CAYLAR
INSTRUMENTATION SCIENTIFIQUE

MAGNETIC SYSTEM DOCUMENTATION

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AF2104-007 MPU8220-064
EAC132C – 9240-040
PSI Suisse
March 2022
Rev 1.0

CAYLAR
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UE CONFORMITY CERTIFICATE

POWER SUPPLY - USER MANUAL

POWER SUPPLY – ETHERNET INTERFACE MANUAL

POWER SUPPLY – MEASUREMENT REPORT

Electromagnet EA132C – MEASUREMENT REPORT

DECLARATION UE OF CONFORMITY

We,

CAYLAR SAS, 14 Avenue du Québec F 91140 VILLEBON SUR YVETTE - FRANCE

declare under our sole responsibility that the products:

Bipolar Power supply ± 60 V ± 100 A, reference: **8220-064**

Electromagnet EA132, reference: **8240-040**

to which this declaration relates are in conformity with the safety provisions for people and things required by the following Council Directives:

Low Voltage Directive : 2014/35/UE

EMC Directive : 2014/30/UE

In order to comply with these Directives, we had used the applicable parts to our products of the following harmonised Standards or other normative documents:

Safety Standard	EN 60950-1: 2006
Emission	EN 61000-6-4: 2007
Immunity	EN 61000-6-2: 2006
	Applied with EN 61000-4-2: 2010
	EN 61000-4-3: 2006
	EN 61000-4-8: 2011
Measurement, control and laboratory equipment	EN 61010-1: 2011

Villebon sur Yvette, on the 27th October 2021.

J.C. Germain
Chairman

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CAYLAR
INSTRUMENTATION SCIENTIFIQUE

Power Supply ± 60 V / ± 100 A

CURRENT REGULATED – 10 PPM CLASS

USER MANUAL

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1. INTRODUCTION

The power supply attached to this manual is a regulated bipolar power supply of **± 60 Volts ± 100 A** belonging to the stability class **10 PPM**.

It is a "four quadrant" type power supply designed to supply inductive loads (electromagnets) up to one henry with a minimum load of 0.45 Ω and a dynamic of 10 A/s.

The current control is assumed by an analog PID regulation set for a specific load (typically the user's electromagnet). Please contact us in case of load change to change PID settings.

This power supply is a fully analog regulated linear power supply. No switching power supply is present in order to ensure the most stable and least disturbed output voltage possible.

It has a smooth zero crossing transient with no drop in output voltage or current when changing polarity and in order to minimize output voltage ripple, series regulation is performed by transistor bars.

The power supply is water-cooled. It is protected against lack of water and condensation, and has internal safety devices.

It can be controlled in three different ways (which can be used at the same time):

- **local mode** from the front panel potentiometers, selectors and buttons.
- **remote mode** from the rear panel SUB-D connectors.
- **digital mode** from ethernet, RS232/485 or front panel keypad.

This power supply integrates a STM32 family microcontroller allowing the management of RS232 and Ethernet interfaces, the keyboard and the display by screens as well as the management of the ADC and DAC converters.

2. SPECIFICATIONS

2.1. General specifications

Mains supply : Three-phase mains 3 x 400 V 10 % 50 Hz + Neutral
Current consumption: < 14 A per phase at 400 V

Minimum charge: **0.47 Ω**

Front panel: On / Off switch
Set of 6 leds indicating the power supply status
Reset default" button
Push buttons Power On and Power Off
2 OLED displays
Setpoint selector Digital / Potentiometers / External
10-turn potentiometer ± 100 % (mid-point setting)
Potentiometer 10 turns 1 % (Optional)
Keyboard

Safety : Thermostats on the heat sinks protect the power supply against cooling faults. There are other safety devices (see §4-8 for more details). External safety inputs are available on the rear SubD connector.

After disconnection, the power supply returns to standby mode. The cause of the power failure is indicated on the front panel by a red LED.
If the cause of the fault has disappeared, the fault can be cleared by pressing the "Reset fault" button.

The power supply has internal fuses see §4-9.

The power supply incorporates an output voltage limitation that limits the current so that it does not exceed the specified voltage, but the power supply does not break down.

Connections :
- Three-phase Line filter with Hypra 16A connector – delivered with a power cord with a HO7RNF-5G6 cable and the 16A plug and a 32A plug for standard wall mounting.
- Power outputs: on threaded studs at the rear, protected by a removable cover.
- Interlock: on the 26-pin HD-SubD socket at the rear of the power supply.
- Network communication : on the 9 pts SubD socket for RS232 link or RJ45 for Ethernet link.
- Circular Hall Probe connector
- Circular lock Modulation connector (Optional)

Chassis : 19-inch cabinet.

Dimensions : height 1.15 m (20 U), depth 800 mm, width 600 mm.

Cooling : Transistor banks and rectifier bridges are water cooled.
The minimum flow rate is 4 litres/ min, with a minimum pressure of 4 bars.

Water : Water inlet and outlet are F 1/2 type.

2.2. Technical datas

Type(s) of regulation : Current regulation

Output current: ± 100 A max, variation limited to **10 A per second.**

Output voltage: ± 60 V max. Output voltage is limited to 75 V (by constuction).

Setpoint :
- In Digital mode, by 19-bit DAC digital setpoint
- In Pot mode, by two 10-turn potentiometers with center point on the front panel, one for coarse adjustment (100%), the other for the optional fine adjustment (1%).
- In External mode, by analog setpoint on the Interlock socket on the rear panel..

Polarity :
- In Digital mode, by the sign of the digital setpoint.
- In Pot mode, the potentiometers are mid-point, the first 5 turns correspond to a negative setpoint and the next 5 turns correspond to a positive setpoint.
- In External mode, the sign of the setpoint determines the polarity, with a true zero crossing.

Load : Electromagnet, minimum resistance of 0.47 Ω.

Stability :
Mains (6+% – 10%) ± (2.10^{-6} Is + 2.10^{-6} In)
Load (± 20%) ± (2.10^{-6} Is + $2\ 10^{-6}$ In)
Long term ± (10^{-5} Is + 10^{-5} In) at constant mains voltage, load and temperature.

Noise: ± 2 (10^{-6} Is + 10^{-6} In) peak-to-peak, between 0.01 Hz and 1 Hz.

Ripple : 2 mV eff. + 10^{-5} Vn

Is is the operating current, In and Vn are the nominal values.

Status indicators:
1 green led in normal operation.
1 blue led to indicate power operation.
1 orange led to indicate maintenance mode.
2 red led for failure (detail at § 4-8)
The first fault that caused the disconnection is stored. The fault can be deleted by pressing the " Reset default " button.
1 other orange led to indicate that the thermostat temperatures have not been reached.

Digital display: 2 digital displays allow to know the status of the power supply, fault, current delivered, voltage delivered, piloting mode, selected interface, etc...and allow the display of the navigation menus.

2.3. Environmental conditions

2.3.1. Operating environment

Ambient temperature : +11°C to +30°C (Note : calibration made at 21°C)

Cooling water : +15°C to +25°C. Tap water is suitable. **AVOID CONDENSATION!**

Humidity : non-condensing conditions.

2.3.2. Storage conditions

Ambient temperature : -10°C to +50°C

Cooling water : purge the water circuits if the temperature drops below 5°C).

3. REAR/FRONT PANNELS DESCRIPTION

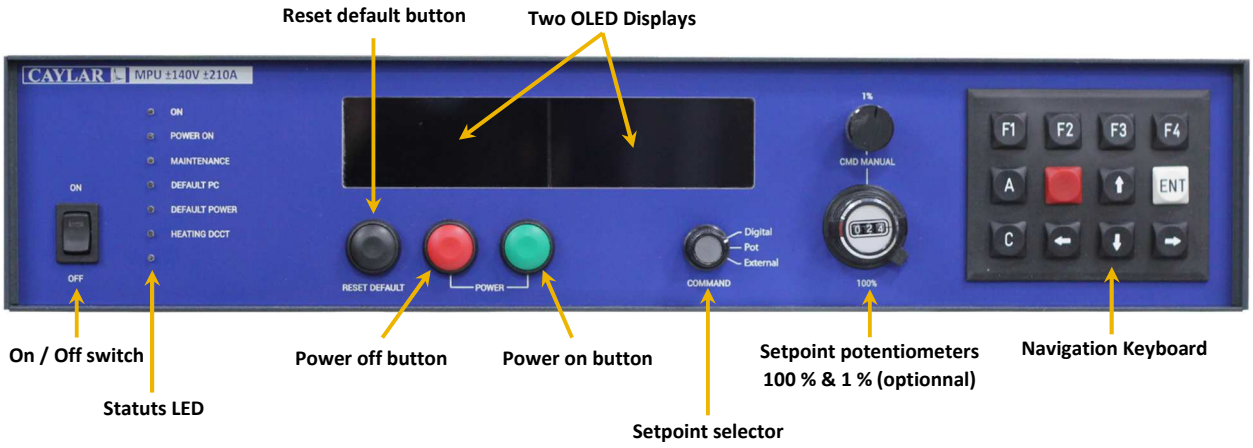
3.1. Front panel

The front panel of this bay power supply has a control panel at the top of it.

This panel allows manual control of the power supply with access to all the power supply's functions.

The control panel also allows to have a visual feedback on the status of the power supply from different LEDs (power, security, heating of the electronics...) and two OLED displays.

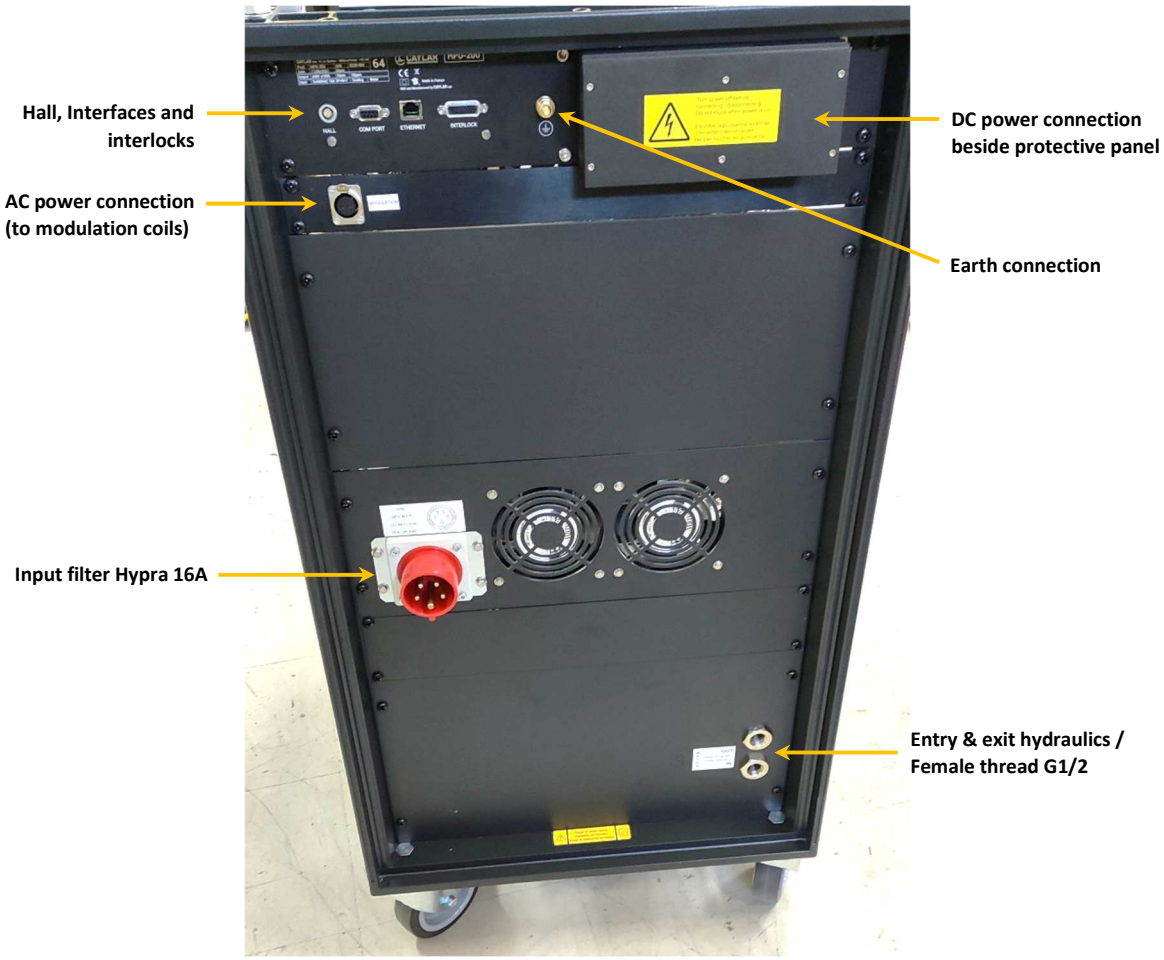
The figure below shows the different actuators and displays present:



3.2. Rear panel

The rear of the power supply presents :

- a top part for Hall, RS232 or LAN interfaces, interlock, ground and power connections and Modulation connection
- a middle part for Mains connection
- a bottom part with hydraulic connections



4. INSTALLATION AND OPERATION

4.1. Installation

Upon receipt of power, open the side panels and inspect / check the mechanical condition of the various elements including the power transformer which is mounted on a damper block, in order to reduce acoustic noise.

Then put the panels back in place.

All connecting cables have been supplied with the power supply (interlocks and power cables).

4.1.1. Wall protection and network connection

The power consumption is 14 A per phase in 400 V configuration.
It must be installed with a wall breaker.
The specifications are as follows:

400 V
Minimum wire cross-section: 6 mm² per phase
Protective fuses: 16 A aM / 500 V ~ time lag per phase

The mains are connected to the power supply through a line filter with an embedded connector.
A HO7RNF 5G6 power cord is delivered with the power supply with the appropriate plug for the connection with the power supply and a 32 A Hypra plug for standard line connection.

If required, special outputs are provided on the rear SubD connector for connecting an emergency stop.

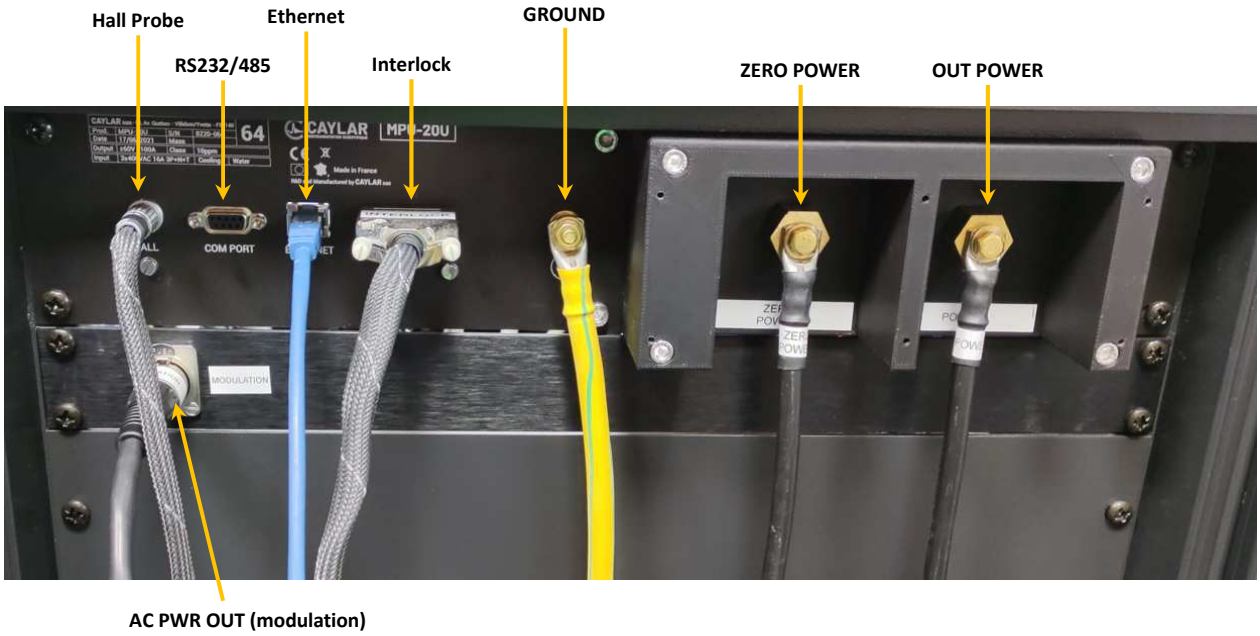
4.1.2. Cabinet grounding

The electromagnetic compatibility requirements (necessary for the CE mark) are met if the cabinet is grounded to the nearest earth by its copper wire connected to the GROUND thread at the rear of the cabinet.

4.1.3. Output connections

To access the power connections, please remove the protective cover.

Details of the upper part showing all the connections :



The cross-section of the output wires must be at least 35 mm².
The output connections are made on M6 stud rods, with a recommended tightening torque between 0.6 m.kg and 0.8 m.kg max.

For the safety at low frequencies, if the output cable has two wires + one ground wire, this can be connected to the ground stud near the power connections.

To reduce noise, it is not recommended to route the output and setpoint cables together.

The output terminals have floating potentials. The potential between each output and the cabinet ground must not exceed 250 V.

The user must ground the system to be in conformity with the regulations about safety.
And this can be done connecting the POWER potential to earth with a power cord.

WARNING: the analog outputs on the " Interlock " connector have a potential close to the " POWER " terminal.

4.1.4. Water

It is recommended to use paste (e.g. Loctite 577) to improve the seal.
The water inlet is through the bottom hole and the outlet through the top hole.
If the inlet and outlet are reversed, the stability of the feed may be degraded.
The recommended minimum flow rate is 4 l/min under a pressure of 4 bars.

A security linked to an internal feed flowmeter requires the recommended minimum flow rate.

4.1.5. Analog signals

The "Remote" setpoint, active in "External" mode only, allows the current to be set to 100% of its value.

± 10 V corresponds to ± 100 A

Current copy:
This output delivers a voltage (±10 V max) proportional to the power output current :
± 10 V for ± 100 A.

Voltage copy :
This output delivers a voltage (±10 V max) proportional to the power output voltage :
± 10 V for ± 60 V.

These cables are not necessary for the first start-up. They are required for operation in "External" mode.

Caution: All three potentials have a common zero.

4.1.6. Rear SubD connector

The constraints of electromagnetic compatibility require the use of a shielded cable, with 360° shielding connection on the connector cover.

For the first commissioning, the minimum configuration is as follows:

- Between 1 and 10 : connect a closed contact
  (flowmeter associated with the electromagnet e.g. emergency stop for example)
- Between 2 and 11 : connect a closed contact (thermalswitches of the associated electromagnet)
- Between 3 and 12 : connect a closed contact (thermalswitches of the associated electromagnet)
- Between 8 and 9 : remote stop contact; must be closed to allow power up

See the chapter on rear connections for more details.

An "Interlock" cable has been delivered with the power supply, this cable offers the connections for the thermalswitches of the coils of the electromagnet and the wiring for the remote flowmeter.

4.2. Pinout of the rear SubD connector

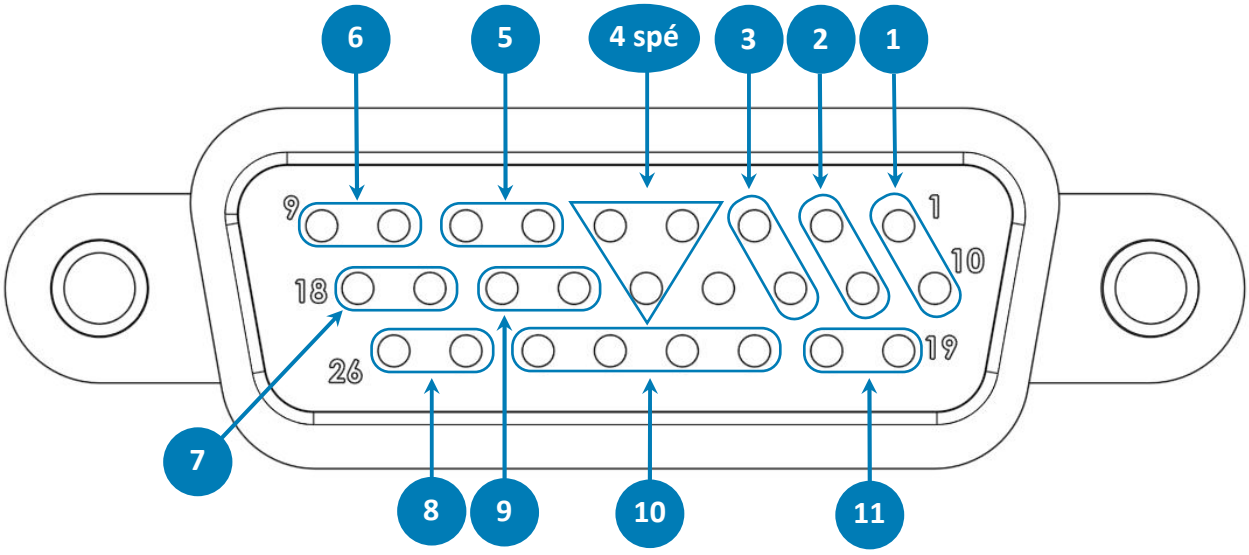
The 26 pts D-sub "Interlock" on the rear panel of the power supply allows the user to control the power supply from his own hardware, such as a PLC. It gives access to the following functions and readings :

- 1-2-3 : Normally closed inputs of external safety devices
- 4 : 24V 400mA power supply available
- 4 spé : 24V 400mA power supply with power status relay for color status led bar inside the electromagnet
- 5 : Powering on - Normally Opened
- 6 : Powering off - Normally Closed
- 7 : Power state
- 8 : Reset
- 9 : Default presence
- 10 : Analog Copies
- 11 : Analog setpoint

The description of the functionalities is detailed below.

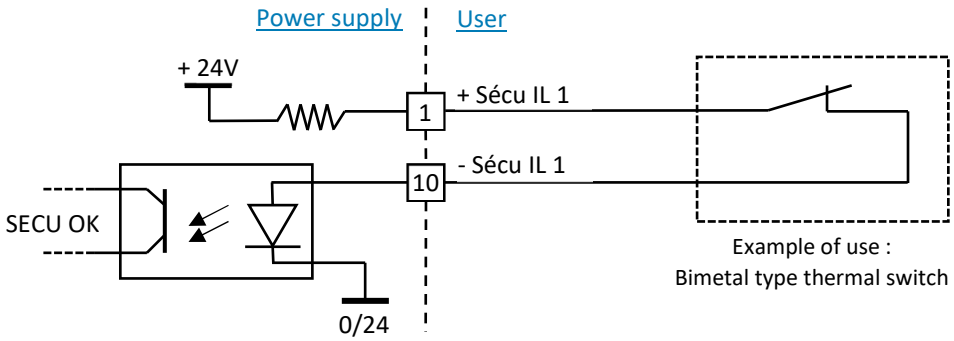
D-sub wiring details

It is a high-density female 26-pin D-sub, the wiring diagram of which is given below:



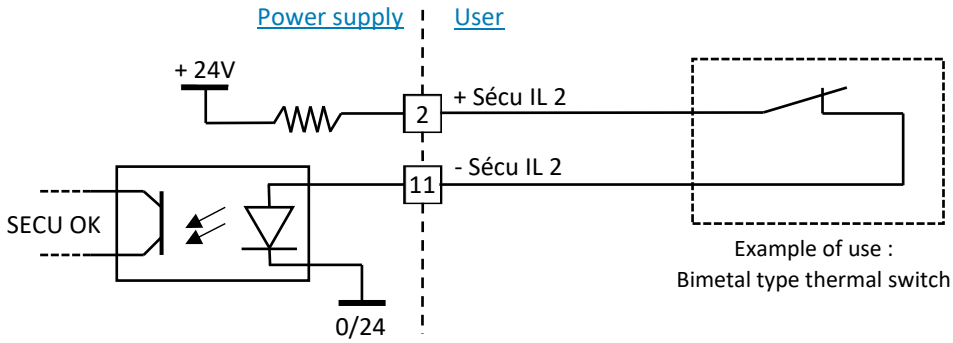
1 Security Interlock 1 - Pin 1 and 10

Triggers an error that puts the power supply in safety mode (see the "fault" section of the manual). Set a normally closed (NC) contact. No error = Contact closed.



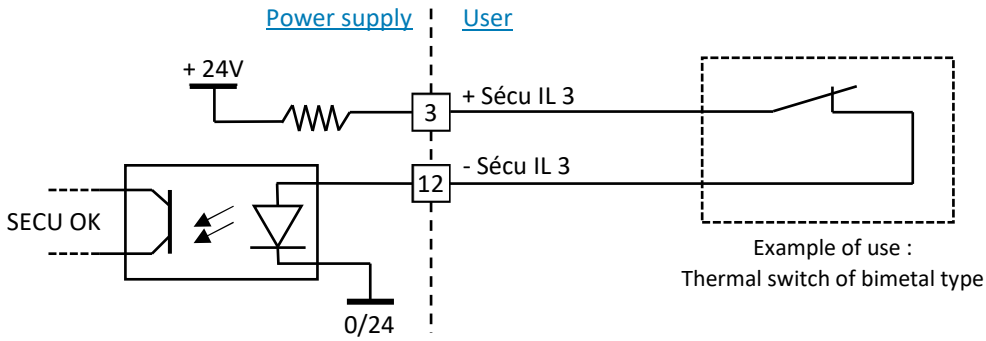
2 Security Interlock 2 – Pin 2 and 11

Triggers an error that puts the power supply in safety mode (see the "fault" section of the manual). Set a normally closed (NC) contact. No error = Contact closed.



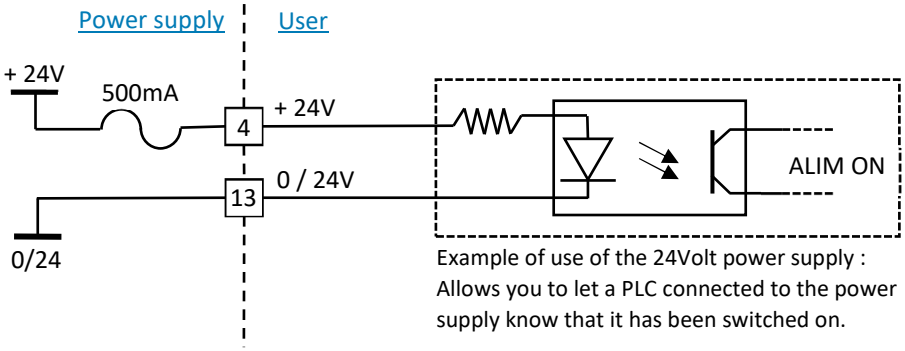
3 Security Interlock 3 – Pin 3 and 12

Triggers an error that puts the power supply in safety mode (see the "fault" section of the manual). Set a normally closed (NC) contact. No error = Contact closed.



4 24 Volts power supply - Pin 4 (+24Volts) and 13 (0/24V)

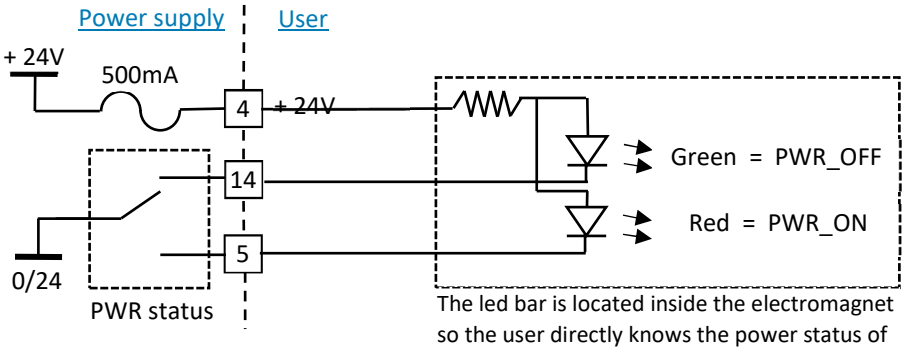
Provides the user with a 24 volt / 400 mA power supply.



Example of use of the 24Volt power supply :
Allows you to let a PLC connected to the power supply know that it has been switched on.

4spé 24 Volts power supply for Magnet light status indication - Pin 4 (+24Volts) and pin 5 and 14

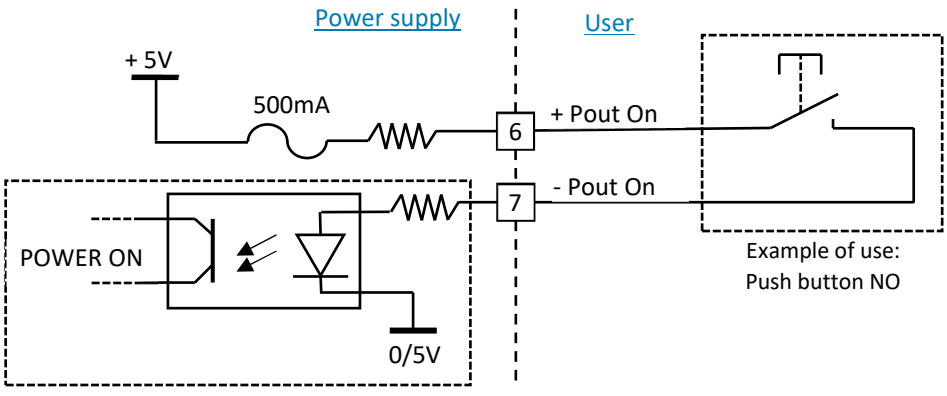
Provides the magnet with a supply to light a led bar located inside the magnet.



The led bar is located inside the electromagnet so the user directly knows the power status of the power supply.

5 Power supply POWER ON – Pin 6 and 7

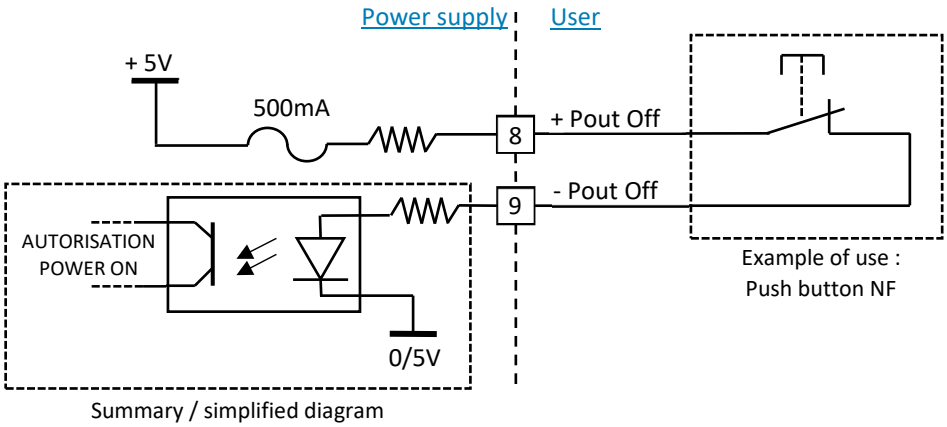
Switches on the power supply (see the "remote control" section of the manual).
Set a normally open (NO) contact. Power on = contact temporarily closed
The contact must be held for a period of at least 0.5 s then can be released.



Summary / simplified diagram

6 Power supply POWER OFF – Pin 8 and 9

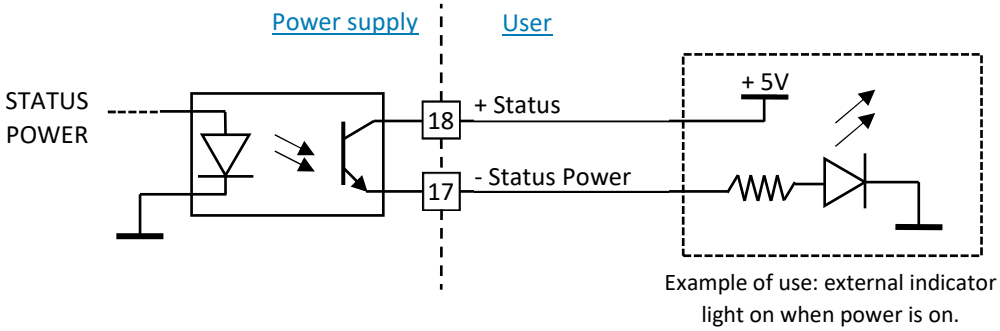
Allows the power supply to be turned on (see the "remote control" section of the manual).
Set a normally closed (NC) contact. Power authorization = contact closed. If the contact opens while the power supply is on, the power is cut off instantaneously.



Summary / simplified diagram

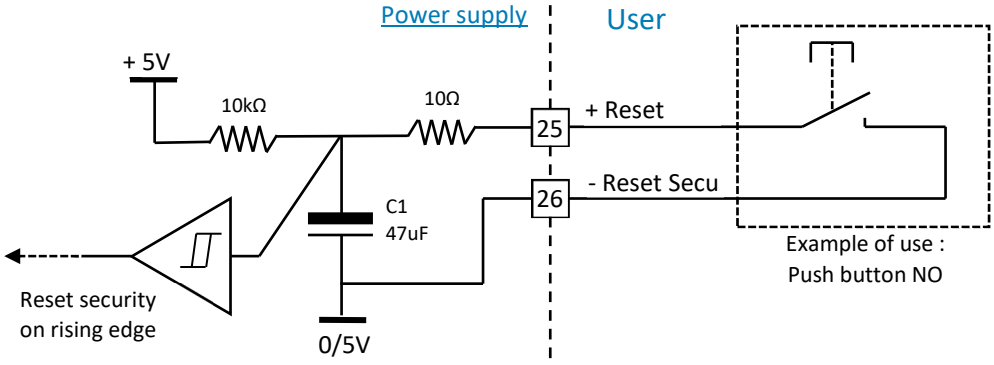
7 Power supply power status copy - Pin 17 and 18

Allows you to know the power status of the power supply (power on or off).It is a relay output (MOSFET type) allowing a maximum of 2 Amps / 60 Volts. Relay closed = Power supply.



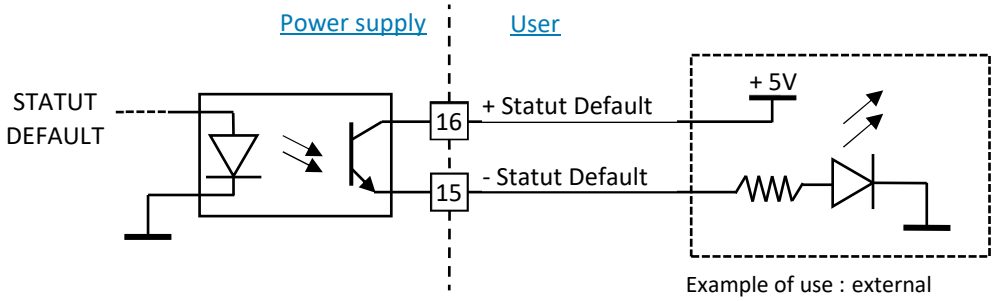
8 Reset of power supply security - Pin 25 and 26

Used to update the status of the power supply safety devices (see the "fault" section of the manual).
Set a normally open contact (NO). Reset = contact closed for a sufficiently long time (min 100 milliseconds). Charging of capacitor C1 will reset the power supply safety devices.
Note : a 10 Ohms resistor is placed at the output (pin 25) to limit the discharge current in the user's cables.



9 Copying of the state of power supply faults (power supply in default or not) - Pin 15 and 16

Allows you to know if one of the power supply safety devices is activated or not (see the "safety devices" section of the manual). This is a relay output (MOSFET type) allowing a maximum of 2 Amperes / 60 Volts to be passed through. Relay closed = Power supply without errors / safety ok.



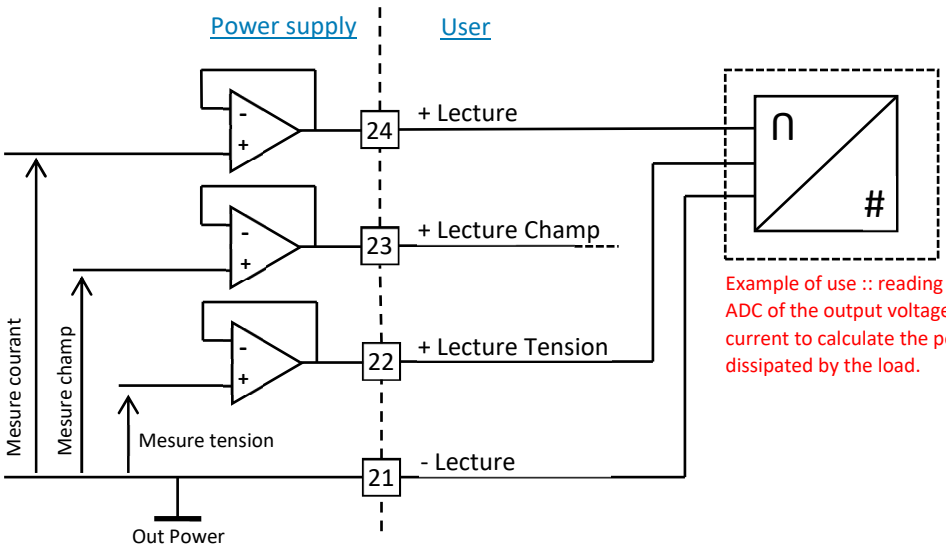
Example of use : external indicator light is on to show that the power supply is safe. ok.

10 Analog current / voltage / field readings (option) - Pin 21, 22, 23 and 24

Allows to read the current and voltage output of the power supply as well as the hall measurement (if hall probe option) from analog voltages proportional to these quantities.

- The reading of the output current is made from a voltage measurement between pins 24 and 21. ± 10 Volts for an output current ± 100 Amperes.
- The output voltage is read back from a voltage measurement between pins 22 and 21. ± 2 Volts for an output voltage ± 60 Volts.
- The field reading is based on a voltage measurement on pins 23 and 21. ± 10 Volts for a field of ± x Tesla.

WARNING: these measurements are made in relation to our electronic zero which is referenced to the potential of the power output of the power supply "OUT POWER".



Example of use :: reading by an ADC of the output voltage and current to calculate the power dissipated by the load.

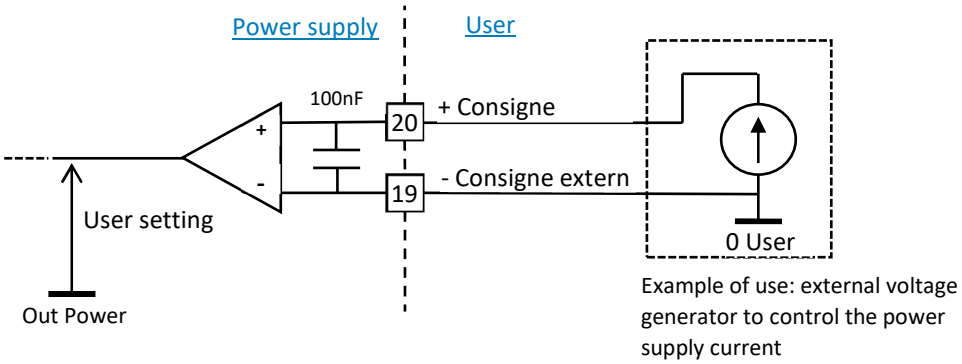
11 External setpoint (EXTERNAL REMOTE) - Pin 19 and 20

Used to apply an external analog setpoint for current or field regulation (field regulation if hall sensor option) of the power supply (see the "power management" section of the manual). ± 10 Volts for an output current of ± 100 Amps.

This setpoint voltage enters on a differential amplifier allowing a common mode of ± 200 Volts max between the electronic zero of the power supply and the user zero connected to " - external setpoint ". In differential mode the input impedance of the AOP is 800 k Ohms. If " External setpoint " is polarized at the zero of our electronics (" Out power ") then the input impedance drops to 400 k Ohms.

A 100 nF filter capacitor placed in differential mode on the setpoint input is also present.

Note: to use this setpoint, the setpoint selector on the front panel must be set to "external".



Example of use: external voltage generator to control the power supply current

4.3. Control configurations

It can be controlled either in local mode by the front panel potentiometers, or in remote mode by analog voltage or digital setpoint.

The remote Start and Stop commands remain accessible at all times.

4.3.1. Local control via potentiometers

To control the power supply in local mode (from the front panel) :

1. Make the wter flow.
2. Apply the phases, by operating the disconnector in the back box.
3. Switch the On/Off switch to "ON", the green "ON" light and the orange "Heating DCCT" light must light up.
4. Set the setpoint selector switch "COMMAND" to the position "Pot".
5. Check the position of the potentiometer 100 % by means of the revolution counter, position at 0A indicated by "555".
6. Press the green "Power" push button to turn on the power supply.
7. The blue "Power on" indicator light will illuminate.
8. Turn the potentiometers 10 turns to reach the desired output current.
9. The output current and voltage are displayed on the front panel. The speed of current change is internally limited to approx. 10 A/s.
10. Press the red Stop button to stop the power supply and return it to standby mode. The power indicator light will go out. It is recommended that the output current of the power supply be reduced to 0A before power off.
11. Toggle down the On/Off switch to completely stop the power supply. Displays and LEDs will turn off after a time corresponding to the complete discharge of the capacitors.

The stability performance of the power supply is achieved after thermostatting of the electronics,

The orange "Heating DCCT" light indicates that performance is not nominal while this light is on. We recommend leaving the power supply on for a shorter operational time.

4.3.2. External control via analog input

To control the power supply in analog remote mode, switch the "COMMAND" setpoint selector switch to the "External" position.

The output current is then proportional to the control voltage present on the 26-point SubD between connections 20 and 19, the other setpoints via potentiometers or digital interface are ignored.

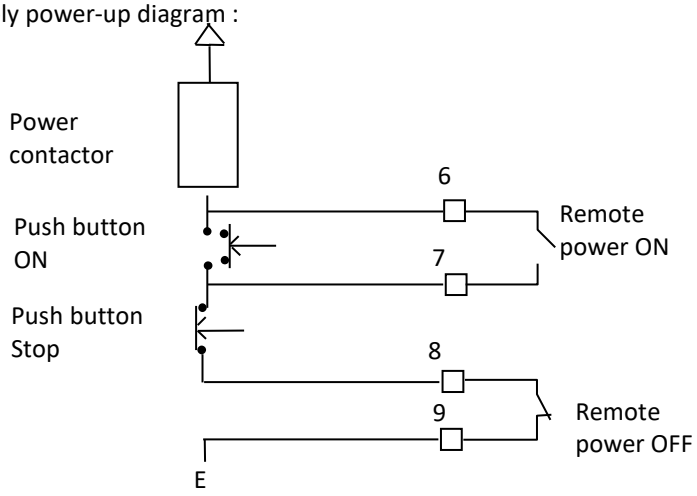
The following remote controls are available:

- Remote Run command (always available, regardless of the position of the setpoint selector switch)
- Remote stop command (always available, regardless of the position of the setpoint selector switch)
- Analog setpoint, by applying a voltage to the analog input of the SubD connector (in External mode only).

To send a remote run command, establish a short contact of about 0.5 s between pins 6 and 7 of the 26-pin SubD at the rear of the power supply.

To send a remote stop command, open connection 8-9 of the rear 26-pin socket for at least 0.5 seconds.

Power supply power-up diagram :



4.3.3. Operation in digital mode via the front panel keypad

To control the power supply in digital mode, switch the "COMMAND" setpoint selector switch to the "Digital" position.

The output current is then proportional to the digital control set on the digital setpoint variable, other setpoints via potentiometers or analog voltage are ignored.

The keypad consists of menu access keys : " A ", " C ", " F1 ", " F2 ", " F3 ", " F4 ".
You can then press the " ← " and " → " keys to navigate through the menus.

At any time, pressing the red (escape) button on the keyboard will exit the menu you are in with a return to main menu.
At any time, pressing the " C " (cancel) button on the keyboard will exit the selection you are in.

If you wish to confirm a value, you must press the "ENT" key.

The keyboard allows access to the following menus :

F1 key :	DC Regulation for settings of setpoint, ramps, modes…
2 x F1 key :	AC Regulation for MODULATION settings of setpoint, form, frequency…
F2 key :	Ethernet configuration
2 x F2 key :	RS232/RS485 configuration
Key F3 :	Security for maintenance and fault listing
F4 key :	Divers / Others

4.3.4. Modulation AC amplifier

This power supply embedded a modulation rack to power AC modulation coil mounted on the associated electromagnet.
This modulation rack can only be controlled by digital setting through the main interface, hit 2 times F1 to access its proper menu.
This modulation rack allows a controlled output current of 12 A pk-pk from 0.01 Hz to 100 Hz with a sinus or triangle waveform.

4.3.1. Command and mode digital via Ethernet or RS232

For remote control by digital interface, please refer to the attached documentation:

AF2104-007-Doc_Ethernet_V3.0

4.3.2. di/dt limitation

An internal circuit limits the di/dt at about 10 A/sec.

As a result, the time necessary to go from 0 A to + 100 A is about 10 seconds.

This time can be modified by CAYLAR on request depending of the inductance of the load.

4.4. Defaults

The red led " DEFAULT PC " lights up if the embedded microcontroller presents a problem, in this case the power supply remains usable in analog mode (setpoint by Potentiometers or External).
If this error occurs, return to 0 and power off the unit and perform a reset by switching the power supply off and on again.

If another fault is detected by the power supply, the red led " DEFAULT POWER " lights up and the power supply breaks down to return to no power mode, and the cause of the break down is indicated on the screens.

There are several possible causes of the fault. Each fault is identified, they are listed below:

POS BANKS FAILED : The most likely cause is a failure of one of the transistor of positive polarity.
Please contact CAYLAR

NEG BANKS FAILED : The most likely cause is a failure of one of the transistor of negative polarity.
Please contact CAYLAR

NEVER try to power on again the unit directly after this faul appears. You may increase the damage.

DCCT : The power supply incorporates a DCCT type current sensor which provides a safety signal. This fault is very exceptional. **Please contact CAYLAR.**

BANK TEMP : This fault lights up when one of the transistor bank is too hot. If possible, check the temperature of the water at the outlet of the power supply. Check the load value and the operating conditions. If the resistance of the load is too low, the power dissipated in the bars is high and the water flow may be insufficient in this case. An imbalance of the currents in the transistor busbars can also be the cause of this fault.

BRIDGE TEMP : This fault lights up when one of the heat sinks of the rectifier bridges is too hot. If possible, check the water temperature at the power supply outlet.

WATER FLOW : The power supply includes a flowmeter with a threshold set at 4 L/min.
If the flow rate of the water circulating inside the supply is below this threshold the supply stops and this fault appears.

CONDENSATION : Open the left side panel of the power supply to see if there is condensation. If the power supply is wet due to condensation, wait until it is dry before restarting. Also wipe off the condensation sensor (gold CI) located behind the water connection at the rear of the cabinet.
Caution: Be sure to disconnect the power supply from the mains before opening it.

MAINS : The power supply incorporates a thermal relay on the three-phase main relay, if the phase current is higher than the set threshold the power supply breaks down and the power supply cannot deliver current. This fault is very exceptional (insulation fault for example).
Please contact CAYLAR

LIMIT POWER : The internal dissipated energy must be limited to prevent the semiconductors from operating at too high junction temperatures. If the internal power dissipation is too high, the power supply will switch off indicating "overpower". This may be due to a load impedance that is too low, or to a current change rate on a load that is much more inductive than expected.

LIMIT CURRENT : This fault occurs if the output current exceeds 110% of its nominal value.This fault usually occurs in remote control, when the applied voltage exceeds ± 11 V.

The power supply was delivered with an " Interlock " cord for connection between the power supply and the electromagnet.

WATER_MAGNET: The opening of the normally closed contact “Water flowswitch” connected on the Sub-D
ILOCK 1 26 pts "Interlock" between pins 1 and 10 causes this fault.

TEMP_COIL1 : The opening of the normally closed contact from the thermostat of the coil 1 connected
ILOCK 2 on the Sub-D 26 pts " Interlock " between pins 2 and 11 causes this fault.

TEMP_COIL2 : The opening of the normally closed contact from the thermostat of the coil 2 connected
ILOCK 3 on the Sub-D 26 pts " Interlock " between pins 3 and 12 causes this fault.

The reading of faults can be done remotely by sending the "GET_ERRORS" command.

To acknowledge the faults, press the " Reset " push button on the front panel.

Acknowledgement can also be performed via the digital interface by sending the "CLEAR_DEFAULT" command.

If the cause of the fault is still present, it cannot be cleared.

4.5. Fuses

Some faults may be caused by a defective fuse.

Fuses are present on each of the 3 power phases.
Never operate the power supply if one of these fuses is missing, this will cause a power failure.

Disconnect the power supply from the mains before opening the panels.

Fuse	Description	Référence.	Location
F1-F2-F3	Size 10 x 38 16 A aM / 500 V~	130 16 LEGRAND	Mounted in fuse holder, on the contact plate. Remove the fan panel at the rear of the power supply.

Most of the other fuses internal to the power supply are thermal fuses: in the event of a fault, their impedance becomes high enough to prevent the power supply from working. After disconnection, they take a few seconds to cool down to a low impedance corresponding to normal operation.

If the power supply cannot be turned on, make sure that the 8-9 connection is made to the SubD 26-pin "Interlock" socket.

If there is no fault and the fuses are good or if a fault cannot be cleared, the power supply has failed.

In this case, **Please contact CAYLAR**

4.6. Maintenance

The power supply does not require any special adjustments as long as no components are replaced.
Care must be taken to avoid dust deposits, if necessary.
In the event of disconnection due to condensation, the small residual deposit that forms on the condensation sensor (gold-plated printed circuit board under the chrome bar at the rear left) must be removed.

Tighten the power connections every two years, paying particular attention to the connections of the power transformer and the power diode bridges.

It may be necessary to replace the chemical capacitors every ten years.

THE POWER SUPPLY MUST WORK WITH ALL ITS PANELS MOUNTED AND HELD BY THEIR SCREWS.

MAINTENANCE MAY ONLY BE PERFORMED BY QUALIFIED PERSONNEL.

DISCONNECT THE POWER SUPPLY FROM THE NETWORK BEFORE DISASSEMBLING THE PANELS.

WHEN REPLACING FUSES, THE POWER SUPPLY MUST BE DISCONNECTED FROM THE NETWORK.

IN CASE THE POWER SUPPLY OPERATES WITHOUT ITS PANELS, ALWAYS KEEP IN MIND THAT DANGEROUS VOLTAGES ARE PRESENT INSIDE.

ONLY QUALIFIED PERSONNEL ARE AUTHORIZED TO OPERATE THE POWER SUPPLY WITHOUT ITS PANELS.

5. NOTES

MANUFACTURER OF ELECTROMAGNETS,
NMR TESLAMETERS,
POWER SUPPLIES

www.caylar.net

CAYLAR
INSTRUMENTATION SCIENTIFIQUE

Power Supply ± 60 V / ± 100 A

CURRENT REGULATED – 10 PPM CLASS

ETHERNET INTERFACE MANUAL

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AF2104-007 / MPU8220-064
PSI Suisse
March 2022
Rev 3.0

CAYLAR
INSTRUMENTATION SCIENTIFIQUE

Summary

Equipment setup

a) Power supply ethernet settings configuration

- Turn on the power supply.

- After the power supply initialization, push the « **F2** » keyboard key to enter into the « ETHERNET» menu. It allows you to configure the various parameters of the Ethernet interface. Each change made in this menu is then permanently saved in the power supply memory. You will therefore find the same parameters during the next power on.
  IMPORTANT NOTE: At any time, you can press the red keyboard key (« **Escape** ») to exit the menu you are in.

- For selecting the various parameters present in the "ETHERNET" menu, use the « ↓ » and « ↑ » keyboard keys. The selected parameter is surrounded by brackets (ex: <xxxxx> where xxxxx is the paramater).

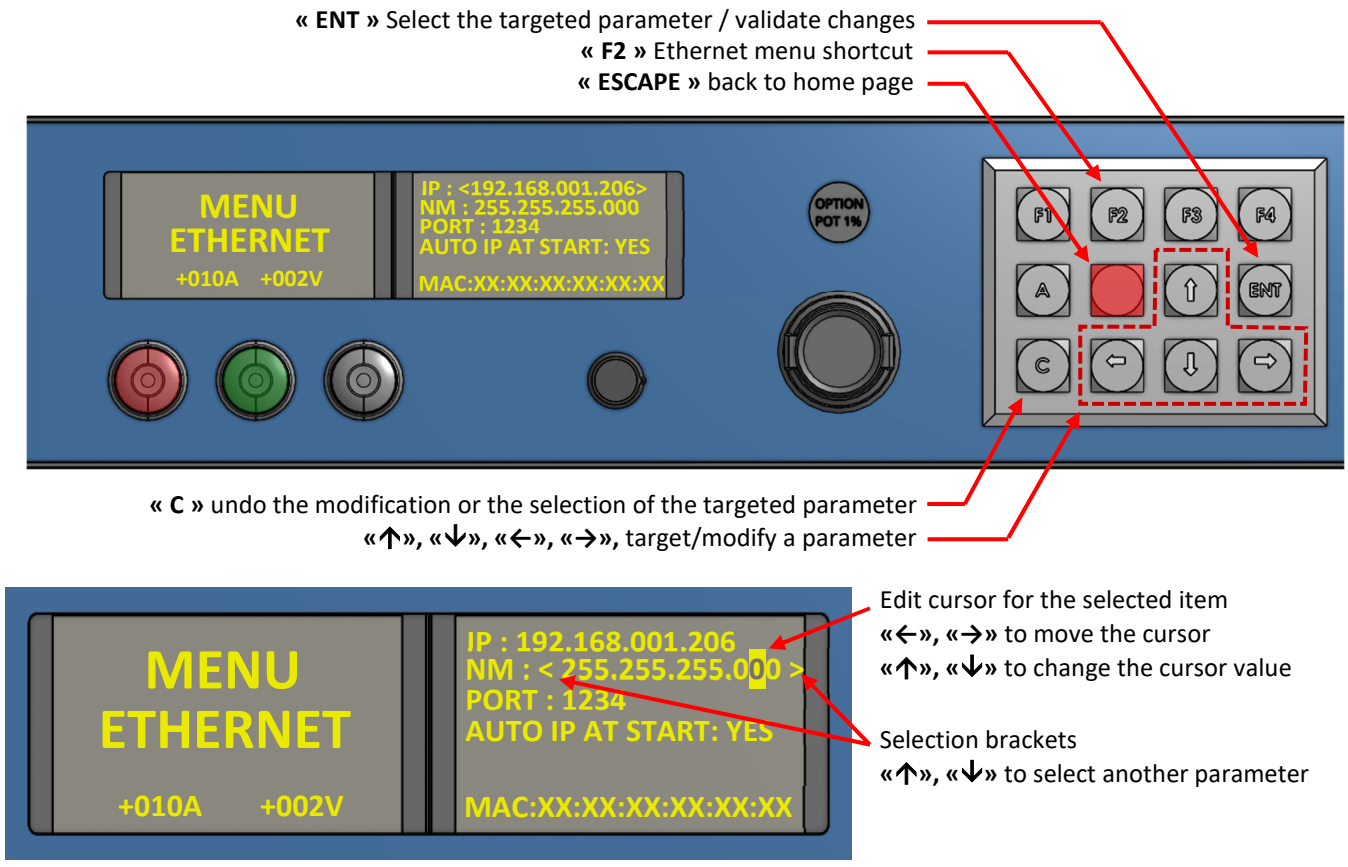
- To modify the selected parameter, push the « **ENT** » keyboard key. The editable part of the parameter is then highlighted to indicate the position of the edit cursor.

- Then use « ← » or « → » keyboard keys to move the edit cursor and « ↓ » or « ↑ » keys to change the selected value. Push « **C** » keyboard key if you want to cancel the modification. If you want to validate the modification then press the « **ENT** » keyboard key.

  NOTE: Leaving the menu by pressing « **Escape** » key or by pressing a shortcut menu like « **F1, F2, F3, F4** » keys also automatically cancels the modification of the selected parameter.

- Power supply Ethernet settings are as follows:
  - « **IP** » : IP address of the power supply (default: 192.168.001.206)
  - « **NM** » : Network Mask of the power supply (default: 255.255.255.000)
  - « **PORT** » : Port of the power supply (not editable - fixed to 1234)
  - « **AUTO IP AT START** » : The activation of an automatic IP search protocol on power on (close to DHCP – default: NO)

The figure below shows a view of the power supply front panel with keyboard and oled displays.



View of the power supply front panel with Ethernet menu open

b) Rear panel cable connection

The RJ45 connector to connect the power supply to its network is located on the rear panel next to the power outputs.

ETHERNET Communication Protocol

a) Introduction

Sending commands :

Ethernet commands must be sent as a string (array of byte) in ASCII format with an « \n », « \r\n » or « \r » character at the end of each order sent. The character string must respect upper/lower characters and spaces.

Multiples commands can be sent in one time or a single command can be sent in multiple parts. Receiving one of the end-of-string characters « \n », « \r\n » or « \r », results in processing the received bytes stored in a 1024-byte buffer.

If a command requires additional arguments, these must be separated by a single space between each argument and with the command. Example: in the command "SET_CURRENT +10", the argument +10 is separated from the command SET_CURRENT by a single space.

Power supply response to a command :

The power supply gives a response for each order received. Feedback responses are returned as strings in ascii format with an end-of-line character (LF or « \n ») at the end of each response. The start of the response always corresponds to the copy of the command sent with an « _OK » added if the command was executed without problem (expect for “GET_XXXXX” commands).

In case of errors during the commands processing the « _OK » confirmation is replaced by « _ERROR ».

In case of unrecognized commands, the power supply will return the following string: «WRONGCOMMAND \n».

In the case of a return of multiple arguments, these are separated by a single space between them.

IMPORTANT NOTE :

- It is important to check the response of the power supply for each command sent to ensure that it has been processed correctly and to avoid power supply saturation in the case of commands sent too quickly at the same time.
- Some commands take time to run, so the power supply response may take time to arrive.

b) List of Commands

*IDN?

Response : **CAYLAR_<serial_number>**	Ex : CAYLAR_MPUXXXX_XXX

Returns the serial number of the power supply.

<serial_number> is a string of variable length and format depend of the generation of the power supply. This number is unique and specific to CAYLAR products.

CLEAR_DEFAULT

Response : **CLEAR_DEFAULT_OK**

Performs a reset of the errors saved (does the same as the reset button in front panel of the power supply).

- Has no effect if no default is present (see GET_DEFAULT_STATE to know if a default is present).
  If a default is still physically present on the power supply, this command also has no effect.
- If the default that triggered the power supply security is fixed but another default has appeared in the meantime, the command has no effect and the power supply remains with the first default triggered. To know the name of the new defect restart the power supply.
- Related commands: « GET_DEFAULT_STATE », « GET_DEFAULT_NAME », « SET_DEFAULT_ON », « SET_DEFAULT_OFF ».

GET_CURRENT

Response : **CURRENT= <current> A**	Ex : CURRENT= +123.456789 A

Returns the last measurement of the output current made by the power supply. The current is measured approximately every second depending on options and settings. The current is returned in amps.

<current> format is « %+.6 lf ».

- Related commands: « SET_CURRENT ».

GET_FIELD

Response : **FIELD= <field> G**	Ex : FIELD= +12345.67 G

Returns the last measurement of the field made by the power supply hall probe. The field is measured approximately every 0.6 second depending on options and settings. The field is returned in Gauss.

<field> format is « %+.2 lf ».

- Field probe is an option, if not present returns « FIELD= +0.00 G ».
- **CAUTION :** In case field regulation option is also present, please first check that the probe is placed in the correct side in the electromagnet before switching to field regulation. To do this, in current regulation, apply a positive current and check that the field reading is also positive. If not, flip the probe 180°.
- Related commands: « SET_FIELD ».

GET_VOLTAGE

Response : **VOLTAGE= <volts> V**	Ex : VOLTAGE= +12.345 V

Returns the last measurement of the output voltage made by the power supply. The output voltage is measured approximately every second depending on options and settings. The voltage is returned in volts. The measurement reference zero is the power output called « zero power ».

<volts> format is « %+.3 lf ».

GET_ADC_DAC_TEMP

Response : **ADC_DAC_TEMP= <temp> Deg**	Ex : ADC_DAC_TEMP= +45.123 Deg

Returns the last measurement of the internal precision components (ADC, DAC and voltage reference) temperatures made by the power supply. The temperature is measured approximately every second depending on options and settings. The temperature is returned in degrees Celsius.

<temp> format is « %+.3 lf ».

- **NOTE :** This measurement is the only temperature measurement performed on the main Analog to Digital Converter (ADC) on the power supply. This is the most accurate temperature measurement. Others temperatures measurements are less precise (see datasheet «temperature measurement performance» section for more details).
- **CAUTION :** Temperature measurements are not calibrated. They are mainly given to monitor relative temperature variations.

GET_BOX_TEMP

Response : **BOX_TEMP= <temp> Deg**	Ex : BOX_TEMP= +31.20 Deg

Returns the last measurement of the internal precision circuits temperatures made by the power supply. The temperature is measured approximately every 0.5 second depending on options and settings. The temperature is returned in degrees Celsius.

<temp> format is « %+.2 lf ».

- **ELECTRONIC TEMPERATURE REGULATION OPTION :** In the case of an electronic temperature-controlled option, this measurement correspond to the temperature present on the box surrounding the precision electronics. Allow to checks that the temperature regulation is stable.
- **CAUTION :** Temperature measurements are not calibrated. They are mainly given to monitor relative temperature variations.

GET_RACK_TEMP

Response : **RACK_TEMP= <temp> Deg**	Ex : RACK_TEMP= +31.20 Deg

Returns the last measurement of the internal mother board temperatures made by the power supply. The temperature is measured approximately every 0.5 second depending on options and settings. The temperature is returned in degrees Celsius.

<temp> format is « %+.2 lf ».

- **CAUTION :** Temperature measurements are not calibrated. They are mainly given to monitor relative temperature variations.

GET_WATER_TEMP

Response : **WATER_TEMP= <temp> Deg**	Ex : WATER_TEMP= +8.05 Deg

Returns the last measurement made by the power supply of the water temperature at the outlet of the cooling circuit. The temperature is measured approximately every 0.5 second depending on options and settings. The temperature is returned in degrees Celsius.

<temp> format is « %+.2 lf ».

- Water temperature measurement is an option, If not present returns « WATER_TEMP= +0.00 Deg ».
- **CAUTION :** Temperature measurements are not calibrated. They are mainly given to monitor relative temperature variations.

GET_WATER_FLOW

Response : **WATER_FLOW= <flow_rate> L/Min**	Ex : WATER_FLOW= +8.5 L/Min

In case of too low water flow : **WATER_FLOW= <2.5 L/Min**

Returns the last measurement made by the power supply of the water flow cooling circuit. The water flow is measured approximately every 0.5 second depending on options and settings. The water flow is returned in liter per minute.

<flow_rate> format is « %+.1 lf ».

- Water flow measurement is an option, If not present returns « WATER_FLOW= <2.5 L/Min ».
- **CAUTION :** Water flow measurements are not calibrated. They are mainly given to monitor relative variations.

GET_DEFAULT_STATE

Response : **DEFAULT_STATE= <state>**	Ex (no default) : DEFAULT_STATE= 0

Returns the default status of the power supply. The returned value corresponds to the status LED state present on the power supply front panel named "DEFAULT POWER".

<state> is a Boolean: 0 = no default / 1 = default present.

- Related commands: « CLEAR_DEFAULT », « GET_DEFAULT_NAME », « SET_DEFAULT_ON », « SET_DEFAULT_OFF ».

GET_DEFAULT_NAME

Response : **DEFAULT_NAME= <name>**	Ex (no error) : DEFAULT_NAME= NO_ERROR

Return the name of the actual default.

<name> is a string corresponding to the error name that triggered the power supply security. It is "NO_ERROR" when there is no default currently present and can be otherwise: "ALIMS_AUX", "MAINS", "QUENCH", "INTERLOCK_3", "LIMIT_POWER", "LIMIT_I", "PC_DEFAULT", "NEG_BANK", "DCCT", "POS_BANK", "BANK_TEMP", "CONDENSATION", "INTERLOCK_2", "BRIDGE_TEMP", "INTERLOCK_1".

- Related commands: « CLEAR_DEFAULT », « GET_DEFAULT_STATE », « SET_DEFAULT_ON », « SET_DEFAULT_OFF ».
- The names "INTERLOCK_X" can change depending on the configuration made for the user by Caylar.

GET_CMD_SELEC

Response : **CMD_SELEC= <cmd_type>**	Ex (selector on the digital position) : CMD_SELEC= 1

Return the position of the setpoint selector source present on the power supply front panel. Allow you to know which current or field control source is used to control the power supply current or field.

<cmd_type> is an integer which corresponds to the position of the selector: 0 = Potentiometer, 1 = Digital (PC), 2 = External.

GET_FIELD_SETPOINT

Response : **FIELD_SETPOINT= <setpoint> G**	Ex : FIELD_SETPOINT= +01200.5 G

Return the last digital field setpoint that the power supply received via Ethernet or that was configured by the user from the keyboard on the power supply. The field setpoint is returned in Gauss.

<setpoint> format is « %+08.1 lf ».

- Field regulation is an option, if not present returns «FIELD_SETPOINT= +00000.0 G».
- Related commands: « SET_FIELD », « GET_CMD_SELEC », « GET_REGUL_TYPE ».
- This setpoint is not necessarily the actual setpoint used by the power supply depending on the position of the front panel command selector and regulation mode (current or field).

GET_CURRENT_SETPOINT

Response : **CURRENT_SETPOINT= <setpoint> A**	Ex : CURRENT_SETPOINT= +125.00000 A

Return the last digital current setpoint that the power supply received via Ethernet or that was configured by the user from the keyboard on the power supply. The current setpoint is returned in Amps.

<setpoint> format is « %+010.5 lf ».

- Related commands: « SET_CURRENT », « GET_CMD_SELEC », « GET_REGUL_TYPE ».
- This setpoint is not necessarily the actual setpoint used by the power supply depending on the position of the front panel command selector and regulation mode (current or field).

GET_REGUL_MODE

Response : **REGUL_MODE= <mode>**	Ex (current regulation) : REGUL_MODE= CURRENT

Returns the actual regulation mode.

<mode> is a string representing the regulation mode: « CURRENT » = current regulation / « FIELD » = field regulation.

- Field regulation is an option, if not present always returns « REGUL_TYPE= CURRENT ».
- Related commands: « SET_REGUL_CURRENT », « SET_REGUL_FIELD ».

GET_RAMP_MODE

Response : **RAMP_MODE= <mode>**	Ex (analog ramp) : RAMP_MODE= ANALOG

Returns the ramp configuration that allows the power supply to clamp the user setpoint variations speed.

<mode> is a string corresponding to the ramp mode: "ANALOG" = ramp is fully analog (fixed maximum setpoint variation speed) / "DIGITAL" = analog ramp with additional digital ramp which restricts the setpoint variations speed in an adjustable way (slower than the analog ramp).

- Related commands: « GET_ANALOG_XXX_RAMP_SPEED », « GET_DIGITAL_XXX_RAMP_SPEED », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».

GET_DIGITAL_RAMP_STATE

Response : **DIGITAL_RAMP_STATE= <state>**	Ex (digital ramp not active) : DIGITAL_RAMP_STATE= 0

Returns whether or not the digital ramp is currently active in the power supply.

<state> is a Boolean corresponding to the digital ramp state: 0 = digital ramp not active / 1 = digital ramp active (current or field is changing to reach the user-defined setpoint).

- This command is valid only for digital ramp mode, in analog ramp mode this command will always return « RAMP_ACTIVE= 0 ».
- Related commands: « GET_RAMP_MODE », « GET_ANALOG_XXX_RAMP_SPEED », « GET_DIGITAL_XXX_RAMP_SPEED », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».

GET_ANALOG_CURRENT_RAMP_SPEED

Response : **ANALOG_CURRENT_RAMP_SPEED= <speed> A/Sec**	Ex : ANALOG_CURRENT_RAMP_SPEED= 10.0 A/Sec

Returns the speed of the analog ramp for the current regulation mode (maximum variation speed). The ramp speed is returned in Amps per second.

<speed> format is « %+.1 lf ».

- This ramp speed is only used by the power supply in current regulation and analog ramp mode.
- This analog ramp speed is not settable and depends on the analog setting made and measured at Caylar.
- Related commands: « GET_RAMP_MODE », « GET_DIGITAL_XXX_RAMP_SPEED », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».

GET_DIGITAL_CURRENT_RAMP_SPEED

Response : **DIGITAL_CURRENT_RAMP_SPEED= <speed> A/Sec**	Ex : DIGITAL_CURRENT_RAMP_SPEED= 5.5 A/Sec

Returns the speed of the digital ramp for the current regulation mode. The ramp speed is returned in Amps per second.

<speed> format is « %+.1 lf ».

- This ramp speed is only used by the power supply in current regulation and digital ramp mode.
- Related commands: « GET_RAMP_MODE », « GET_ANALOG_XXX_RAMP_SPEED », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».

GET_ANALOG_FIELD_RAMP_SPEED

Response : **ANALOG_FIELD_RAMP_SPEED= <speed> G/Sec**	Ex : ANALOG_FIELD_RAMP_SPEED= 1000.0 G/Sec

Returns the speed of the analog ramp for the field regulation mode (maximum variation speed). The ramp speed is returned in Gauss per second.

<speed> format is « %+.1 lf ».

- This ramp speed is only used by the power supply in field regulation and analog ramp mode.
- This analog ramp speed is not settable and depends on the analog setting made and measured at Caylar.
- Related commands: « GET_RAMP_MODE », « GET_DIGITAL_XXX_RAMP_SPEED », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».
- Field regulation is an option.

GET_DIGITAL_FIELD_RAMP_SPEED

Response : **DIGITAL_FIELD_RAMP_SPEED= <speed> G/Sec**	Ex : DIGITAL_FIELD_RAMP_SPEED= 550.0 G/Sec

Returns the speed of the digital ramp for the field regulation mode. The ramp speed is returned in Gauss per second.

<speed> format is « %+.1 lf ».

- This ramp speed is only used by the power supply in current regulation and digital ramp mode.
- Related commands: « GET_RAMP_MODE », « GET_ANALOG_XXX_RAMP_SPEED », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».
- Field regulation is an option.

GET_ACTUAL_CURRENT_RAMP_SPEED

Response : **CURRENT_RAMP_SPEED= <speed> A/Sec**	Ex : CURRENT_RAMP_SPEED= 10.0 A/Sec

Returns the actual ramp speed for the current regulation mode (regardless on the actual ramp mode: analog or digital). The ramp speed is returned in Amps per second.

<speed> format is « %+.1 lf ».

- Related commands: « GET_RAMP_MODE », « GET_ANALOG_XXX_RAMP_SPEED », « GET_DIGITAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».
- This ramp speed is only used by the power supply in current regulation.

GET_ACTUAL_FIELD_RAMP_SPEED

Response : **FIELD_RAMP_SPEED= <speed> G/Sec**	Ex : FIELD_RAMP_SPEED= 500.0 G/Sec

Returns the actual ramp speed for the field regulation mode (regardless on the actual ramp mode: analog or digital). The ramp speed is returned in Gauss per second.

<speed> format is « %+.1 lf ».

- Related commands: « GET_RAMP_MODE », « GET_ANALOG_XXX_RAMP_SPEED », « GET_DIGITAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».
- This ramp speed is only used by the power supply in current regulation.
- Field regulation is an option.

GET_MAINTENANCE_STATE

Response : **MAINTENANCE_STATE= <state>**	Ex (no maintenance) : MAINTENANCE_STATE= 0

Returns if the power supply is currently in maintenance mode. The service mode indicates that an operator is physically touching the power supply and that no Ethernet controls can control the power supply.

<State> is a Boolean corresponding to the maintenance state : 0 = no maintenance is performed on the power supply / 1 = maintenance is in progress on the power supply.

- If maintenance is in progress, no « SET_ » type commands can be used.
- Related commands: « SET_MAINTENANCE_ON ».

GET_POWER_STATE

Response : **POWER_STATE= <state>**	Ex (power is on – current delivering) : POWER_STATE= 1

Returns the power state of the power supply.

<State> is a Boolean corresponding to the power state of the power supply: 0 = power is off / 1 = power is on.

- Related commands: « SET_POWER_ON », « SET_POWER_OFF ».

GET_HALL_PROBE_TEMP

Response : **HALL_PROBE_TEMP= <temp> Deg**	Ex : HALL_PROBE_TEMP= +45.468 Deg

Returns the last measurement of the internal hall probe temperatures made by the power supply. The temperature is measured approximately every 0.5 second depending on options and settings. The temperature is returned in degrees Celsius.

<temp> format is « %+.3 lf ».

- Allow the user to checks that the hall probe temperature regulation is stable and when the probe warm-up is done.
- **CAUTION :** Temperature measurements are not calibrated. They are mainly given to monitor relative temperature variations.
- Hall probe temperature regulation is an option.

GET_MODUL_SETPOINT_FREQ

Response : **MODUL_SETPOINT_FREQ= <freq> Hz**	Ex : MODUL_SETPOINT_FREQ= +33.56 Hz

Return the last configured AC Current modulation frequency setpoint that the power supply received via Ethernet or that was configured by the user from the keyboard on the power supply. The frequency setpoint is returned in Hz.

<freq> format is « %+.2 lf ».

- AC Current modulation is an option.

GET_MODUL_SETPOINT_CURRENT

Response : **MODUL_SETPOINT_CURRENT= <amps> App**	Ex : MODUL_SETPOINT_CURRENT= +5.50 App

Return the last configured AC Current modulation current amplitude setpoint that the power supply received via Ethernet or that was configured by the user from the keyboard on the power supply. The current amplitude setpoint is returned in amps pic to pic.

<amps> format is « %+.2 lf ».

- AC Current modulation is an option.

GET_MODUL_STATE

Response : **MODUL_STATE= <state>**	Ex (AC current modulation ON) : MODUL_STATE= 1

Return the actual AC Current modulation power state.

<state> is a Boolean : 1 = AC current modulation is ON / 0 = AC current modulation is OFF.

- The AC current modulation power is independent from the main power DC current regulation so it can be ON when the main DC power is OFF.
- AC Current modulation is an option.

GET_MODUL_WAVEFORM

Response : **MODUL_WAVEFORM= <waveform>**	Ex (sinus waveform settled) : MODUL_WAVEFORM= 0

Return the actual AC Current modulation waveform.

<waveform> is a Boolean : 1 = TRIANGLE waveform / 0 = SINUS waveform.

- AC Current modulation is an option.

GET_MODUL_CURRENT_AMPLI

Response : **MODUL_CURRENT_AMPLI= <ac_amps> App**	Ex : MODUL_CURRENT_AMPLI= +11.01 App

Returns the last measurement of AC current modulation current amplitude made by the power supply. The current amplitude feedback is measured approximately every 0.5 second depending on options and settings. The current amplitude is returned in amps pic to pic.

<ac_amps> format is « %+.2 lf ».

- AC Current modulation is an option.

GET_MODUL_FIELD_AMPLI

Response : **MODUL_FIELD_AMPLI= <ac_field> Gpp**	Ex : MODUL_FIELD_AMPLI= +89.58 Gpp

Returns the last measurement of hall probe AC field amplitude made by the power supply. The AC field amplitude feedback is measured approximately every 0.5 second depending on options and settings. The AC field amplitude is returned in gauss pic to pic.

<ac_field> format is « %+.2 lf ».

- AC Current modulation is an option / Field probe is an option.

SET_POWER_ON

Response : **SET_POWER_ON_OK**

Response if a power default is active : **SET_POWER_ON_ERROR DEFAULT_ON**

Response if maintenance is on : **SET_POWER_ON_ERROR MAINTENANCE_ON**

Power up the power supply. Does the same as press the green « POWER ON » button on power supply front panel for a time ranging from 0.2 to 2 seconds depending on the power supplies.

- Related commands: « GET_POWER_STATE », « SET_POWER_OFF ».

SET_POWER_OFF

Response : **SET_POWER_OFF_OK**

Response if maintenance is on : **SET_POWER_OFF_ERROR MAINTENANCE_ON**

Cut the power supply. Does the same as press the red « POWER OFF » button on power supply front panel.

- **CAUTION:** This command turn off the power instantly, regardless of the actual current supplied by the power supply. Turn off a power supply that supplies high current in an inductive load can cause material damage despite the internal protections of our power supplies such as freewheel diodes! It is strongly recommended to check that the current is around zero before performing this command (see the command « GET_CURRENT »). Also pay attention to the fact that the current setpoint is ramped and so the actual current therefore takes a certain time to reach the user setpoint, especially when we ask 0 Amps before turn off the power supply.
- Related commands: « GET_POWER_STATE », « SET_POWER_ON ».

SET_RAMP_MODE <mode>	Ex : SET_RAMP_MODE DIGITAL
Response : **SET_RAMP_MODE_OK <mode>**	Ex : SET_RAMP_MODE_OK DIGITAL
Response in case of bad argument <type> : **SET_RAMP_TYPE_ERROR BAD_ARG**	
Response if maintenance is on : **SET_RAMP_MODE_ERROR MAINTENANCE_ON**	

Change the ramp mode used by the power supply.

<mode> is a string corresponding to the ramp mode: "ANALOG" = ramp is fully analog (fixed maximum setpoint variation speed) / "DIGITAL" = analog ramp with additional digital ramp which restricts the setpoint variations speed in an adjustable way (slower than the analog ramp).

- Related commands : « GET_RAMP_MODE », « GET_ANALOG_XXX_RAMP_SPEED », « GET_DIGITAL_XXX_RAMP_SPEED », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_DIGITAL_XXX_RAMP_SPEED » where XXX may be « CURRENT » or « FIELD ».
- When switching from analog to digital ramp mode during an analog ramp, the ramp speed remains the same until the next digital setpoint variation.
- The digital ramp only has an effect with digital setpoint changes. Please check the setpoint selector position on the power supply front panel.

SET_MAINTENANCE_ON
Response : **SET_MAINTENANCE_ON_OK**
Response if maintenance is on : **SET_MAINTENANCE_ON_ERROR MAINTENANCE_ON**

Allows the user to switch the power supply to maintenance mode to prevent Ethernet commands from being able to control the power supply when an operator is physically working on it.

- **CAUTION :** The maintenance mode can only be physically removed from the power supply front panel. The maintenance selector is available in the "SECURITIES" menu by pressing the F3 keyboard key.
- Related commands : « GET_MAINTENANCE_STATE »

SET_CURRENT <setpoint>	Ex : SET_CURRENT 10.25 / SET_CURRENT -120
Response : **SET_CURRENT_OK <amps> A**	Ex : SET_CURRENT_OK +10.250000 A / SET_CURRENT_OK -120.000000 A
Response in case of unrecognized argument <setpoint> : **SET_CURRENT_ERROR BAD_ARG**	
Response in case of overrange in <setpoint> argument : **SET_CURRENT_ERROR OVERRANGE**	
Response in case of power off state with « CMD UPDATE : PON ONLY» (1) : **SET_CURRENT_ERROR POWER_OFF**	
Response in case of field regulation mode : **SET_CURRENT_ERROR FIELD_REG**	
Response if maintenance is on : **SET_CURRENT_ERROR MAINTENANCE_ON**	

Set the digital current setpoint in current regulation.

<setpoint> format can be double, float or integer / signed or not signed given in amps. Positive number only for monopolar power supplies.

<amps> format is « %.6 lf ». <amps> is the recopy of <setpoint> for the power supply feedback response.

- This command only takes effect when the front panel setpoint selector source is set to digital (PC).
- If the « CMD UPDATE » parameter (available from the « DIVERS » Menu – F4 shortcut key) is set to « PON/OFF » : when a new setpoint is receive from a set current command during a power off state the setpoint is saved and effective at the next power on. Otherwise the command is ignored and not stored.
- Related commands : « GET_CURRENT_SETPOINT »

SET_FIELD <setpoint>	Ex : SET_FIELD 1200.25 / SET_FIELD -120
Response : **SET_FIELD_OK <field> G**	Ex : SET_FIELD_OK +1200.2 G / SET_FIELD_OK -120.0 G
Response in case of unrecognized argument <setpoint> : **SET_FIELD_ERROR BAD_ARG**	
Response in case of overrange in <setpoint> argument : **SET_FIELD_ERROR OVERRANGE**	
Response in case of power off state with « CMD UPDATE : PON ONLY» (1): **SET_FIELD_ERROR POWER_OFF**	
Response in case of current regulation mode : **SET_FIELD_ERROR CURRENT_REG**	
Response if maintenance is on : **SET_FIELD_ERROR MAINTENANCE_ON**	

Set the digital field setpoint in field regulation (from hall probe).

<setpoint> format can be double, float or integer / signed or not signed given in gauss. Positive number only for monopolar power supplies.

<field> format is « %.1 lf ». <field> is the recopy of <setpoint> for the power supply feedback response.

- This command only takes effect when the front panel setpoint selector source is set to digital (PC).
- If the « CMD UPDATE » parameter (available from the « DIVERS » Menu – F4 shortcut key) is set to « PON/OFF » : when a new setpoint is receive from a set current command during a power off state the setpoint is saved and effective at the next power on. Otherwise the command is ignored and not stored.
- Related commands : « GET_FIELD_SETPOINT »
- Field regulation is an option.

SET_DIGITAL_CURRENT_RAMP_SPEED <setpoint>	Ex : SET_DIGITAL_CURRENT_RAMP_SPEED 2.5
Response : **SET_DIGITAL_CURRENT_RAMP_SPEED_OK <speed> A/Sec**	Ex : SET_DIGITAL_CURRENT_RAMP_SPEED_OK 02.5 A/Sec
Response in case of unrecognized argument <setpoint> : **SET_DIGITAL_CURRENT_RAMP_SPEED_ERROR BAD_ARG**	
Response in case of overrange in <setpoint> argument : **SET_DIGITAL_CURRENT_RAMP_SPEED_ERROR OVERRANGE**	
Response if maintenance is on : **SET_DIGITAL_CURRENT_RAMP_SPEED_ERROR MAINTENANCE_ON**	

Set the speed of the digital current ramp.

<setpoint> format can be double, float or integer / signed or not signed given in amps per second. Positive number only.

<speed> format is « %04.1 lf ». <speed> is the recopy of <setpoint> for the power supply feedback response.

- The speed settled by this command is only taken into account by the ramp when the power supply is in current regulation and digital ramp mode.
- Related commands : « GET_ANALOG_XXX_RAMP_SPEED », « GET_DIGITAL_XXX_RAMP_SPEED », « GET_REGUL_TYPE », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_REGUL_XXX » where XXX may be « CURRENT » or « FIELD ».

SET_DIGITAL_FIELD_RAMP_SPEED <setpoint>	Ex : SET_DIGITAL_FIELD_RAMP_SPEED 500.2
Response : **SET_DIGITAL_FIELD_RAMP_SPEED_OK <speed> G/Sec**	Ex : SET_DIGITAL_FIELD_RAMP_SPEED_OK 0500 G/Sec
Response in case of unrecognized argument <setpoint> : **SET_DIGITAL_FIELD_RAMP_SPEED_ERROR BAD_ARG**	
Response in case of overrange in <setpoint> argument : **SET_DIGITAL_FIELD_RAMP_SPEED_ERROR OVERRANGE**	
Response if maintenance is on : **SET_DIGITAL_FIELD_RAMP_SPEED_ERROR MAINTENANCE_ON**	
Set the speed of the digital field ramp. <setpoint> format can be double, float or integer / signed or not signed given in gauss per second. Positive number only. <speed> format is « %04.0 lf ». <speed> is the recopy of <setpoint> for the power supply feedback response. • The speed settled by this command is only taken into account by the ramp when the power supply is in field regulation and digital ramp mode. • Related commands : « GET_ANALOG_XXX_RAMP_SPEED », « GET_DIGITAL_XXX_RAMP_SPEED », « GET_REGUL_TYPE », « GET_ACTUAL_XXX_RAMP_SPEED », « SET_REGUL_XXX » where XXX may be « CURRENT » or « FIELD ». • Field regulation is an option.	

SET_DEFAULT_ON
Response : **SET_DEFAULT_ON_OK**
Response if maintenance is on : **SET_DEFAULT_ON_ERROR MAINTENANCE_ON**
Allows the user to turn on a user power default remotely. • **CAUTION:** This command turn off the power instantly, regardless of the actual current supplied by the power supply. Turn off a power supply that supplies high current in an inductive load can cause material damage despite the internal protections of our power supplies such as freewheel diodes! • Can be used as external security controlled by another instrument or program. • The power supply will remain in default until it receive the command « SET_DEFAULT_OFF » cancelling this command followed by a « CLEAR_DEFAULT » command. • NOTE: Interlock defaults I/O input are also available on the power supplies read panel for the user to generate their own power default with external controller like Arduino, siemens controller…

SET_DEFAULT_OFF
Response : **SET_DEFAULT_OFF_OK**
Response if maintenance is on : **SET_DEFAULT_OFF_ERROR MAINTENANCE_ON**
Allows the user to cancel his power default made with the command « SET_DEFAULT_ON ». • The power supply will remain in default after this command until the next power defaults reset (see « CLEAR_DEFAULT » command).

SET_REGUL_CURRENT
Response : **SET_REGUL_CURRENT_OK**
Response if maintenance is on : **SET_REGUL_CURRENT_ERROR MAINTENANCE_ON**
Switch the power supply to current regulation. • Related commands : « GET_REGUL_TYPE », « SET_CURRENT ».

SET_REGUL_FIELD
Response : **SET_REGUL_FIELD_OK**
Response if regul hall option not present : **SET_REGUL_FIELD_ERROR NO_HALL_OPTION**
Response if power supply is powered on : **SET_REGUL_FIELD_ERROR POWER_IS_ON**
Response if maintenance is on : **SET_REGUL_FIELD_ERROR MAINTENANCE_ON**
Switch the power supply to field regulation. • Field regulation is an option. • Related commands : « GET_REGUL_TYPE », « SET_FIELD ». • Field regulation cannot be set when the power is on, unlike current regulation. • **IMPORTANT CAUTION:** - It is strongly recommended when switching to field regulation to wait at least one minute before turn on again the power because of the configuration of the analog power supply circuit that can cause oscillations in some cases. - Please check that the hall probe is positioned in the correct side inside the electromagnet before proceeding to field regulation. The hall probe must read a positive field for a positive current. If the probe is inverted, the regulation drive the current in the wrong side in a saturated way, which triggers a software security that automatically cuts the power and display a message on the screen.

SET_MODUL_WAVEFORM <waveform>	Ex : SET_MODUL_WAVEFORM SINUS
Response : **SET_MODUL_WAVEFORM_OK <waveform>**	Ex : SET_MODUL_WAVEFORM_OK SINUS
Response in case of unrecognized argument <waveform> : **SET_MODUL_WAVEFORM_ERROR BAD_ARG**	
Response if maintenance is on : **SET_MODUL_WAVEFORM_ERROR MAINTENANCE_ON**	
Set the AC current modulation signal form. <waveform> is a string corresponding to the signal form: can be « SINUS » or « TRIANGLE ». • Current and field AC modulation controls and readbacks are calibrated only for the « SINUS » waveform. The triangle signal is currently an option in development. • Related commands : « SET_MODUL_CURRENT_AMPLI », « SET_MODUL_FREQ », « SET_MODUL_ON », « SET_MODUL_OFF ». • AC Current modulation is an option.	

SET_MODUL_CURRENT_AMPLI <setpoint>	Ex : SET_MODUL_CURRENT_AMPLI 5.5
Response : **SET_MODUL_CURRENT_AMPLI_OK <amps> App**	Ex : SET_MODUL_CURRENT_AMPLI_OK 5.50 App
Response in case of unrecognized argument <setpoint> : **SET_MODUL_CURRENT_AMPLI_ERROR BAD_ARG**	
Response in case of overrange in <setpoint> argument : **SET_ MODUL_CURRENT_AMPLI _ERROR OVERRANGE**	
Response if maintenance is on : **SET_MODUL_CURRENT_AMPLI_ERROR MAINTENANCE_ON**	
Set the AC current modulation amplitude pic to pic. <setpoint> format can be double, float or integer / signed or not signed given in amps pic to pic. Positive number only. The configurable amplitude range is [0.00 - 12.00] App. <amps> format is « %+.2 lf ». <amps> is the recopy of <setpoint> for the power supply feedback response. • Related commands : « SET_MODUL_WAVEFORM », « SET_MODUL_FREQ », « SET_MODUL_ON », « SET_MODUL_OFF ». • AC Current modulation is an option.	

SET_MODUL_FREQ <setpoint>	Ex : SET_MODUL_FREQ 33.5
Response : **SET_MODUL_FREQ_OK <freq> Hz**	Ex : SET_MODUL_FREQ 33.50 Hz
Response in case of unrecognized argument <setpoint> : **SET_MODUL_FREQ_ERROR BAD_ARG**	
Response in case of overrange in <setpoint> argument : **SET_ MODUL_FREQ _ERROR OVERRANGE**	
Response if maintenance is on : **SET_MODUL_FREQ_ERROR MAINTENANCE_ON**	

Set the AC current modulation frequency.

<setpoint> format can be double, float or integer / signed or not signed given in hertz. Positive number only. The configurable frequency range is [0.01 - 100.00] Hz.

<freq> format is « %+.2 lf ». <freq> is the recopy of <setpoint> for the power supply feedback response. Related commands : « SET_MODUL_WAVEFORM », « SET_MODUL_CURRENT_AMPLI », « SET_MODUL_ON », « SET_MODUL_OFF ».

- AC Current modulation is an option.

SET_MODUL_ON
Response : **SET_MODUL_ON_OK**
Response if maintenance is on : **SET_MODUL_ON_ERROR MAINTENANCE_ON**

Turn on the AC current modulation power.

- The AC current modulation is independent from the main power DC current regulation so it can be used when the main DC power is off.
- Related commands : « SET_MODUL_WAVEFORM », « SET_MODUL_CURRENT_AMPLI », « SET_MODUL_FREQ », « SET_MODUL_OFF ».
- AC Current modulation is an option.

SET_MODUL_OFF
Response : **SET_MODUL_OFF_OK**
Response if maintenance is on : **SET_MODUL_ON_ERROR MAINTENANCE_ON**

Turn off the AC current modulation power.

- Related commands : « SET_MODUL_WAVEFORM », « SET_MODUL_CURRENT_AMPLI », « SET_MODUL_FREQ », « SET_MODUL_ON ».
- AC Current modulation is an option.

Programs examples

Python 3.7 example

This program connects to the power supply via python socket Ethernet library. It requests the last current measurement made by the power supply and print the result in the python console.

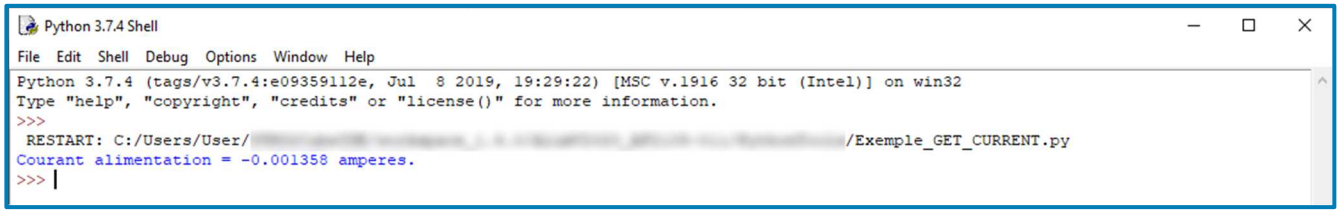
For more information about the socket library please read :

https://python.doctor/page-reseaux-sockets-python-port

Screenshot of the program :

```
#!/usr/bin/env python
# coding: utf-8

"""
Ce micro code est donné comme exemple pour voir comment communiquer
avec une alimentation de puissance CAYLAR via socket ethernet.
Ce programme demande le courant présent dans l'alimentation ciblée
à l'instant où le programme est lancé et print le résultat dans la console.
"""

import socket
import traceback

alim_sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
alim_sock.settimeout(5)
alim_ip = "192.168.1.245" #remplacer par l'adresse IP de votre alimentation ici.
alim_port = 1234

try:
    alim_sock.connect((alim_ip, alim_port))
    alim_sock.send(bytes("GET_CURRENT\n", "ascii"))
    current = float(alim_sock.recv(50).decode('ascii').split(' ')[1])
    print("Courant alimentation = " + str(current) + " amperes.")

except:
    print("Socket error ...")
    traceback.print_exc()

finally:
   alim_sock.close()
```

Screenshot of the program output (Console View) :



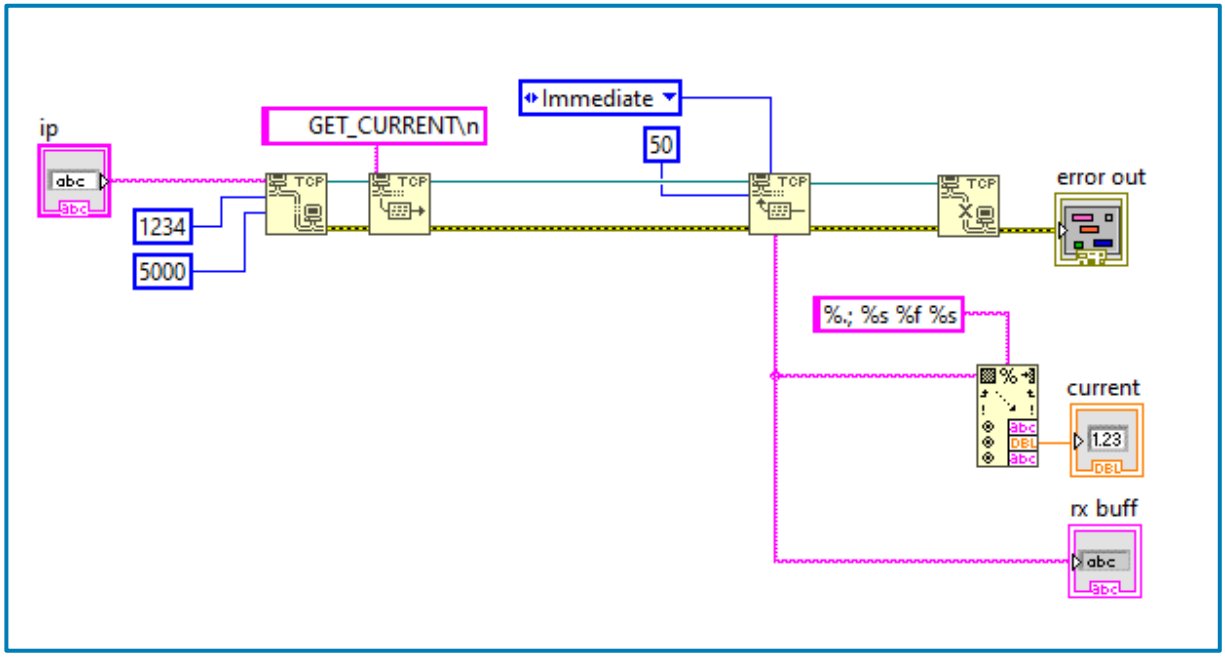
LabVIEW Example

This program connects to the power supply via the TCP protocol. It requests the last current measurement made by the power supply and displays the result on the front panel of LabVIEW.

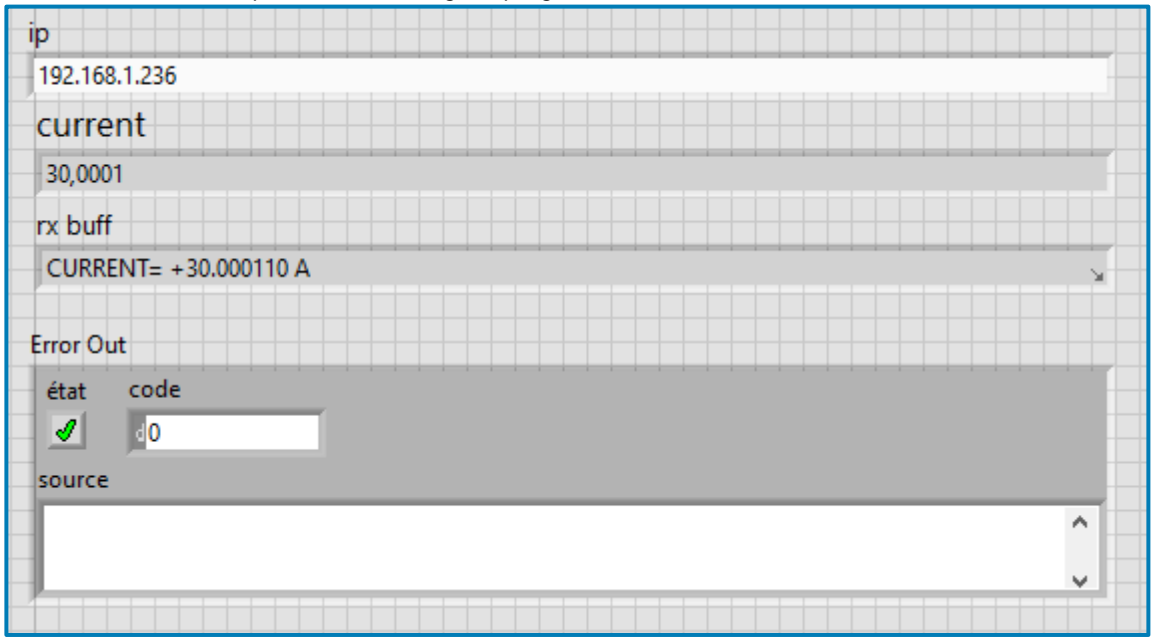
Use the LabVIEW TCP blocks in the block palette:
Functions > Data Communication > Protocols > TCP.

Useful link : http://www.ni.com/product-documentation/2710/en/

Screenshot of the program :



Screenshot of the front panel after running the program :



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Notes

MANUFACTURER OF ELECTROMAGNETS,
NMR TESLAMETERS,
POWER SUPPLIES

www.caylar.net

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Power Supply ± 60 V / ± 100 A

CURRENT REGULATED – 10 PPM CLASS

Measurement Report

Caylar SAS
14 avenue du Québec
BP 612
91140 Villebon-sur-Yvette
Tél +33 1 69 29 91 62

AF2104-007 / MPU8220-064
PSI Suisse
March 2022
Rev 1.0

Villebon-sur-Yvette (France)
The 21/03/2022,

Report

n° : AF2104-007 - MPU B60V100A Measurement Report

Bipolar Power Supply

± 60 V ± 100 A – 10 ppm

Delivered with mains cable set, power cable set and Interlock for EA132C – 9240-040

SUMMARY

I. TEST CONFIGURATION / OPERATING ENVIRONMENT

Mains

Line three-phase + Neutral : 400 V ± 10 % / 50 Hz between phase + Neutral

Interlock

The 26 pts D-sub "Interlock" on the rear panel of the power supply is connected to the EA132C electromagnet and is wired as follow :

Between 1 and 10 : Interlock 1 / Waterflowswitch sensor with normally closed contact

Between 2 and 11 : Interlock 2 / Coil1 Thermalswitch sensor with normally closed contact

Between 3 and 12 : Interlock 3 / Coil2 Thermalswitch sensor with normally closed contact

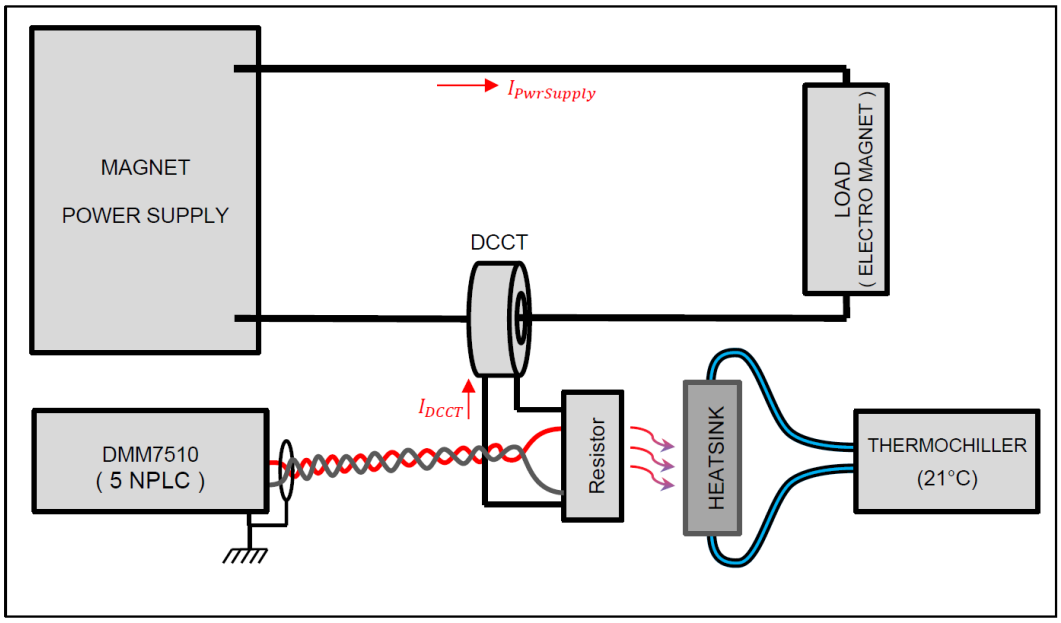
Between 8 and 9 : Strap for normally closed contact

Cooling

Water is connected and flowing inside the power supply and the electromagnet with the necessary requirements.

Measurement setup

Our power supplies are fully tested according the following setup for calibration and long-term validation :



II. TEST & MEASUREMENTS

The “ON” indicator led lights up when the mains are connected to the power supply and the On / Off switch is toggle to the ON position.

The OLED displays also lights and indicate several information about the power supply status.

Auxiliary power supplies

All the auxiliary power supplies are check and are nominal.

They concern 24 V for contactors, 5 V for microcontroller, ± 15 V for DCCT, ± 15 V for PID and Conversion and very low drift Voltage Reference.

Faults detection

Some defects are simulated, the red led " DEFAULT POWER " lights up and the power supply breaks down to return to no power mode, and the cause of the break down is indicated on the screens.

POS BANKS :	External voltage applied between "secu" and common R output of positive banks : threshold at 4.23 V
NEG BANKS :	External voltage applied between "secu" and common R output of positive banks : threshold at 4.32 V
BANK TEMP :	Waterflow switch failure detection inhibited and waterflow stopped
BRIDGE TEMP :	Thermalswitch disconnected
WATERFLOW :	Power supply waterflow stopped
CONDENSATION :	Water leak simulated on sensor
MAINS :	Push button "test" of sensor depressed
LIMIT POWER :	Low load connected
LIMIT CURRENT :	External remote voltage applied exceeding ± 11 V corresponding to 110 %
WATER_MAGNET :	Magnet waterflow stopped
TEMP_COIL 1 :	Thermalswitch of coil 1 of the associated electromagnet disconnected
TEMP_COIL 2 :	Thermalswitch of coil 2 of the associated electromagnet disconnected

The red led " DEFAULT PC " lights up if the embedded microcontroler presents a problem, in this case the power supply remains usable in analog mode (setpoint by Potentiometers or External).

DEFAULT PC : Embedded microcontroller forced to reset by pressing reset pushbutton

Power consumption and rectified voltages

VPh1/N = 235 Vrms ; VPh2/N = 233 Vrms ; VPh3/N = 234 Vrms (nominal voltage is 230 V).

IPh1 = 12.6 A r.m.s. ; IPh2 = 12.8 A r.m.s. ; IPh3 = 12.7 A r.m.s.

At Iout = 0 A	Vf+ = + 85.4 V ripple < 20 mV pk-pk	Vf- = - 85.5 V ripple < 20 mV pk-pk
At Iout = + 100 A	Vf+ = + 77.6 V ripple < 500 mV pk-pk ripple < 480 mV at 50 Hz ripple < 300 mV at 300 Hz	
At Iout = - 100 A		Vf- = - 77.5 V ripple < 500 mV pk-pk ripple < 490 mV at 50 Hz ripple < 310 mV at 300 Hz

Output voltage and current

Load: magnet ; equivalent R = 0.50 Ω, equivalent L ≈ 0.2 H

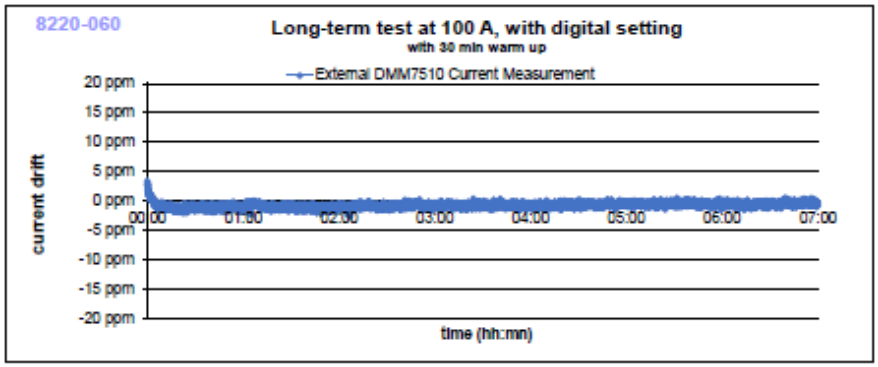
At Iout = + 100.02 A, Vout = + 52.69 V with a ripple of 5 mV pk-pk

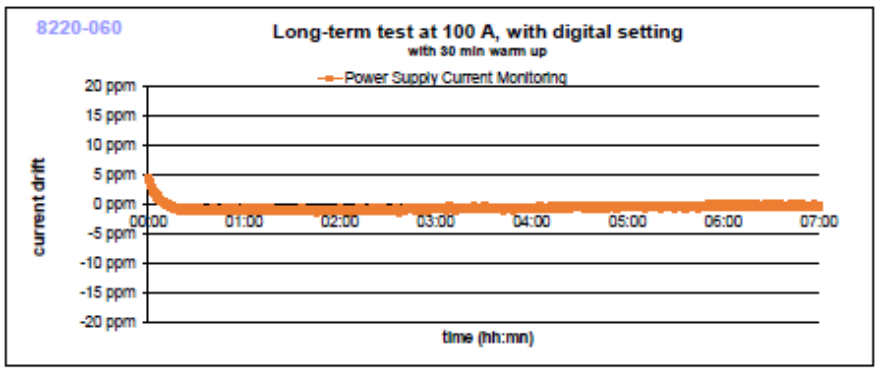
At Iout = - 100.01 A, Vout = - 52.61 V with a ripple of 4 mV pk-pk

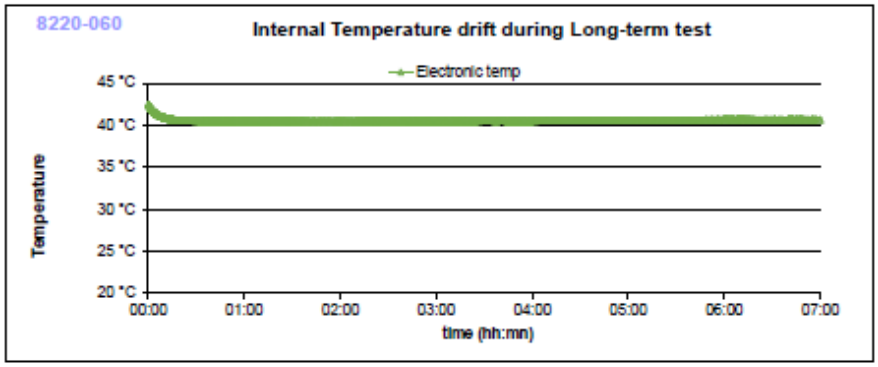
Longterm

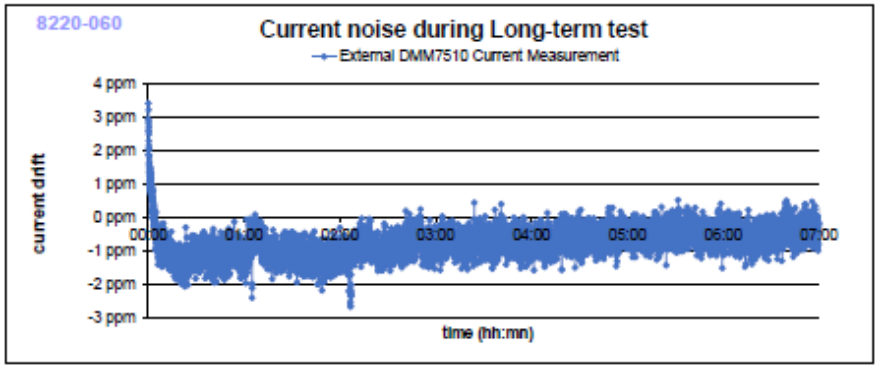
The setup has been described previously and the power supply had been running at maximum output current on its nominal load.

The result is as follows :









III. NOTES

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Electromagnet EA132C

Measurement Report

Caylar SAS
14 avenue du Québec
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Tél +33 1 69 29 91 62

AF2104-007 / 9240-040
PSI Suisse
March 2022
Rev 1.0

Villebon-sur-Yvette (France)
The 21/03/2022,

Report

n° : AF2104-007 – EA132C Measurement Report

Electromagnet EA132C

Delivered with 2 set of pole caps for :

- **39 mm airgap - Nominal Field ≈ 1.38 T @ 100 A**
- **80 mm airgap – Nominal Field ≈ 1.38 T @ 100 A**

Resistance ≈ 0.5 Ohms ± 10 % / Inductance ≈ 0.15 H

Weight 150 kg

SUMMARY

I. MAGNET CHARACTERIZATION

Resistance

The two coils of the electromagnet are wired in series. The coils present the same resistance.

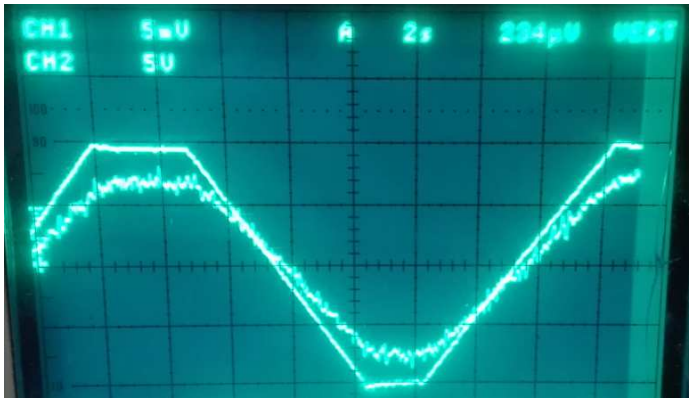
The measurements were performed at cold start @ 20°C and at nominal current after thermal stabilisation with a water cooling of 6 L/min.

The voltage across the magnet is measured between 47 V and 52 V giving a resistance variation between 0.47 Ohm and 0.52 Ohm.

Inductance measurement

Measurements were performed with a 4Q Voltage power amplifier.

Here under are the kind of waveforms of the current and voltage measurement with an analogue ramp limitation.



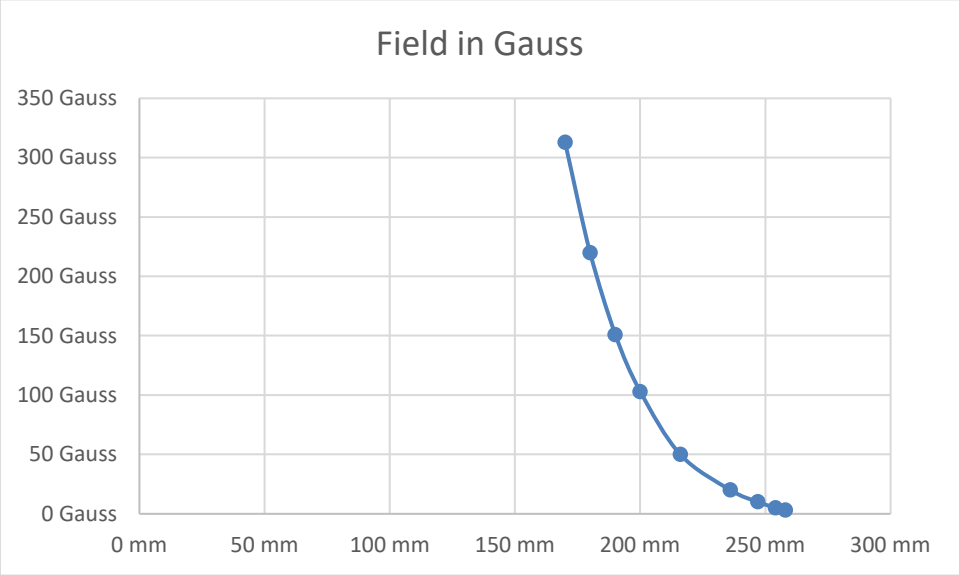
We use a 10 A/s ramp rate, the voltage measurement in relation of UL = R.I + L . di/dt

Thus the inductance of the electromagnet is about 150 mH.

Leakage field

The leakage field was measure along the horizontal axis from the center of the magnet and is given above

Distance from center in mm	0	170	180	190	200	216	236	247	254	258
Distance from coil extremity in mm	-170	0	10	20	30	46	66	77	84	88
Field in Gauss	13842	313	220	151	103	50	20	10	5	3



II. MAPPING DESCRIPTION

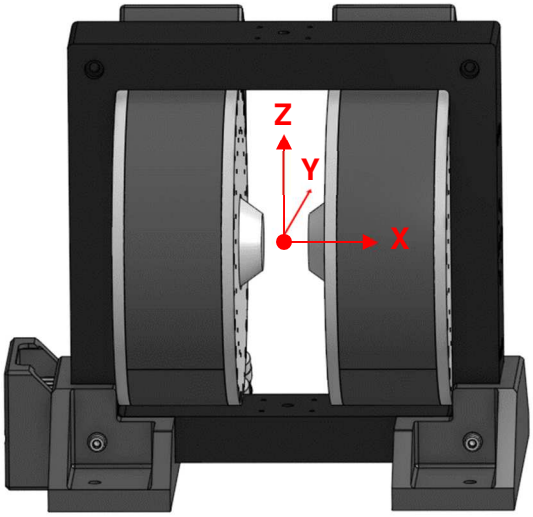
The measured volume and the accuracy of the sensor placement are ensured by a KUKA KR10 R900-2 industrial robot with pose repeatability of ± 0.02 mm.

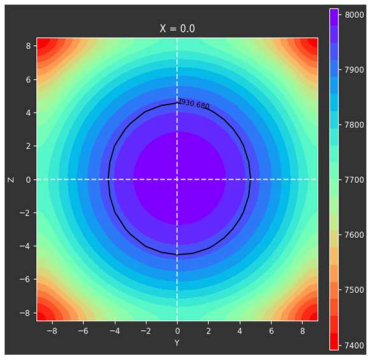
The magnetic field measurement is performed by a Hall gaussmeter with a resolution of ± 0.1 Gauss and, if the electromagnet is homogeneous enough, the magnetic field measurement is performed by a NMR Gaussmeter.

The mapping is performed during NMR loop control to ensure a constant field if possible.

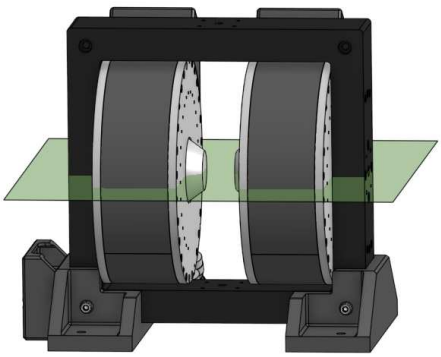
Here under is the representation of the different planes.

Field mapping coordinates origin and result view

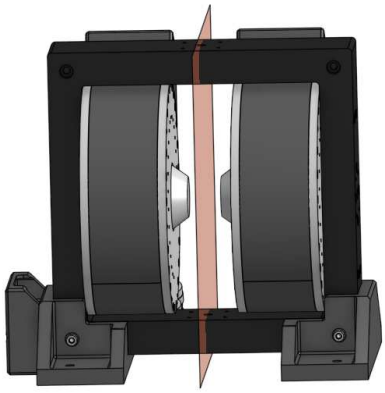




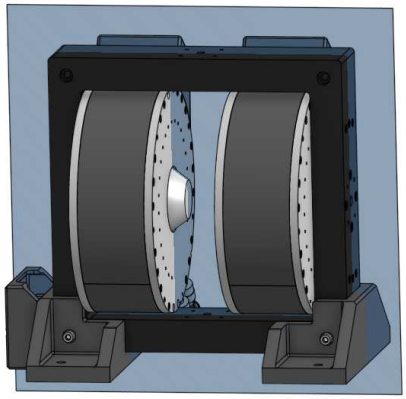
The black line indicates the 1 % homogeneous area and is showed as above. The two white dotted lines represent the two slice lines of the two 1D views from the 2D figure
The 1D figures are given below 2D figures.



Plane normal Z



Plane normal X



Plane normal Y

III. D115 / D70 GAP 39 MM WITH TAPERED AXIAL HOLE D10 TO D6

Theorical simulation results

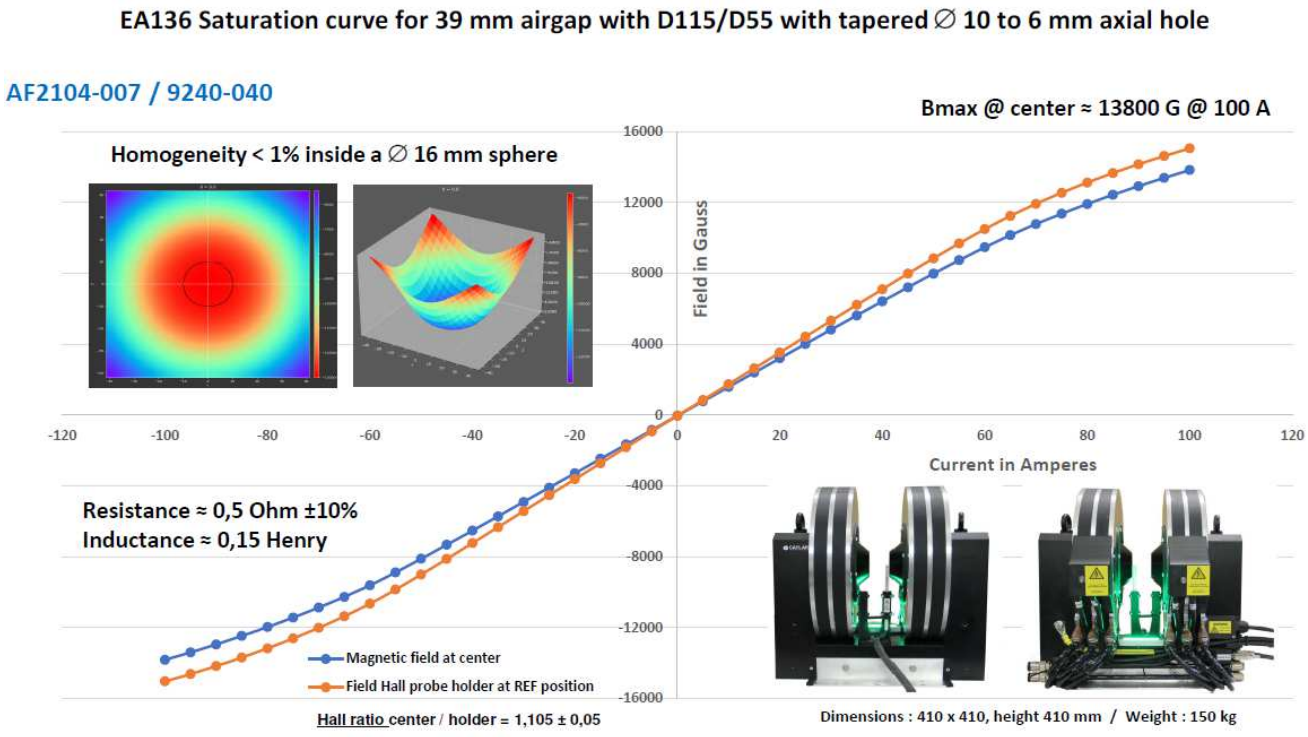
Max field at 100 A: 1.29 T

Homogeneity in 15x15x15mm volume: 1.53 % (197 G)

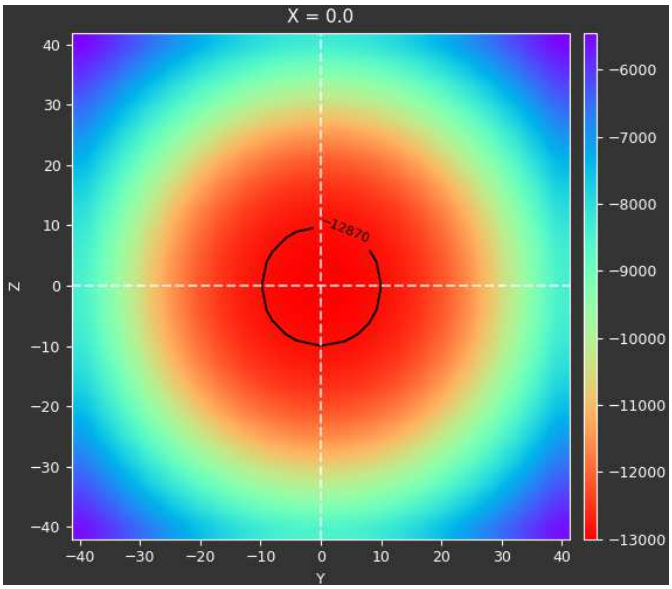
Homogeneity in 15x15 // to the pole: 0.9 % (116 G)

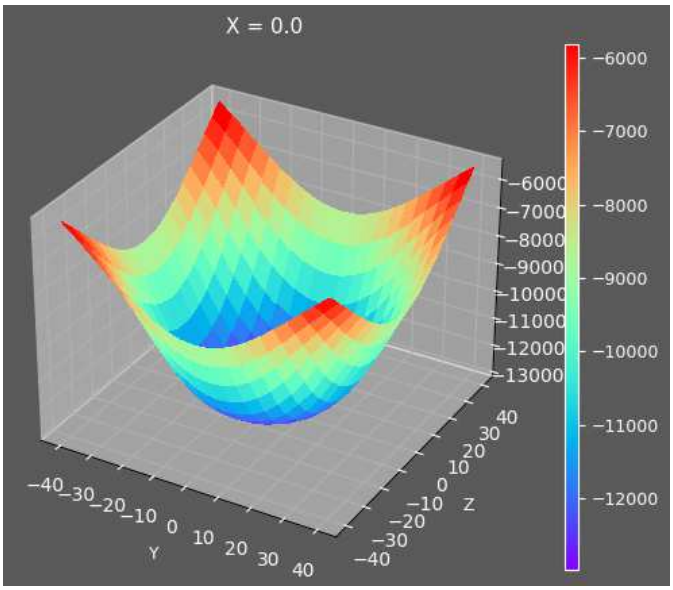
Measured performances

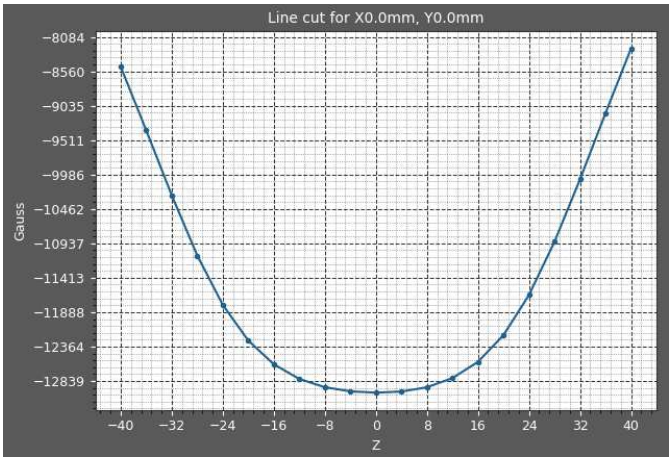
Saturation

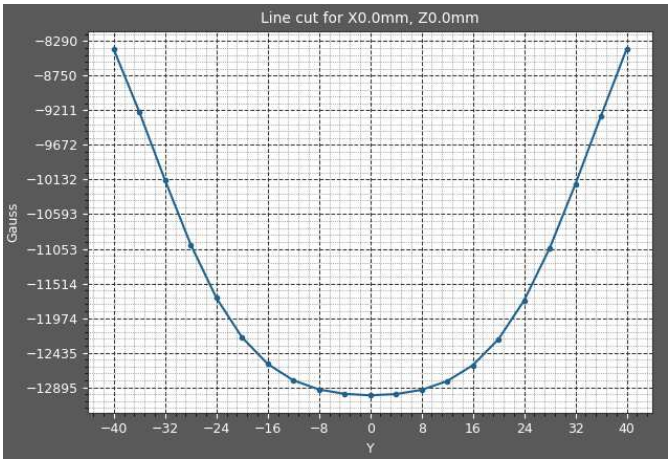


Homogeneity @ + 13000 Gauss – Plane normal X = 0

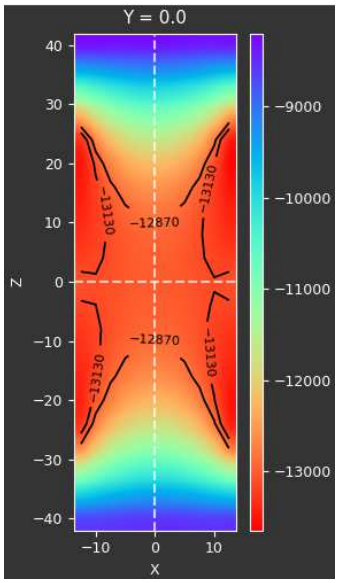


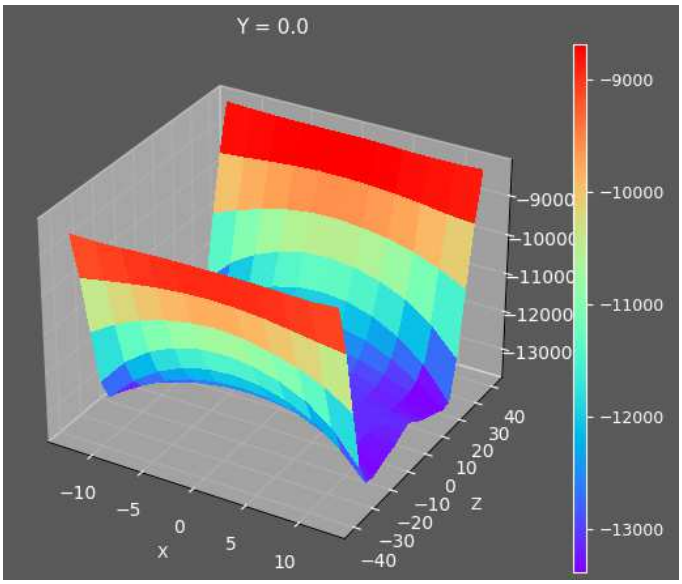


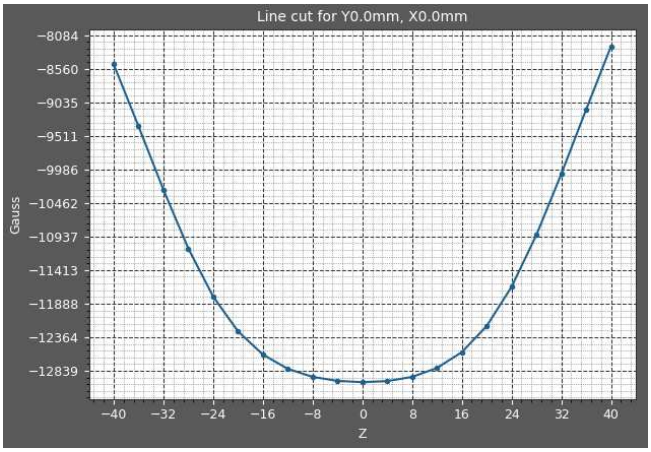


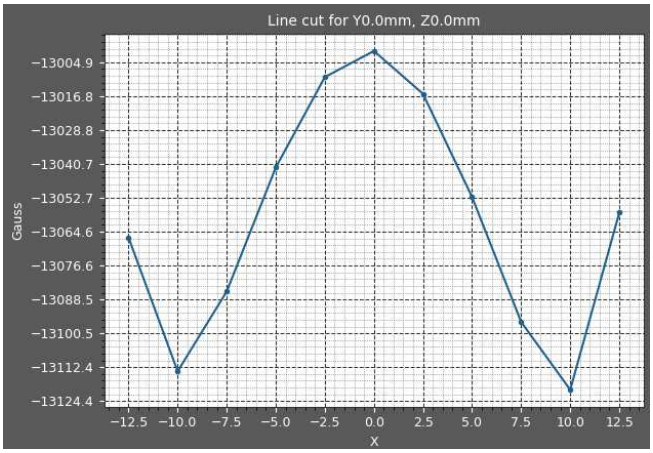


Homogeneity @ + 13000 Gauss – Plane normal Y = 0

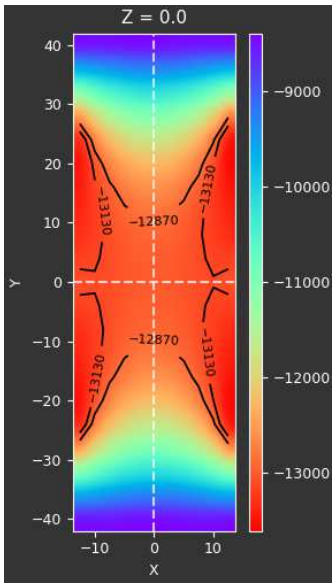


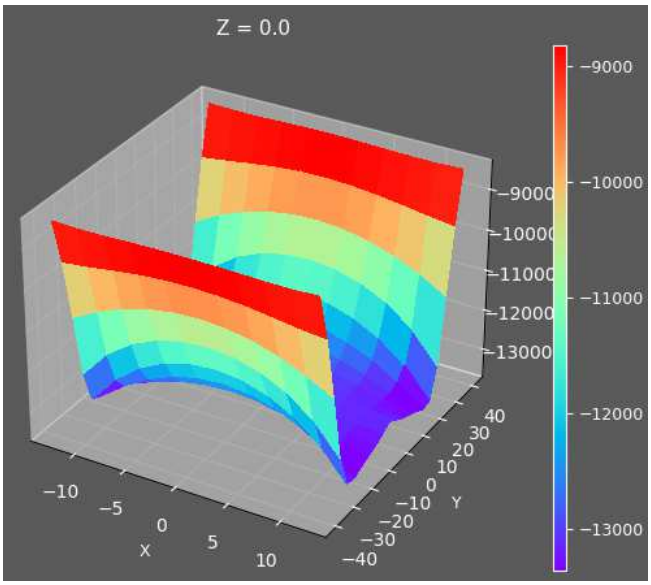


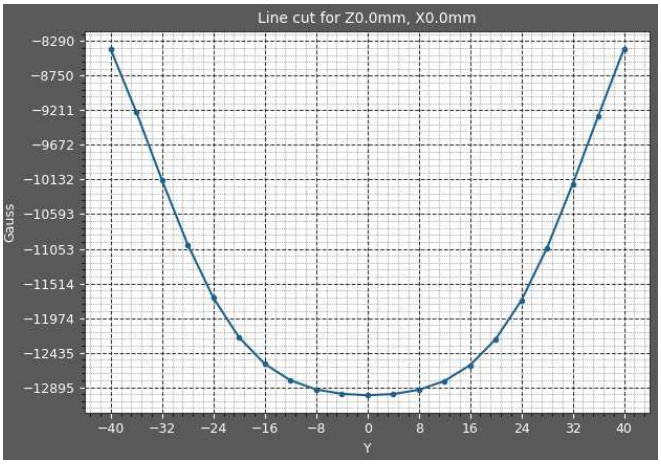


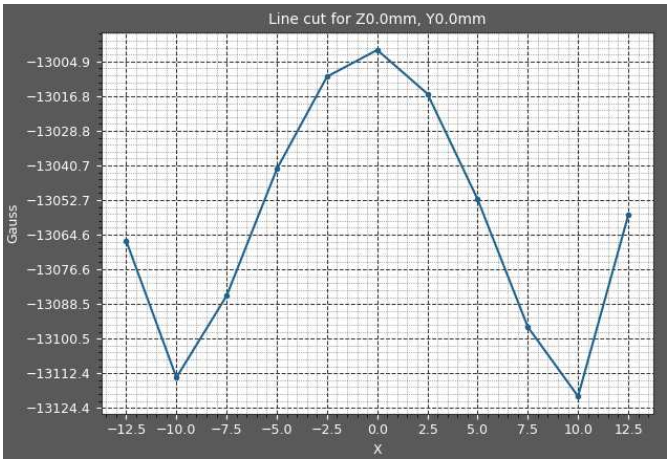


Homogeneity @ + 13000 Gauss – Plane normal Z = 0









IV. D115 / D105 GAP 80 MM WITH AXIAL HOLE D10

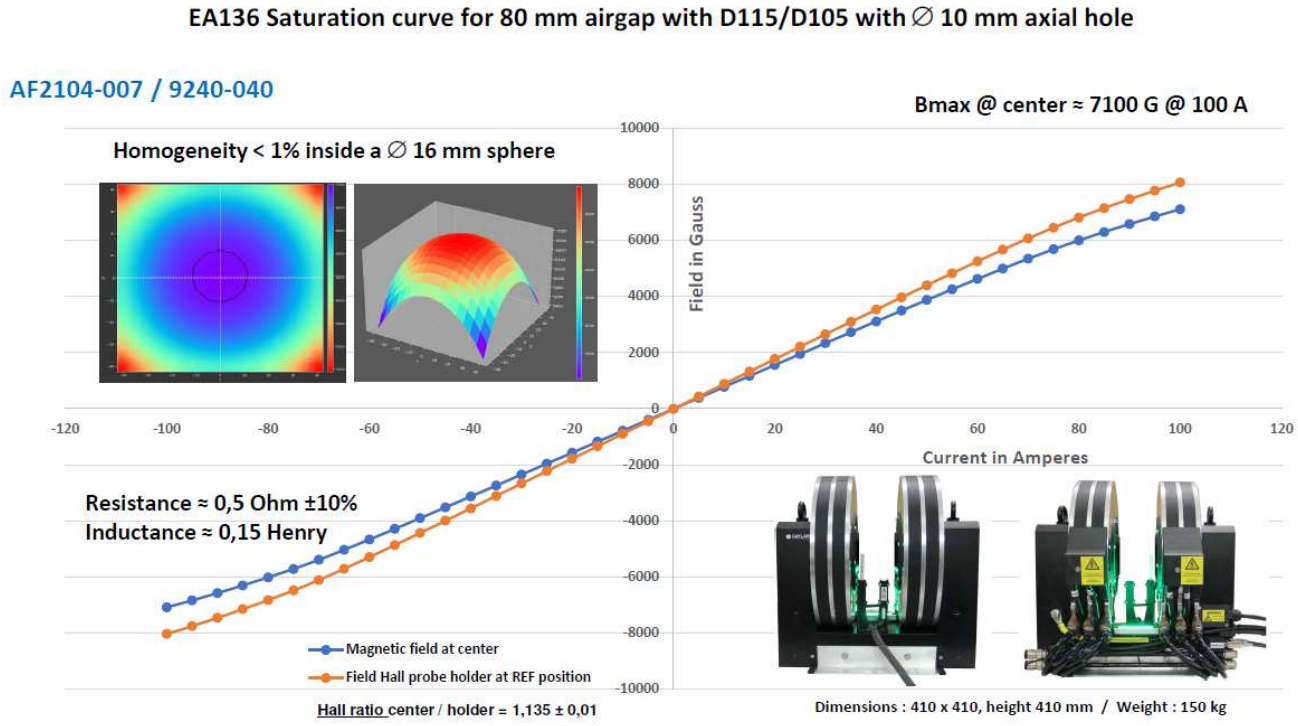
Theorical simulation results

Max field at 100 A: 0.70 T

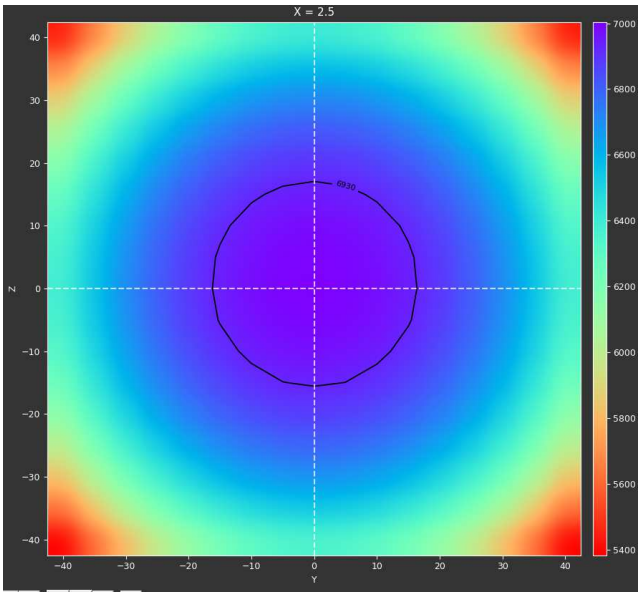
Homogeneity in 15x15x15mm volume: 0.92 % (64 G)

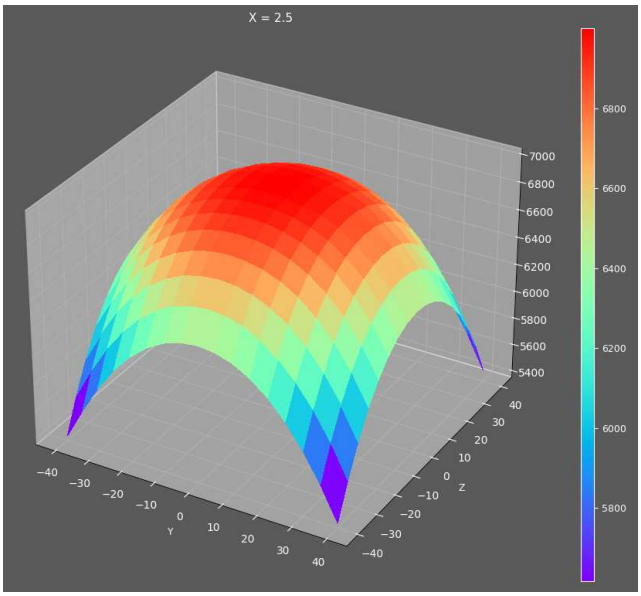
Homogeneity in 15x15 // to the pole: 0.48 % (34 G)

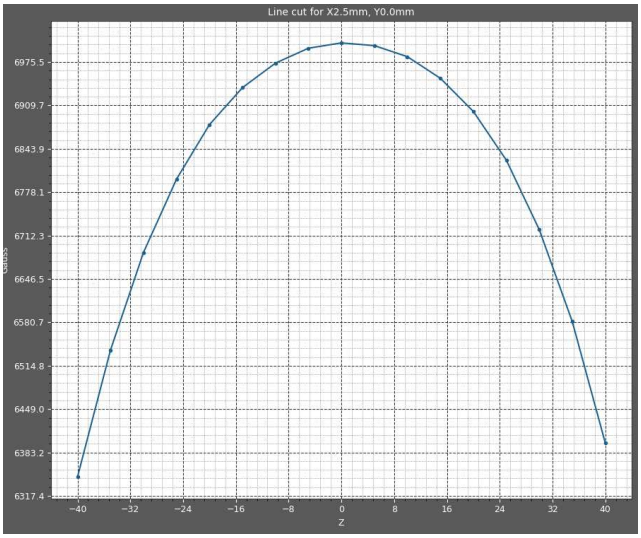
Measured performances

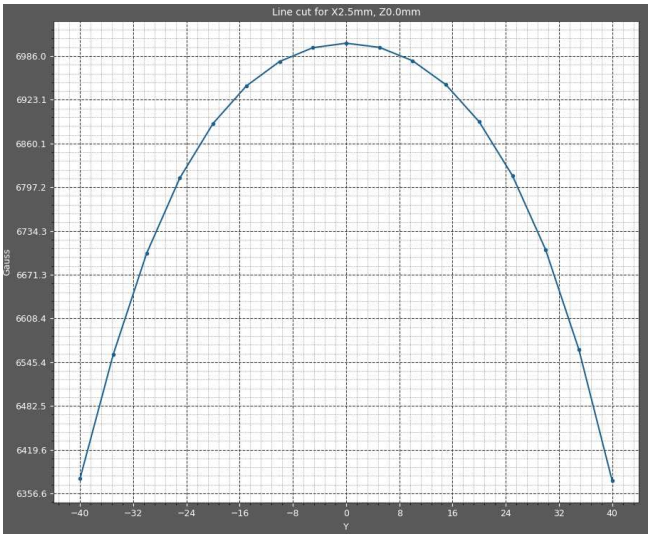


Homogeneity @ + 7000 Gauss – Plane normal X = 2.5

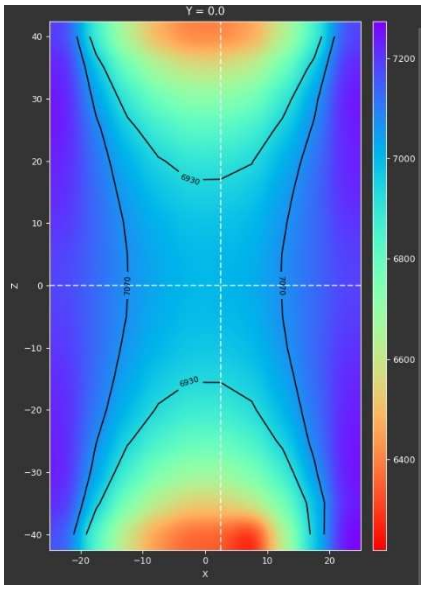


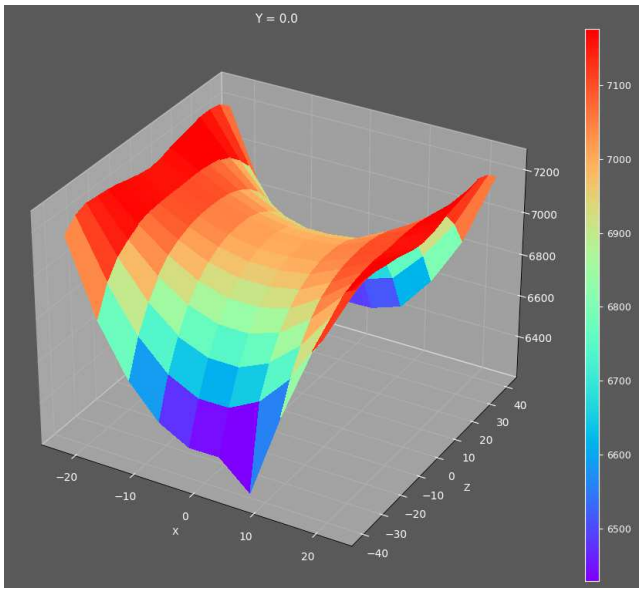


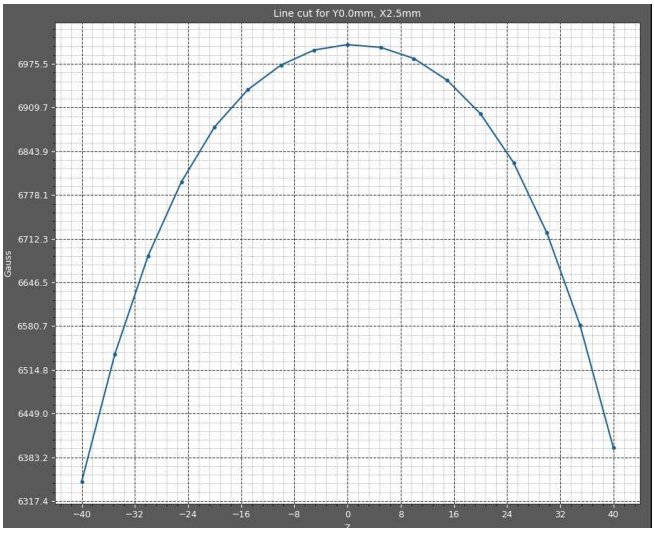


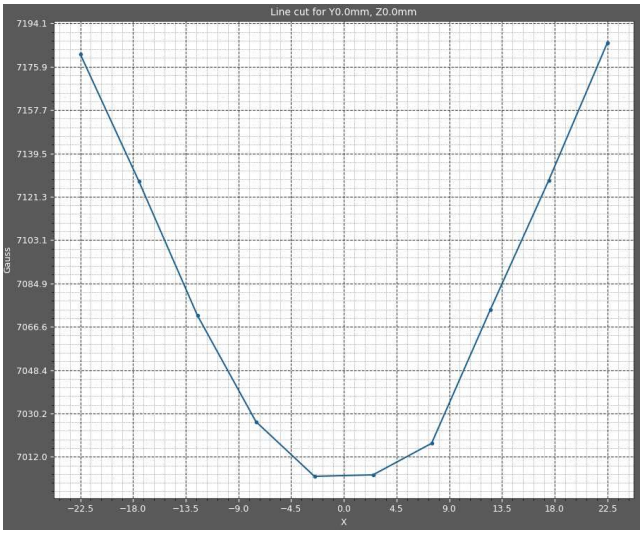


Homogeneity @ + 7000 Gauss – Plane normal Y = 0

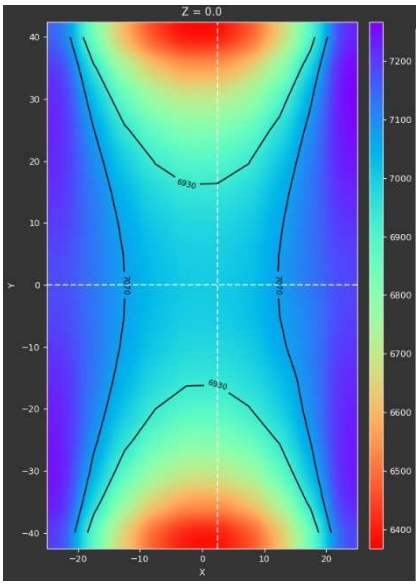


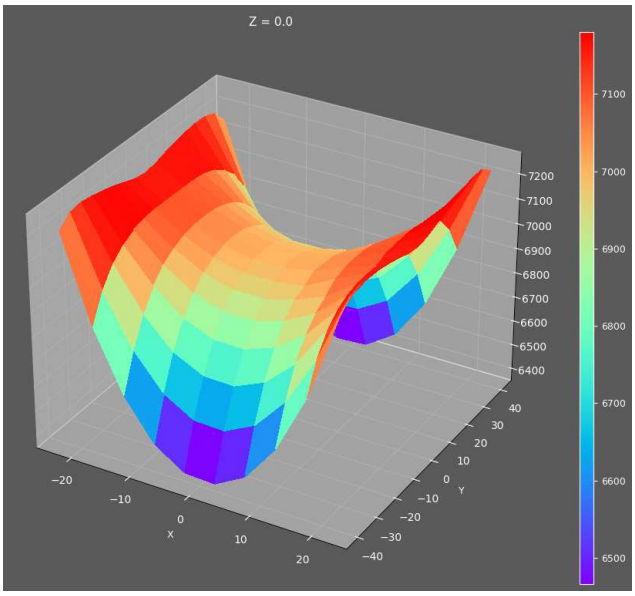


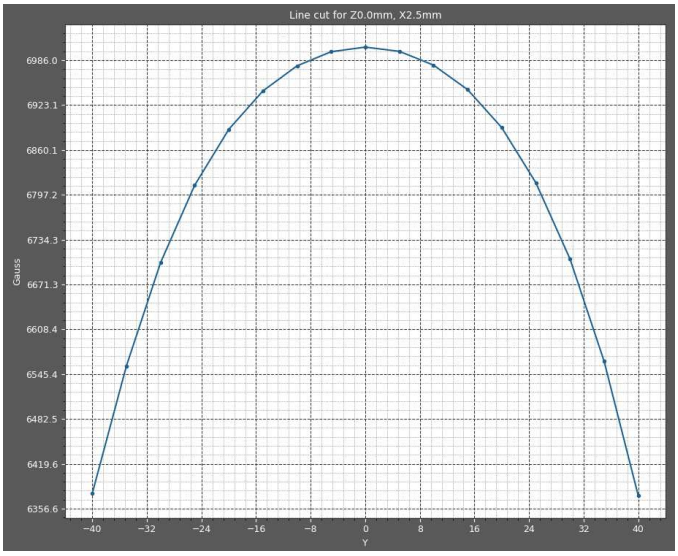


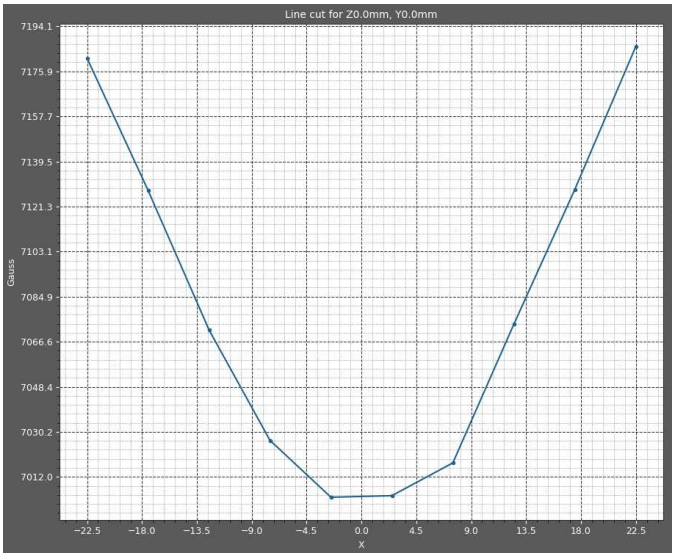


Homogeneity @ + 7000 Gauss – Plane normal Z = 0









V. NOTES

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