.e. faults status, output status, selected range, etc.

## 1.2 4Q10120PS at a glance

The 4Q10120PS power amplifier is composed by a single 19-inch 2U crate. The unit and its I/O connections can be easily seen in **Figure 1** (front view) and **Figure 2** (rear view); **Figure 3** shows the output bus bar connections (metallic cover has been removed).

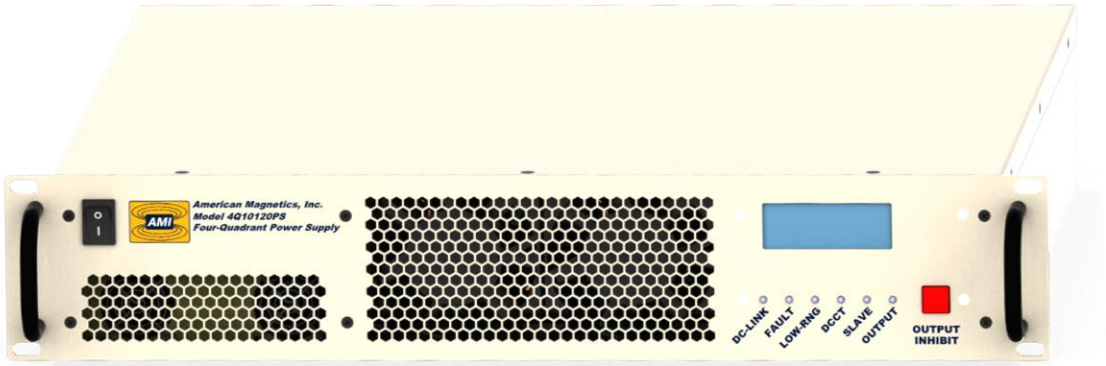



**Figure 1:** *4Q10120PS front view.*

On the front side of the 4Q10120PS unit there are placed (starting from left): a power switch to supply the internal AC/DC Bulk power supply (N.B. auxiliary power supply dedicated to control electronics is always ON, see **Sec.1.3**), an alphanumeric display, six status LEDs and OUTPUT INHIBIT button for enabling disabling the output.

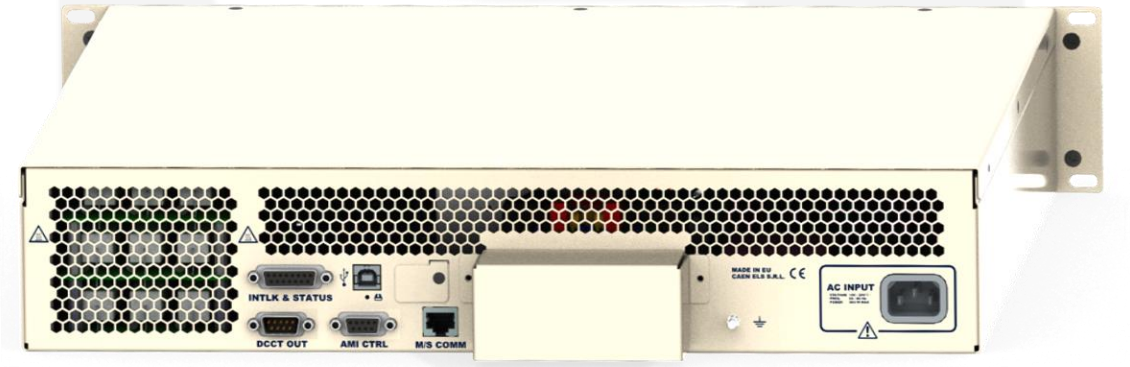



**Figure 2:** *4Q10120PS Rear View with output bus bars cover on.*

On the rear side of the unit are placed, starting from the right: AC power line input, the output bus-bars terminals, an RJ45 socket for parallel operation, D-Sub connectors dedicated to (i) control the amplifier, (ii) supply and read DCCT and (iii) interlock/status. A USB type B connector is used as a service port to update the firmware and configuration. A Functional Ground stud (M4 x 8 mm) is also available if necessary for the operation.

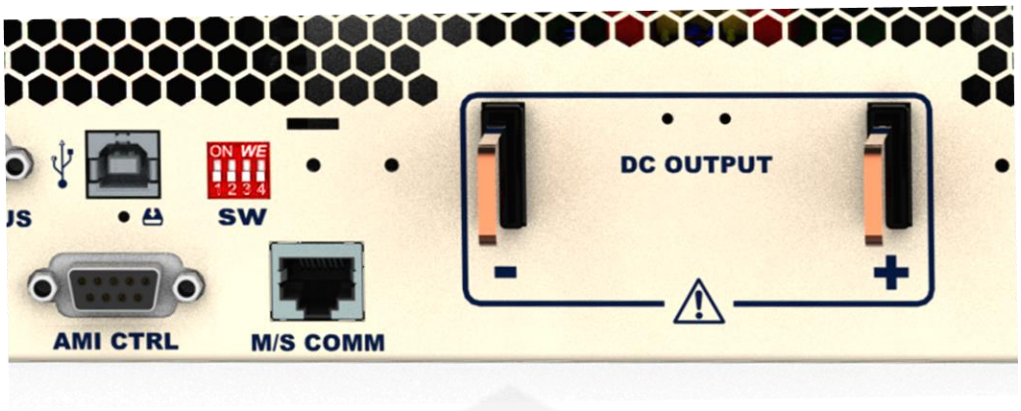



**Figure 3:** *4Q10120PS Rear View without output bus bars and DIP-Switch covers.*

Under the SW cover, a DIP-Switch selector is available to configure the output voltage range of the amplifier.

On the left side of the rear panel exhaust air might be very hot during the dissipation operation. In that position the dissipation resistor is cooled with forced air fans so any object shall be kept away from that area.

**CAUTION**

This power supply is fan cooled, the air intake is at the front panel and the exhaust is at the rear panel. Keep any object away from that area in order to avoid blockage of air ventilation and overheating.

## 1.3 Operation and functions

The block diagram of the power amplifier is presented hereafter:

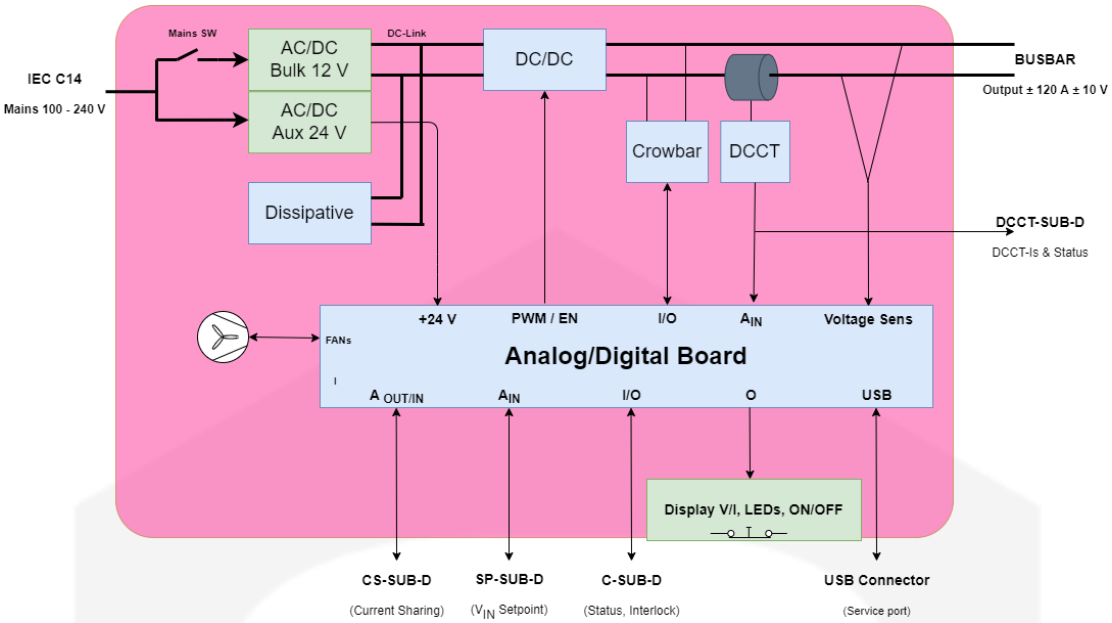



**Figure 4:** *4Q10120PS block diagram*

Mains input is feeding both AC/DC converters: the Auxiliary 24V AC/DC is always ON to continuously supply the control electronics while the Bulk 12V AC/DC can be switched ON and OFF by means of the front panel switch.

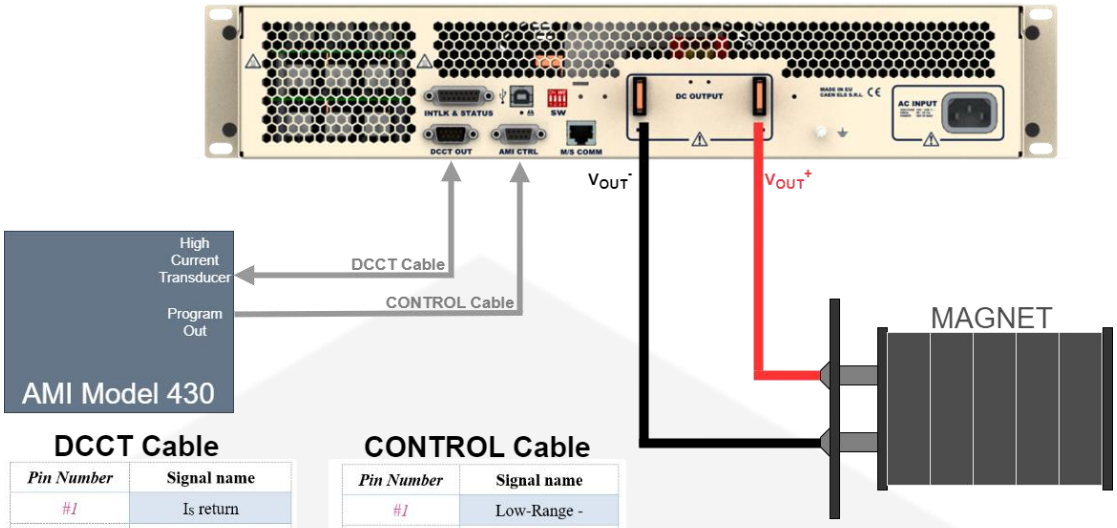
During sourcing operation, the Bulk is feeding the DC-Link voltage meanwhile Dissipative circuitry is inactive; the latter enters into operation when sinking operation are needed.

The DC/DC stage is made by four H-Bridge stages, whose MOSFETs are switching at 100 kHz. Each H-Bridge stage is controlled by PWM signals generated by the Analog/Digital (A/D) Board that regulates the duty-cycle in order to reduce the gap between the sensed output voltage and the setpoint. The setpoint must be externally provided (see **Sec.2.6.5**), e.g. by means of an **AMI Model 430 Power Supply Programmer** (see "Model 430 Power Supply Programmer – Installation, Operation, and Maintenance Instructions") as reported in the sketch in **Figure 5.**

The DC/DC stage can be enabled/disabled by the user or alternatively disabled by the A/D Board in case of a Fault. When disabled, the crowbar will be automatically activated, as protection for the DC/DC stage. Indeed, by shorting the output bars, the crowbar provides a path for recirculate the current that may come from the load. Furthermore, as a protection against overvoltage events, the crowbar shorts the output in case the output voltage exceeds 12.5 V as well (**Sec.1.3.9**).

A DCCT is also installed for the output current sensing. It is a standard CAEN ELS CT-200, featuring current-output with a current-ratio of 1:1000. DCCT shall be supplied by an external ± 15 V power supply through the DCCT-SUB-D connector (see **Sec.2.6.4**), see **Figure 5.**

On the same connector, there is also the secondary output current that is a scaled copy (1:1000) of the actual output current.




**DCCT Cable**

| *Pin Number* | Signal name |
|---|---|
| *#1* | $I_S$ return |
| *#2* | N.C. |
| *#3* | Status - |
| *#4* | DCCT GND |
| *#5* | -15 V |
| *#6* | $I_S$ |
| *#7* | N.C. |
| *#8* | Status + |
| *#9* | +15 V |

**CONTROL Cable**

| *Pin Number* | Signal name |
|---|---|
| *#1* | Low-Range - |
| *#2* | GND |
| *#3* | GND |
| *#4* | N.C. |
| *#5* | Supply Status |
| *#6* | Low-Range + |
| *#7* | $V_{IN}$ Setpoint |
| *#8* | GND |
| *#9* | N.C. |

**Figure 5:** *Sketch of the connection between the* 4Q10120PS *unit and an AMI Model 430 Power Supply Programmer,* ***Secs.2.6.4*** and ***2.6.5***.

The DCCT secondary current is also intercepted by a 5.6 **Ω** shunt resistor mounted on the A/D Board that is used to monitor and display the output current.

### 1.3.1 Output Ranges

The 4Q10120PS is basically a power amplifier that can operate continuously in all four quadrants: sourcing and sinking V and I. The output voltage is controlled by an analog voltage input. This input accepts signals ranging from -10V to +10V and generates an output which is proportional to the input signal, i.e. –Full-Scale (FS) for a -10V input, 0 for a 0V input and +FS for a +10V input. The ± FS value depends on the DIP-Switch (see **Figure 3**) selection and on the Low-Range command. The Low-Range command is a specific control signal available in the SP-SUB-D connector (**Sec.2.6.5**), that allows to switch the FS (except in case of FS = 0 V) to only 2 V at any time.

The following tables summarize the available Range selections:

| $V_{IN}$ Setpoint | Output Full-scale (Low Range OFF) | | | |
|---|---|---|---|---|
| | DIP-Switch 00 | DIP-Switch 01 | DIP-Switch 10 | DIP-Switch 11 |
| ***0 V*** | 0 V – 120 A | 0 V – 100 A | 0 V – 75 A | 0 V – 60 A |
| ***10 V*** | **5** V – 120 A | **6** V – 100 A | **8** V – 75 A | **10** V – 60 A |
| ***-10 V*** | **-5** V – 120 A | **-6** V – 100 A | **-8** V – 75 A | **-10** V – 60 A |

| $V_{IN}$ Setpoint | Output Full-scale (Low Range ON) | | | |
|---|---|---|---|---|
| | DIP-Switch 00 | DIP-Switch 01 | DIP-Switch 10 | DIP-Switch 11 |
| ***0 V*** | 0 V – 120 A | 0 V – 100 A | 0 V – 75 A | 0 V – 60 A |
| ***10 V*** | **2** V – 120 A | **2** V – 100 A | **2** V – 75 A | **2** V – 60 A |
| ***-10 V*** | **-2** V – 120 A | **-2** V – 100 A | **-2** V – 75 A | **-2** V – 60 A |

**Table 2:** DIP-Switch *configuration vs. Analog input Setpoint Ranges in case of Low-Range OFF (upper table) and ON (lower table).*

Depending on the customer needs, i.e. technical specifications of the load/magnet, the DIP-Switch is already set by the manufacturer before shipment.

### 1.3.2 Basic operation

The 4Q10120PS state machine is sketched in **Figure 6**.

Once the module is powered with the Mains through the IEC connector (**Sec.2.4.2**) and the front Bulk Mains switch is ON the Output will be enabled (N.B. the presence of the Mains ensures that all the control electronics is active regardless of the position of the Bulk Mains switch). This means that after an eventual blackout, the output will be automatically enabled and will jump to the corresponding set point.

The front panel button OUTPUT INHIBIT (see **Figure 1**) is used to change the output status: if the output is enabled, a press of the button will disable the output (and activate the crowbar); if the output is disabled, with or without a fault, a press of the button will try to reset the active faults and enable the output. If the faults are not resettable, the module will stay disabled in the fault status.

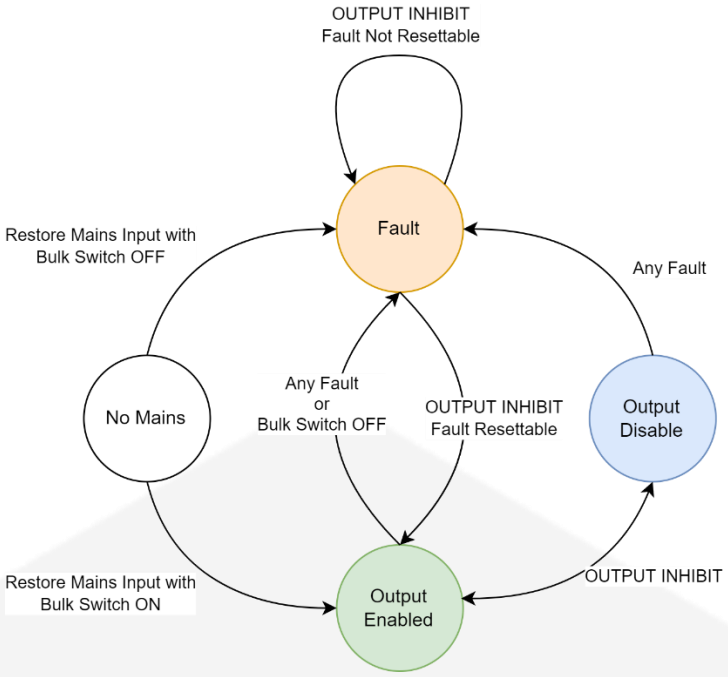



**Figure 6:** 4Q10120PS *State Machine.*

### 1.3.3 Faults

The following table summarizes the possible faults that can disable the output.

| *Fault Name* | Causes |
|---|---|
| *DCCT* | • **The internal DCCT is experiencing a malfunction**<br>• **The DCCT is not receiving the correct ± 15 V supply**<br>• **There is not a shunt connected to the DCCT** |
| *DC-Link* | • **The Mains BULK switch is OFF**<br>• **The internal AC/DC Bulk is not working properly**<br>• **DC-Link overcurrent** |
| *Crowbar* | • **Output voltage has exceeded the 12.5V threshold**<br>• **Crowbar is not working properly** |
| *Over Temp* | • **DC/DC stage temperature has exceeded the threshold**<br>• **Dissipator module temperature has exceeded the threshold** |
| *Output Over Current* | • **Output current has exceeded the threshold** |
| *Input Over Current* | • **Input current has exceeded the threshold** |
| *Over Power* | • **Output power has exceeded the threshold (Sec.1.3.4)** |
| *Fan Fault* | • **A fan is blocked or fails to reach the target RPM** |
| *External Interlock* | • **External interlock caused the output to turn-off** |
| *Parallel Fault* | • **Parallel link fault**<br>• **Master and Slave modules are not configured correctly** |

**Table 3:** 4Q10120PS *Fault List*

Faults are displayed on the front panel display and/or with the dedicated LEDs. In case multiple faults are present at the same time, only the first detected will be indicated on the display.

### 1.3.4 Output Overpower

The 4Q10120PS can work continuously at 2% over its absolute power rating.

The module is able to work at a power between 2% and 5% over its rating (i.e. between 102% and 105%) for a 20-second period before turning-off tripping an over-power fault.

If the actual output power drawn from the power supply is more than 5% above its nominal ratings the power unit will shut down after 1 second.

This behaviour is summarized in the following Table:

| *Output Power* | Time of Operation |
|---|---|
| *> -632 W*<br>*< 632 W* | **Continuous** |
| *> -651 W*<br>*< 651 W* | **120 seconds** |
| *≤ -651 W*<br>*≥ 651 W* | **1 second** |

**Table 4:** *Output Over Power on 230 Vac Mains.*

### 1.3.5 Cooling and Ventilation

The module is air-cooled by variable-speed fans. Air is drawn in from the front panel and expelled through the back panel. Internally, there are three main heat-sensitive sections, each cooled by independent fans:

- **AC/DC section**, where the fans are always ON. This occurs only when the Power Switch on the front panel is set to ON. The higher the output power, the higher the fan speed (when the amplifier is sourcing).

- **DC/DC section**, where the fans are regulated depending on the output current: the higher the output current, the higher the fans speed (e.g. at 0 A the fans are OFF and at ±120 A the fans are at their maximum speed). The fan regulation also depends on the temperature of this section; they speed up when the temperature exceeds 39°C and stop when it falls below 33°C.

- **Dissipative section**, where the fans are normally OFF and turn ON whenever a negative power is sunk from the load. The fan regulation also depends on the temperature of this section; they speed up when the temperature exceeds 45°C and stop when it falls below 33°C.

The crowbar can operate without fan cooling; since specifically designed in case of power blackout, during which the magnet current can recirculate in the crowbar even without auxiliary power.

Pay attention that the exhaust air on the rear side can be very hot when operating in power sinking regime.

**WARNING**

Back panel can be very hot when the module is operating in sinking mode, keep area behind the module clear and DO NOT TOUCH the case when in operation.

**CAUTION**

This power supply is fan cooled, the air intake and the exhaust are at the front and rear panel, respectively. Upon installation, allow cooling air to reach the front panel ventilation inlets. Allow minimum 10 cm of unrestricted air space at both the front and the rear of the unit.

### 1.3.6 Constant Voltage Regulation

The module is working in constant voltage mode, so it keeps the output voltage at the reference value (see **Figure 4**). This power amplifier is designed to mainly operate in DC mode so only slow variation of the set point can be followed by the output. Nevertheless, the DC/DC stage is true-bipolar, so it can reproduce a pure sine wave from –Full scale to +Full scale with a frequency up to at least 150 Hz, depending on the selected range. **Figure 7** shows a typical step-response of the output on a resistive load.

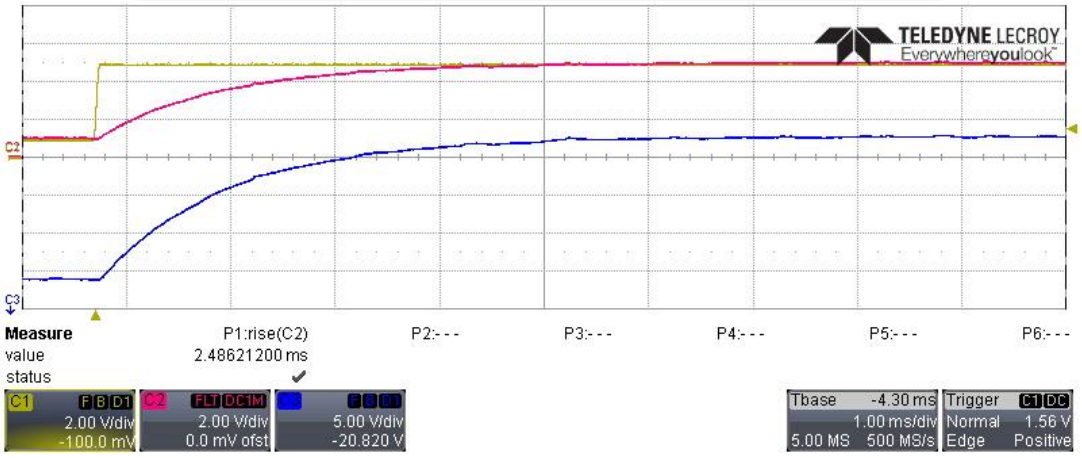



**Figure 7:** *Voltage output step response. Range 10 V, 0 – 5 V step, 0.2Ω load. The red curve is the output voltage, the yellow one the setpoint reference and the blue one the external DCCT output.*

### 1.3.7 Parallel Operation

Two modules can be connected in parallel to double the output current and power. Configuration between master and slave is done by the DIP-Switch selector switch on the back panel (see **Secs.2.6.3** and **4.1.2**), the dedicated LED, on the front panel, will display if the module is configured as Slave. The Master module detects automatically either if there is a Slave module connected in parallel or if it has to operate as a standalone unit. When two modules are connected in parallel, user shall interface only with the Master module which takes care of the communication with the Slave module. The Master-Slave system will operate, from the control point of view, as a standalone unit with doubled output current and doubled power. On the Master module the total current (i.e., the sum of Master and Slave module) is displayed while the Slave module on the other hand indicates just the information message about the Master/Slave operation.

### 1.3.8 Interlock and Status signals

On the back side of the module (see **Figure 2**), the C-SUB-D connector "INTL & STATUS" provides the following signals (**Sec.2.6.1**):

- **Enable ON**: a Dry-Contact input signal; when shorted it enables the output;
- **External Interlock**: a Dry-Contact input signal; by default, it shall stay open, when shorted it triggers the Fault and disables the output. External Interlock polarity can be changed by software command;
- **Reset Fault**: a Dry-Contact input signal; when shorted, it resets any Faulty condition present in the power supply;
- **Fault Status**: an Open/Close contact, that opens when a Fault is triggered. It is normally closed (when no Faults are present);
- **Output Status**: a magnetic relay provides three available contacts, Normally-Open (NO-TAP), Normally-Close (NC-TAP) and Common (C-TAP). By default, when the output di Disabled, the NO-TAP contact is open while the NC-TAP contact is closed; on the other hand, when the output is Enabled, the NO-TAP contact will be closed, NC-TAP will be.

External Interlock and the two control signals (Enable ON and Reset Fault) on "INTLK & STATUS" connector can be disabled by software command.

### 1.3.9 Crowbar

The crowbar is triggered for any of the following conditions:

- **Output Disabled**: when the DC/DC stage is disabled;
- **Output Overvoltage**: when the output voltage (between output busbars) exceeds the threshold of 12.5 V;
- **Fault**: when a generic fault is triggered disabling the output.

The crowbar is located before the DCCT (see **Figure 4**); in this way, the output current is measured even in case the crowbar is active. When the crowbar is activated, its resistance is less than 1 mΩ, resulting in a power loss of 10 W at 120 A. The crowbar circuit mounts a backup supercapacitor that can provide energy for 5 days without the auxiliary power, keeping the output shorted for 5 days after a Mains blackout. As already mentioned in **Sec.1.3.5**, since the low power dissipation fans are not required to cool down the crowbar circuit.

If no-further faults are present, it is possible to recover the module from the active crowbar condition by pressing the OUTPUT INHIBIT button (or via the dry-contact signals in the dedicated connector, **Sec.2.6.1**). During the transition from active-crowbar-status to Output Enabled, the short circuit hold by the crowbar will be released and the DC/DC stage will be enabled: if some current is present on the output busbar, it will change smoothly its path from the crowbar to the DC/DC stage, in order not to have an overvoltage on the output.

During the transition from active-crowbar to Output Enabled, the output voltage shall be set to 0 V for at least 20 ms, to avoid any overvoltage event that could potentially trigger the crowbar again.

## 1.4 Front Panel Feautures

The front panel of the 4Q10120PS provides basic control and error & status indicators (refer to **Figure 8** for details):

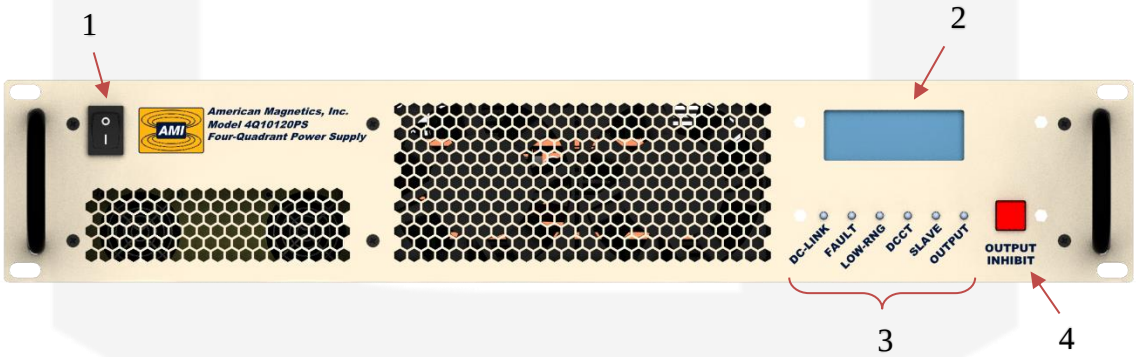



**Figure 8:** 4Q10120PS *front panel view.*

1. **Mains Switch**: Power ON/OFF control for AC/DC Bulk power supply that provides the internal DC-Link Voltage.
2. **Display**: The Front panel alphanumeric display features four rows showing the following information (see **Figure 9**):
   I. Output Range, selected by the DIP-Switch (e.g. 120 A 5 V), **Sec.1.3.1**;
   II. Realtime output current (Io) with 0.25% of accuracy, i.e. 300 mA;
   III. Realtime output voltage (Vo) with 0.25% of accuracy, i.e. 25 mV;
   IV. Status of the power supply:
   - Status ok; no-faults are present and Output is enabled;
   - Fault: Name (only the first Fault detected will be displayed, **Sec.1.3.3**).

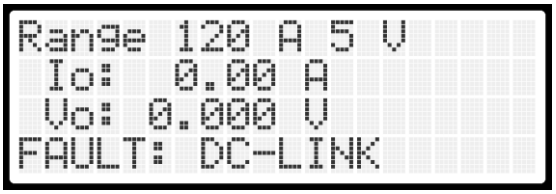



**Figure 9:** *Local Display during a DC-Link Fault.*

3. **LEDs:** provide fundamental information as follows (N.B.: when the Mains switch is OFF, all LEDs are inactive, except for the DCCT LED):
   I. **DC-Link:** Green if status is OK, Red if either the internal AC/DC Bulk is not working properly or the DC-link has experienced and overcurrent;
   II. **Fault**: normally-off, Red if a Fault is present;
   III. **Low-Range**: normally-off, Green if Low-Range is ON;
   IV. **DCCT**: normally-off, Red if DCCT experienced a Fault;
   V. **Slave**: normally-off, Green if the module is configured as Slave;
   VI. **Output:** Green if Output is enabled, Red if inhibited.

4. **OUTPUT INHIBIT:** this button toggles the output from enabled to disabled status. When Faults are present, it tries to restore the status clearing the Faults before to enable the output.

## 1.5 Rear Connections

The 4Q10120PS amplifier controls and all the connections are located on the rear panel (refer to **Figure 10** for details):

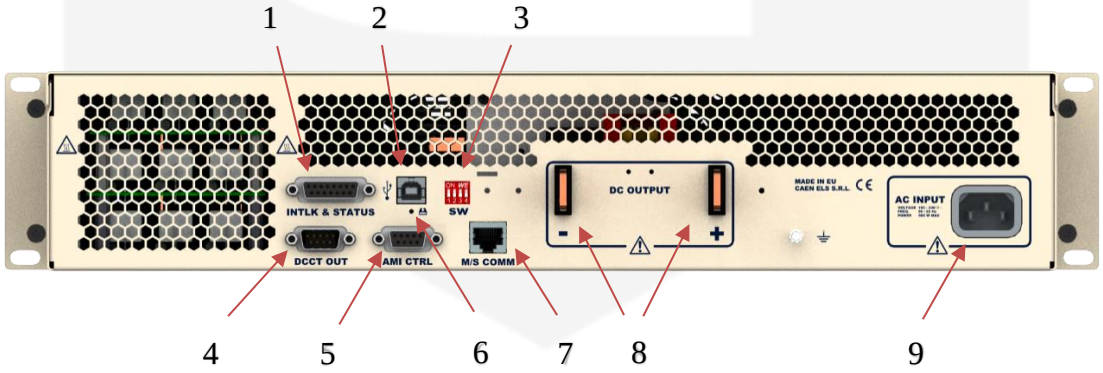



**Figure 10:** *Connection overview.*

1. Interlock & Status connector [D-SUB A female (DA-15)];
2. Service Port connector, firmware update and module configuration [USB TYPE-B], **Sec.2.6.2**;
3. DIP-Switch configuration selector, **Sec.2.6.3**;
4. DCCT output connector [D-SUB male (DB-9)], **Sec.2.6.4**;

5. Program in (Voltage setpoint) connector [D-SUB female (DB-9)], **Sec.2.6.5**;
6. Firmware update mode pushbutton;
7. Master-Slave link (Parallel operation) connector (RJ45 socket), **Sec.2.6.6**;
8. Busbar output;
9. Mains IEC C-14 connector, **Sec.2.4**.

# Installation

This chapter contains instructions for initial inspection and preparation for use.

## 2.1 Preparation for use

In order to be operational, the power amplifier must be connected to an appropriate AC source. The AC source voltage should be within the power supply specification (**Sec.6**).

**WARNING**

Do not apply power before reading this chapter

**Table 5** below, describes the basic setup procedure. User shall follow the instructions in the given sequence to properly prepare the power supply for use.

| *Step* | Checklist | Description |
|---|---|---|
| *1* | **Initial inspection** | Physical inspection of power supply |
| *2* | **Mounting** | Installing the power supply, ensuring proper ventilation |
| *3* | **AC Input Power Connection** | Connect the power supply to the AC source |
| *5* | **Load connection** | Wire size selection, Remote Sensing |
| *4* | **Control cable connection** | Connect the power supply to your system |

**Table 5:** *Installation checklist.*

## 2.2 Initial inspection

Prior to shipment, this power supply was inspected and found free of mechanical or electrical defects. Upon unpacking of the power supply, inspect for any damage which may have occurred in transit.

The inspection should confirm that there is no exterior damage to the power supply (i.e. broken switch or connectors) and that the whole panel and display are not scratched or cracked. Keep all packing material until the inspection has been completed. If a damage is detected, compile the RMA form available to the CAEN ELS web site.

## 2.3 Mounting

The 4Q10120PS module can be used either as a desktop unit or as a rack-mount device since the unit form factor is designed to be installed in a standard 2U 19-inch cabinet.

**CAUTION**

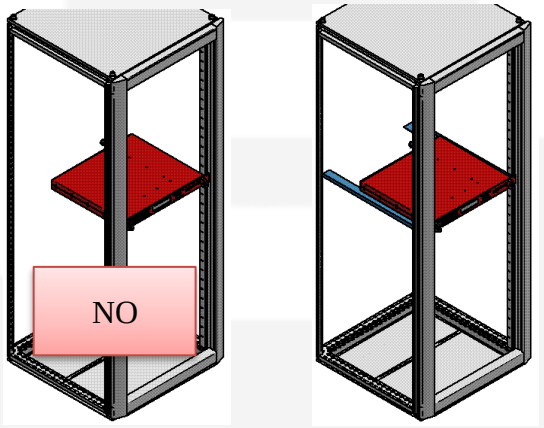
This power supply is fan cooled, the air intake and the exhaust are at the front and rear panel, respectively. Upon installation, allow cooling air to reach the front panel ventilation inlets. Allow minimum 10 cm of unrestricted air space at both the front and the rear of the unit.

### *2.3.1 Rack Mounting*

The 4Q10120PS amplifier is designed to fit in a standard 19-inch equipment rack.

**CAUTION**

Use rack support rails to provide adequate support for the power supply.



## 2.4 AC Input Power Connection

The AC line input connector on the rear panel is a standard IEC 60320 C14 male inlet socket. Two fuses, with fuse holders, are present in the internal PCB and are not available on the rear panel. Ratings for the fuses are 10 A, 250 V, time-delay.

**WARNING**

Do not open the box to replace the fuses. Only specialized personnel can open and replace the fuses. Contact CAEN ELS support for maintenance.

### 2.4.1 AC Source requirement

The 4Q10120PS power supply is designed for universal AC input range since it can operate with nominal input voltage from 100 $V_{AC}$ to 240 $V_{AC}$ (input range voltage from 90-254 $V_{AC}$) and nominal input frequency ranging from 50 Hz to 60 Hz (input frequency range from 47 Hz to 63 Hz). Installation Category shall be **CAT II** so maximum impulse voltage on the network mains must be below 2500 V.

### 2.4.2 AC Input Cord

The 4Q10120PS power supply is directly shipped with the corresponding power cord (suitable for the destination country of the purchase). Power supply side connector is a standard IEC C13 plug. Current rating for the connector is 10A. Wire size for detachable power supply cord, not longer than 2 m, shall be at least 0.75 $mm^2$. Wire size for fix installation shall be at least 1.5 $mm^2$.

**WARNING**

There is a potential shock hazard if the power supply chassis is not connected to an electrical safety ground via the safety ground in the AC input connector!

**WARNING**

Remove the AC input power, by disconnecting the C13 plug, before making or changing any rear panel connection, ensure that all connections are securely tightened before applying power.

**CAUTION**

Always arrange the device such that AC-input cord and inhibit button are easily achievable by the operator.

## 2.5 Load connection

**WARNING**

Remove the AC input power, before making or changing any rear panel connection. Ensure that all connections are securely tightened before applying power.

**WARNING**

Models shall not float outputs more than ±200VDC above/below chassis ground.

### 2.5.1 Wire selection

Two factors must be considered for the selection of the wires:

- Current carrying capacity -> Cross section area;
- Maximum wire length;
- Insulation voltage;

Wire size should be selected to enable voltage drop per lead to be less than 0.5 V at the maximum power supply current to prevent excessive output power consumption. Suggested wire sizes are listed in the following table:

| *Wire Cross Section Area [mm²]* | Resistivity [Ω/km] | Maximum Cable length in meters to limit voltage drop to be less than 1 V (0.5 V per lead) | | | |
|---|---|---|---|---|---|
| | | 60 A | 75 A | 100 A | 120 A |
| *16* | 1.12 | 14.5 | 11.5 | - | - |
| *25* | 0.72 | 23 | 18.5 | 13.5 | - |
| *35* | 0.52 | 32 | 25.5 | 19 | 16 |
| *70* | 0.26 | 64 | 51 | 38 | 32 |

**Table 6:** Wire selection.

### 2.5.2 Lug terminal connection

**CAUTION**

Screws provided with the 4Q10120PS should be used for screw the cable lug. Maximum length of the screws is 20 mm. Longer screws may damage the power supply.
Tightening torque shall be between 30 to 35 Nm.
Always use both spring washer and plane washer for a reliable connection.

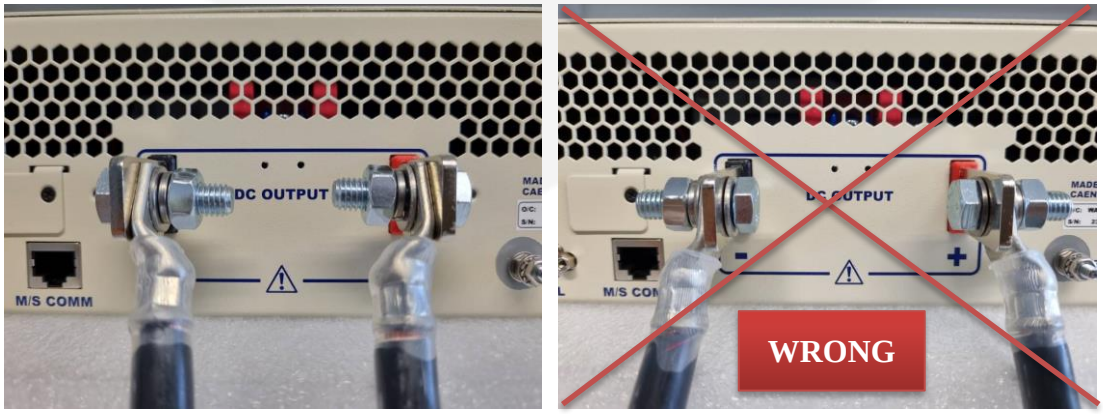
Loads have to be connected directly to the Busbars using lug terminals for M8 screws. Always use both spring washer and plane washer for a reliable connection [see **Figure 11(a)**]. Tightening torque shall be about 30 – 35 N·m. Pay attention to put the lug terminals as well as the nuts on the inside with respect to the Busbars [**Figure 11(a)**] and not on the outside [**Figure 11(b)**], otherwise they can cause short circuits when placing the protective cover.

**WARNING**

To avoid short circuits, place the lug terminals as well as the nuts on the inside with respect to the Busbars

**WARNING**

To avoid arcs that can burn the skin always install the safety cover that is protecting the output terminals from accidental contact with metallic parts. The lug terminals shall also be isolated with shrinking tube to avoid any accidental contact that may shorts the output together.




**(a)** **(b)**

**Figure 11:** Output terminal connections: (a) correct screws arrangement; (b) wrong placement with nuts and lug terminals on the outside.

The symbols "+" and "-" on the rear panel indicate the positive and negative polarity of the terminal, respectively.

After securing both output connections, it is necessary to mount the metallic protective cover on these output terminals.


**Figure 12:** *Metal protective cover on the output terminal connections.*

## 2.6 Control Cable connection

In this section the connectors available on the rear panel (see **Figure 10**) of the power amplifier are presented in order to understand their functionality and corresponding connections.

### 2.6.1 Interlock and Signals connector (INTLK & STATUS)

On the back side of the module the C-SUB-D 15 pins connector marked as **INTLK & STATUS** provide the following signals:

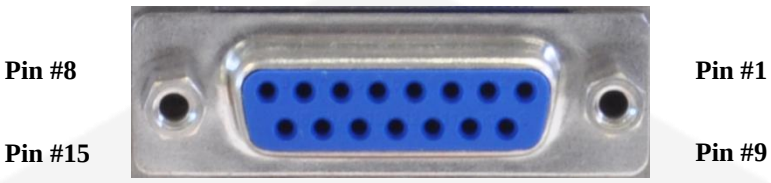



**Figure 13:** *I/O Connector.*

The pin index of the D-Sub 15 rear connector is summarized in the following table:

| *Pin Number* | Direction | Signal name |
|---|---|---|
| *#1* | | N.C. |
| *#2* | OUTPUT | Fault Status C |
| *#3* | OUTPUT | Magnetic Relay Common Contact (C-TAP) |
| *#4* | | N.C. |
| *#5* | INPUT | Reset Fault + |
| *#6* | INPUT | Interlock - |
| *#7* | | N.C. |
| *#8* | INPUT | Enable + |
| *#9* | OUTPUT | Fault Status E |
| *#10* | OUTPUT | Magnetic Relay Normally Closed Contact (NC-TAP) |
| *#11* | OUTPUT | Magnetic Relay Normally Open Contact (NO-TAP) |
| *#12* | INPUT | Reset Fault - |
| *#13* | | N.C. |
| *#14* | INPUT | Interlock + |
| *#15* | INPUT | Enable - |

**Table 7:** INTLK & STATUS *D-sub pin-out. N.C. stands for Not Connect.*

A mating connector, a standard D-Sub 15 Pin Male type, can be installed in order to use/access these signals.

**WARNING**

All terminals shall not float more than ±48 VDC above/below chassis ground.

**CAUTION**

Voltage between C-TAP and NC-TAP or NO-TAP relay pins shall never exceed ± 48 V.
Maximum current rating for the Magnetic Relay is 1 A; so that current trough pins #3 and #10 or pins #3 and #11 shall never exceed 1 A.
Output Fault Status is a BJT semiconductor: max Collector Emitter voltage is 80 V and current 50 mA. Anyway, we suggest do not exceed 48V.
Do not apply voltage between any input interlock and its corresponding return.

All the pins are galvanically isolated from ground and outputs terminal, nevertheless the absolute maximum voltage, referred to ground, that pins can sustain is 48V. The inputs signals have their own return connection. The interlock is hardware-activated when the positive pin and its negative pin are shorted together.

Output Fault Status is a BJT semiconductor with max Collector Emitter voltage of 80 V and current 50 mA. Anyway, we suggest do not exceed 48V. When the power supply status is faulty the BJT is OFF.

### 2.6.2 USB Connector

The USB connector is a standard USB Type B connector and it is used to update the firmware. If a firmware update is available, this can be done using serial_flash_programmer.exe utility that needs the following software to be installed (it can be found in the same directory as the firmware update utility on supplied USB Flash drive):

- C run-time libraries (CRT);
- USB to UART Bridge Virtual COM Port (VCP) drivers.

The CRT libraries can be installed using the vc_redist_xXX.exe (vc_redist.x86.exe or vc_redist.x64.exe, for 32-bit and 64-bit operating systems respectively).

The VCP drivers can be installed by running CP210x_Universal_Windows_DriverV11.2.0. For details about the drivers installation, read the CP210x_Universal_Windows_Driver_ReleaseNotes.

#### 2.6.2.1 Firmware Update Procedure

**CAUTION**

Never try to update the firmware if the module's output is enabled.

A firmware update is basically an ".hex" extension file. Save locally the file to a specific directory of your computer (preferably save it in the same directory of serial_flash_programmer.exe utility).

To perform the update, ensure firstly that the module is in OFF-status and switch-off the AC/DC Bulk power supply through the Mains switch. Then unplug the device from the Mains grid. The module has now to be turned on in FIRMWARE UPDATE MODE by plugging AC mains while keeping the update mode button pressed (see **Figure 10**). The LEDs will change their colour from green to steady orange and the display will show "FIRMWARE UPDATE MODE".

Connect the computer's USB port to the USB-B port of the module through an USB cable.

By using Windows Device Manager, identify COM port number - locate Ports (COM & LPT) in the list, expand it and check for USB Serial Port. Open Command Prompt (CMD) and change the actual directory to the folder of serial_flash_programmer.exe.

Launch the update utility including the following parameters:

- -a <file_directory\file_name> firmware update filename including the complete directory path (mandatory parameter);
- -p COM<num>, e.g., COM9 (mandatory parameter);
- -b <num> baud-rate (optional parameter).

Example:

```
C:\FW>serial_flash_programmer.exe -p COM32 -a C-AMI-120-10.hex
```

Firmware update takes around a minute with default baud rate. Once the procedure is complete, the module automatically exits from the firmware update mode.

### 2.6.3 DIP-Switch selector (SW)

Four DIP-Switch are hidden under the cover visible in **Figure 14** and they allow the selection of the output range and Master/Slave configuration, as reported in **Table 8**. Depending on the customer needs, i.e. technical specifications of the load/magnet, the DIP-Switch is already set by the manufacturer before shipment. Anyway, the user can verify the selected output range from the display on the front panel (**Sec.1.4**).

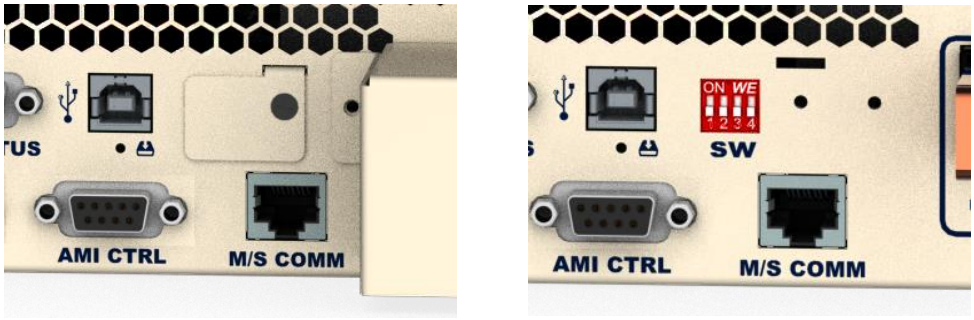



**Figure 14:** *DIP-Switch with and without cover.*

| ***DIP-Switch*** | **Position** | **Selection** |
|---|---|---|
| *#1 & 2* | 0 0 | Range **5 V – 120 A** |
| | 0 1 | Range **6 V – 100 A** |
| | 1 0 | Range **8 V – 75 A** |
| | 1 1 | Range **10 V – 60 A** |
| *#3* | - | Not used |
| *#4* | 1 | Module is Configured as **Slave** |
| | 0 | Module is Configured as **Master** |

**Table 8***: DIP-Switch configuration for output range selection and master/slave mode.*

### 2.6.4 DCCT OUT

The DB-9 male connector marked with **DCCT OUT** (see **Figure 15**) is directly connected to the internal CT-200 DCCT (see blocks diagram in **Figure 4**). Its pinout is reported in **Table 9**.


**Figure 15:** *DCCT connector.*

| *Pin Number* | Signal name |
|---|---|
| *#1* | $I_S$ return |
| *#2* | N.C. |
| *#3* | Status - |
| *#4* | DCCT GND |
| *#5* | -15 V |
| *#6* | $I_S$ |
| *#7* | N.C. |
| *#8* | Status + |
| *#9* | +15 V |

**Table 9:** *Pinout of DCCT OUT connector.*

As remarked in **Table 9**, the internal DCCT needs to be powered with an external ± 15 V supply (refer the CAEN ELS CT-200 User's Manual for detailed description and use of DCCT), e.g. by a AMI Model 430 Power Supply Programmer through its dedicated **High Current Transducer** connector (see "Model 430 Power Supply Programmer – Installation, Operation, and Maintenance Instructions").

We report the sketch of the connection between the 4Q10120PS and an AMI Model 430 Power Supply Programmer in **Figure 16** for convenience.

N.B.: Current absorption of CT-200 is around 260 mA.

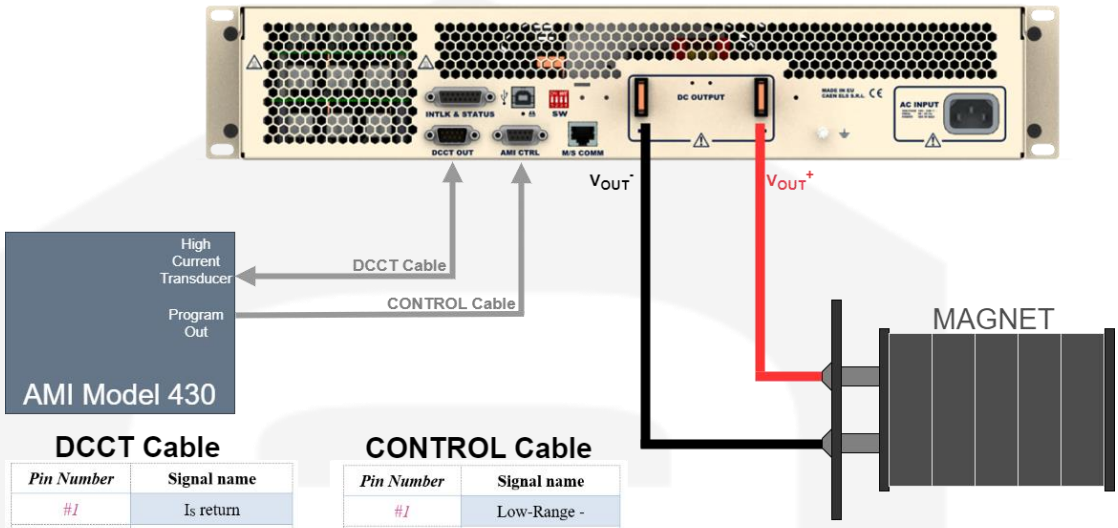
**CAUTION**

DCCT voltage supply shall never exceed ± 15.9 V
A current protection device (fuse) should be provided on the source to limit the maximum input current to ± 500 mA.
We suggest do not exceed 48V between pin #3 and #8.

The DCCT electrical connection is galvanically isolated from ground.

**WARNING**

DCCT electrical connection shall not float more than ±48 VDC above/below chassis ground.




**DCCT Cable**

| *Pin Number* | Signal name |
|---|---|
| *#1* | Is return |
| *#2* | N.C. |
| *#3* | Status - |
| *#4* | DCCT GND |
| *#5* | -15 V |
| *#6* | Is |
| *#7* | N.C. |
| *#8* | Status + |
| *#9* | +15 V |

**CONTROL Cable**

| *Pin Number* | Signal name |
|---|---|
| *#1* | Low-Range - |
| *#2* | GND |
| *#3* | GND |
| *#4* | N.C. |
| *#5* | Supply Status |
| *#6* | Low-Range + |
| *#7* | VIN Setpoint |
| *#8* | GND |
| *#9* | N.C. |

**Figure 16:** *Sketch of the connection between* 4Q10120PS *unit and an AMI Model 430 Power Supply Programmer.* **Table 9** *and* ***Table*** **10** *are aslo reported.*

### 2.6.5 Setpoint Connector (AMI CTRL)

A standard non-isolated D-SUB female connector, marked as **AMI CTRL**, is used to receive the output voltage setpoint. The pinout of the connector is reported in **Table 10**.

The voltage setpoint is provided by an external control unit, e.g. AMI Model 430 Power Supply Programmer through its dedicated **Program Out** connector (see "Model 430 Power Supply Programmer – Installation, Operation, and Maintenance Instructions"), see **Figure 16**.


**Figure 17:** *AMI CTRL connector.*

| *Pin Number* | Signal name |
|---|---|
| *#1* | Low-Range - |
| *#2* | GND |
| *#3* | GND |
| *#4* | N.C. |
| *#5* | Supply Status |
| *#6* | Low-Range + |
| *#7* | $V_{IN}$ Setpoint |
| *#8* | GND |
| *#9* | N.C. |

**Table 10:** Pinout of the *AMI-CTRL connector.*

**CAUTION**

Do not apply voltage between any of pins 1, 5, 6 and GND.
L-Range + and – are referred to ground, do not apply any voltage between pins 1 and 6.
Do not apply voltage higher than ± 15 V between pins 7 and GND.
GND is tight to Chassis Earth so Setpoint voltage shall be refereed to ground.

Shorting pins 1 and 6 will result in selecting the low range ± 2 V.

If the output of the power supply is Enabled, pin 5 is high (i.e. 5 V TTL), otherwise is 0 V.

Pin 7 receives a bipolar voltage setpoint, where 10 V correspond to the positive set full scale and -10 V to the negative set full scale.

### 2.6.6 Parallel link (M/S COMM)

The Master/Slave connector is a RJ45 connector and it is used to share information between the Master and Slave modules.

**Figure 18:** *RJ-45 M/S COMM connector*.

The connector is used to:

- switch ON/OFF the Slave;
- share Fault information between the modules;
- send the set point to the Slave;
- share current readout to the Master module for current sharing.

For Master Slave link, use a standard CAT5 F/UTP straight-through cable, with maximum length of 50 cm.

## 2.7 Maintenance

Concerning maintenance, no-particular actions shall be taken to improve the life-time of the module, expect for the remotion of the eventual collected dust over time.

**WARNING**

- Do NOT open the box top cover
- Return the product to the manufacturer for service and repair to ensure that safety features are maintained

# USB Debug Commands

This chapter describes the basic serial commands used for the debug/configuration of the power supply. First, a serial communication with the device needs to be established and, to this aim, any software that allows a communication through the serial interface, (e.g. Putty). Default baud rate is 9600 bauds.

## 3.1 Command syntax

Commands must be sent in ASCII format and are composed by a "command field" and a "parameter field", separated each other by a colon (":" or "0x3A" in hexadecimal notation). Commands are NOT case sensitive (conversion to uppercase characters is performed internally). Each command must terminate with the termination sequence, i.e. a "carriage return\line feed" sequence "\r\n" - ("0x0D 0x0A" in hexadecimal notation or commonly CRLF). Analogously, the response from the power supply is terminated with a CRLF sequence. For the sake of simplicity, the termination sequence is omitted in the following examples, but it should always be present.

**Command Example:**

```
VER:?\r\n
```

Where VER is the command field, ":" is the parameter's separation character, "?" is the first parameter field, "\r\n" is the termination sequence of the command.

Generally, commands can be grouped in two categories: Write commands and Read commands.

For Write commands, there are two specific replies that indicate if the command has been correctly elaborated or not:

- ACKnowledge (`ACK`): the command is valid and it was correctly elaborated by the unit;
- Not AcKnowledge (`NAK`) the command is either not valid or it has not been accepted by the unit;

For Read commands, the replies are formed by an echo string, followed by the corresponding read value and separated by the ":" separation character.

## 3.2 Command Table

| *Command* | Read /Write | Parameter | Detailed description | Reply value |
|---|---|---|---|---|
| **ENAD** | R | ? | Queries the last applied enable delay | ASCII indicating the enable delay |
| | W | Delay Value | Sets the enable delay | ACK or NAK |
| **ERR** | R | | Displays error register | ASCII indicating the error register |
| **HELP** | R | | Displays commands | List of all available commands in ASCII |
| **INFO** | R | CDATE \| SN \| RNG : ? | Displays module infos | ASCII indicating the required information of the module |
| **INH** | W | | Disables the output | ACK |
| **IOEN** | R | ? | Queries the enable status of the interlock and status signals | ENABLED or DISABLED |
| | W | 1 or 0 | Enables/disables interlock and status signals | ACK or NAK |
| **IPOL** | R | ? | Queries the interlock polarity | NO or NC |
| | W | NO or NC | Sets the interlock polarity | ACK or NAK |
| **MRDC** | R | | Reads dc-link state | 0 or 1 |
| **MRI** | R | | Displays instantaneous output current | ASCII indicating output read current value |
| **MRP** | R | | Displays instantaneous output power | ASCII indicating output read power value |
| **MRST** | R | | Resets errors | ACK |
| **MRV** | R | | Displays instantaneous output voltage | ASCII indicating output read voltage value |
| **REBOOT** | W | UPDT | Reboots the module in firmware update mode | ACK or NAK |
| **RNGCD** | R | ? | Queries the last applied range delay | ASCII indicating the range delay |
| | W | Delay value | Sets the range delay | ACK or NAK |
| **STATUS** | R | | Displays status register | ASCII indicating the status register |
| **TO** | R | OVPFLT \| DCCTFLT \| OVTFLT \| OOVCFLT \| FANFLT : ? | Queries the timeout value for a specific error | ASCII indicating the timeout value |
| | W | Timeout value | Sets the timeout value for a specific error | ACK or NAK |
| **VER** | R | ? | Queries the firmware version | ASCII indicating the firmware version |

## 3.3 Basic commands

In the following section, the basic commands that allow to configure the power unit are described. When examples are provided, the command sent by the PC will be left-justified, whereas the response from the power supply will be right-aligned.

### 3.3.1 ENAD command

The ENAD command is used to set the delay between the Supply Status signal (pin #5 of AMI CTRL connector) and the Enable of the output. The command has the following format:

```
ENAD:delay
```

where delay is the delay time expressed in milliseconds [ms]. The delay value has to be in the range [5ms; 500ms] and is stored in the internal memory of the microcontroller, therefore there is no need to set it again after a power cycle.

To read the last applied delay, the query command ENAD:? has to be used. In this case, the response has the following format:

```
delay
```

where *delay* is the applied delay time expressed in milliseconds [ms].

**Command Example:**

Sets 10ms delay

```
ENAD:10
                                                    ACK
```

Reads the applied delay

```
ENAD:?
                                                    10
```

### 3.3.2 ERR command

The ERR command displays the error register.

The following table shows the internal error register structure:

| Bit # | Bit name | Description |
|---|---|---|
| #00 - #01 | | Internal use |
| #02 | EXTINTLK | External interlock fault condition |
| #03 | OVCFLT | Over current fault condition |
| #04 | DCLFLT | DC link fault |
| #05 | CBFLT | Crowbar fault |
| #06 | DCCTFLT | DCCT fault |
| #07 | OVTFLT | Over temperature fault |
| #08 | OVPFLT | Over Power fault |
| #09 | OOVCFLT | Output over current fault |
| #10 | FANFLT | Fans fault |
| #11 | PARFLT | Parallel fault |
| #12 - #15 | | Not used |

### 3.3.3 HELP command

The HELP command displays a list of all the available commands.

### 3.3.4 INFO command

The INFO command returns the information regarding the calibration date, the serial number and the actual full-scale range. The command has the following format:

```
INFO:item:?
```

where *item* can be one of the following:

- CDATE for calibration date.
- SN for serial number;
- RNG for the full-scale range;

The response has the following format:

```
info
```

where *info* is a string representing the required piece of information:

- CDATE: the string is in the format dd/mm/yyyy;
- SN: the string represents the serial number;
- RNG: the string can be "120A 5V" / "100A 6V" / "75A 8V" / "60A 10V".

**Command Example:**

Queries all the items

```
INFO:CDATE:?
                                                    23/08/2023
INFO:SN:?
                                                    23Y34W0717
INFO:RNG:?
                                                      120A 5V
```

### 3.3.5 INH command

The INH command disables the output of the power supply. The reply can only be ACK.

**Command Example:**

```
INH
                                                          ACK
```

### 3.3.6 IOEN command

The IOEN command is used to enable/disable the interlock and status signals provided through the INTLK&STATUS connector (**Sec.1.3.8**). The command has the following format:

```
IOEN:value
```

where *value* can either be 1 or 0 to enable or disable the signals, respectively.

To read the enable status of the interlock and status signals, the query command IOEN:? has to be used. In this case, the response has the following format:

```
status
```

where *status* can be either DISABLED or ENABLED.

**Command Example:**

Enables the interlock and status signals

```
IOEN:1
                                                    ACK
```

Reads the status

```
IOEN:?
                                                    ENABLED
```

### 3.3.7 IPOL command

The IPOL command sets the polarity of the interlock signals provided through the INTLK&STATUS connector (**Sec.1.3.8**). The command has the following format:

```
IPOL:value
```

where *value* can either be 1 or 0 to set normally closed (NC) or normally open (NO), respectively. By default, the polarity is NO.

To read the interlock polarity, the query command IPOL:? has to be used. In this case, the response has the following format:

```
polarity
```

where *polarity* can be either NO or NC.

**Command Example:**

Sets the interlock polarity to NC

```
IPOL:1
                                                    ACK
```

Reads the polarity

```
IPOL:?
                                                    NC
```

### 3.3.8 MRDC command

The MRDC command reads the state of the AC/DC Bulk voltage. The response to the MRDC command is in the following format:

```
state
```

where *state* is the state of the bulk and can be either 1 or 0, depending on whether the bulk is correctly working or not, respectively

**Command Example:**

Reads the status of the AC/DC Bulk when it is ok

```
MRDC
                                                                    1
```

### 3.3.9 MRI command

The MRI command displays the instantaneous output current value.

### 3.3.10 MRP command

The MRI command displays the instantaneous output power value.

### 3.3.11 MRST command

The MRST command resets all the errors in the status register and enables the output. The MRST command should be sent only after the source of the error is removed, otherwise the power supply fails in re-enabling the output. The response is always ACK.

**Command Example:**

```
MRST
                                                                  ACK
```

### 3.3.12 MRV command

The MRI command displays the instantaneous output voltage value.

### 3.3.13 REBOOT command

The REBOOT command is used to reboot the power supply in firmware update mode. It is an alternative to using the update mode button. The REBOOT command should be sent only after having turned off the AC/DC Bulk power supply through the Mains switch. If the AC/DC Bulk is still on, the command will reply NAK. The REBOOT command has the following syntax:

```
REBOOT:mode
```

where *mode* is the reboot mode and can only be UPDT.

**Command Example:**

```
REBOOT:UPDT
                                                                  ACK
```

### 3.3.14 RNGCD command

The RNGCD command is used to set the delay between the moment when the Low Range inputs are shorted and the moment when the range is effectively changed. The command has the following format:

```
RNGCD:delay
```

where *delay* is the delay time expressed in microseconds [µs]. The delay value has to be in the range [1µs; 10s] and is stored in the internal memory of the microcontroller, therefore there is no need to set it again after a power cycle.

To read the last applied delay, the query command RNGCD:? has to be used. In this case, the response has the following format:

```
delay
```

where *delay* is the applied delay time expressed in microseconds [µs].

**Command Example:**

Sets 25µs delay

```
RNGCD:25
                                                    ACK
```

Reads the applied delay

```
RNGCD:?
                                                    25
```

### 3.3.15 STATUS command

The STATUS command displays the status register.

The following table shows the internal status register structure:

| *Bit #* | *Bit name* | *Description* |
|---|---|---|
| #00 | STATE | output state 0 - OFF; 1 - ON |
| #01 | ERROR | if any error presents the bit is set to 1 |
| #02 | SLAVE | 0 - master; 1 - slave |
| #03 | PARALLEL | 0 - standalone mode; 1 - parallel mode |
| #04 | LRNG | 0 - preset range; 1 - low range |
| #05 | RANGE1 | range bit 0 |
| #06 | RANGE2 | range bit 1 |
| #07 | IOENABLED | 0 - IO control disabled; 1 - IO control enabled |
| #08 - #15 | | internal use |

### 3.3.16 TO command

The TO command is used set the timeout value of specific errors. The default value is 1s, which means that the power supply is disabled if the corresponding source of error is present for more than 1 second. The command has the following format:

```
TO:source:value
```

where *source* is the error source and can be one of the following:

- EXTINTLK for external interlock input;
- OVPFLT for over-power fault;
- DCCTFLT for DCCT fault;
- OVTFLT for over-temperature fault;
- OOVCFLT for output over-current fault;
- FANFLT for fan fault.

and *value* is the timeout value expressed in milliseconds [ms]. The timeout value has to be in the range [1ms; 65535ms] and is stored in the internal memory of the microcontroller, therefore there is no need to set it again after a power cycle.

To read the last applied timeout, the query command TO:source:value:? has to be used. In this case, the response has the following format:

```
value
```

where *value* is the applied timeout value expressed in milliseconds [ms].

**Command Example:**

Sets 500ms delay for the DCCT fault

```
TO:DCCTFLT:500
                                                                ACK
```

Reads the timeout value for the over-temperature fault

```
TO:OVTFLT:?
                                                               1000
```

### 3.3.17 VER command

The VER command returns the information regarding the current installed firmware version. The response to the VER command is in the following format:

```
VER:fw_version
```

where VER is the echo string and *fw_version* is the current firmware version.

**VER Command Example:**

```
VER:?
                                                          VER:1.000
```

# Parallel Connection

This chapter describes how to setup the parallel operation of two 4Q10120PS modules.

## 4.1 Preparation

Two 4Q10120PS modules can operate in parallel to double the maximum output current and power, setting-up a Master/Slave configuration through the following steps:

| *Step* | Checklist | Description |
|---|---|---|
| *1* | **Master-Slave connection** | Connect RJ-45 master and slave M/S COMM (**Sec.4.1.1**) |
| *2* | **Configure DIP-Switch** | Set Slave DIP-Switch #4 to 1<br>Set Master DIP-Switch #4 to 0 (**Sec.4.1.2**) |
| *3* | **DCCT connection** | Connect DCCT-SUB-D in parallel (**Sec.4.1.3**) |
| *4* | **Busbar connection** | Connect output busbar in parallel using suitable cables (**Sec.4.1.4**) |
| *5* | **Control connection** | Interface to the control unit (**Sec.4.1.5**) |
| *6* | **Mains connection** | Supply with AC Mains Slave and Master simultaneously (**Sec.4.1.6**) |

### 4.1.1 Master to Slave connection

Connect the Slave module to Master using a standard CAT5 straight-through cable (refer also to **Sec.2.6.6)**.

### 4.1.2 Configure DIP-Switch

Set the DIP switches on both modules for parallel operation (**Sec.2.6.3**). The slave module shall have the switch#4 set to 1, the master to 0. Pay attention not to connect two modules configured as Masters in parallel.

### 4.1.3 DCCT connection

The two DCCTs integrated in both Master and Slave modules shall be connected in parallel: connection schematic is presented in **Figure 19.** The two secondary currents of DCCTs are merged together, so that the measuring shunt will receive the sum of secondary currents. Ratio between primary current and secondary current will be alway 1:1000.

The Status signals (C and E, **Sec.2.6.4**) shall be connected in series, in order to include the possibility that just one DCCTs can trigger a DCCT Fault if not working properly.

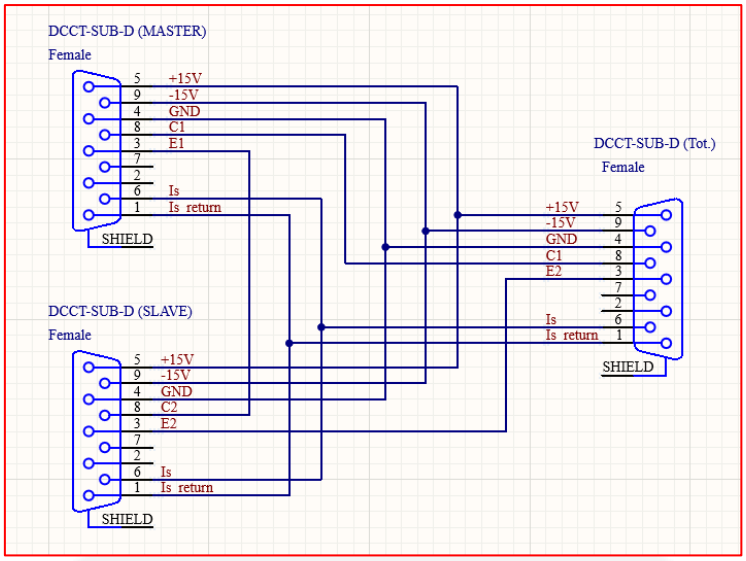



**Figure 19:** *DCCT Cable for Parallel Operation.*

### 4.1.4 Busbar connection

Output Busbar shall be connected in parallel with adequate cable size (**Sec.2.5.1**). If the Master and Slave module are stacked each other, a 16 $mm^2$ cross section wire can be used to connect the output terminals of the units. A recommended connection scheme is here after reported:

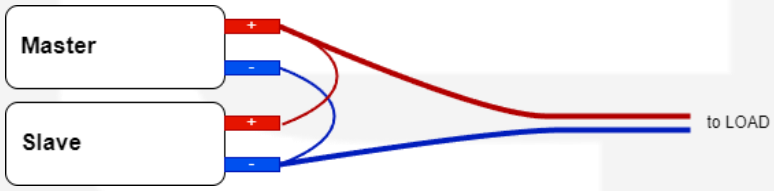



**Figure 20:** Recommended *output cable connection.*

Master module communicate the compensated voltage set point to the Slave module, in order to share the same output current on both modules. The display of the Master unit will show the total output current.

### 4.1.5 Control connection

When two modules are operating in parallel mode, only the Master module provides the control interface. Consequently, the AMI-CTRL cable (**Sec.2.6.5**) from the control unit (e.g. AMI Model 430 Power Supply Programmer) to the Master module is needed only. Furthermore, all the control inputs on the Slave module are not active (i.e. AMI CTRL connector, INTLK & STATUS and OUTPUT INHIBIT pushbutton).

### 4.1.6 Mains connection

Master and Slave modules need an initial synchronization after the switching-ON of the A/D Board (i.e., after Auxiliary AC/DC is switched-ON). To allow the sync process, Slave unit shall be powered ON before the Master unit or simultaneously but not after the Master.

# Mechanical Dimensions

The mechanical dimensions of the 4Q10120PS unit are presented in **Figure 21**:

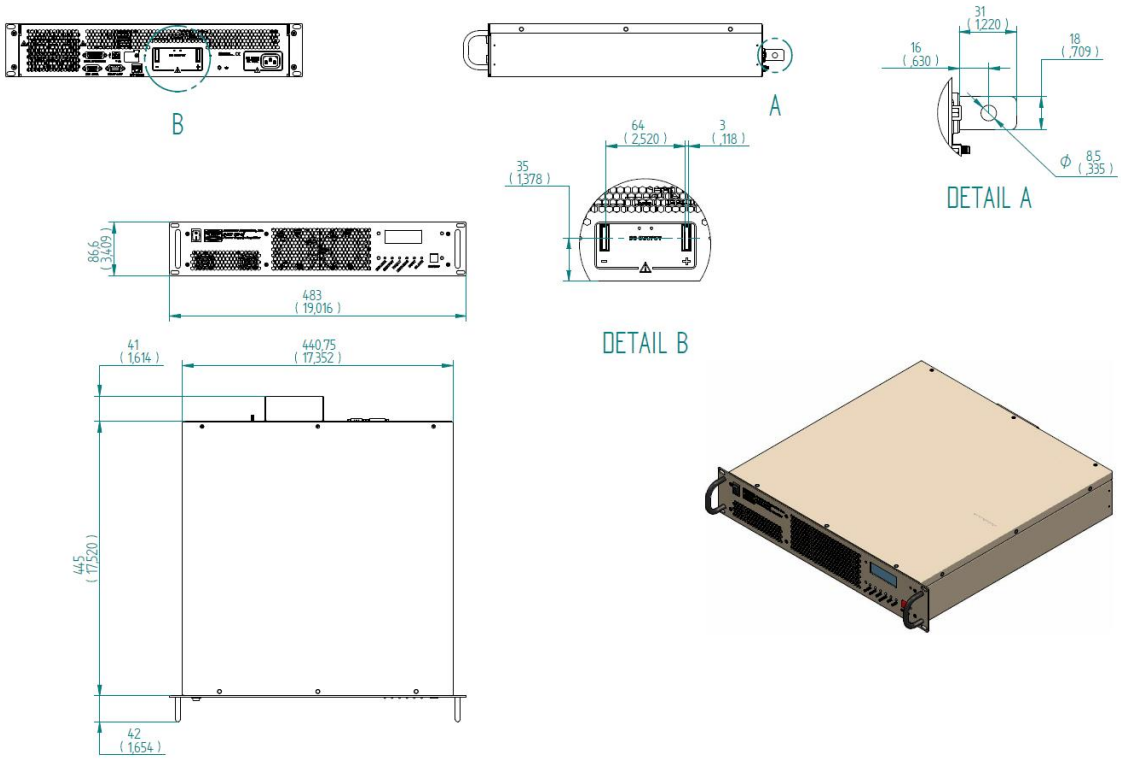



**Figure 21:** 4Q10120PS *Mechanical Drawings, mm (inch).*

# Technical Specifications

The main technical specifications for the 4Q10120PS are hereafter presented:

| Technical Specifications | 4Q10120PS | | | | |
|---|---|---|---|---|---|
| ***Max Output Current*** | ±120 A | | | | |
| ***Max Output Voltage*** | ±10 V | | | | |
| ***Max Output Power*** | ± 620 W | | | | |
| ***Topology*** | Full 4-Quadrant, Zero-Crossing | | | | |
| ***Control Mode*** | Voltage Control (CV) | | | | |
| ***Floating Output*** | Up to 200 V | | | | |
| ***Current Sensing*** | LEM High-Precision Current Transducers CT-200 | | | | |
| ***Analog Control Input*** | ± 10 V | | | | |
| ***Setting Voltage Range*** | 2 V | 5 V | 6 V | 8 V | 10 V |
| ***Max Output Current per Range*** | 120 A | 120 A | 100 A | 75 A | 60 A |
| ***Current Reading Accuracy (Display)*** | < 0.1%/FS | | | | |
| ***Voltage Reading Accuracy (Display)*** | < 0.1%/FS | | | | |
| ***Noise + Ripple (RMS)*** (0.1Hz – 1kHz bandwidth) | < 8 mV on 0.2Ω resistive load | | | | |
| ***Accuracy*** | < 0.1%/FS | | | | |
| ***Long Term Stability (8 h)*** (Max deviation from mean value) | 16 ppm/FS with FS=10V and I=60A<br>53 ppm/FS with FS=2V and I=120A | | | | |
| ***Thermal coefficient*** | < 6 ppm/K/FS | | | | |
| ***Analog Bandwidth (-3 dB)*** | > 150 Hz<br>(Depending on the selected range) | | | | |
| ***Local Control*** | LCD display + OUTPUT INHIBIT Button | | | | |
| ***External Signals*** | 1 input - Enable/Disable Output<br>1 input - External Interlocks<br>1 input - Reset Fault<br>1 output - Output Status Signal<br>1 output - Fault Status Signal | | | | |
| ***Mechanical Dimensions (L×W×H)*** (*Without connectors*) | 19" x 2U x 450 cm | | | | |

| | |
|---|---|
| ***Input Nominal Voltage*** | 100 - 240 V~ |
| ***Input Nominal Frequency*** | 50/60 Hz |
| ***Input Voltage Range*** | 90-264 V~(1) |
| ***Input Frequency Range*** | 47-63 Hz |
| ***Power Factor (Typ.)*** | 0.97 |
| ***Max Input Current*** | 7.7 A @ 110 $V_{AC}$<br>3.7 A @ 220 $V_{AC}$ |
| ***Max Input Power*** | 900 W |
| ***Efficiency***<br>(From AC Mains to DC output) | 82% at 10V/60A (220V input)<br>79.7% at 10V/60A (110V input) |
| ***Weight typ.*** | 11 Kg |
| ***Operating Temperature*** | 5 … 50 °C(2) |

Notes:

1. At 90V input the maximum output power is 95%, i.e., 570W)
2. See derating curve (Figure 22)

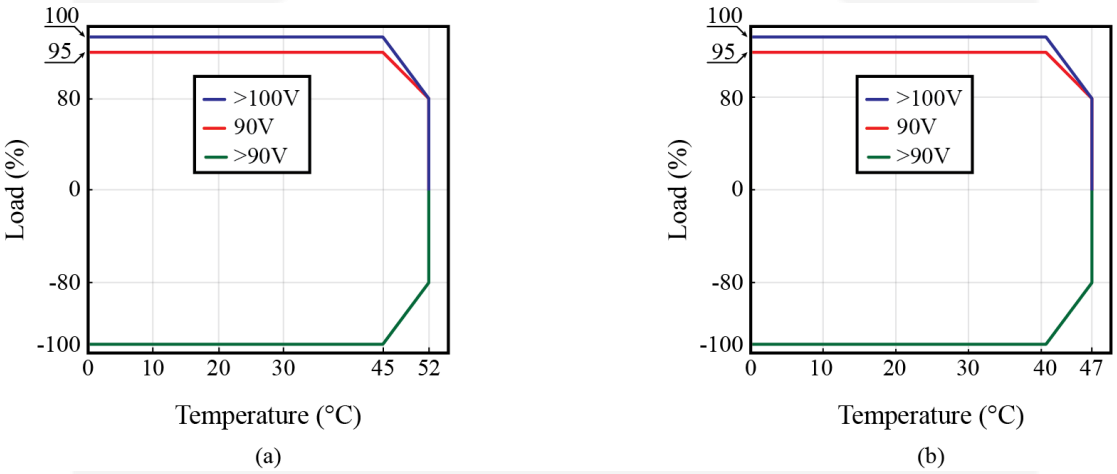



**Figure 22:** *Derating curve of output power vs ambient temperature: (a) without isolation and (b) with the power supply thermally isolated.*

**Table 11:** CT-200 Technical Specifications.

| **Technical Specifications** | *CT-200*<br>*Integrated DCCT* |
|---|---|
| ***Current Transfer Ratio*** | 1:1000 |
| ***Maximum DC Primary (Full Scale)*** | ± 200 A |
| ***Max Output Power*** | ± 620 W |
| ***Max DC Secondary*** | ± 200 mA |
| ***External Shunt Resistor*** | 0 … 35 Ω |
| ***Small Signal Bandwidth (± 3dB)*** | 100 kHz |
| ***Equivalent Input Noise*** | < 1.5 ppm/FS @ 200 Hz |

| | |
|---|---|
| | < 10 ppm/FS @ 50 kHz |
| ***Temperature Coefficient*** | < 0.5 ppm/°C |
| ***Non-Linearity*** | < 10 ppm |
| ***Induction into Primary*** | < 20 $\mu V_{RMS}$ |
| ***Maximum Offset (Typ.)*** | < 10 ppm |
| ***Supply Voltage*** | ± 15 V (± 6 %) |
| ***Current Consumption*** | 60 mA + Is |
| ***Accuracy (Typ.)*** | < 50 ppm/FS |
| ***Operating Temp. Range*** | 0°C – 50°C |

**Table 12:** *CT-200 Technical Specifications.*