CT-BOX

Digital Current Measurement & Calibration System

ELUCS

DC Current Transducers

CAENels
Gear For Science

User's Manual

PRECISION CURRENT TRANSDUCERS

Rev.3 - January 2025

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EU DECLARATION OF CONFORMITY

Product:

Current Transducer Box – Digital Current Measuring System
CAEN ELS s.r.l. – Current Transducer Box
CT-Box series

CT-Box-100
CT-Box-150
CT-Box-200
CT-Box-300
CT-Box-400
CT-Box-600
CT-Box-1000

Manufacturer:

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This declaration of conformity is issued under the sole responsibility of the manufacturer.

Object of the Declaration:
Digital Current Measuring System
Brand: CAEN ELS s.r.l.
Model Family: CT-Box

The object of the declaration described above is in conformity with the relevant Union harmonisation legislation:

2014/30/EU relating to electromagnetic compatibility
2014/35/EU relating to the making available on the market of electrical equipment designed for use within certain voltage limits

References to the relevant harmonised standards used or references to the other technical specifications in relation to which conformity is declared:

EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use - EMC requirements.
EN 61010-1:2010 Safety requirements for electrical equipment for measurement, control, and laboratory use -- Part 1: General requirements.

Signed for and on behalf of: CAEN ELS s.r.l.

Trieste –January 29th, 2025

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Document Revision	Date	Comment
0.9	June 23th 2015	Draft release
1.0	January 28th 2016	First Release
1.1	December 23rd 2016	Address Changed
1.2	February 8th 2017	New technical specifications added as from recent tests
1.3	December 10th 2017	New features added
1.4	March 13th 2018	Data Representation section corrected
1.5	April 8th 2019	Aligned with 2.xxx FW
1.6	September 28th 2021	New features added
1.7	March 18th 2022	FW upgrade section
1.8	November 23rd 2022	Added UKCA compliance logo
2	August 8th 2024	Updated address and revision numbering
3	January 29th 2025	Updated disposal instructions Add EU Declaration of Conformity

Safety information - Warnings

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

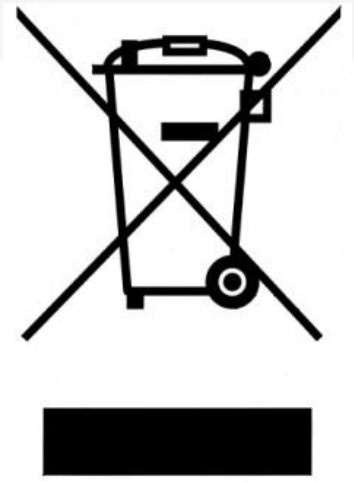
Do NOT open the boxes.

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

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

Disposal of the Product

This device contains a non-rechargeable, non-replaceable button cell battery. The disposal of the equipment must be managed in accordance with Directive 2012/19/EU on waste electrical and electronic equipment (WEEE). The crossed bin symbol indicates that the device must not be disposed of with regular residual waste. Use authorized collection points to ensure proper disposal and minimize environmental impact.



Read over the instruction manual carefully before using the instrument.
The following precautions should be strictly observed before using the CT-BOX device:

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

CAUTION

- This instrument is designed for indoor use and in area with low condensation.

The following table shows the general environmental requirements for a correct operation of the instrument:

Environmental Conditions	Requirements
Operating Temperature	10°C to 40°C
Operating Humidity	30% to 85% RH (non-condensing)
Storage Temperature	-10°C to 60°C
Storage Humidity	5% to 90% RH (non-condensing)

1. Introduction

This chapter describes the general characteristics and main features of the CT-BOX digital measuring solution.

1.1 The CT-BOX Measuring System

The CT-BOX by CAEN ELS is a stand-alone digital measuring system designed to measure DC and AC currents with high accuracy, wide-bandwidth, high precision and extremely high stability.

The system is developed to be used with the CAEN ELS the CT-series current output DCCTs, allowing high performance measurements of currents up to 1000 A. The device integrates temperature-stabilized components as a burden resistor, signal conditioning networks and a precision 24-bit ADC in order to have temperature dependence lower than 1 ppm/K. The digital section interfaced to the ADC performs a calibrated measurement in order to drastically reduce the non-ideal behavior thus providing a very high accuracy. The ADC sampling frequency can be configured up to 100 kHz which allows the acquisition of high frequency components and fast current transients for data analysis.

The CT-BOX is housed in a light, robust and extremely compact metallic box that can be also installed in 1U – 19" rack with the available optional mounting brackets.

The system is also equipped with a plug-and-play GUI acquisition software package called ***CT-BOX-Viewer*** that allows controlling, configuring and acquiring data from multiple units and via different interfaces. More information on the CT-BOX-Viewer operation can be found on the corresponding software guide.

1.2 The CT-BOX at a Glance

The CT-BOX unit and its I/O connections can be seen in the **Figure 1** (front) and in the **Figure 2** (rear).

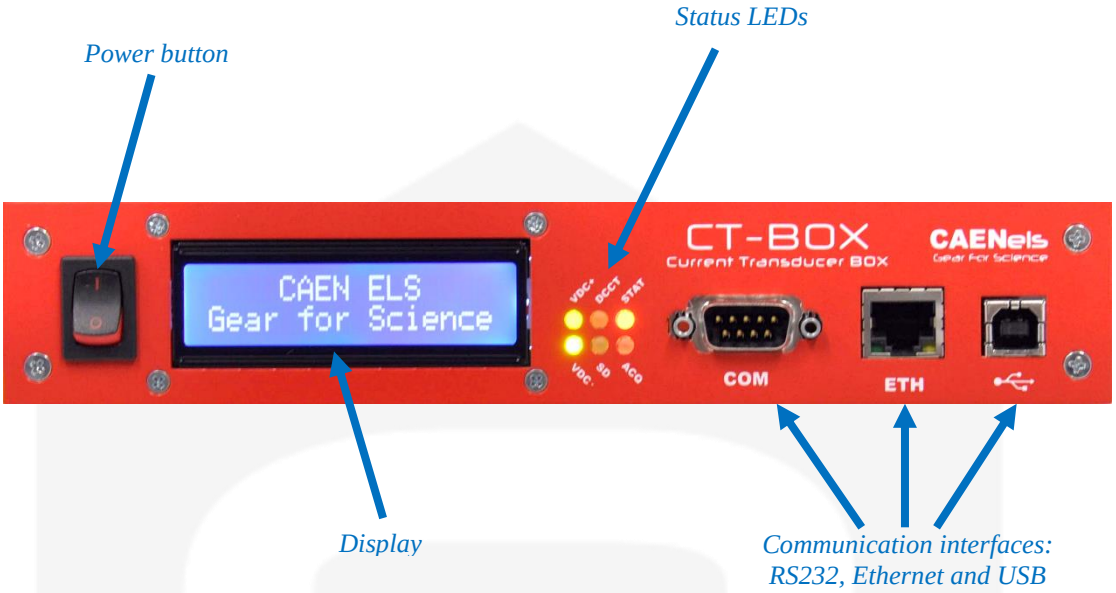


Figure 1: front view of a CT-BOX unit

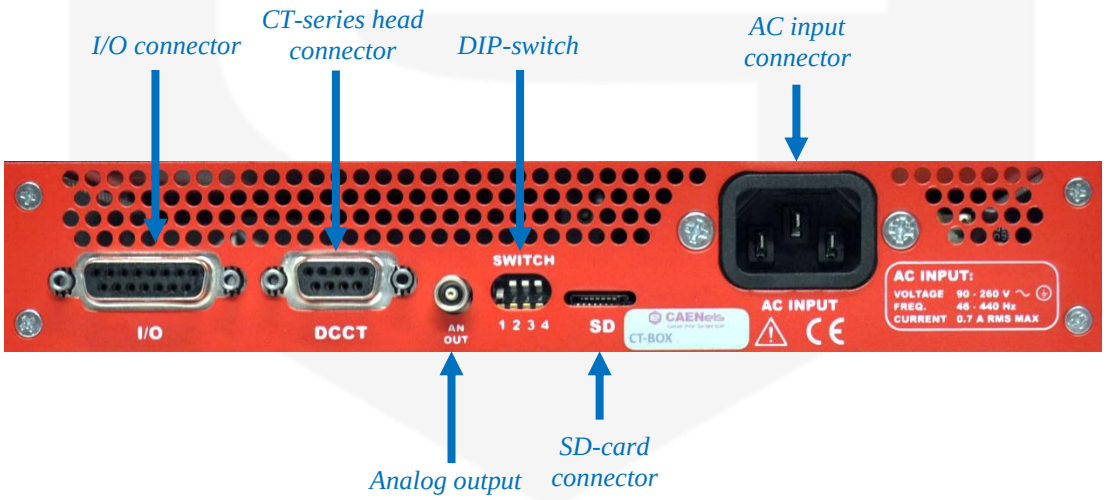


Figure 2: rear view of a CT-BOX unit

The power switch, display, status led indicators and communication connectors are placed on the front side of the CT-BOX unit. The power button is used to switch on or switch off the device. This switch does not fully disconnect the device from the mains power supply. The display shows useful information like the mode of operation, current

readings etc. In addition to the display there are also six LEDs that show the following information:

LED name	Description
VDC+	*Positive Voltage "Power good" LED:* *turned ON indicates that the +15V supply is correctly regulated*
VDC-	*Negative Voltage "Power good" LED:* *turned ON indicates that the -15V supply is correctly regulated*
DCCT	*DCCT presence LED:* *turned ON indicates that the correct DCCT is connected* *flashing indicates that the connected DCCT is not the calibrated one* *turned OFF indicates that the DCCT is not connected or it is faulty*
SD	*SD operation LED* *turned ON indicates that the SD card is in use*
STAT	*General status LED* *turned ON (and OFF shortly) indicates that a fault status occurred* *flashing indicates that the unit is working properly*
ACQ	*Acquisition LED* *turned ON indicates that the unit is acquiring and elaborating the measured data*

Table 1: Front LED description

All the communication connectors are present on the front panel. On the rear side of the unit are placed the I/O connector, the CT-series DCCT Head connector, analog output monitor, configuration DIP-switches, SD-card connector and the AC mains input connector. The I/O connector is an expansion connector that allows to connect an additional external temperature sensor, triggers and alarm. The CT-series connector is used to connect the CT-BOX unit with its calibrated CT-series DCCT head. The analog output monitor gives a voltage value, which is proportional to the measured current (the analog monitor has worse accuracy respect to the digital acquisition). The SD-card slot allows connecting an external SD-card to save measurement data (data-logger mode) and the DIP switch is used for firmware update and start-up mode configuration.

The AC power line input (extended range) is on the rear right side of the enclosure.

1.3 CT-BOX Versions

The CT-BOX unit is available in the following versions, depending on the maximum current measuring range:

Product Code	Ordering Code	Description
CT-BOX-100	WCTBOX100XAA	*100A Current Transducer Digital Box with Local Display and Ethernet, USB, RS-232 Communication Interfaces*
CT-BOX-150	WCTBOX150XAA	*150A Current Transducer Digital Box with Local Display and Ethernet, USB, RS-232 Communication Interfaces*
CT-BOX-200	WCTBOX200XAA	*200A Current Transducer Digital Box with Local Display and Ethernet, USB, RS-232 Communication Interfaces*
CT-BOX-300	WCTBOX300XAA	*300A Current Transducer Digital Box with Local Display and Ethernet, USB, RS-232 Communication Interfaces*
CT-BOX-400	WCTBOX400XAA	*400A Current Transducer Digital Box with Local Display and Ethernet, USB, RS-232 Communication Interfaces*
CT-BOX-600	WCTBOX600XAA	*600A Current Transducer Digital Box with Local Display and Ethernet, USB, RS-232 Communication Interfaces*
CT-BOX-1000	WCTBOX1000XA	*1000A Current Transducer Digital Box with Local Display and Ethernet, USB, RS-232 Communication Interfaces*

Table 2: CT-BOX models

In addition it is possible to order optional mounting brackets for standard 19-inch cabinet installation as shown hereafter:

Figure 3: CT-BOX with mounting brackets for 1U – 19" cabinet

The ordering code for the additional mounting bracket is the following:

Product Code	Ordering Code	Description
CT-BOX-MB	WCTBOXMBXAAA	*CT-BOX Mounting Brackets for 1U - 19" cabinet installation*

Table 3: CT-BOX optional mounting brackets

1.4 Start Operation in 5 Steps

The CT-BOX can be operated straightforward following these simple steps.

1.4.1 Package Content

The CT-BOX bundle is composed of six different items. Please check that all the listed elements are present upon receipt of the package.

①

②

③

④

⑤

Manuals
FAT Report
User's CD
4-GB MicroSD card

⑥

The items shown are hereafter described:

① CT-BOX central unit;
② 0-FLUCS DCCT transducer/head;

③ AC power cord;
④ USB cable (type-A to type-B) and Ethernet cable (RJ-45 plugs);
⑤ Connection cable between CT-BOX central unit and 0-FLUCS DCCT transducer/head;
⑥ User's CD, Manuals, Factory Acceptance Test (FAT) and 4-GB MicroSD card;

The mounting brackets are optional and they need to be ordered separately (they are included in the package at the time of delivery only if included in the order).

1.4.2 Connect the CT-BOX

Please connect the CT-BOX central unit ① to the AC power line with the provided cable – i.e. item ③ - as shown hereafter.

Figure 4: AC power cord connection

Connect the DCCT transducer/head ② to the rear connector of the CT-BOX central unit ① with the dedicated cable (DE-9 to DE-9 cable – i.e. item ⑤).

Figure 5: Connection of the DCCT cable

Please be sure to secure the connector with the fixing screws on both ends of the cable.

1.4.3 Turn On the CT-BOX

Turn on the CT-BOX central unit ① by switching the power button on the front panel of the unit to "1" – i.e. ON – position.

Figure 6: Power switch ON position

Once the device powers up, the display and LEDs should turn on and light up.

1.4.4 *CT-BOX Viewer* Installation

Install the CT-BOX Viewer software included in the User's CD (item ⑥) or download the latest version from the corresponding product page on CAEN ELS website (www.caenels.com). Please keep software up to date by checking for new releases periodically.

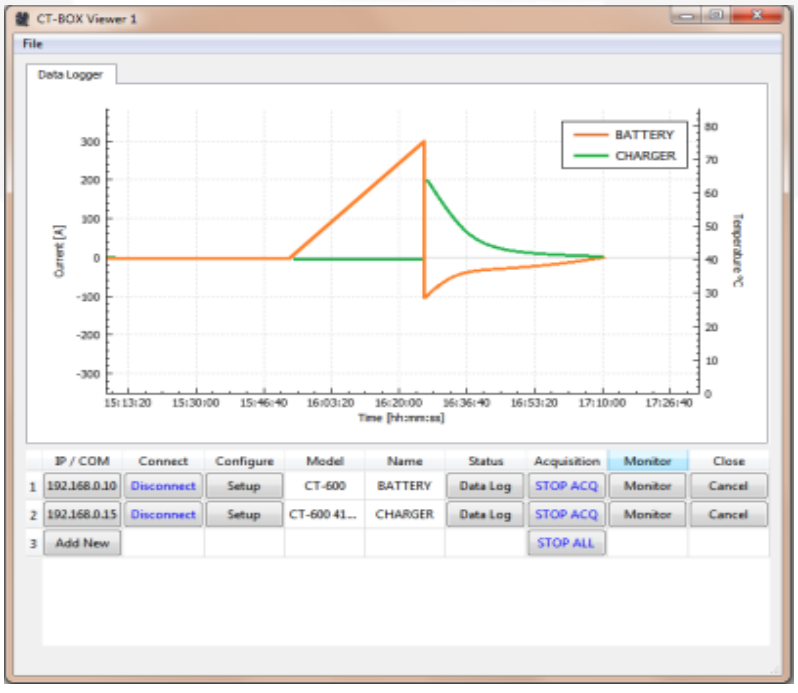


Figure 7: *CT-BOX Viewer* software application

Please refer to the "CT-BOX Viewer - Quick Start Guide" to check all features and capabilities of the control software.

1.4.5 Connect and Play

There are two suggested ways to communicate with the CT-BOX central unit, using the provided USB cable or a standard Ethernet connection. Both of them are described hereafter.

1.4.5.1 Ethernet Communication

Connect a standard Ethernet cable ④ between an external PC and the CT-BOX central unit ①.

Figure 8: Ethernet connection

Follow the instructions and communication settings presented in the section "Ethernet Interface" hereafter in this document.

1.4.5.2 USB Communication

Connect the USB cable (type-A to type-B) provided in the package (item ④) between an external PC and the CT-BOX central unit ①.

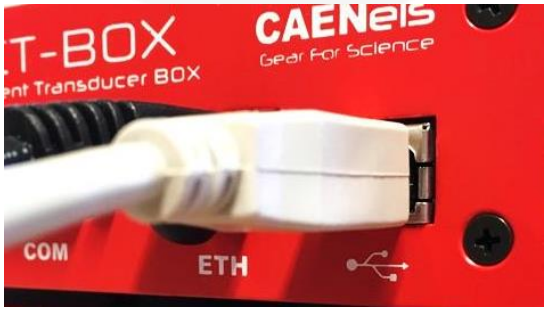


Figure 9: USB connection

Follow the instructions and communication setting presented in the section "USB Interface" hereafter in this document.

1.5 Start-Up Configuration

The CT-BOX unit can be configured to start-up (after a power cycle) with two different configurations:

- ***Saved*** configuration;
- ***Desktop*** configuration.

Please note that these two alternate configurations are only valid for start-up and they do not affect the other functionalities of the unit in any manner. These start-up modes can be set by a DIP switch placed on the rear side of the CT-BOX enclosure.

1.5.1 *Saved* Configuration

The CT-BOX starts with the last saved configuration that was configured to the device. The position of the DIP switch #4 of the rear panel needs to be set as shown hereafter (HIGH position):

Figure 10: *Saved* Configuration at start-up

The device will be configured directly at start-up with the last configuration – e.g. Data-logger or Oscilloscope mode, all other parameters. This allows to starting up the device with the last configuration that was set by the user.

1.5.2 *Desktop* Configuration

The CT-BOX starts with a standard configuration if the position of the DIP switch #4 of the rear panel is set as shown hereafter (LOW position):

Figure 11: *Desktop* Configuration at start-up

This configuration is extremely useful when there is the need to use the CT-BOX as a simple readout indicator of a current that needs to be measured as it could be in cases of direct measurement on the field or in laboratory desktop setups.

When configured and starting up in this *Desktop* mode the CT-BOX does not need any PC to be connected and it indicates the current readings directly on the display placed on the front side (as it gets internally configured as Data-Logger at 1-Hz acquisition frequency).

1.6 Temperature Stabilization

The CT-BOX unit has internal temperature-stabilized sections that allow obtaining almost negligible temperature dependence of the measurements. Dependence of the measurements from external ambient temperature are kept the best-in-class for this type of instruments and below 1 ppm/FS (FS = Full scale), equivalent to < 0.0001 %/FS.

Being the thermal stabilization a physical slow process by nature, an initial amount of time of 30 minutes is needed in order to be within the internal limits. All specifications of the unit are guaranteed after this initial period.

The CT-BOX unit is then continuously monitoring the temperature in the critical sections and the correct operation – i.e. temperature stabilization – is indicated by the status of the bit #6 of the internal Status Code ("ADC Temp OK"). Further information on this status code are presented hereafter in the document.

2. Software Commands

This chapter describes the software commands used for the communication with the CT-BOX unit. The CT-BOX is provided with the following communication interfaces:

- Ethernet TCP/IP 10/100 Mbit;
- UDP (only for output data stream in OSC mode);
- USB 2.0;
- RS232 interface with a fixed 115.200 baud rate.

The command structure is the same for all communication interfaces.
It is strongly suggested to use the standard Ethernet or the USB 2.0 interfaces, since they do not limit the throughput performance of the device; for the less-performing but simple RS232 serial interface – dg fixed baud rate at 115.200 bps – there are some restrictions.

The CT-BOX can be used only in data-logger mode when communicating via the RS232. For further information please refer to the following detailed command description.

2.1 Command Syntax

The CT-BOX commands and replies syntax is described in the following sections:

- **Commands to the CT-BOX** must be sent in ASCII format and are composed of a *"command field"* and one, two or none *"parameter fields"*, separated by a colon (*':'* or *'0x3A'* in hexadecimal notation). The number of *"parameter fields"* depends on the specific command. Commands are **NOT case sensitive** and therefore the command string can be sent either using uppercase or lowercase characters (conversion to uppercase characters is performed

internally by the CT-BOX unit). Each instruction must be terminated with a '*carriage return*' character '**\r**' (or *'0x0D'* in hexadecimal notation or commonly CR). A command example is hereafter described:

ACQ:ON\r

- *"**ACQ**"* is the command field;
- *':'* is the parameter's separation character;
- *'**ON**'* is the first parameter field;
- *'**\r**'* is the termination character of the command.

Commands are processed one at a time; therefore, **user must wait for a response from the unit before sending the next command**.

- **Replies FROM the CT-BOX** are all formatted in upper case and are terminated with the *'carriage return\line feed'* sequence ('**\r\n**'). The reply from the device depends on the specific command; for more information about the single command please refer to the specific command section.

  There are two specific replies commonly used and indicate if the command has been correctly elaborated or not. These replies are hereafter presented:

  - **ACK**nowledge (*'**ACK**'*) indicates that the command is valid and it was correctly elaborated by the device:

    ACK\r\n

    - *"**ACK**"* is the **ACK**nowledged response to a valid command;
    - *'**\r\n**'* is the termination sequence of the reply.

  - **N**ot **A**c**K**nowledge (*"**NAK**"*) indicates that the command is either not valid or that it was not accepted by the device; the *"NAK"* reply is followed by an *"error code"* field, which can be used to determine the cause of the error (see the appendix for a detailed list of all possible error codes):

    NAK:2:1\r\n

    - *"**NAK**"* is the **N**ot **A**c**K**nowledged response to an invalid command;
    - *':'* is the parameter's separation character;
    - *'2:1'* is a sample error code;

- ***'\r\n'*** is the termination sequence of the reply.

The list of commands used by the CT-BOX and the corresponding syntax is hereafter presented as well as a description of each command purpose and any special requirements related to the specific command. The commands are described and grouped in categories based on their purpose.

Two modes of operation can be selected for the measurement purposes:

- **OSCILLOSCOPE mode** allows to obtain the measurements up to 100 kHz, thus letting to acquire high frequency components and fast current transients. In this mode the data can be read using the communication interfaces, the data saving to the SD card is not allowed. The measurements are sampled at 100 kHz. If such speed is not needed, it is possible to reduce the acquired data frequency down to 1 Hz using the sampling time command (TS command). If Ethernet is used as communication interface, data is streamed out using UPD protocol.

- **DATA-LOGGER mode** is dedicated for long-time acquisition with a slower sampling rate. The current measurements can be read using the communication interface and/or can be stored on the connected SD card. Optionally it is possible also to read and/or store also the temperature of the head and/or the external temperature (which can be measured using an external sensor attached to the expansion connector on the back of the CT-BOX unit). In this mode of operation, the acquisition frequency can be set in the range 0.1 Hz – 10 Hz using the FREQ command.

The difference in the operation of the two available modes is summarized in the following table:

Parameter	Oscilloscope mode	Data-Logger mode
Sampling frequency	1 Hz – 100 kHz	0.1 Hz – 10 Hz
Data representation	Binary	ASCII
Representation length	Fixed	Variable
Acquisition values	Status, index, current	Index, status, current, 2 optional temperatures
Saving data to the SD card	Not allowed	Allowed

Table 4: Compilation between the two modes of operation

The two different modes of acquisition use different settings so the CT-BOX commands are organized as follows:

- General purpose commands, that are used in both acquisition modes. This type of commands are marked with the following yellow icon:

- Oscilloscope commands, that are used only in oscilloscope mode of operation, are marked with the following blue icon:
- Data-logger commands, that are used only in data-logger mode of operation, are marked with the following green icon:

2.1.1 Data Representation

The data representation depends over different parameters, such as the acquisition mode and other related settings. In the following paragraphs the various data representations are described in detail:

- **OSCILLOSCOPE mode:** in this mode of operation the data can be acquired at a very high rate (up to 100 kHz). To optimize the communication bandwidth and to reduce the computational time required to elaborate the received data, the acquisition is represented in binary format. The binary representation improves the data rate transmission as it avoids the overhead due to the ASCII format conversion and reduces the amount of sent data. Every acquisition at selected sampling frequency is represented with three numbers at fixed length of 64 bits (8 bytes):

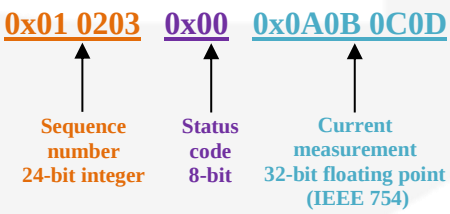


Figure 12: Data representation in the oscilloscope mode

Note that sequence number and current measurements are sent least significant byte first. For example above, the datagram socket would actually read the data from receiving buffer in the following order:

0x03 0x02 0x01 0x00 0x0D 0x0C 0x0B 0x0A

The first 24 bits number (3 bytes) represent the sequence number, starting from #1 (0x00 0001), which is reset at every acquisition (the acquisition can be started and terminated by the ACQ command). This number is

represented in unsigned binary format, so for example: **0x00 001F** represents the acquisition #31.

The fourth byte represents the status code of CT-BOX. The bit meanings are shown in the following table (#8 is the MSB):

Status Code Bit #	Bit Name	Description
#1	**No Error**	*CT-BOX is acquiring correctly*
#2	**DCCT Head Fault**	*The DCCT Head has experienced a fault*
#3	**Buffer Overrun**	*The CT-BOX cannot send data to the host computer*
#4	**SD-Card Full**	*The SD-Card is full and no data can be saved*
#5	**SD Error**	*Error in writing file on SD-Card*
#6	**ADC Temp OK**	*The temperature of the CT-BOX is OK*
#7	**Alarm**	*The current is outside the limits*
#8	**Alarm Direction**	*If this bit is high then the current is over the limit, if low then it is under the limit*

Table 5: Status code

The third 32-bit number (4 bytes) indicates the measured current in Ampere [A] represented as single precision floating point number (IEEE 754), so for example the hex number **0x4120 0000** represents +10 A. The structure of each 32-bit (4 bytes) single floating precision number IEEE 754 is in the following format:

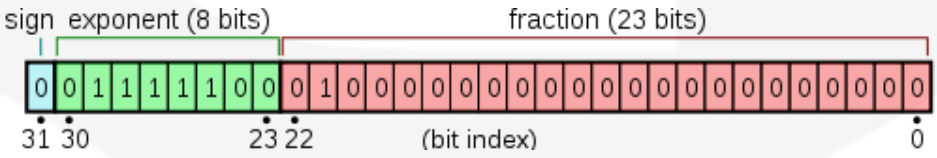


Figure 13: IEEE 754 standard – float unit

This is the only possible representation in the oscilloscope mode. The acquisition speed is settable using the TS command. In this mode of operation, the data can be only sent to the communication stream. If the data saving to the SD card is not allowed, due to the high acquisition speed.

- **DATA-LOGGER mode:** this mode of operation is suitable for longer data acquisitions with lower acquisition speed. The acquisitions are represented with 3 numbers separated by a space character '\s' and every acquisition is terminated with two termination characters - carriage return, line feed '\r\n':

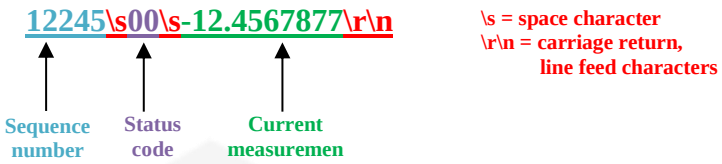


Figure 14: Data representation in Data-Logger mode

The example above indicates an example of a single acquisition, where the acquisition sequence number in ASCII decimal format is 12245, the status code in ASCII hexadecimal format is 00 and the measured current in ASCII decimal format is -12.4567877 Ampere. The non-printing characters are displayed in red. The structure of the status code is represented in Table 5.

Due to the lower acquisition speed, it is possible to acquire not only the measured current, but also additional temperature information (optional fields). For this reason, the data representation depends also on the number of additional temperature fields (none, one or two). The number of additional temperature fields can be selected with the ACQT command. Also in this case the values are separated by a space '\s' and every acquisition is terminated with carriage return/line feed characters '\r\n'. In the following picture a simple example is represented with 2 temperature fields enabled:

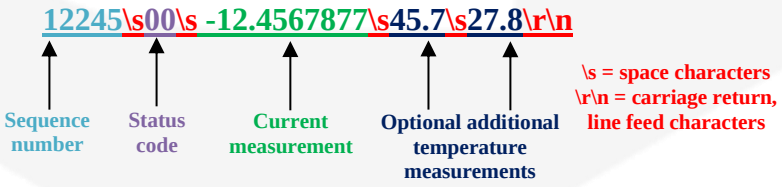


Figure 15: Data representation with two external temperature measurement

The first value field indicates the acquisition sequence number in ASCII integer decimal representation. This value is reset ad every acquisition start. The second 8-bit field represents the status of the CT-BOX as described in the Oscilloscope mode. The third, fourth and fifth numbers represent the measurements in ASCII fractional decimal representation. The current is represented in Ampere [A] and the optional temperature(s) in degree Celsius [°C].

The acquisitions in the Data-logger mode have a variable character's length. For additional information regarding the optional temperature fields, please see the ACQT command.

2.2 Basic Commands

The basic CT-BOX commands are described in this section. These commands allow to operate all standard acquisition functions and to access the regular functionalities of the CT-BOX device.

2.2.1 MODE Command 

The MODE command allows selecting the mode of operation of the CT-BOX device. Two modes of operation can be selected for the measurements acquisition:

- **Oscilloscope:** this mode of operation allows to obtain the measurements up to 100 kHz, letting to acquire high frequency components and fast current transients;
- **Data-logger:** this mode of operation is ideal for long-time acquisition with a slower sampling rate; in this mode of operation is allowed to save the data on the SD card.

The commands to select the mode of operation are the following:

- "MODE:OSC\r" to select the Oscilloscope mode;
- "MODE:DLOG\r" to select the Data-logger mode.

The device replies with acknowledge ("ACK\r\n"), when the command is correctly interpreted; otherwise if the command is not accepted, the unit replies with a "NAK:*x*:*y*\r\n" string, where the *"x:y"* field indicates the error code (see the List of Error Codes appendix).

The command used to read the actual MODE setting is: "MODE:?\r". The reply to the read command is in the following form: "*acquisition_mode*\r\n", where *acquisition_mode* is "OSC" for Oscilloscope mode and "DLOG" for Data-logger mode.

MODE Command: (MODE:*parameter*\r)

Parameter	Command description	Type of command	Return value
OSC	Set the device in Oscilloscope mode	Set	ACK
DLOG	Set the device in Data-logger mode	Set	ACK
?	Read the device acquisition mode	Read	OSC - when the device is in Oscilloscope mode DLOG – when the device is in Data-logger mode

Table 6: MODE command

Examples:

MODE example for Oscilloscope mode set:

MODE:OSC\r →

← ACK\r\n

MODE read example:

MODE:?\r →

← OSC\r\n

2.2.2 GET Command

The purpose of the GET command is to read back the actual measured current. The syntax of the command is the following: "GET\r". The returned data depends on the selected mode of operation and the relative sampling period. The format of the returned measurement is always expressed in **ASCII floating number** with 7 decimals numbers in Ampere [A] with the '\r\n' termination characters.

GET Command: (GET\r)

Command description	Type of command	Return value
Get the current reading	Read	Current value in Amps

Table 7: GET command

Example:

GET example:

GET\r\n →

← -14.1234567\r\n

2.2.3 GETT Command

The purpose of the GETT command is to read the temperature of the CT-sensor head or of the connected external temperature sensor. For more information regarding the external temperature sensor, see the CT-BOX overview chapter.

The syntax of the command is the following:

- "GETT:HEAD\r" to read the temperature of the CT-sensor head and
- "GETT:EXT\r" to read the temperature of the external temperature sensor. If the external sensor is not connected the value -9999.0 is returned.

The format of the returned temperatures is always expressed in **ASCII floating number** with one decimal number in Celsius [°C] with the '\r\n' termination characters.

GETT Command: (GETT:*parameter*\r)

Parameter	Command description	Type of command	Return value
HEAD	Read the temperature of the CT-sensor head	Read	Temperature value in Celsius
EXT	Read the temperature of the external temperature sensor	Read	Temperature value in Celsius

Table 8: GETT command

Examples:

GETT head temperature read example:

GETT:HEAD\r →

← 36.7\r\n

GETT external sensor temperature read example:

GETT:EXT\r →

← 25.3\r\n

2.2.4 ACQ Command

The ACQ command starts or stops the current measurements acquisition from the CT-BOX device. This command can be used in both modes: Oscilloscope and Data-logger. The instrument starts to acquire the measurements as soon as the command "ACQ:ON\r" is received. A stop command "ACQ:OFF\r" has to be sent in order to terminate the data acquisition. At power-up of the device the acquisition is not active.

When the ACQ command is correctly processed, the unit replies with the acknowledge ("ACK\r\n"); otherwise if the command is not accepted, the unit replies with a "NAK:*x:y*\r\n" string, where the *"x:y"* field indicates the error code (see the Error Codes appendix).

The command used to read the actual ACQ status is: "ACQ:?\r". The reply to the read command is in the following form: "*acquisition_status*\r\n", where *acquisition_status* is "ON" when the device is acquiring the data and "OFF" when the acquisition is stopped.

ACQ Command: (ACQ:*parameter*\r)

Parameter	Command description	Type of command	Return value
ON	Start the measurements acquisition	Set	ACK
OFF	Stop the measurements acquisition	Set	ACK
?	Read the acquisition status	Read	ON – the device is acquiring the data OFF – the acquisition is stopped

Table 9: ACQ command

The data stream to the communication interface is visible only if the acquisition (ACQ) and printing (PRINT) are enabled. For more detail regarding the data representation see the Data Representation section.

Examples:

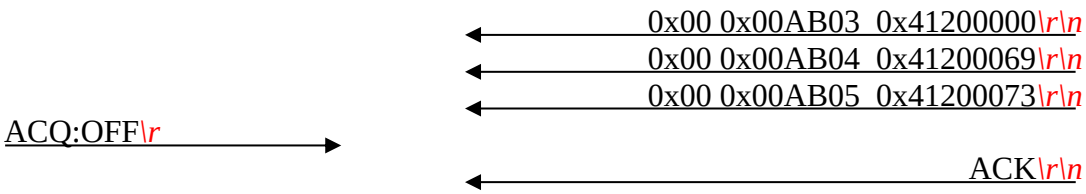
ACQ ON example in Oscilloscope mode with PRINT enabled:

ACQ:ON\r →

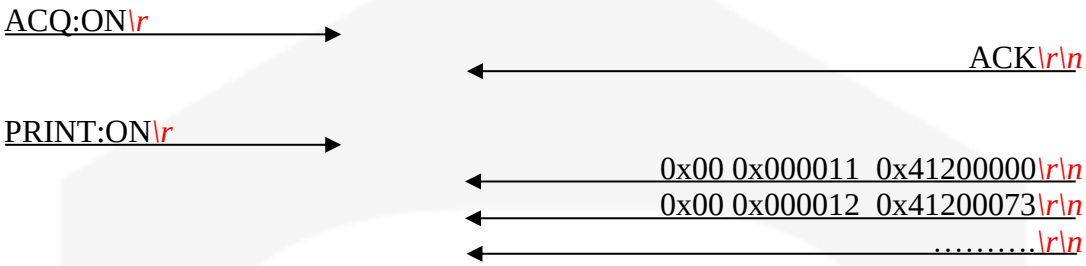
← ACK\r\n
← 0x00 0x000001 0x41200000\r\n
← 0x00 0x000002 0x41200000\r\n
← ……\r\n

ACQ OFF example in Oscilloscope mode with PRINT enabled:

← ……\r\n



ACQ ON example in Oscilloscope mode with PRINT enabled afterwards (note in this case the first acquisition 0x01 – 0x10 are not displayed, because the PRINT command is enabled afterwards):



2.2.5 PRINT Command

The PRINT command allows enabling or disabling the printing of the measured data to the communication stream. This command can be used in both modes: Oscilloscope and Data-logger. The printing to the communication stream is enabled as soon as the command "PRINT:ON\r" is received. A disable command "PRINT:OFF\r" has to be sent in order to stop the printing.

When the command is correctly processed, the unit replies with an acknowledge ("ACK\r\n"). If an error happened during the acquisition (for example a communication buffer overrun), the PRINT is automatically stopped. To resume printing, it is necessary to use the PRINT enable command.

The command used to read the actual PRINT status is: "PRINT:?\r". The reply to the print status read is in the following form: "*print_status*\r\n", where *print_status* is "ON" when the printing is enabled and "OFF" when the printing is disabled.

PRINT Command: (PRINT:*parameter*\r)

Parameter	Command description	Type of command	Return value
ON	Enable printing on the communication stream	Set	ACK
OFF	Disable printing on the communication stream	Set	ACK
?	Read the printing configuration	Read	ON –printing is enabled OFF –printing is disabled

Table 10: PRINT command

The communication stream is not related only on the PRINT Command, but it depends also on the ACQ Command, which is used to start or stop data acquisition. For example if the PRINT is enabled and the acquisition is disabled, the device will not send any data to the communication stream. For more detailed information, see the ACQ Command chapter.

Example:

PRINT example in Oscilloscope mode with acquisition enabled beforhand (note in this case the first acquisition 0x01 – 0x10 are not displayed, because the PRINT command is enabled afterwards):

PRINT:ON\r →

← ACK\r\n
← 0x00000011 0x41200000\r\n
← 0x00000012 0x41200073\r\n
← .....\r\n

2.2.6 TS Command

The TS (Time Sampling) command allows to set the time interval of the data sent to the used communication interface in **Oscilloscope mode**. This command does not affect the behavior of the Data-logger mode.

The allowed sampling time interval goes from 10 µs up to 1.000.000 µs (1s), with incremental step of 10 µs. Values with a different incremental step or outside this range are not accepted. For example, if a 0.5s interval is needed, then the sampling time has to be set to 500.000 µs.

The command "TS:*sampling_interval*\r" is used to set the sampling interval for the Oscilloscope mode, where *sampling_interval* is the time interval expressed in µs in the interval [10 – 1.000.000], with incremental step of 10. When the TS command is correctly processed, the CT-BOX replies with an acknowledge ("ACK\r\n").

The command used to read the actual TS setting is: "TS:?\r". The reply to the read command is in the following form: "*sampling_interval*\r\n", where *sampling_interval* is the time interval used for sending the data to the communication stream expressed in µs.

TS Command: (TS:*parameter*\r)

Parameter	Command description	Type of command	Return value
Sampling interval in µs	Set sampling time used in OSC mode	Set	ACK
?	Read sampling time used in OSC mode	Read	Sampling interval in µs

Table 11: TS command

Examples:

TS example to set the sampling time in oscilloscope mode to 50 µs (the data stream in this case will have the following frequency: 1/50 µs = 20 kHz):

TS:50\r →

← ACK\r\n

TS read:

TS:?\r →

← 50\r\n

2.2.7 FREQ Command

The FREQ command allows setting the acquisition frequency **in the Data-logger mode**. This command does not affect the behavior of the Oscilloscope mode. The Data-logger mode is suitable for long time acquisition. The command can accept the sampling frequencies in the following range: [0.1Hz – 10 Hz].

The command "FREQ:*sampling_freq*\r" is used to set the sampling interval for the Data-logger mode, where *sampling_freq* is the frequency expressed in Hz in the interval [0.1 – 10]. When the TS command is correctly processed, the CT-BOX replies with an acknowledge ("ACK\r\n").

The command used to read the actual FREQ setting is: "FREQ:?\r". The reply to the read command is in the following form: "*sampling_freq* \r\n", where *sampling_freq* is the acquisition frequency used to acquire the measurements in Data-logger mode (expressed in Hz).

FREQ Command: (FREQ:*parameter*\r)

Parameter	Command description	Type of command	Return value
Acquisition frequency	Set the Data-logger acquisition frequency	Set	ACK
?	Read the Data-logger acquisition frequency	Read	Acquisition freqcueny

Table 12: FREQ command

Examples:

FREQ example to set the acquisition frequency in Data-logger mode to 2.5 Hz:

FREQ:2.5\r →

← ACK\r\n

FREQ read:

FREQ:?\r →

← 2.5\r\n

2.2.8 ACQT Command

The ACQT (ACQuisition Temperature) command allows to set the number (one, two or none) and type of acquired temperature channels (CT-head and External sensor) in the **Data-logger mode**. This command does not affect the behavior of the Oscilloscope mode. As described in the Data representation chapter, in the Data-logger mode it is possible to acquire also the temperature of the CT-sensor head and/or the temperature of the external connected temperature sensors. This setting takes effect to the communication data stream and to the SD-card savings.

The command "ACQT:*xxx*\r" is used to set the temperature acquisition configuration, where *xxx* is a ASCII number filed, with the following structure:

- *'000'*: the optional temperature readings are disabled;
- *'010'*: External temperature sensor readings enabled;
- *'100'*: DCCT head temperature readings enabled;
- *'110'*: External sensor and DCCT head temperature readings enabled.

When the ACQT command is correctly processed, the CT-BOX replies with an acknowledge ("ACK\r\n").

The command used to read the actual ACQT setting is: "ACQT:?\r". The reply to the read command is in the following form: "*xxx*\r\n", where *xxx* is the ASCII number setting representing the temperature acquisition setting.

ACQT Command: (ACQT:*parameter*\r)

Parameter	Command description	Type of command	Return value
Two number ASCI setting	Set the number and type of the temperature acquisition setting	Set	ACK
?	Read the temperature acquisition setting	Read	Two number ASCI setting

Table 13: ACQT command

Examples:

ACQT example to enable the temperature acquisition only from the DCCT head:

ACQT:10\r →

← ACK\r\n

ACQT read example:

ACQT:?\r →

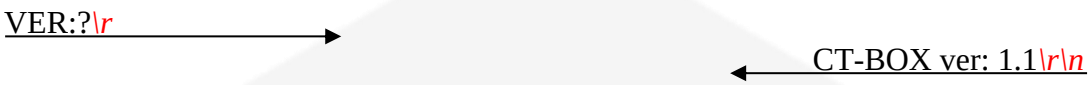
← 100\r\n

2.2.9 VER Command

The VER command allows to read the information about the CT-BOX firmware version. The reply to the "VER\r" command is in following format: "*firmware_release*\r\n", where *firmware_release* indicates the installed CT-BOX firmware release.

Example:

VER *example:*



2.2.10 CTBOX Command

The CTBOX command allows to read some information related to the CT-BOX unit and to set an identification name to the device.

The command "CTBOX:DES:?\r" can be used to read the serial number of the CT-BOX device. This command is factory defined and so it is read-only. The reply to this command is in following format: "*serial_number*\r\n", where *serial_number* indicates the unit serial number.

The command "CTBOX:NAME:*description*\r" can be used to set the user defined name or description to the CT-BOX device, where *description* is the name or description associated to the device. The maximum length of this field is 15 characters. When the command is correctly interpreted, the device replies with an acknowledge ("ACK\r\n"). This filed is useful to associate a user-defined name the case of a larger installation.

The command "CTBOX:NAME:?\r" can be used to read the user-defined description of the device. The reply to this command is in following format: "*name*\r\n", where *name* indicates the user-defined name or description of the CT-BOX unit.

CTBOX Command: (CTBOX:*parameter#1*:*parameter#2*\r)

Parameter #1	Parameter #2	Command description	Type of command	Return value
DES	?	Read the producer-defined serial number of the CT-BOX unit	Read	Fabric-defined serial-number of the CT-BOX unit
NAME	description	Set the user-defined CT-BOX name or description	Set	ACK
NAME	?	Read the user-defined CT-BOX name or description	Read	User-defined name or description of the CT-BOX unit

Table 14: CTBOX command

Exampes:

Read the CT-BOX serial number example:

CTBOX:SN:?\r →

← 150012\r\n

Set the CT-BOX user-defined name as "Dipole" example:

CTBOX:NAME:DIPOLE\r →

← ACK\r\n

Read the CT-BOX user-defined name example:

CTBOX:NAME:?\r →

← DIPOLE\r\n

2.2.11 DCCT Command

The DCCT command allows to read some information related to the DCCT Head connected to the device.

The command "DCCT:DES:?\r" can be used to read the model and serial number of the DCCT Head who is calibrated with the CT-BOX. Also this command is factory defined and so it is read-only. The reply to this command is in following format: "*model_serial_number*\r\n", where *serial_number* indicates the DCCT Head serial number.

The command "DCCT:MODEL:?\r" can be used to read the model and serial number of the DCCT Head currently connected to the CT-BOX. Also this command is factory defined and so it is read-only. The reply to this command is in following format: "*model_serial_number* \r\n", where *serial_number* indicates the unit serial number.

DCCT Command: (CTBOX:*parameter#*)

Parameter #1	Parameter #2	Command description	Type of command	Return value
DES	?	Read the fabric-defined DCCT Head match with	Read	Matched DCCT model and Serial number
MODEL	?	Read the fabric-defined DCCT Head model and Serial number	Read	Connected DCCT model and Serial number

Table 15: DCCT command

Examples:

Read the CT-BOX serial number example:

CTBOX:SN:?\r →

← 150012\r\n

2.2.12 PTURNS Command

The PTURNS (Primary Turns) command allows to set number of primary turns. The full-scale current can then be scaled by a factor of *N*, with *N* = number of turns of the primary conductor around the hole of the CT-sensor.

As an example: a primary full-scale current of 600 A can be easily scaled by a factor 2 (applying two primary turns – picture on the left), and so the obtained full-scale will be 300 A or by a factor 3 (applying three turns – picture on the right) and so the obtained full-scale will be 200 A. Do not apply rated nominal full-scale primary current (for example 600A for CT-600) when carrying out multiple turns on primary conductor hole.

The PTURNS command allows to configure the number of turns applied to the CT-sensor head in order to scale the CT-BOX readings by the factor of turns *N*. The factory defined number of turns is #1 (no turns applied to the primary conductor).

The command "PTURNS:*N*\r" sets the number of the turns (*N*) applied to the CT-sensor head in order to have the CT-BOX readings scaled by the same value of turns. The given value *N* has to be equal to the number of turns applied to the CT-sensor head. The accepted "number of turns" is in the range [1-100]. When the command is correctly interpreted, the device replies with an acknowledge ("ACK\r\n").

The command used to read the actual configured number of turns is: "PTURNS:?\r". The reply to the read command is in the following form: "*number_of_turns*\r\n", where *number_of_turns* is the configured number of turns.

PTURNS Command: (PTURNS:*parameter*\r)

Parameter	Command description	Type of command	Return value
Number of turns	Set the number of turns applied to the CT-sensor head	Set	ACK
?	Read the configured number of turns	Read	Number of turns

Table 16: PTURNS command

Examples:

PTURNS example to set the number of turns to 3:

PTURNS:3\r →

← ACK\r\n

PTURNS read:

PTURNS:?\r →

← 3\r\n

2.2.13 OFFSET Command

The CT-BOX device is already factory-calibrated during the production process. However, at power-up the device has a very small offset error (<10 ppm), due to the intrinsic magnetic properties of the DCCT technology. In order to have a very accurate measure it is possible to null also this offset. To perform the offset compensation it is necessary to execute the command "OFFSET:ZERO\r", **when the primary current is equal to 0** (no current is flowing through the CT-sensor). When the command is correctly interpreted the unit replies with an acknowledge ("ACK\r\n").

OFFSET Command: (OFFSET:*parameter*\r)

Parameter	Command description	Type of command	Return value
ZERO	Set the current measured current as zero of the CT-BOX device	Set	ACK

Table 17: OFFSET command

Example:

OFFSET compensation command example (the compensation has to be realized when the primary current is equal to 0):

OFFSET:ZERO\r →

← ACK\r\n

2.2.14 STATUS Command

The CT-BOX has an internal status register that shows the actual status and configuration of the instrument. The command used to read the status register is "STATUS:?\r". The reply to the read command is in the following form: "*status_register*\r\n", where *status_register* is the ASCII representation of the internal status register value. This is a read-only register.

The status register has the following structure, where the bit #32 is the MSB:

Bit #	Bit name	Description
#1	*ACQ status*	*Indicates that the unit is acquiring the data*
#2	*Error condition*	*Indicates that an error occurred (See Error register for more detailed information regarding the error).*
#3	*Alarm status*	*Indicates the alarm status (see Alarm command).*
#4	*Alarm direction*	*Indicates the direction of the alarm: it is high when an overcurrent event happened and low in case of an undercurrent event. This bit has sense only if the Alarm status is high.*
#5	*SD write*	*Indicates that the SD is used for saving the measured data.*
#6	*SD mounted*	*Indicates that the SD is mounted (See SAVE command for additional information).*
#16 - #7	*Reserved*	*For internal or future use.*
#17	*MODE setting*	*Indicates the status of the MODE setting (0 = Oscilloscope, 1 = Data logger).*
#19 - #18	*ACQT setting*	*Indicates the status of the ACQT setting:* *'000': the optional temperature readings are disabled;* *'010': External temperature sensor readings enabled;* *'100': DCCT head temperature readings enabled;* *'110': External sensor and DCCT head temperature readings enabled.*
#20	*Reserved*	*For internal or future use.*
#21	*PRINT setting*	*Indicates the status of the PRINT setting (1 = enabled).*
#22	*SAVE setting*	*Indicates the status of the SAVE setting (1 = enabled).*
#23	*ALARM setting*	*Indicates the status of the ALARM setting (1 = enabled).*
#24	*Trigger setting*	*Indicates the status of the TRG setting (1 = enabled).*
#25	*Trigger direction*	*Indicates the trigger direction (1= trigger out, 0 = trigger in).* *This bit has sense only if the Trigger setting is high.*
#32 - # 26	*Reserved*	*For internal or future use.*

Table 18: STATUS register structure

Example:

STATUS read (for example the read 0x110001 indicates that the ACQ status is enabled – bit #1 is 1; the mode of operation is oscilloscope – bit #17 is 1 and the PRINT is enabled – bit #21 is 1:

STATUS:?\r →

← 0x110001\r\n

2.2.15 ERR Command

The CT-BOX has an internal Error register that shows the eventual error status of the device that could occurred during the normal device operation. Reading this register allows to identify the actual error(s) of the device. The command used to read the error register is "ERR:?\r". The reply to the read command is in the following form: "*error_register*\r\n", where *error_register* is the ASCII representation of the internal control register value.

The error register has the following structure:

Bit #	Bit name	Description
#1	*SD mount error*	*Error in mounting the SD card.*
#2	*SD open error*	*Error in opening the SD card.*
#3	*SD write error*	*Error in writing on the SD card.*
#4	*SD sync error*	*Error in sync operation on the SD card.*
#5	*SD close error*	*Error in closing operation on the SD card.*
#6	*SD full error*	*Error that occurs when the SD card is full.*
#7 - #8	*Reserved*	*For internal or future use.*
#9	*DCCT head error*	*Indicates that the DCCT head is not connected or is not working properly.*
#10 - #16	*Reserved*	*For internal or future use.*
#17	*Buffer overflow error*	*A buffer overflow occurred. To solve this problem it is suggested to reduce the acquisition frequency.*
#18	*DCCT match error*	*Indicates that the DCCT head is not connected or that it is not calibrated together with the CT-BOX.*
#32 - #19	*Reserved*	*For internal or future use.*

Table 19: Error register structure

The bits of this registers act as latches so when an error occurs corresponding bit will remain high until the general error clear command is sent to the unit. If the errors are solved the relative bits will remain 0 after the error clear, otherwise the error bits will return high.

The "Error condition" bit in of the status register is a logic OR of the bits of the Error Register bits, so it is high when one or more bits of the Error Register are high.

The command used to read the control register is "ERR:CLR\r". When the command is correctly interpreted the unit replies with an acknowledge ("ACK\r\n").

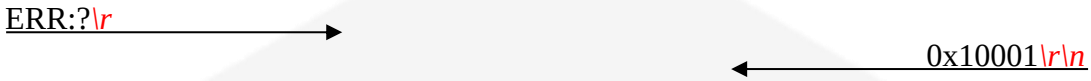
ERR Command: (ERR:*parameter*\r)

Parameter	Command description	Type of command	Return value
CLR	Reset the Error register	Set	ACK
?	Read the Error register	Read	ASCII representation of the internal Error register value.

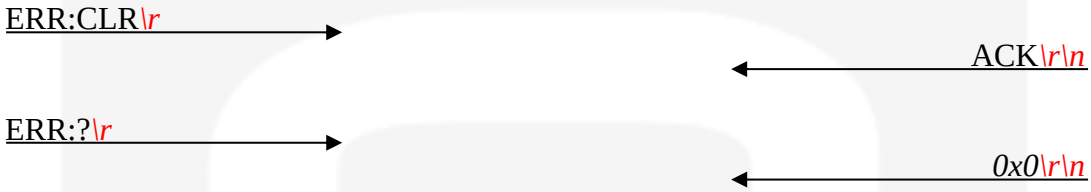
Table 20: ERR command

Examples:

Error register read example (for example the value 0x10001 indicates that there was an SD mount error – bit #1 is high and a buffer overflow – bit#17 is high):



Error register clear example:



2.3 Advanced Commands

The advanced functionalities of the CT-BOX are described in the following chapters.

2.3.1 ALARM Command

The CT-BOX allows to detect when the measured current is outside of a desired current range. The command that sets this functionality is called ALARM command. The alarm checks are performed at the selected acquisition frequency, so they depend over the:

- TS setting in the Oscilloscope mode of operation,
- FREQ setting in the Data-Logger mode of operation.

The command "ALARM:ON\r" is used to enable the alarm check functionality, otherwise the command "ALARM:OFF\r" is used to disable it. The command used to read the actual ALARM configuration is: "ALARM:?\r". The reply to the read command is in the following form: "*alarm_status*\r\n", where *alarm_status* is "ON" if the alarm status is enabled or "OFF" if it is disabled.

Whenever the Alarm condition occurs the "Alarm flag" bit is set and latched in the Status register. It stays set also when the alarm condition is removed. The command "ALARM:CLR\r" clears the Alarm condition and so also the "Alarm flag" bi in the Status register.

ALARM Command: (ALARM:*parameter*\r)

Parameter	Command description	Type of command	Return value
ON	Enable the Alarm check functionality	Set	ACK
OFF	Disable the Alarm check functionality	Set	ACK
CLR	Clear the Alarm	Set	ACK
?	Read the Alarm check setting	Read	ON – if the alarm functionality is enabled OFF – if alarm functionality is disabled

Table 21: ALARM command

The command "ALARM:ULIM:*current_threshold*\r" sets the upper alarm threshold, and the "ALARM:LLIM:*current_threshold*\r" sets the lower alarm threshold, where *current_threshold* is the upper or lower limit expressed in Ampere [A]. If the parameter is correctly elaborated the CT-BOX replies with an acknowledge ("ACK\r\n").

The commands used to read the threshold limits are: "ALARM:ULIM:?\r" for the upper limit and "ALARM:LLIM:?\r" for the lower limit. Both command generate the reply in the following form: "*current_threshold* \r\n", where *current_threshold* is the upper or lower limit expressed in Ampere [A].

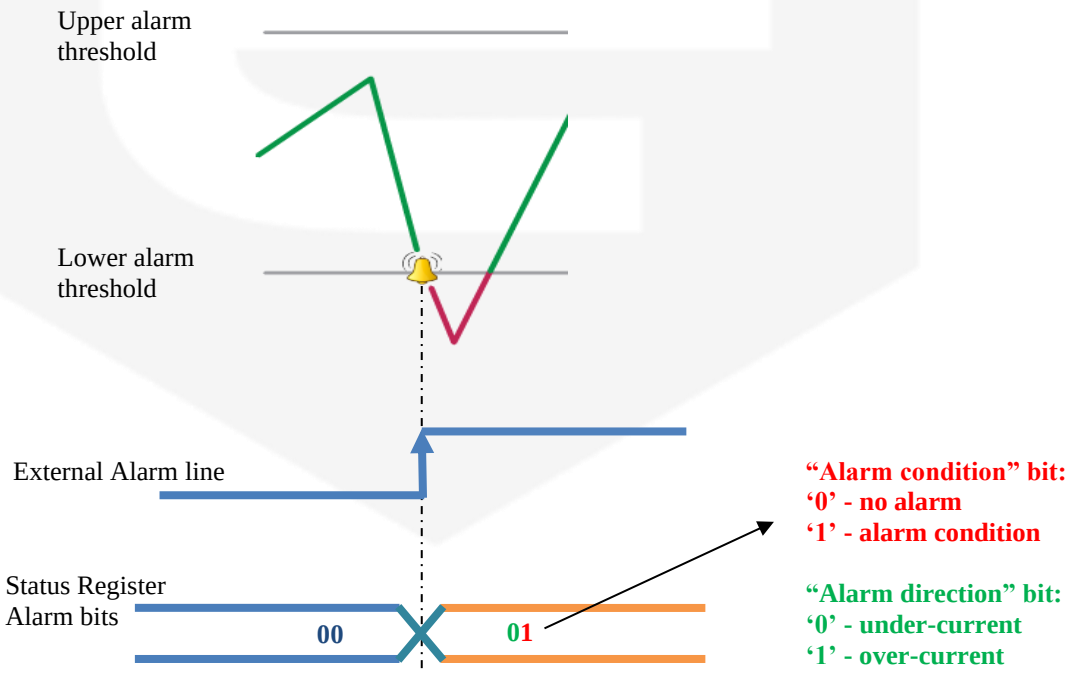
ALARM Command – limit set: (ALARM:*parameter#1:parameter#2*\r)

Parameter#1	Parameter #2	Command description	Type of command	Return value
ULIM	Current in Amps	Set the upper limit current threshold	Set	ACK
ULIM	?	Read the upper limit current threshold	Read	Upper threshold limit in Amps
LLIM	Current in Amps	Set the lower limit current threshold	Set	ACK
LLIM	?	Read the lower limit current threshold	Read	Lower threshold limit in Amps

Table 22: ALARM limit command

The alarm checking is performing only when the acquisition is enabled (ACQ:ON setting). When the acquired current is outside the configured range, the alarm condition is set. In this condition the D-SUB "Alarm" line is driven high and the magnetic relay is switched, so the Normally Open contact (Relay NO) becomes Closed (see section "*I/O Connector*").

The Alarm condition is also reported on the Status Register. The "*Alarm Status*" bit indicates the alarm condition (*'0'* – no alarm; *'1'* – alarm condition). The *"Alarm Direction"* indicates the alarm direction condition (*'0'* – detected a current under the LLIM; *'1'* – detected a current over the ULIM).



Examples:

ALARM checking enabling example:

ALARM:ON\r →

← *ACK\r\n*

ALARM Upper Threshold limit set to 100A example:

ALARM:ULIM:100\r →

← ACK\r\n

ALARM:ULIM:?\r →

← *100\r\n*

2.3.2 SAVE Command

The SAVE command allows to enable or disable saving the measured data to the external SD-card. This function works only in the **Data-Logger mode**. This function is disabled in the Oscilloscope mode, because the acquired data quantity is too large to be transferred on the SD-card.

The saving to the SD memory card is enabled as soon as the command "SAVE:ON\r" is received. A disable command "SAVE:OFF\r" has to be sent in order to stop the data saving function.

When the command is correctly processed, the unit replies with an acknowledge ("ACK\r\n"). If an error happened during the data saving (for example a SD card is full or SD card write error), the SAVE is automatically stopped and the relative error condition is signaled in the Error register and the "Error condition" bit is set in the Status register. This error does not affect the acquisition. To resume the saving the acquisition has to be stopped, the fault has to be solved. At this point the SAVE can be enabled again.

Please pay attention: the **SD card must be mounted** before starting the acquisition with SAVE function enabled (see SD:MOUNT command).

The command used to read the actual SAVE status is: "SAVE:?\r". The reply to the save status read is in the following form: "*save_status*\r\n", where *save_status* is "ON" when the saving is enabled and "OFF" when the saving is disabled.

SAVE Command: (SAVE:*parameter*\r)

Parameter	Command description	Type of command	Return value
ON	Enable saving to the SD card	Set	ACK
OFF	Disable saving to the SD card	Set	ACK
?	Read the saving configuration	Read	ON – saving is enabled OFF – saving is disabled

Table 23: SAVE command

Examples:

Enable the data saving to the external SD-card:

SAVE:ON\r →

← ACK\r\n

Read the saving configuration:

SAVE:? \r →

← ON\r\n

2.3.3 SD Command

The SD command allows to manage the SD memory card. When the SD card is inserted in the appropriate slot it must be mounted before the CT-BOX can use it. The command "SD:MOUNT\r" allows to mount the SD-card. Otherwise the SD card must be unmounted before it is removed from the CT-BOX device. The command to unmount the SD card is: "SD:UNMOUNT\r".

The command used to read the SD card status is "SD:?\r". The reply to the read command is in the following form: "*sd_status*\r\n", where *sd_status* is "MOUNT" if the SD card is mounted or "UNMOUNT" if it is unmounted.

If needed the SD memory card can be remotely reset using the "SD:RST\r" command. When the SD card reset is executed the CT-BOX replies with an acknowledge ("ACK\r\n"). The remote reset action is equivalent as the SD card is removed from its slot and then inserted again. After the remote SD card reset the user must perform "SD:MOUNT\r" command so the CT-BOX prepares the card for use.

There are also four commands that are used for the management of the SD data contents. These commands are:

- SD:LS lists all the files that are on the SD card,
- SD:RM removes the selected file from the SD card,
- SD:SIZE informs the user about the size of the selected file,
- SD:READ reads the content of the selected file and prints the data on the active communication stream.

The command used to show the list of all SD card files is: "SD:LS\r". The reply to the read command is in the following form: "*sd_filename1*\r\n*sd_filename2*\r\n...", where *sd_filename1* is the name of the first file found on the SD card, the *sd_filename2* is the name of the second file found on the SD card, etc. After the last filename is printed the CT-BOX sends the acknowledge ("ACK\r\n") to inform the user that the list of files reached the end.

The user can remove selected file from the SD card using the "SD:RM:*sd_filename*\r" command, where the "*sd_filename*" stands for the filename of the file to be removed. After the filename is removed the CT-BOX sends the acknowledge ("ACK\r\n") to inform the user that the operation succeeded.

The size of a file on the SD card is determined with the "SD:SIZE:*sd_filename*\r" command, where the "*sd_filename*" stands for the filename of the file which size is needed. The CT-BOX replies with the "*sd_filename_size*\r\n...", where the "*sd_filename_size*" stands for the size of the file expressed in bytes.

The contents of a file on the SD card can be read with the "SD:READ:*sd_filename*\r" command, where the : "*sd_filename*" stands for the filename of the file which contents are needed. The CT-BOX replies with the stream of data which is identical as the data in the selected file. After the data are printed the CT-BOX sends the acknowledge ("ACK\r\n") to inform the user that the operation succeeded.

SD Command: (SD:*parameter1*:*parameter2*\r)

Parameter#1	Parameter #2	Command description	Type of command	Return value
MOUNT	not-present	Mount SD card	Set	ACK
UNMOUNT	not-present	Unmount SD card	Set	ACK
?	not-present	Read the SD card status	Read	MOUNTED UNMOUNTED
RST	not-present	Reset the SD card	Set	ACK
LS	not-present	List all files on the SD card	Read	List of files
RM	filename	Remove the file	Set	ACK
SIZE	filename	Show the file's size	Read	Size of the file
READ	filename	Read the file	Read	Contents of the file

Table 24: SD command

Examples:

Mount the SD-card:

SD:MOUNT\r →

← ACK\r\n

Read the SD-card status:

SD:? \r →

← MOUNT\r\n

2.3.4 TRG Command

The CT-BOX has also two external trigger signals (trigger in and trigger out), which can be used to synchronize the acquisition of different CT-BOX units or to relate the acquisition to an external event (triggered acquisition).

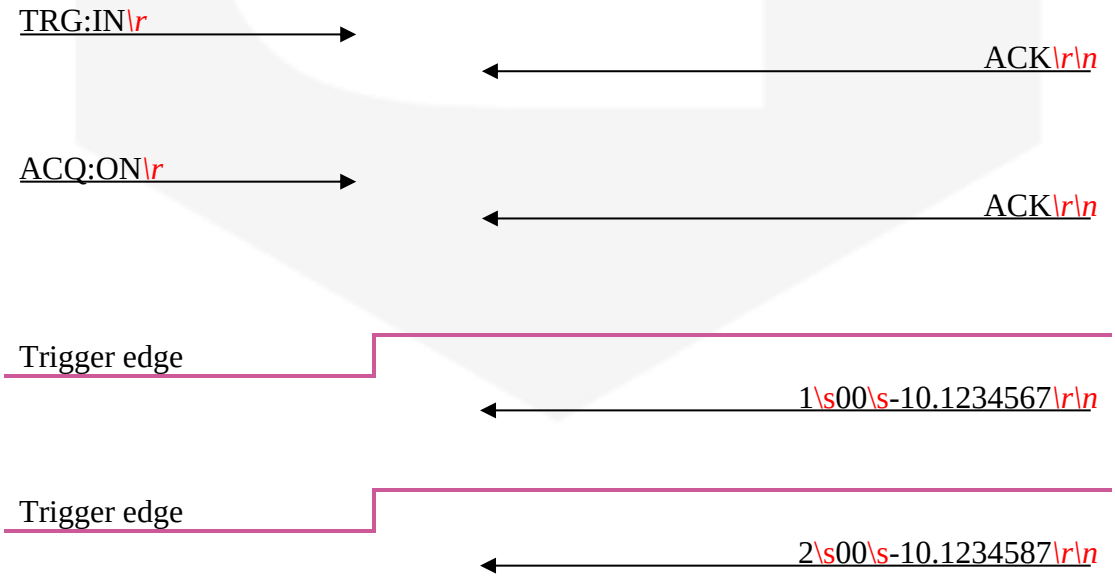
2.3.4.1 Triggered Acquisition

To relate the acquisition to an external event, it is necessary to enable the trigger input. This can be done using the command "TRG:IN\r". The behavior of the triggered acquisition depends over the mode of operation.

If the triggered acquisition is enabled in the **Data-Logger mode,** the CT-BOX waits for a rising edge of the trigger input signal to start a conversion. In this mode the device does not start immediately the acquisition after the ACQ:ON, but it waits for a trigger pulse. When the device receives a rising edge on the trigger input signal, it starts the data acquisition over the selected period and then it returns the averaged acquisition on that period. Once the acquisition is finished, the unit waits for a successive rising edge on the trigger input to start the successive acquisition.

Example:

Triggered acquisition example in Data-Logger mode:

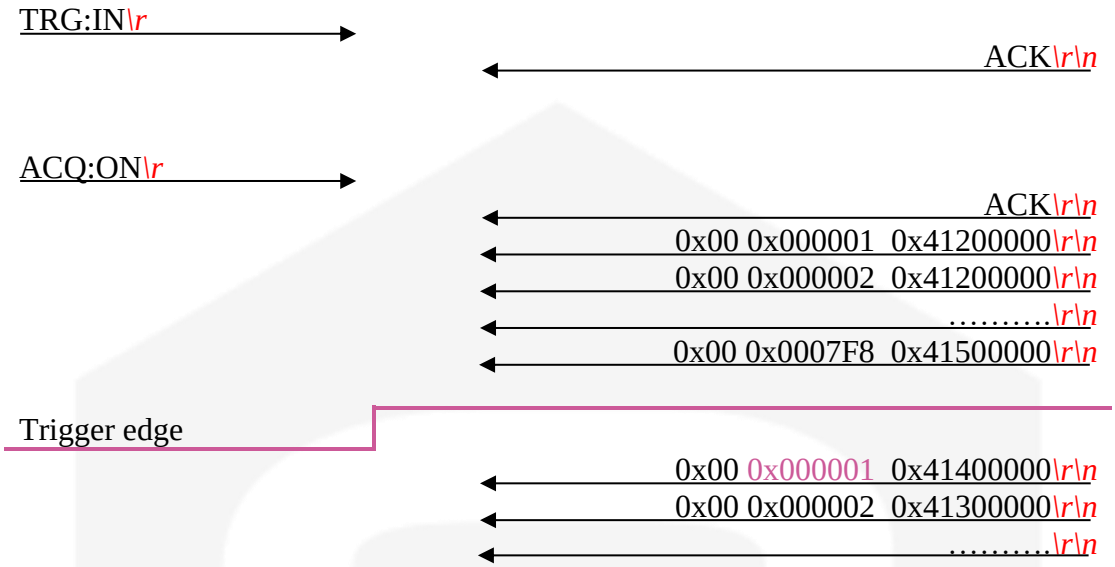


In **Oscilloscope mode** the behavior of the triggered acquisition is different. In this mode the device starts immediately the acquisition after the ACQ:ON command and the rising edge of the trigger input resets the sequence number associated to the

acquisition. If a sequence number is equal to 0, a rising edge of the trigger signal was detected.

Examples:

Triggered acquisition example in Oscilloscope mode with PRINT enabled:



The command used to exit from the triggered acquisition mode is "TRG:OFF\r". The command used to read the actual trigger setting is: "TRG:?\r". The reply to the read command is in the following form: "*trg_setting*\r\n", where *trg_setting* is "IN", "OFF" according the actual trigger setting.

Parameter	Command description	Type of command	Return value
IN	Sets trigger as input	Set	ACK
OFF	Disables trigger function	Set	ACK
?	Reads the trigger status	Read	IN – trigger is set as output OFF – trigger is disabled

Table 25: TRG command in trigger acquisition mode

2.3.5 IP Command

The IP address of CT-BOX can be changed with the IP command. The command "IP:*ip_address*\r" has to be used to set the new IP address, where the "*ip_address*" stands for desired IP address in ASCII format (123.456.789.123). After the successful IP address change the CT-BOX replies with an acknowledge ("ACK\r\n"). The new IP address takes effect after CT-BOX reset.

The command used to read the IP address setting is: "IP:?\r". The reply to the read command is in the following form: "*ip_address*\r\n", where *ip_address* is actual IP address in ASCII format (123.456.789.123).

IP Command: (IP:*parameter*\r)

Parameter	Command description	Type of command	Return value
?	Reads the actual IP address	Read	IP Address
IP Address	Sets new IP address	Set	ACK

Table 26: IP command

Examples:

Read the IP address:

IP:?\r →

← 192.168.1.10\r\n

Set a new IP address:

IP:123.456.789.123\r →

← *ACK\r\n*

2.3.6 MASK Command

The Ethernet Subnet mask of the Ethernet communication of the CT-BOX can be changed with the MASK command. The command "MASK:*subnet_mask*\r" has to be used to set the new subnet mask, where the "*subnet_mask*" stands for desired subnet mask in ASCII format (e.g. 255.255.255.0). If the command is correctly interpreted, the CT-BOX replies with an acknowledge ("ACK\r\n"). The new subnet mask takes effect after CT-BOX reset.

The command used to read the subnet mask setting is: "MASK:?\r". The reply to the read command is in the following form: "*subnet_mask*\r\n", where *subnet_mask* is actual subnet mask in ASCII format (e.g. 255.255.255.0).

MASK Command: (MASK:*parameter*\r)

Parameter	Command description	Type of command	Return value
?	Reads the actual subnet mask	Read	Subnet mask
Subnet mask	Sets new subnet mask	Set	ACK

Table 27: MASK command

2.3.7 GATE Command

The default gateway of Ethernet communication can be changed with the GATE command. The command "GATE:*gateway*\r" allows to set the default gateway, where the "*gateway*" stands for desired gateway in ASCII format (e.g. 192.168.0.1). If the command is correctly interpreted, the unit replies with an ("ACK\r\n"). The new gateway takes effect after CT-BOX reset.

The command used to read the actual gateway setting is: "GATE:?\r". The reply to the read command is in the following form: "*gateway* \r\n", where *gateway* is actual gateway in ASCII format (e.g. 192.168.0.1).

GATE Command: (GATE:*parameter*\r)

Parameter	Command description	Type of command	Return value
?	Reads the actual gateway	Read	Gateway
Gateway	Sets new gateway	Set	ACK

Table 28: GATE command

2.3.8 PORT Command

By default, in oscilloscope mode the data is sent out using UDP protocol to remote host port 20001. Application that receives the data must bind a datagram socket to this port. If required, this port can be changed using "PORT:#port\r" command to satisfy user's specific needs, e.g. if multiple CT-BOX are connected to the same host, each one can send data to different port.

PORT Command: (PORT:*parameter*\r)

Parameter	Command description	Type of command	Return value
?	Reads current port number	Read	Port
#port	Sets new port number	Set	ACK

Table 29: PORT command

2.3.9 HWRESET Command

The CT-BOX can be remotely reset with the HWRESET command. The user must execute the "HWRESET:FORCE\r" command to perform the device reset. Before the CT-BOX is reset it replies with acknowledge ("ACK\r\n").

HWRESET Command: (HWRESET:*parameter*\r)

Parameter	Command description	Type of command	Return value
FORCE	Resets the CT-BOX	Set	ACK

Table 30: HWRESET command

2.3.10 TIME Command

The CT-BOX contains also a Real-Time Clock (RTC). The RTC time can be read using the "TIME:?\r" command. The CT-BOX replies with the "*time*\r\n", where the *time* is ASCII formatted string: *hours.minutes.seconds*. This setting is used in the Data-Logger mode.

The RTC time can be changed with the "TIME:*time*\r" command, where the *time* stands for ASCII formatted string: *hours.minutes.seconds* . After the successful time change the CT-BOX replies with acknowledge ("ACK\r\n").

TIME Command: (TIME:*parameter*\r)

Parameter	Command description	Type of command	Return value
?	Reads the time	Read	Time String
Time String	Sets new time	Set	ACK

Table 31: TIME command

2.3.11 DATE Command

The RTC date can be read using the "DATE:?\r" command. The CT-BOX replies with the "*date*\r\n", where the *date* is ASCII formated string: *day.month.year*. This setting is used in the Data-Logger mode.

The RTC can be changed with the "DATE: *date* \r" command, where the *date* stands for ASCII formatted string: *day.month.year*. After the successful date change the CT-BOX replies with acknowledge ("ACK\r\n").

DATE Command: (DATE:*parameter*\r)

Parameter	Command description	Type of command	Return value
?	Reads the date	Read	Date String
Date String	Sets new date	Set	ACK

Table 32: DATE command

2.3.12 SCALE Command

This command is used when performing calibration. At full-scale reference primary current this command calculates and stores proper positive and negative gains. Be aware that by issuing this command factory calibration data are lost. Thus, the command is to be used only in special cases and can be used only after having unlocked the password protection to avoid accidental calibration loss.

First argument of the function is reference primary current direction. Calibration is performed separately for positive and negative current. Second argument is the reference current measurement.

SCALE Command: (SCALE:*parameter#1*: *parameter#2*\r)

Parameter#1	Parameter #2	Command description	Type of command	Return value
POS	Reference current in Amps	Calculates calibration parameters	Set	ACK
NEG	Reference current in Amps	Calculates calibration parameters	Set	ACK

Table 33: SCALE command

2.3.13 GAIN Command

This command is used to read or store calibration parameters. It is password-protected to avoid accidental calibration loss.

GAIN Command: (GAIN:*parameter#1*: *parameter#2*\r)

Parameter#1	Parameter #2	Command description	Type of command	Return value
POS	Positive Gain	Stores calibration parameters	Set	ACK
POS	?	Returns calibration parameters	Read	Positive Gain
NEG	Negative Gain	Stores calibration parameters	Set	ACK
NEG	?	Returns calibration parameters	Read	Negative Gain

Table 34: GAIN command

2.3.14 PASSWORD Command

The PASSWORD command can be used to unlock or lock the access to the protected commands.

PASSWORD Command: (PASSWORD:*parameter*\r)

Parameter	Command description	Type of command	Return value
"*Password*"	Sets the password	Set	ACK
LOCK	Lock the protected commands	Set	ACK

Table 35: PASSWORD command

The "password" to enable the protected commands is "*CAL-ADMIN*". To disable the commands again use "LOCK" as the first parameter of the command.

3. Connectors and Interfaces

The communication with the CT-BOX can be performed using different interfaces: Ethernet TCP-IP 10/100 Mbps, USB 2.0 and RS232 (serial interface with fixed baud rate at 115.200 bps). The device automatically recognized the used communication interface. The suggested communication interfaces are the Ethernet or USB; the serial interfaces are not recommended due to the bottleneck of the communication speed, which can limit the performances of the CT-BOX. For this reason, the Oscilloscope mode acquisition is not allowed with the serial communication interface.

3.1 Ethernet Interface

The device is shipped with default IP address, subnet mask, and gateway and TCP-IP communication port:

Parameter	Factory value
IP address	**192.168.0.10**
Subnet mask	**255.255.255.0**
Gateway	**192.168.0.1**
TCP/IP port	**10001**
remote port (UDP)	**20001**

Table 36: Factory Ethernet settings

Even if the CT-BOX device can be connected to a LAN network, a point-to-point Ethernet connection is strongly recommended in order to obtain minimum delay, maximum data rate performance and to avoid possible communication problems – i.e. increasing communication reliability. This implies that the host PC and the CT-BOX should reside on the same Ethernet subnet.

3.2 USB Interface

To use the USB interface, it is necessary to install the ST VCP (Virtual COM Port) driver. The driver can be download from the following link:

http://www.st.com/web/en/catalog/tools/PF257938#

Once download, simply run the installer and follow the installation procedure. After the installation go to your installation directory, for example: "*C:\Program Files (x86)\STMicroelectronics\Software\Virtual comport driver*" and go to your OS version directory [Win 7] or [Win 8] and then double click on:

- **dpinst_x86.exe** for a 32-bits OS version;
- **dpinst_amd64.exe for** a 64-bits OS version.

When the USB is connected with the CT-BOX a COM port will be recognized and under the Device Manager it is possible to view the associated COM port:

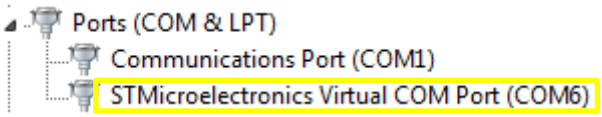


Figure 16: Device Manager COM port

Now the driver is correctly installed and it is possible to communicate with the device simply using the associated Virtual COM port directly in the CT-BOX Viewer software.

3.2.1 Firmware Upgrade

The firmware of the CT-BOX device can be updated with a USB cable. A specific third-party software is required to perform this operation, depending on the operating system there are two tools that can be used:

- DfuSE is lightweight firmware upgrade tool available on older versions of Windows® OS. Use firmware upgrade file with ***.dfu*** extension;
- STM32CubeProgrammer is multi-OS software tool for programming. Use firmware upgrade file with ***.hex*** extension when selecting this option;

3.2.1.1 DfuSE software

DfuSE software can be downloaded from the following link:

http://www.st.com/web/en/catalog/tools/FM147/CL1794/SC961/SS1533/PF257916

After download the DfuSE software, simply run the installer and follow the installation procedure. After the installation, prepare the CT-BOX for the firmware update, following the subsequent steps:

- Switch OFF the CT-BOX unit using the main switch, present on the front panel of the device;
- Set the SWITCH #1 on the rear panel to be positioned high, as illustrated in Figure 17;

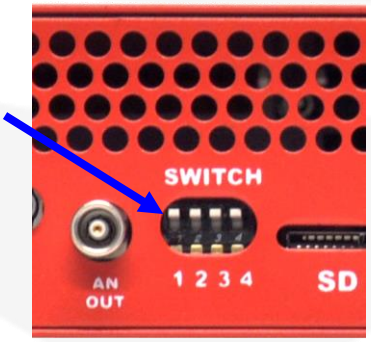


Figure 17: SWITCH position for update firmware

- Connect the CT-BOX to the computer using the USB cable;
- Switch ON the CT-BOX using the main switch, present on the front panel of the unit;
- The Windows® OS shall find and install the driver for the USB port;
- Launch the DfuSe Demonstration software. It should automatically find the DFU Device (i.e. the CT-BOX) connected to the USB port.

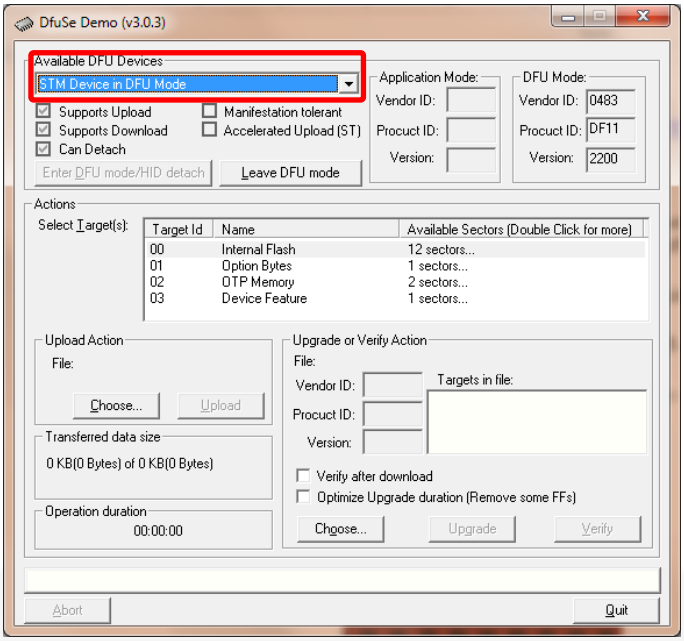


Figure 18: DfuSe Demonstration

- Under ***Upgrade or Verify Action*** **(**Figure 19), click on "*Choose*" and select the new firmware file (.dfu) to download into the CT-BOX:

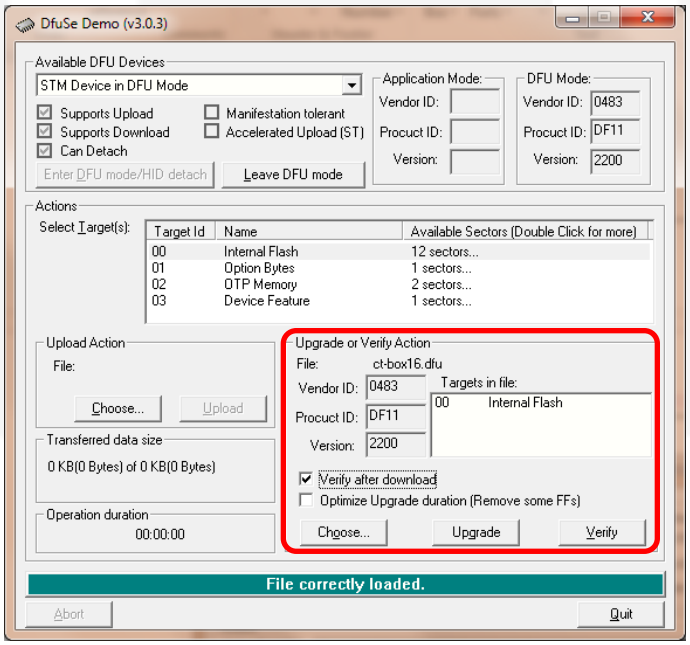


Figure 19: DfuSe Upgrade setup

- Check the boxes "*Verify after download*" (Figure 19) and click "Upgrade";
- The DfuSe will download the new firmware in the CT-BOX and verify the operation;
- Switch OFF the CT-BOX;
- Set the SWITCH #1 on the rear panel to be positioned low, as illustrated in Figure 20;

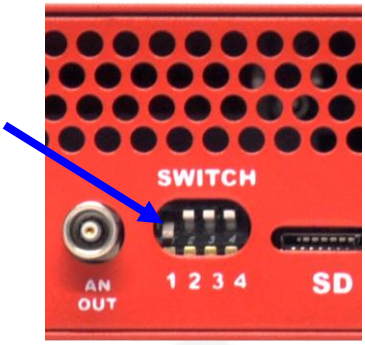


Figure 20: SWITCH position for normal use

- Switch ON the CT-BOX. Now the CT-BOX is updated with the just installed firmware.

3.2.1.2 STM32CubeProgrammer

Alternatively, STM32CubeProgrammer software tool can be used to update the firmware. It is supported on broader range of operating systems and architectures:

- Linux® 64-bit
- Windows® 7/8/10/11 32-bit and 64-bit
- macOS ® (minimum version OS X ® Yosemite)

The STM32CubeProgrammer is available for download from:

https://www.st.com/en/development-tools/stm32cubeprog.html#get-software

To install it on Windows, extract the zip package and run SetupSTM32CubeProgrammer.exe file.

When using Linux install the libusb1.0 package first by using the following command: ***sudo apt-get install libusb-1.0.0-dev*** and then copy the rules files located under ***Driver/rules*** folder in ***/etc/udev/rules.d/*** on Ubuntu ("*sudo cp *.*/etc/udev/rules.d*"). Then extract the zip package and execute SetupSTM32CubeProgrammer-vx.y.z.linux, which guides you through the installation process.

After the installation, prepare the CT-BOX for the firmware update, following the steps below:

- Switch OFF the CT-BOX unit using the main switch, present on the front panel of the device;
- Set the SWITCH #1 on the rear panel to be positioned high, as illustrated in Figure 21;

Figure 21: SWITCH position for update firmware

- Connect the CT-BOX to the computer using the USB cable;
- Switch ON the CT-BOX using the main switch, present on the front panel of the unit;
- The Windows® OS shall find and install the driver for the USB port;
- Launch the STM32CubeProgrammer software tool. On the right-hand side set the interface to USB, click on refresh button and finally on connect:

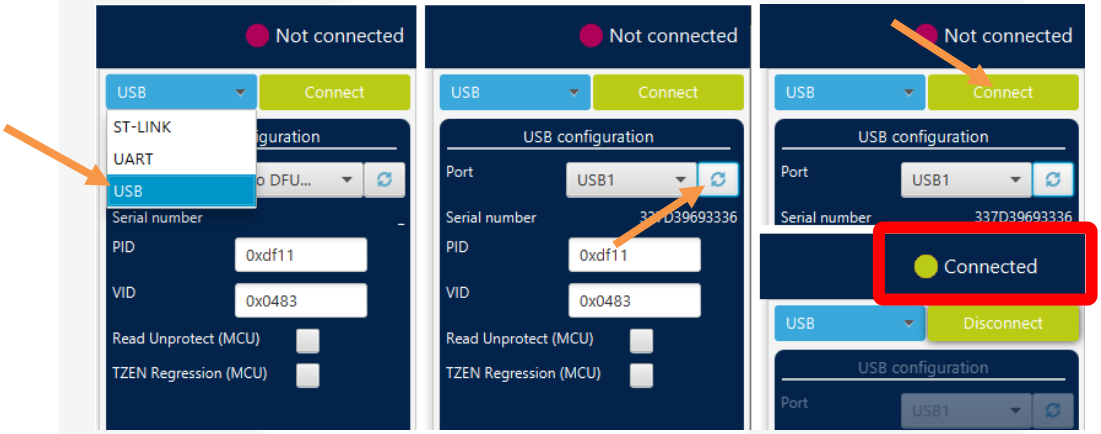


Figure 22: Interface selection

- Go to ***Erasing & Programming*** window, and select Click the ***Browse*** button to select the location of the firmware file with ***.hex*** extension on your device.

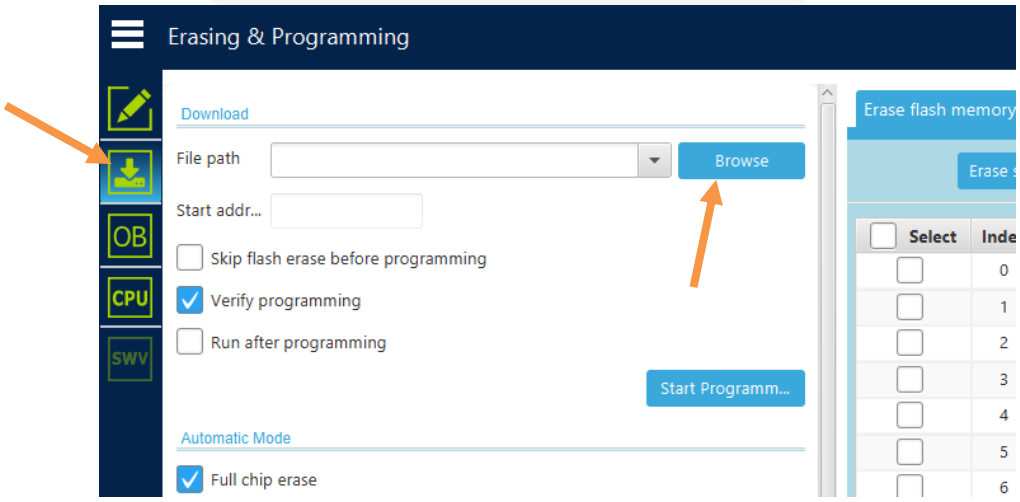


Figure 23: Erasing & Programming window

- Check the box ***Verify programming*** and click ***Start Programming*** (Figure 24);

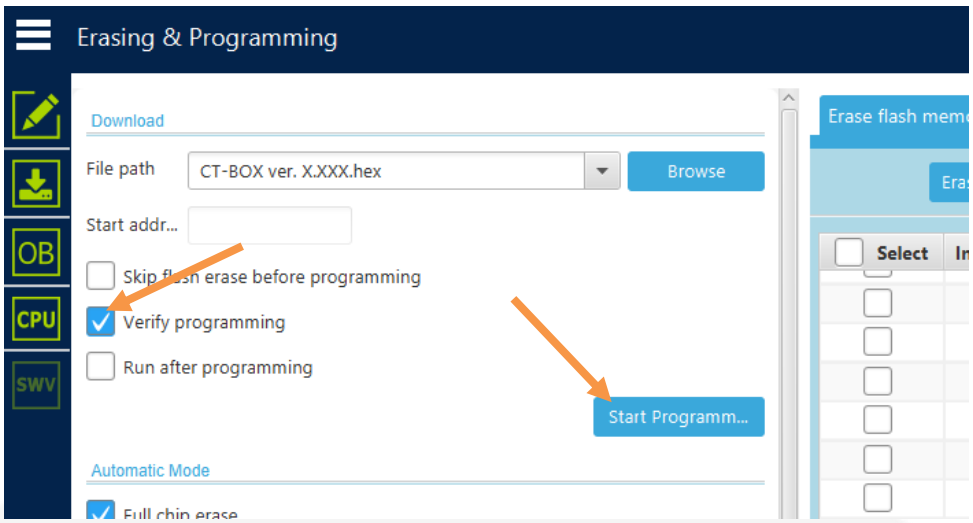


Figure 24: Programming new firmware

- The STM32CubeProgrammer will download the new firmware in the CT-BOX and verify the operation;
- Switch OFF the CT-BOX;
- Set the SWITCH #1 on the rear panel to be positioned low, as illustrated in Figure 25;

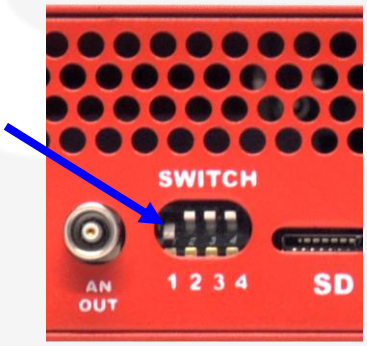


Figure 25: SWITCH position for normal use

- Switch ON the CT-BOX. Now the CT-BOX is updated with the just installed firmware.

3.3 Power Connector

The input power connector is a standard IEC 60320-1 C14. The input voltage is extended so can be used with mains voltage from 90 to 260 V at 47 – 63 Hz. Power consumption of the unit is less than 30W.

The ON/OFF switch on the front panel allows turning ON or OFF the device, but it will not disconnect completely the internal circuit from the AC mains.

3.4 I/O Connector

The I/O connector is an expansion connector that allows connecting different signal and to interface the unit to the external environment. An additional external temperature sensor, triggers and alarm can be all connected and are available on this I/O connector type, a standard D-SUB DA-15S (female). The pinout configuration is here presented:

Pin #	Function	Description
1	**TSENS VDD**	Power for External Temperature Sensor
2	**TSENS GND**	Ground reference for Temperature Sensor
3	*Do Not Connect – Internal Use*	
4	**Trigger Out**	5 V TTL Trigger Out signal
5	**GND**	Ground reference
6	**Relay NC**	Normally Closed Contact of Magnetic Relay
7	**Relay NO**	Normally Open Contact of Magnetic Relay
8	**GND**	Ground reference
9	**TSENS Data**	Data Bus for External Temperature Sensor (compatible sensor: Maxim DS18B20)
10	*Do Not Connect – Internal Use*	
11	*Do Not Connect – Internal Use*	
12	**GND**	Ground reference
13	**Alarm**	5 V TTL Alarm signal (Output)
14	**Relay C**	Common Contact of Magnetic Relay
15	**Trigger IN**	LVTTL Trigger In signal – 5V tolerant

Table 37: I/O connector pinout

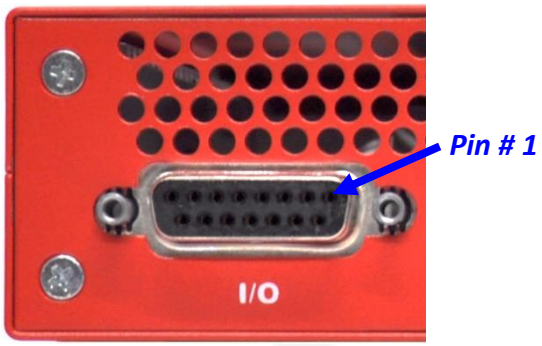


Figure 26: I/O connector

Signal levels for Trigger Output and Alarm are 5V TTL compatible. The maximum rated output current for these signals is 8 mA (i.e. the load impedance should be of 625 Ω or greater).

The Trigger Input signal is LVTTL (3.3V) with 5V tolerance. High logic level should be of 2.0V or greater while low logic level should be of 0.8V or lower.

Maximum voltage rating between Relay contacts is 50V and maximum current that can be carried is 1A.

A simple schematic description of the connector pins and their geometrical coupling, which greatly simplifies signal routing and connecting by having signals divided in "groups", is shown hereafter:

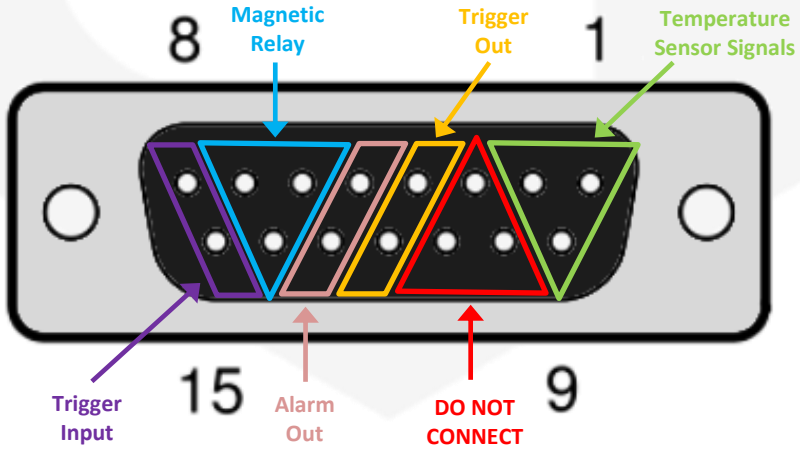


Figure 27: I/O connector description – rear panel

3.4.1 External Temperature Sensor

The CT-BOX can read the temperature of the DCCT head with a sensor that is integrated into the 0-FLUCS current sensor. Data are transmitted on the DE-9 to DE-9

cables and this feature is completely transparent for the user which is able to read the sensor internal temperature value on the software.

The CT-BOX allows also to monitor an external temperature value – e.g. in the environment where the DUT is or the ambient temperature – with its connections on the I/O connector.

As described in the previous section, pins 1, 2 and 9 of the unit can be used to interface and supply an external temperature sensor. A compatible type of sensor is the **Maxim DS18B20**. An example of connection between the current sensor and the CT-BOX central unit is hereafter shown.

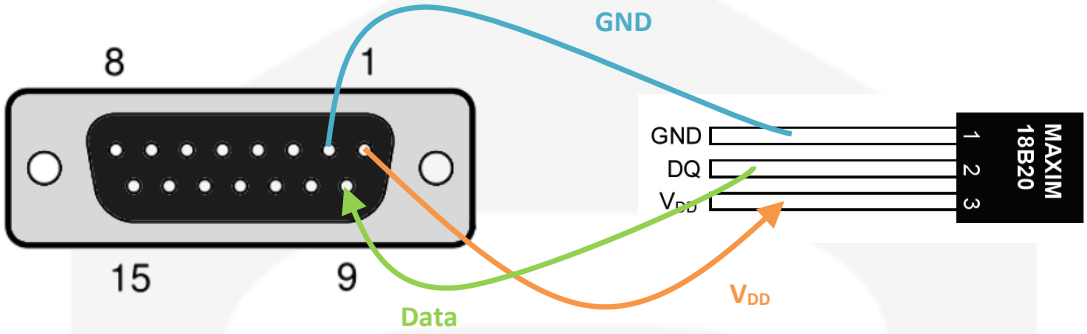


Figure 28: external temperature sensor connection to CT-BOX I/O connector

3.5 DCCT Connector

The DCCT connector is used to connect the DCCT Head through the included cable D-SUB DE-09P to DE-09S. This is providing the power source to the DCCT and is receiving the secondary current measurement.

Figure 29: DCCT connector

3.6 Analog Output

The analog output monitor presents a voltage value which is proportional to the measured current. The voltage output range is rated at ±10 V; the output voltage is scaled depending on the DCCT primary measured current with a Full-Scale measured current corresponding to a 10V output on this monitor. The monitor is directly connected to a shunt resistor by means of an instrumentation amplifier and it is factory calibrated in order to have < 100 ppm of initial accuracy. This output monitor is not thermally-stabilized so that it may present a drift greater than the digital reading of the CT-BOX. It is for this reason that it is suggested to use this monitor signal mainly for debugging purposes – e.g. connecting to an oscilloscope – and to use the CT-BOX as the main readout unit.

Figure 30: Analog Output connector

The performance of this output monitor is guaranteed only when connecting a load – e.g. oscilloscope input, etc. – with equivalent impedance higher than 500 kΩ.

3.7 SD-Card Socket

The SD-Card slot on the rear side of the unit can host a Micro SD-Card with the following characteristics:

Parameter	Value
Supported Class	4, 6, 10 and UHS 1
Interface	*SD and SDHC*
BUS	I
Size	2 and 4 GB

Table 38: Supported SD-cards

Please note that a Micro SD-card with 4-GB capacity is already included in the CT-BOX standard package.

4. Technical Specifications

Main technical specifications for the CT-BOX unit are shown in the following table:

Characteristic	Value
AC Line Input	90 – 260 VAC 46 - 440 Hz
Maximum Power Consumption	30 W
Current Accuracy	< 0.005%
Current Resolution	24 bit
Sampling Frequency	0.1 Hz – 100 kHz
Thermal Coefficient	< 1 ppm/K
Local Current Display	7 ½ digits
LED Indicators	Power OK DCCT Head OK Status SD Card R/W Acquisition running
Digital Interfaces	Ethernet 10/100 TCP/IP USB 2.0 RS-232
Analog Monitor	± 10V (LEMO Coaxial)
Trigger Modes	Digital Interface (Soft-Trigger) TTL 5V on I/O connector
Alarm Output	TTL 5V Magnetic Relay
External temperature sensor range	-40 – 125 °C
Temperature Readings Resolution	12 bit
Temperature Readings Accuracy	± 0.5 °C
Temperature Range	10 – 40 °C
Linearity	< 25 ppm/FS

Drift (48h)	<10 ppm/FS
Offset	< 1 ppm/FS (Zero Offset Function)
Dimensions	180 x 220 x 41 mm

4.1 Noise

The CT-BOX noise depends over the averaging performed by the device, this affecting the ENOB (Effective Number Of Bits). In the following graph the CT-BOX noise characteristic and the equivalent ENOB are represented:

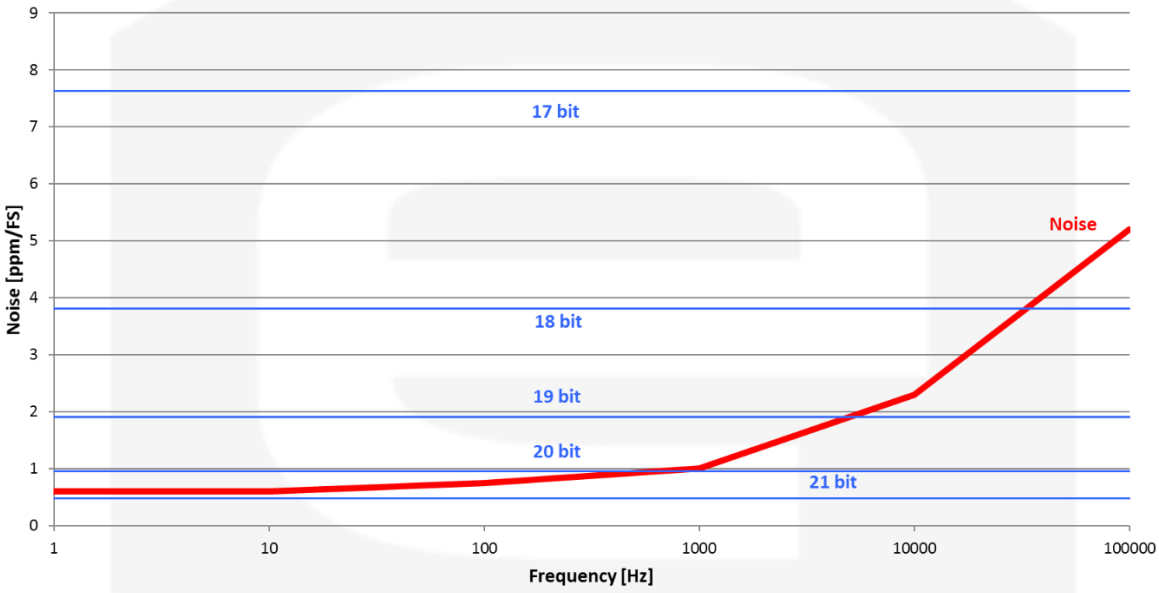


Figure 31: Typical Noise in terms of ppm/FS for different sampling rates and equivalent ENOB. Measurement performed using a CT-600 transducer

5. Mechanical Dimensions

The mechanical dimensions of the CT-BOX unit, including connectors, are hereafter presented:

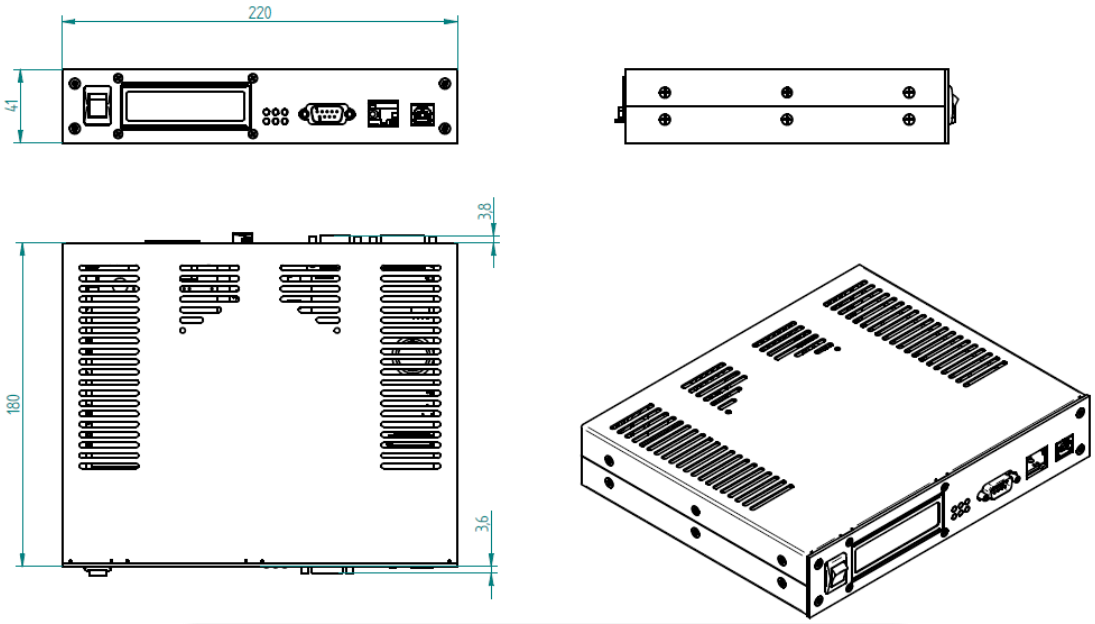


Figure 32: CT-BOX mechanical dimensions

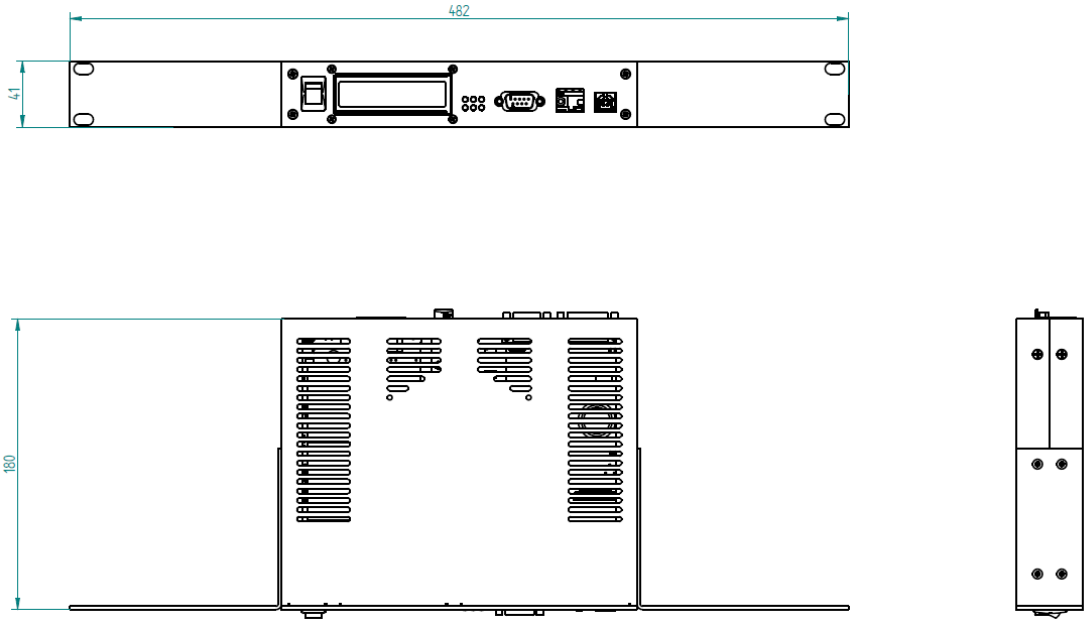


Figure 33: CT-BOX with Mounting Brackets

6. Appendix

6.1 List of Error Codes

The CT-BOX unit replies with a **N**ot **A**c**K**nowledge ("NAK") if the received command is not correct or it is not accepted. This "NAK" reply is followed by a two digit *"error code"* field, which indicates the error cause and/or type. The list of the possible error codes is shown in the following table:

Error Code	Brief description of error
0	*Command not recognized*
1	*Parameter is wrong*
2	*Parameter is out of expected range*
3	*Parameter cannot be modified when CT-BOX is acquiring data*
4	*Printout stream has been interrupted, repeat the issued command or restart printout stream with PRINT:ON command*
5	*Command is not supported in current mode*
6	*Command cannot be executed when CT-BOX is acquiring data*
7	*RS232 communication is only supported in DLOG mode*
8	*DCCT head is not connected to CT-BOX*
9	*Other DCCT error*
10	*CT-BOX name parameter string is too long*
11	*CT-BOX is already acquiring data*
12	*SD-Card file create error*
13	*SD-Card file close error*
14	*SD-Card write to file error*
15	*SD-Card File cannot be synchronized*
16	*SD-Card is not present*
17	*SD-Card cannot list files*

18	*SD-Card cannot be mounted*
19	*SD-Card cannot be unmounted*
20	*It is not possible to remove the file*
21	*It is not possible to open the file*
22	*It is not possible to read the file*
23	*Password required*
24	*OFFSET detected value is not accepted, because it is too big*
25	*Wrong password*