Easy - Driver

Compact Digital Bipolar Power Supply Series

CAENels
Gear for Science

User's Manual

MAGNET POWER SUPPLY SYSTEMS

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This product is  compliant.

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EASY-DRIVER USER MANUAL

This manual covers the following standard power supplies models:

- **EASY-DRIVER 0520**
- **EASY-DRIVER 1020**
- **EASY-DRIVER 0112**
- **EASY-DRIVER 0220**

This manual covers the custom model named as following:

EASY-DRIVER yyzz Cxxx

Where:

- yy is the maximum output current expressed in Amps
- zz is the maximum output voltage expressed in Volts
- xxx is the custom model code

Custom models available:

- **EASY-DRIVER 1020 C001**

Additional useful manuals are:

- Visual EASY-DRIVER - Quick Start Guide

For technical assistance please refer to the following contact:

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Table of contents

Document Revision	Date	Comment
1.0	October 10th 2015	First Release
1.1	December 14th 2015	Final and additional images inserted
1.12	June 11th 2016	Review Installation chapter and Technical Specification chapter Display
1.13	July 7th 2016	Updated Table 10 for Custom model 0112
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1.17	July 18th 2017	Update related to accessible and not accessible memory fields
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1.19	August 26th 2019	C001 model added
1.20	November 22nd 2022	Added UKCA compliance logo

Safety information

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

Environmental Conditions	Requirements
Environment	Indoor use
Operating Temperature	0°C to 50°C
Operating Humidity	20% to 80% RH (non-condensing)
Altitude	Up to 2000 m
Pollution degree	2
Overvoltage Category	II
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: Documentation must be consulted in all cases where this symbol is marked
- **O** Off (Power)
- **I** On (Power)
- **WARNING** The WARNING sign denotes a hazard. An attention to a procedure is called. Not following procedure correctly could result in personal injury. AWARNING 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 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 boxes

CAEN ELS d.o.o. 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 d.o.o. 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 if it is used in a manner not specified in this manual.
- Do not use the device if it is damaged. Before you use the device, inspect the instrument for possible cracks or breaks before each use.
- Do not operate the device around explosives gas, vapor or dust.
- Always use the device with the cables provided.
- 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

1. Introduction

This chapter describes the general characteristics and main features of the EASY-DRIVER digital bipolar power supply series.

1.1 EASY-DRIVER Overview

High efficiency, extreme reliability, overall performance and easiness of configuration and maintenance are the key features of the EASY-DRIVER power supply units.

The EASY-DRIVER series has four commercially available current-controlled digital bipolar power supply modules:

- **EASY-DRIVER 0520**, rated at ±5A@±20V output;
- **EASY-DRIVER 1020**, rated at ±10A@±20V output.
- **EASY-DRIVER 0112**, rated at ±1A@±12V output;
- **EASY-DRIVER 0220**, rated at ±2A@±20V output.

Each power supply unit fits in a single 19-inch 1U crate and implements a completely digital control loop with a specific Pulse Width Modulation (PWM) generation technique that makes the system extremely versatile and easy to "tune" to any load condition.

Each power unit is composed as follows:

- an auxiliary AC/DC section that powers up the control electronics;
- a power AC/DC section that feeds the DC/DC output power stage electronics;
- a full-bridge DC/DC section with a control-communication section, made up by two different Digital Signal Processors, signal conditioning stages and a power section are implemented;

One of these two DSP performs the current control loop while the other one supervises all processes as communication, diagnostics and interlock handling.

Remote communication is guaranteed by means of an Ethernet 10/100 auto-sensing socket accessible from each module front panel.

1.2 System Parts

The EASY-DRIVER unit is housed in a 1U – 19" crate that has embedded cooling (front-to-rear air flow). The front panel of the EASY-DRIVER is shown in **Figure 1**.

Figure 1: front view of the EASY-DRIVER unit

Output connections, interlock and status signals and the AC Mains Power socket are all placed on the rear panel of the power supply crate as shown in **Figure 2**.

Figure 2: front view of the EASY-DRIVER unit

DC Output connectors are terminal-type ones that allows for easily connecting direct cables (suggested cross sectional area for load cables is rated at 6 mm^2, or AWG 10 – AWG 9).

The output connection terminal direction is indicated as shown in **Figure 3**.

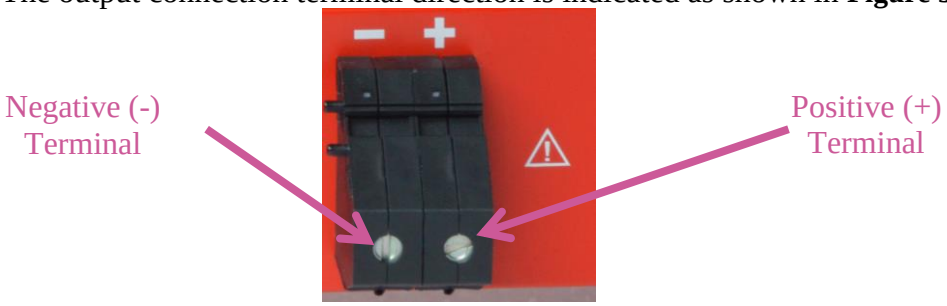


Figure 3: output connection of the EASY-DRIVER

The LEDs, visible from the power unit front panel (shown in **Figure 4**), are indicators of the power supply status and have to be interpreted as follows:

- **DC LINK** LED: the green light indicates that the bulk power supply is working correctly;
- **AUX PS** LED: the green light indicates that the control electronic section voltage – i.e. 3.3V, directly obtained from auxiliary AC/DC – is correctly working;
- **RX** LED: the green light toggles at every character reception and it is a communication heartbeat indicator;
- **DIAG** LED: the green light toggles at every diagnostic routine execution. If this LED is not toggling, the internal diagnostic routines are not correctly performed by the module.
- **ON** LED: the blue light indicates that the EASY-DRIVER output turned on and it is correctly regulating output current;
- **FAULT** LED: the red light indicates that the power supply has experienced a generic fault that can be either an internal protection trip or an external interlock intervention. This light does not turn off after a fault until a module reset has been performed.

It is important to notice that the blue ON light and the red FAULT light cannot be turned on at the same moment because the module cannot correctly regulate output current if a fault is experienced and the output stage of the power supply is disabled.

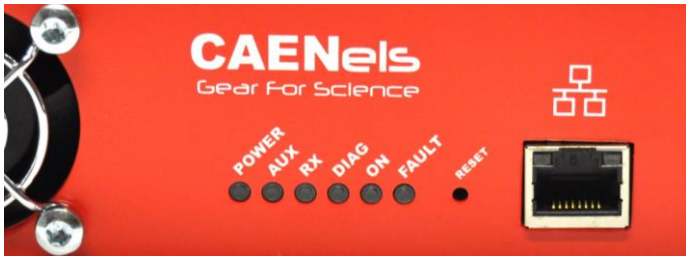


Figure 4: front panel indicators

2. Installation

Please read carefully this general safety and installation information before using the product.

2.1 Preparation for use

In order to be operational the power supply must be connected to an appropriate AC source. The AC source voltage should be within the power supply specification. Do not apply power before reading, Section 2.2, 2.3, 2.4, 2.5, 2.6 and 2.7.

Table 1 below, describes the basic setup procedure. Follow the instructions in the sequence given to 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, Interlock
4	First switch-on	Switch-on checkout procedure

Table 1: 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 such as broken switch or connectors and that the all panel and display are not scratched or cracked. Keep all packing material until the inspection has been completed. If damage is detected, compile the RMA form available to the CAEN ELS web site.

2.3 Mounting

The EASY-DRIVER 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 19-inch cabinet.

CAUTION

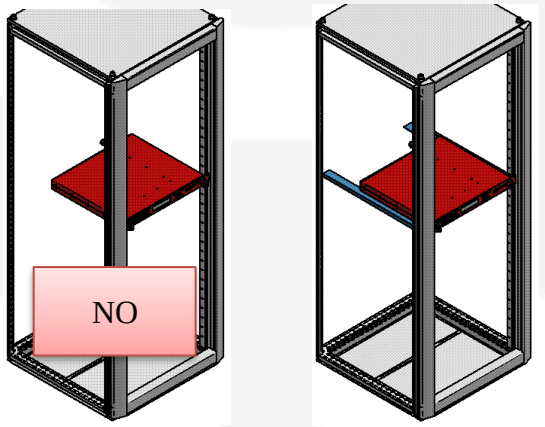
This power supply is fan cooled, the air intake is at the front panel and the exhaust is at the rear panel. Upon installation allow cooling air to reach the front panel ventilation inlets. Allow minimum 10 cm of unrestricted air space at the front and the read of the unit.

2.3.1 Rack Mounting

The EASY-DRIVER power supply series is designed to fit in a standard 19" equipment rack.

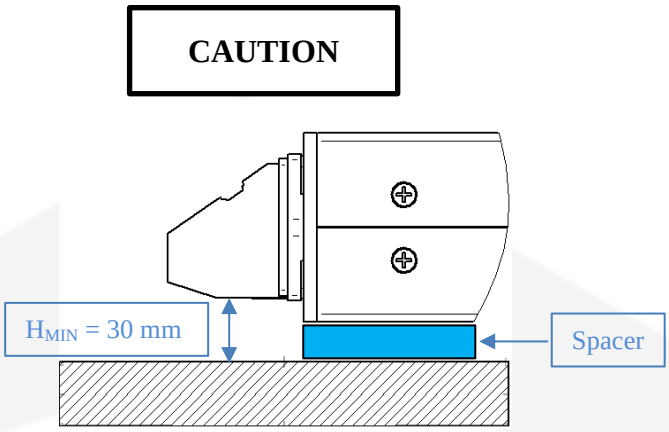
CAUTION

Use a support bar to provide adequate support for the power supply.



2.3.2 Desktop use

The EASY-DRIVER power supply series can be used as desktop unit but a proper spacer shall be provided between the desk and the power supply in order to allow cable route from the bottom of the output connector to the load.



2.4 AC Input Power Connection

The AC line input connector on the rear panel is a standard IEC C14 male inlet socket, with include fuse holder (**Figure 5**).

The required fuses characteristics for all the models are (**T5AL250V**):

- Size: **20 x 5 mm**
- Current rating: **5A**
- Blow characteristic: **Time delay**
- Breaking Capacity: **35 A**
- AC Voltage rating: **250V**

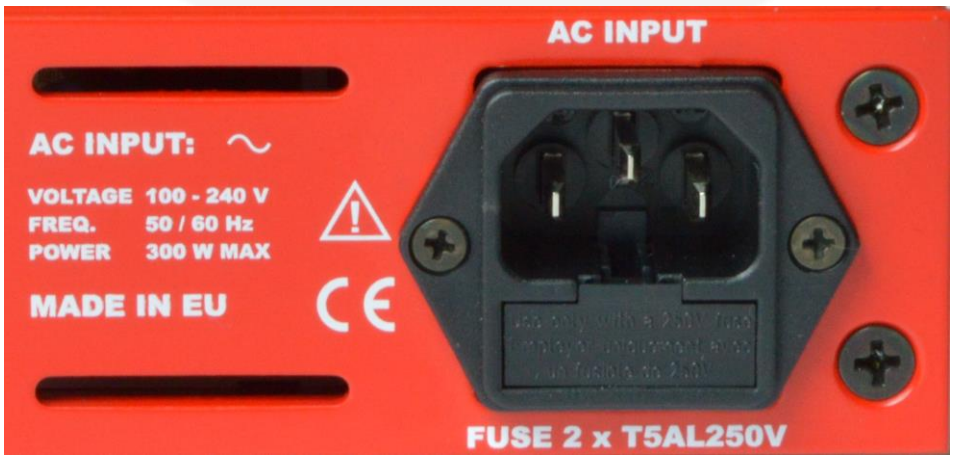


Figure 5: AC Power Line input socket

2.4.1 AC Source requirement

The EASY-DRIVER power supplies are designed for universal AC input range since it can operate with voltage from 100V to 240V and input frequency ranging 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

All the EASY-DRIVER power supplies are 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 6 A (or 10 A). Wire size for detachable power supply cord, shall be at least 0.75 mm^2. Wire size for fix installation shall be at least 1 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!

2.5 Load connection

WARNING

Turn off the AC input power before making or changing any rear panel connection, Ensure that all connections are securely tightened before applying power. There is a potential shock hazard when using a power supply with a rated output greater than 60 V

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

2.5.2 Wire cross section and length

Wire size should be selected to enable voltage drop per lead to be less than 1 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 2 V (1 V per lead)	
		5 A	10 A
2.5	8.21	24	12
4	5.09	39	19.5
6	3.39	59	29.5
10	1.95	102.5	51
16	1.24	161	80.5

Table 2: Wire selection – example for 0520 and 1020 models

Wire range allowed from the output connectors is from 0.5 to 16 mm^2, but wire cross section below 2.5 mm^2 are discourage to be used for minimize power losses and voltage drops. If values of Table 2 are used the maximum voltage to the load will be limited to:

EASY-DRIVER nominal output voltage – maximum 20 V

EASY-DRIVER power supplies could be connected to the load with a single insulation wires which have voltage rating of at least 60 V_{DC}.

To make a secure and reliable connection a "Wire Ferrule Terminal" is strongly suggested to use within the pilled wire as illustrated in **Figure 6**. Dimension of the Ferrule have to be suitable for the wire cross section being used.

Figure 6: Wire Ferrule Terminal

Tightening torque shall be between 1.2 to 2.4 Nm

2.6 Interlock connection

Each EASY-DRIVER power unit has one input interlock and one output status signal that are directly available on the rear panel interlock connector. The interlock connector is *Weidmuller* 4-pin male connectors (Ordering Code 1599150000). The mating connector that is provided with the EASY-DRIVER is the Weidmuller 1943580000.

The corresponding pin out is shown **Figure 7**:

Figure 7: Interlock connector on the unit rear panel

The pin index is summarized in Table 3:

Pin Number	Description
1	Interlock (+)
2	Interlock return (-)
3	Status Relay Common
4	Status Relay Normally Open

Table 3: Rear Interlock Connector pin out

WARNING

Status Relay Common pin and Status Relay Normally Open pin shall not float more than +/-60VDC above/below chassis ground.

CAUTION

Voltage between Interlock (+) and Interlock return (-) shall never exceed ± 12 V.
Voltage between Interlock return (-) and Protective Ground shall never exceed ± 12 V.
Voltage between Status Relay Common and Status Relay Normally Open shall never exceed ± 60 V.
Maximum current rating for the Status Relay is 400mA; current trough pins 3 and 4 shall never exceed 400 mA.

The interlock contacts can be configured to switch off the output. The Interlock pins accept a 5 V to 12 V signal or Open-Short contact (i.e. dry-contact) to disable and trigger the Interlock Fault. Activation direction must be configured by setting "1" or "0" in the EEPROM cell 29, see **Table 4**.

A solid state relay connection indicates the output status of the module: when ON, it closes the contact between pin 3 and 4 ("COM" and "NO").

2.6.1 Interlock connection on model 1020 C001

The custom model C001 provides to the end-user a different logic for interlock triggering.

When the user applies +24V between pins 2 and 1 in **Figure 7** and cell 29 is set to 1, the interlock triggers.

On the contrary, when the user does not provide +24V between pins 2 and 1 in **Figure 7** and cell 29 is set to 0, the interlock triggers.

2.7 Grounding

The EASY-DRIVER is configured to operate in floating mode either the positive or negative output terminals can be grounded. Always use two wires to connect the load to the power supply regardless of how the system is grounded.

WARNING

Outputs shall not float more than +/-60VDC above/below chassis ground.

3. EASY-DRIVER Description

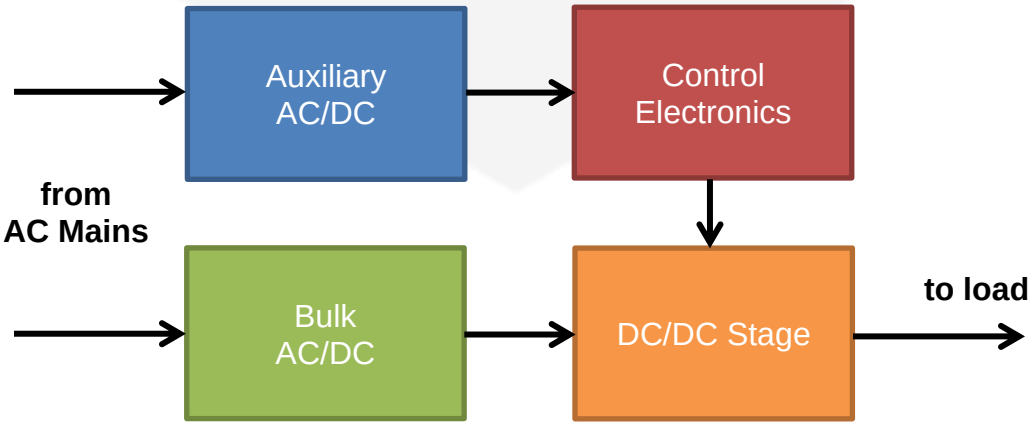
3.1 System Architecture

A description of the EASY-DRIVER unit is herein presented with some in-depth explanations on the basic power supply functionalities.

The power unit is composed as follows:

- an auxiliary AC/DC section that powers up the control electronics;
- a power AC/DC section that feeds the DC/DC output power stage electronics;
- a full-bridge DC/DC section with a control-communication section.

Basic internal connections between basic building blocks are hereafter represented:



The AC/DC module feeds the power to the output regulation stage and it is

internally rated at 24V and 225W.

Another auxiliary AC/DC section supplies the power to the control and communication electronics that controls the output stage power semiconductors and supervises overall processes.

This output stage is based on a full-bridge topology that allows smooth zero-crossing behavior to the unit and full bipolar operation.

3.2 Internal Protections

Each EASY-DRIVER module is equipped with multiple internal protections (hardware and software) to avoid unwanted behaviors or eventual damages to the unit and also to let users run the power supply safely.

All hardware protections installed are here listed:

- Input AC Fuse;
- Over-voltage clamping;

Several software protections, some of them redundant, are also implemented and here listed:

- DC-Link under-voltage protection;
- MOSFETs over-temperature;
- Shunt resistor over-temperature;

An overview of all available protections, as well as a brief description of their behavior, is presented in the following sections.

3.2.1 Input AC Fuses

The module input current is limited by two mains fuses.

3.2.2 Over-Voltage Clamping

The over-voltage behavior obtained from the energy stored by a large inductive load is heavily limited by a clamp power circuit rated at 110 % of DC-Link voltage.

3.2.3 DC-Link Under-Voltage

The DC-Link under-voltage protection operates whenever the DC-Link voltage, monitored by an internal 12-bit ADC, drops below a user-definable threshold.

This situation can be caused by a generic AC/DC Power Converter failure that do not provide voltage to the the DC/DC board.

The intervention of this protection disables the output stage driving signals; as in the other cases, a FAULT condition is generated and a "DC-Undervoltage" flag is set in the EASY-DRIVER power supply status register. The AC/DC generic failure may be recovered by switching Off and On the Mains power switch.

3.2.4 MOSFETs Over-Temperature

The MOSFETs composing the power supply output stage are all connected to an heatsink that is monitored by a high-gain temperature sensor.

The internal logic disables the H-Bridge when the temperature rises the defined threshold value, stored in EEPROM cell #20, and sets a "MOSFET over-temperature" flag in the status register, thus generating a FAULT condition that, as in the other cases, needs to be reset before enabling the output again.

3.2.5 Shunt Resistor Over-Temperature

The temperature of the precision shunt resistor used for current sensing is directly monitored on its case by another high-gain sensor connected to another channel of a 12-bit ADC.

The DSP disables the output stage – i.e. H-bridge – when this temperature rises above a user-defined threshold value, stored in EEPROM cell #21, and sets a "Shunt over-temperature" flag in the status register, thus generating a FAULT condition that needs to be reset before enabling the output again.

3.3 EEPROM Memory Mapping

Each power supply module has an on-board EEPROM memory that stores all information about calibration parameters, module identification, thresholds, etc. Some fields can be user-defined to exactly fit the power supply to the specific application.

The EEPROM cell size is 32 bytes and, being the content stored in ASCII string format, the total string can contain 31 bytes + '\r' termination character.

The EEPROM structure is presented in **Table 4**:

Cell #	Cell Caption	Description
0	c0I_set	Zero-order current calibration coefficient
1	c1I_set	1st-order current calibration coefficient
2	c2I_set	2nd-order current calibration coefficient
3	c3I_set	3rd-order current calibration coefficient
4	Imax	Maximum settable current set-point
5	c0V_read	Zero-order voltage calibration coefficient
6	c1V_read	1st-order voltage calibration coefficient
7	c2V_read	2nd-order voltage calibration coefficient
8	c3V_read	3rd-order voltage calibration coefficient
9	c0 DC_Link	Zero-order DC-link calibration coefficient
10	c1 DC_Link	1st-order DC-link calibration coefficient
11	c2 DC_Link	2nd-order DC-link calibration coefficient
12	c3 DC_Link	3rd-order DC-link calibration coefficient
13	KP - proportional constant	PID regulator proportional gain
14	KI - integral constant	PID regulator integrative gain
15	KD - derivative constant	PID regulator derivative gain
18	Newton-Raphson Iterations	Number of iterations for inverse calibration
19	Diagnostic Iterations	Number of iterations for internal diagnostics
20	Max MOSFET Temperature	Maximum MOSFET heatsink temperature
21	Max SHUNT Temperature	Maximum shunt resistor temperature
22	Serial Number	Module serial number
23	Undervoltage Protection	Under-voltage protection threshold
24 … 25	reserved	
26	Calibration Date	Date of last calibration
27	Identification	Module identification name
28	reserved	
29	External Interlock Activation Level	"0": Fault when INTK shorted "1": Fault when INTK open
30	Slew Rate [A/s]	Module start-up slew rate value

Table 4: EEPROM Structure

Please note that:

- *only cells marked in **green** are **NOT** read only*

In order to make changed parameters effectively updated and in operation it is necessary to send the MPUP command to the EASY-DRIVER module first. (see 'MPUP Command' Section for more information).

Please refer to Table **4** to write values to configure correctly the EASY-DRIVER module and note that the command to be used is:

- 'MWG' command to write the respective "value" cell content;

Example: suppose that the proportional term value – K_p – of the internal PID digital regulator has to be changed to 0.0015. Referring to **Table 4**, this value is accessible and it is placed at cell number 13.

The following command needs to be sent to the EASY-DRIVER unit:

MWG:13:0.0015\r

and should receive an acknowledgment reply from the power supply – i.e. '#AK\r'. In order to make the module apply the value K_p = 0.0015 to its internal regulator it is necessary to send the MPUP\r command.

3.3.1 "Value" Section Cells

Herein, in order to correctly configure and check the power supply operation, a brief description of the user-definable cells is presented:

- **K_P** – *cell 13*: this value is the proportional gain coefficient of the internal digital PID regulator;

- **K_I** – *cell 14*: this value is the integral gain coefficient of the internal digital PID regulator;

- **K_D** – *cell 15*: this value is the derivative gain coefficient of the internal digital PID regulator;

- **Identification** – *cell 27*: this value, a string, defines the EASY-DRIVER module identification name (and can be read with the 'MRID\r' command);

- **Slew Rate** – *cell 30*: this value [A/s] determines the slew-rate value of the power supply. The module ramps, using the command 'MRM\r', at a defined set-point with this pre-defined value of slew-rate.

3.4 Status Register

Each EASY-DRIVER unit has an internal 8-bit status register that contains all useful information about the power supply operation; this register is updated in real-time and it is always accessible by the users via the remote connection.

The internal status register structure is presented in **Table 5** (bit 7 is the MSB and bit 0 the LSB):

Status bit	Cell Caption
7	reserved
6	reserved
5	EXTERNAL INTERLOCK
4	SHUNT TEMPERATURE
3	MOSFET TEMPERATURE
2	DC UNDERVOLTAGE
1	FAULT
0	MODULE ON

Table 5: 8-bit internal status register

The status register value can be directly read by users using the 'MST\r' command. The returned item is a 2-digit hexadecimal ASCII string, corresponding to the equivalent status register. A brief description of all the binary flags is here presented:

- **Module ON** – *bit 0*: this bit is set if the module is enabled and correctly regulating output current;

- **Fault** – *bit 1*: this bit is set if the module has experienced a fault – e.g. generated by an external interlock or an internal protection trip – and the status register has not been reset;

- **DC Undervoltage** – *bit 2*: this bit is set when a DC–Link under-voltage condition – i.e. voltage drops below a user-defined threshold – has been recognized. The setting of this bit implies the simultaneous setting of the fault bit;

- **MOSFET Temperature** – *bit 3*: this bit is set when a MOSFET over-temperature condition has been experienced. The setting of this bit implies the simultaneous setting of the fault bit;

- **Shunt Temperature** – *bit 4*: this bit is set when a shunt case over-temperature condition has been experienced. The setting of this bit implies the simultaneous setting of the fault bit;

- **External Interlock** – *bit 5*: this bit is set when the corresponding external interlock trips. The setting this external interlock bit implies the simultaneous setting of the fault bit;

4. Local Display

The EASY-DRIVER power supply module has a local LCD display that allows visual monitoring of some information.

The start-up screen shows in sequence the following information:

- the module type ID and firmware release.

- the module IP address

- the module MAC address

When the firmware initialization has been completed the display shows the output status of the module (i.e. current and voltage, Io and Vo respectively) as indicated in **Figure 8**:

Figure 8: local display with current and output voltage monitor

5. Remote Control

The EASY-DRIVER power supply module can be remotely controlled via a standard Ethernet 10/100 link using a predefined set of commands.

5.1 Preliminary Information

In order to ensure a correct communication with the unit, the following rules have to be pointed out:

- commands **TO** the power supply module must be sent with a **'\r'** (carriage return, 0x0D hexadecimal number) termination character;
- replies **FROM** the power supply also have a **'\r'** (carriage return, 0x0D hexadecimal number) termination character.

A complete list of commands (except for reserved commands) is herein presented and an overview for each command syntax and functionality follows.

The extreme configurability of this power supply leads to a very widespread command list, thus typical users may only need a small set of commands in order to run the EASY-DRIVER in a satisfying way.

5.2 List of Commands

The user-available commands, as well as a brief description and their read or write functionality, are summarized in the following table:

Command	Description	Read/Write
FDB	Feedback command	W
MOFF	Turn the module OFF	W
MON	Turn the module ON	W
MRESET	Reset the module status register	W
MRG	Read selected EEPROM "value" cell	R

MRI	Read output current value	R
MRID	Read module identification	R
MRM	Set output current value (ramp)	W
MRP	Read DC-Link voltage value	R
MRSR	Read current Slew Rate	R
MRT	Read output stage heatsink temperature	R
MRTS	Read regulation shunt temperature	R
MRV	Read output voltage value	R
MST	Read module internal status register	R
MVER	Power Supply firmware version	R
MWG	Write selected EEPROM "value" cell	W
MPUP	Reload EEPROM values in DSP	W
MWSR	Write current Slew Rate	W
MWI	Set output current value (no ramp)	W

Table 6: EASY-DRIVER module Command List

It is important to notice that some commands are write-only commands (e.g. MRM to set output current) and some others are read-only commands (e.g. MRI to read output current value).

5.3 Commands Overview

The power supply controller replies every time that a termination character '\r' is received. Replies could have different behaviors:

- an acknowledgment '#AK\r' string is sent back in case of a correct setting command;
- a non-acknowledgment '#NAK\r' string is sent back in case of a wrong/unrecognized command or if the system is in local operation mode and a write command is sent to the controller (write commands are marked with a 'W' in **Table 6**);
- a standard reply, preceded by a '#' and followed by a '\r' character, is sent back as a response to a reading command.

A brief description for each command, in alphabetical order, is herein presented with some example annotations; the correct interpretation for these examples is as follows:

Command sent TO the power supply →

← **Reply FROM the power supply**

5.3.1 "FDB" Command

The FDB command was especially developed for operation on global feedback control systems. This command allows in a single write/read operation to set the main power supply parameters (as ON-OFF, output current value, etc.) and to have a reply from the power supply containing data on output current value, its setpoint and its status register.

The feedback command syntax is as follows:

FDB:set_reg:i_set\r

where:

- *set_reg*: is the 1-byte setting register of the power supply, formatted as an hexadecimal string;
- *i_set*: is the output current set-point value in [A].

The PS response after a FDB command is in the following form:

#FDB:status_reg:i_set:i_read\r

where:

- *status_reg*: is the 8-bit wide *status register* of the power supply, formatted in an hexadecimal string; this status string has a fixed-length of 2 byte (2 ASCII characters equivalent to hex numbers) and its structure is hereafter indicated;
- *i_set*: is the string containing the output current actual setpoint value in [A]; string length is 8 bytes (i.e. 8 characters): sign + 2 integers + "." + 4 decimal digits (eg. 1,02A it is returned as +01.0200);
- *i_read*: is the output current readback string in [A]; its length is equal to 8 bytes: sign + 2 integers + "." + 4 decimal digits;

The *status_reg* structure is presented in the following table:

Status Register Structure (8-bit)	
Bit 7…6	reserved
Bit 5	EXTERNAL INTERLOCK FLAG
Bit 4	SHUNT TEMPERATURE
Bit 3	MOSFET TEMPERATURE
Bit 2	DC LINK UNDERVOLTAGE
Bit 1	FAULT
Bit 0	MODULE ON

Table 7: Status register

The *set_register* must be interpreted and set as follows:

FDB command register (8bit):	Bit Function:
Bit 7	BYPASS COMMAND
Bit 6	ON/OFF
Bit 5	RESET
Bit 4	RAMP
Bit 3…0	don't care

Table 8: Set register

It is important to notice that the feedback command can be used as a simple "read" command by setting the Bit 7 of the *set_register* to 1 (BYPASS COMMAND). By doing this, the PS replies to the command with its internal data (output current, setpoint and status register) but does not set current or consider the other *set_register* parameters.

Examples:

Suppose that the power supply is ON and it is regulating at a +2.0000A output current. The user then sends the following command:

FDB:50:-03.2453\r →

← #FDB:01:-03.2453:+02.0000\r

the power supply turns ON (and it is already ON) and sets its output current to -3.2453A reaching its setpoint with a ramp (defined by the slew-rate value stored in the power supply non-volatile memory).

The reply must be interpreted as follows:

- Module is ON;
- NO faults are present;
- the last "stored" set-point is -3.2453A;
- actual output current readback value is 2.0000A.

In this example, the *set_register* was set to 50 = 01010000_{binary} (bit 6 sets/keeps the module ON while bit 4 make the power supply perform a ramp to reach the new set-point).

5.3.2 "MOFF" Command

The 'MOFF\r' command is intended to turn off the EASY-DRIVER output driver, thus disabling the output current terminals.

The 'MOFF\r' command automatically sets a "disabling" signal for the H-Bridge driver; possible voltage overshoots obtained from the energy stored by a large inductive load is heavily limited by a clamp power circuit rated at 110 % of DC-Link voltage.

Replies from the EASY-DRIVER to a 'MOFF\r' command are in the form '#AK\r'.

Examples:

MOFF example when the EASY-DRIVER module is ON and sourcing current:

MOFF\r →

← #AK\r

MOFF example when the EASY-DRIVER module output is already disabled::

MOFF\r →

← #AK\r

5.3.3 "MON" Command

The 'MON\r' command is intended to turn on the EASY-DRIVER output driver, thus enabling the output current terminals and allowing the power supply to regulate and feed current to the connected load.

After the reception of an 'MON\' command, the power supply automatically sets output current to 0A (zero) when enabling the output.

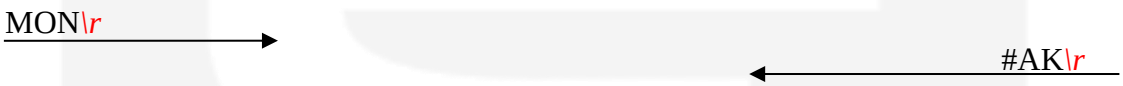
Replies from the power supply to a 'MON\r' command are in the form '#AK\r' – when the command is correctly executed - or '#NAK\r'. The '#NAK\r' reply is obtained if:

- the power supply module is in a FAULT condition (it is necessary to reset the status register after a generic fault condition in order to turn the power supply ON again - see command 'MRESET\r').

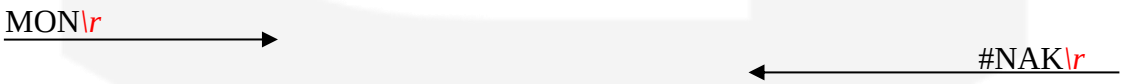
Sending a 'MON\r' command when the module output is already enabled also generates an acknowledgment response – i.e. '#AK\r'.

Examples:

MON example when there is no fault conditions:



MON example when the system has experienced a fault:



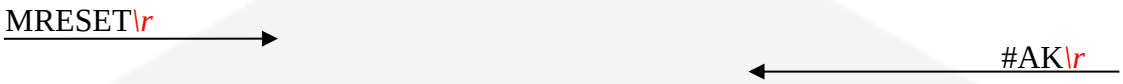
5.3.4 "MRESET" Command

The 'MRESET\r' command has to be used in order to perform a complete reset of the module status register: this is needed, for example, to enable the output again after a fault condition has been fixed.

Replies from the EASY-DRIVER module are always in the form '#AK\r'.

Examples:

MRESET example:



5.3.5 "MRG" Command

The 'MRG\r' command returns the value stored in the "value" parameter of a desired EEPROM cell. The correct form for the reading request is as follows:

#MRG:cell_num\r

where:

- *cell_num* is the EEPROM cell number.

The on-board EEPROM memory - used to store module information as calibration parameters, identification, thresholds – has 512 cells, so that *cell_num* is limited between 0 and 511.

The "value" section of the EEPROM is used to store calibration parameters, identification, thresholds, etc. and other user-definable factors. For more information on how to write parameters in the "value" area of the memory, please refer to "MWG Command" section.

Replies from the EASY-DRIVER power supply are in the following format:

cell_content\r

where:

- *cell_content* is the *cell_num* content in an ASCII representation.

The MRG command, being a reading command, returns a response in any module condition.

Examples:

MRG example for cell 23 (containing DC undervoltage threshold [V]):

MRG:23\r →

← 0.2\r

5.3.6 "MRI" Command

The 'MRI\r' command returns the readback value of the power supply actual output current.

Current readback values have a 20-bit resolution (19-bit + sign) and they are presented with a 5-digit precision.

Replies from the power supply to this command are in the following form:

#MRI:value\r

where:

- *value* is the output current value readback [A].

The MRI command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRI example when the module is OFF:

MRI\r →

← #MRI:+0.00004\r

MRI example when the module is ON and regulating:

MRI\r →

← #MRI:-28.34563\r

5.3.7 "MRID" Command

The 'MRID\r' command returns the EASY-DRIVER identification name as a string.

The reply from the power supply contains the value stored in cell 27 of the module EEPROM and it assumes the following format:

#MRID:module_id\r

where:

- *module_id* is the module identification stored in non-volatile memory, as an ASCII string.

This command is equivalent to the 'MRG:27\r' command, being the cited cell content the user-selected module identification name.

The MRID command, being a reading command, returns a response in any module condition.

Examples:

MRID example with the module identification "SkewMag1.3":

MRID\r →

← #MRID:SkewMag1.3\r

5.3.8 "MRM" Command

The 'MRM' command is used to set the value of the desired output current set-point:

#MRM:value\r

where:

- *value* is the output current desired set-point [A].

The difference between the 'MWI\r' command and the 'MRM\r' command is that the first one generates a direct change in output current characterized by the PID regulator parameters (slew-rate value is discarded and the command is ideally suited for small output current changes and feedback purposes) while the second one makes the power supply go from the previous to the actual current value performing a ramp, defined by a slew-rate (in A/s) stored in the EEPROM cell 30.

The EASY-DRIVER module responds with acknowledgment command '#AK\r' if the value is correctly set and with a '#NAK\r' if:

- the set *value* is out-of-range (the maximum settable current value is user-defined and stored in EEPROM cell 4);
- the module is OFF (it is necessary to turn the module ON first);
- the module performing a ramp (it is necessary to wait for the power supply to end the previous ramp);

Examples:

MRM example with the EASY-DRIVER module in OFF state:

MRM:-1.872\r →

← #NAK\r

MRM example with the EASY-DRIVER module ON and not ramping:

MRM:3.1234\r →

← #AK\r

5.3.9 "MRSR" Command

The 'MRSR\r' command returns the value of the power supply actual ramp slew rate setting.

Replies from the EASY-DRIVER power supply to this command are in the following format:

#MRSR:value\r

where:

- *value* is the used Slew Rate for ramp [A/s].

Example:

MRSR example with the EASY-DRIVER module in OFF state:

MRSR\r →

← #MRSR:10.0000\r

5.3.10"MWSR" Command

The 'MWSR' command is used to set the value of the ramp slew rate:

#MWSR:value\r

where:

- *value* is the Slew Rate for the ramp [A/s].

The accepted slew rate values are in the range [0-1000]. The start-up slew rate value is the one that is set in the EEPROM memory.

Example:

MWSR example:

5.3.11"MRP" Command

The 'MRP\r' command returns the value of the bulk power supply actual voltage, i.e. DC Link, measured at the EASY-DRIVER module input terminals.

Replies from the power supply to this command are in the following format:

#MRP:value\r

where:

- *value* is the measured DC Link voltage [V].

This value is presented to the user only with 10 mV resolution.

The MRP command, being a reading command, returns a response in any module condition.

Examples:

MRP example:

5.3.12"MRT" Command

The 'MRT\r' command returns the value of the temperature directly measured on an output stage MOSFET heatsink.

This value is presented to the user with a 0.01 °C (= 0.01 K) resolution.

Replies from the EASY-DRIVER power supply to this command are in the following format:

#MRT:value\r

where:

- *value* is the temperature value [°C = Celsius] measured on a MOSFET stage heatsink.

The MRT command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRT example:

MRT\r →

← #MRT:32.8\r

5.3.13"MRTS" Command

The 'MRTS\r' command returns the value of the temperature directly measured on the regulation shunt resistor case.

This value is presented to the user with a 0.01 °C (= 0.01 K) resolution.

Replies from the power supply EASY-DRIVER controller to this command are in the following form:

#MRTS:value\r

where:

- *value* is the temperature value [°C = Celsius] measured on the regulation shunt resistor case.

The MRTS command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRTS example:

5.3.14"MRV" Command

The 'MRV\r' command returns the readback value of the power supply actual output voltage, measured at the EASY-DRIVER module output terminals.

As for the output current, voltage readback values have a 20-bit resolution (19-bit + sign) and they are presented with a 5-digit precision.

Replies from the power supply controller to this command are in the following form:

#MRV:value\r

where:

- *value* is the output voltage readback [V], measured at the module output terminals.

The MRV command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRV example when the module is OFF:

MRV\r →

← #MRV:+0.00012\r

MRV example when the module is ON and regulating output current:

MRV\r →

← #MRV:-8.34563\r

5.3.15 "MST" Command

The 'MST\r' command returns the value of the power supply internal status register (8 bit).

Replies from the EASY-DRIVER power supply to this command are in the following format:

#MST:value\r

where:

- *value* is the ASCII representation of the internal status register value, composed by 2 hexadecimal digits, and corresponding to the 8-bit wide status register.

The MST command, being a reading command, returns a response in any module condition.

Examples:

MST example with the module ON:

MST\r →

← #MST:01\r

MST example with the module OFF and experienced a fault after MOSFET over-temperature:

MST\r →

← #MST:0A\r

5.3.16 "MVER" Command

The 'MVER\r' command returns information about the EASY-DRIVER module currently installed firmware version.

The response to an 'MVER\r' command is in the following format:

#MVER:EASY-DRIVER:mod:DSP_ver\r

where:

- *mod* is the EASY-DRIVER model type – e.g. "0520" or "1020";
- *DSP_ver* is the DSP firmware versions currently installed on the module.

It is important to notice that EASY-DRIVER modules include two firmware versions – one for the communication DSP one for the control DSP – keep them up to date by checking for updates/upgrades on the website (www.caenels.com). Every time a DSP firmware is updated, the entire firmware package assumes the same version number.

The MVER command, being a reading command, returns a response in any module condition.

Examples:

MVER example for a 10A-20V module with firmware version 1.1.2 installed:

MVER\r →

← #MVER:EASY-DRIVER:1020:1.1.2\r

5.3.18 "MWG" Command

The 'MWG' command lets users write a desired "value" (cell_content) item in a defined EEPROM cell.

The correct form format for this command is as follows:

MWG:cell_num:cell_content\r

where:

- *cell_num* is the EEPROM cell number;
- *cell_content* is the ASCII content to be written to the EEPROM cell *cell_num*.

This "value" section of the EEPROM is used to store descriptive calibration parameters, identification, thresholds, etc. Only some cells can be overwritten – please refer to **Table 4**.

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated when:

- the cell number *cell_num* is out-of-range;
- the selected cell is read only;

Examples:

MWG example of a correct write (cell 13 is user accessible):

MWG:13:0.055\r →

← #AK\r

MWG example (cell 1 is read only):

MWG:1:15.234\r →

← #NAK\r

Note:

In order to make changed parameter effectively updated and in operation it is necessary to send the MPUP command to the EASY-DRIVER module first, see 'MPUP Command' Section for more information.

5.3.19"MPUP" Command

The parameters stored in the EEPROM that are essential for the operation of the power supply like calibration parameters, thresholds values, PID values, are loaded in DSPs at start-up. After a modification of any cell of the EEPROM to effectively update and make operative the new value it is possible to use the 'MPUP\r' command either than reboot the EASY-DRIVER.

Replies from the EASY-DRIVER to 'MPUP\r' command are in the form '#AK\r' when the command is correctly executed.

This command must be used when the output of EASY-DRIVER is in OFF mode.

Examples:

MPUP example when the EASY-DRIVER module is OFF:

MPUP\r →

← #AK\r

MPUP example when the EASY-DRIVER module output is enabled:

MPUP\r →

← #NAK\r

5.3.20"MWI" Command

The 'MWI' command can be used to set the output current value and it is used when fast set-point changes are needed.

The use of this command is alternative to the MRM (Module RaMping): the power supply reaches the desired output current value just using the PID regulator parameters, without ramping with the pre-defined slew rate to the new set-point.

This command is usually needed when running feedback-related applications and for small changes in the output current.

The correct form format for this command is as follows:

MWI:value\r

where:

- *value* is the desired output current value [A].

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated, as it is for the MRM command, when:

- the set *value* is out-of-range (the maximum settable current value is user-defined and stored in EEPROM cell 4);
- the module is OFF (it is necessary to turn the module ON first);

Examples:

MWI example with the module OFF:

MWI:-2.5569\r →

← #NAK\r

MWI example with the module ON and already regulating:

MWI:3.50\r →

← #AK\r

It is very important to notice that, even if the module is ON and regulating the output current correctly, an MWI command can generate a voltage clamping intervention if the current change step is too large and the PID parameters are not well matched for the particular load.

6. IP Address Configuration

In order to correctly configure the IP address remotely after the EASY-DRIVER module has been shipped there are two possible ways:

- the DeviceInstaller® software;
- a basic Telnet connection to Port 9999;

Please note that all modules are shipped with a standard IP address:

- **192.168.0.10**

It is very important, before running the IP address configuration procedure, to set the host machine – i.e. PC – address to "static" and its IP to 192.168.0.X (X is different from 10).

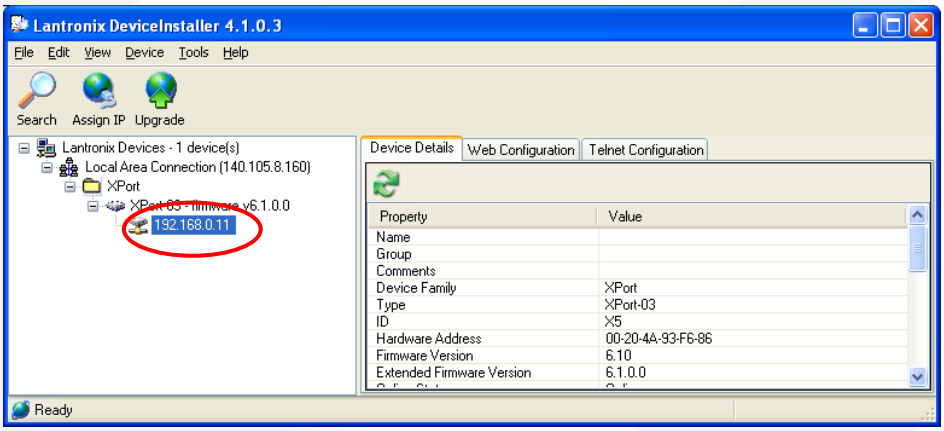
Standard communication port for the Ethernet device is 10001.

6.1 DeviceInstaller® Software

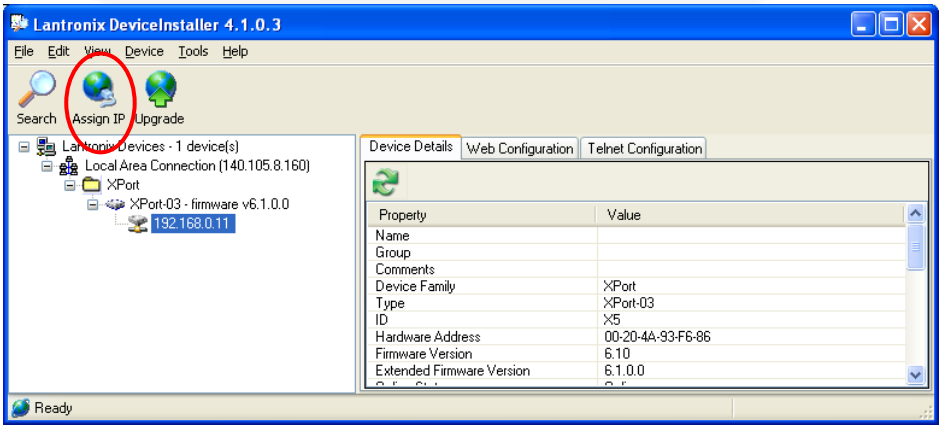
The DeviceInstaller® software can be downloaded from the Lantronix website www.lantronix.com and the Telnet connection can be established either using the software itself or a simple command line socket (on all operating systems). The EASY-DRIVER power supplies can be connected to a global LAN or point-to-point (recommended in order to obtain minimum delays, maximum speed performance and to avoid possible communication problems). Please note that for a point-to-point direct connection a twisted Ethernet cable must be used.

The next few steps must be followed in order to assign a new IP address to the module:

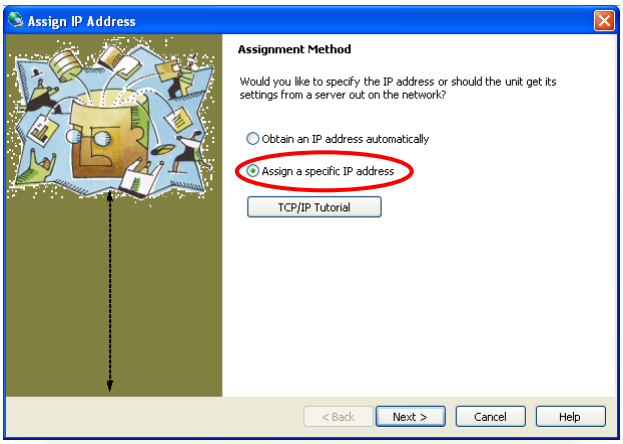
- Connect to the EASY-DRIVER unit with a twisted Ethernet cable;
- Verify that the "Link LED" on the RJ45 connector is turned on (amber for a 10Mbps connection or green for a 100Mbps connection);
- Launch the "DeviceInstaller" program;
- Select the XPort device that you want to change the IP address to;



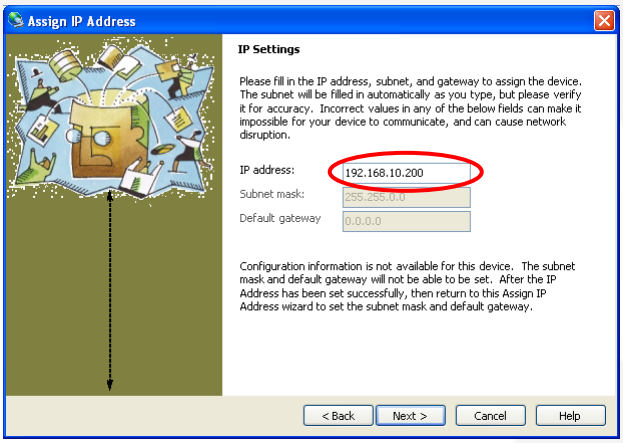
- Click on the "Assign IP" icon;



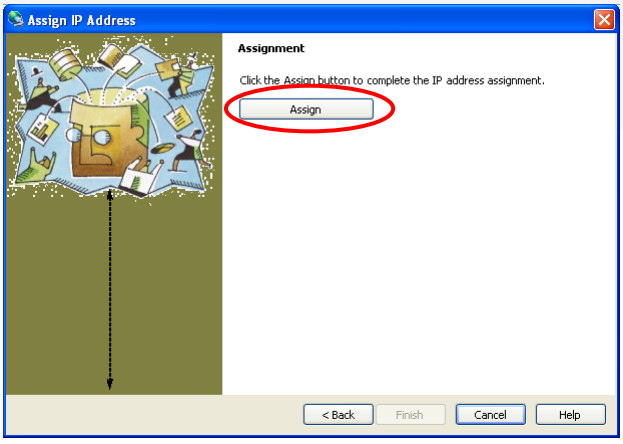
- Select "Assign a specific IP address" and then click "Next";



- Complete the "IP address" field and click on "Next";



- Click on the "Assign" button;



- Wait for the assignment procedure to end, and then click "Finish".

  The new module IP address should now be assigned and the success of the operation can be verified on the "DeviceInstaller" main window (if the window does not refresh, click on "Search").

7. EASY-DRIVER Remote Reboot

The EASY-DRIVER module can be rebooted either locally (by pushing the RESET button on the front panel) or remotely.

The procedure to remotely reboot the module is the following:

A. Establish a UDP connection with the EASY-DRIVER on the **port 30704**

B. write to the module port the following 9-bytes commands, separated with 100ms waits:

- 0x 19 04 00 00 00 04 00 00 00
- wait 100ms
- 0x 1A 04 00 00 00 00 00 00 00
- wait 100ms
- 0x 1B 04 00 00 00 00 00 00 00
- wait 100ms
- 0x 1B 04 00 00 00 04 00 00 00

C. now the module should turn on again and will be ready for operation in about 5s.

It is important to notice that after executing point C., connection to port 30704 must be closed and, in order to correctly operate the power supply again, a new connection to the EASY-DRIVER module IP address standard port - i.e. 10001 - must be established.

The reboot process here describe will not reboot the Ethernet to Serial converter (XPort). Reboot of the XPort device can be done only by a power cycle, i.e. switching Off and On the main switch.

8. Technical Specifications

Technical Specifications for EASY DRIVER power units are hereafter presented.

	EASY-DRIVER			
	"0520" Model	"1020" Model	"0220" Model	"0112" Model
Output current range	± 5 A	± 10 A	± 2 A	± 1 A
Output voltage range	± 20 V			± 12 V
Maximum output power	100 W	200 W	40 W	12 W
Maximum Efficiency (typ.)	> 65%	> 80 %	> 50 %	> 20 %
Topology	Bipolar			
Current setting resolution	16 bit			
Output current readback	20 bit			
Output voltage readback	20 bit			
Output current ripple on resistive load (RMS) – in ppm/FS	< 100	< 40	< 200	< 100
Output current stability	< 40 ppm / FS typical			
Thermal Coefficient	< 40 ppm / FS			
Switching Frequency	> 100 kHz			
Closed Loop Bandwidth	1 kHz			
Accuracy	< 0.05%			
External Interlocks/States	1 Input: magnet fault 1 Output: power supply status			
Internal Interlocks	DC Link Under-Voltage MOSFETs Over-Temperature Shunt Over-Temperature			
Hardware protections	Input Fuses Passive Crowbar (Over-Voltage)			

Auxiliary ADC Read-Backs (12 bit resolution)	DC-Link Voltage MOSFETs Temperature Shunt Temperature
Cooling	Forced Air Convection – Front-to-Rear
Drivers	EPICS
Connection	Ethernet 10/100 Mbit TCP-IP
Extra-Features	User-settable Slew Rate Value Firmware Remote Update
Dimensions	19" × 1U × 264 mm 19" × 1U × 295 mm - *with output connector*
Input Nominal Voltage	100-240 VAC 50-60 Hz 300 W MAX
Input Range Voltage	90-260 VAC 50-60 Hz 300 W MAX
Input Fuses	2 x T5AL250V (20 x 5 mm)

Table 9: EASY-DRIVER Main Technical Specification

8.1 Custom Models Technical Specifications

Technical Specifications for EASY DRIVER custom power units are hereafter presented:

	EASY-DRIVER
	"1020 C001" Model
Output current range	± 10 A
Output voltage range	± 20 V
Maximum output power	200 W
Maximum Efficiency (typ.)	> 80 %
Topology	Bipolar
Current setting resolution	16 bit
Output current readback	20 bit
Output voltage readback	20 bit

Output current ripple on resistive load (RMS) – in ppm/FS	< 40
Output current stability	< 40 ppm / FS typical
Thermal Coefficient	< 40 ppm / FS
Switching Frequency	> 100 kHz
Closed Loop Bandwidth	1 kHz
Accuracy	< 0.05%
External Interlocks/States	1 Input: magnet fault via external 24V 1 Output: power supply status
Internal Interlocks	DC Link Under-Voltage MOSFETs Over-Temperature Shunt Over-Temperature
Hardware protections	Input Fuses Passive Crowbar (Over-Voltage)
Auxiliary ADC Read-Backs (12 bit resolution)	DC-Link Voltage MOSFETs Temperature Shunt Temperature
Cooling	Forced Air Convection – Front-to-Rear
Drivers	EPICS
Connection	Ethernet 10/100 Mbit TCP-IP
Extra-Features	User-settable Slew Rate Value Firmware Remote Update
Dimensions	19" × 1U × 264 mm 19" × 1U × 295 mm - *with output connector*
Input Nominal Voltage	100-240 VAC 50-60 Hz 300 W MAX
Input Range Voltage	90-260 VAC 50-60 Hz 300 W MAX
Input Fuses	2 x T5AL250V (20 x 5 mm)

Table 10: EASY-DRIVER custom models Main Technical Specification

9. Mechanical Dimensions

Mechanical dimensions of the EASY-DRIVER power supply crate are hereafter shown (all dimensions in mm):