Digital Fluxgate Magnetometer

Contents

1 Introduction

The Digital Fluxgate Magnetometer Version 2010 is a state of the art, high precession, low noise vector magnetometer. It is useable in a wide range of applications like continuous recording of the magnetic field in observatories, magnetic exploration campaigns and in technical applications e.g. magnetic cleanliness measurements. The small-sized, lightweight vector compensated magnetic field sensor is built up of self-manufactured low noise ring cores and a self-supporting Helmholtz coil system. Due to the near-sensor digitalization of fluxgate signals, sensitive analog electronics can be reduced to a minimum, which lowers the noise and increases the stability.
The magnetometer can be controlled stand-alone via a touch screen or remote over a TCP/IP network connection or a serial link. Magson offers several add-ons to extend the functionality e.g. a second magnetic field sensor for using the device as a gradiometer, a GPS receiver, inclinometers, a rotary encoder, electronics and sensor heaters and a 200 Hz version. The magnetometer is controlled by a powerful ARM9 microcontroller with a Linux operation system. It has the following features:

- Measurement of 3 or 6 magnetic field components (Measurement range ±100000 nT)
- Measurement of electronics and sensor temperature
- Optional: measurement of inclination (2 axis each sensor)
- Optional: measurement of rotary encoder angle
- Magnetometer control and data output via touch screen, network services and serial interface
- Data recording on SD card with different sampling rates (ASCII or binary data format)
- Manually triggered measurement including geographical position
- Simultaneous data access and recording
- Synchronization of time and position determination with a GPS receiver
- Optional: temperature control

2 The fluxgate sensor

The magnetic field is measured by a vector compensated ringcore fluxgate sensor.
The sensor consists of two crossed ringcores, three pick-up coils and a tri-axial Helmholtz coil system for field feedback. The noise level of the ringcores is in less than 15pT/√Hz @ 1Hz.The field sensitive ringcores are kept by the feedback system always in zero field. This vector compensation allows the measurement of all three components of the magnetic field vector in the center of the sensor. The stability of the offsets depends on the individual characteristics of the ringcores, however scale values and non-orthogonality depends on stability of the feedback coil system only. The scale value is very linearly and depending on the expansion coefficient of the feedback system.

The magnetometer can be used with the fluxgate mini sensor and with the titanium sensor.

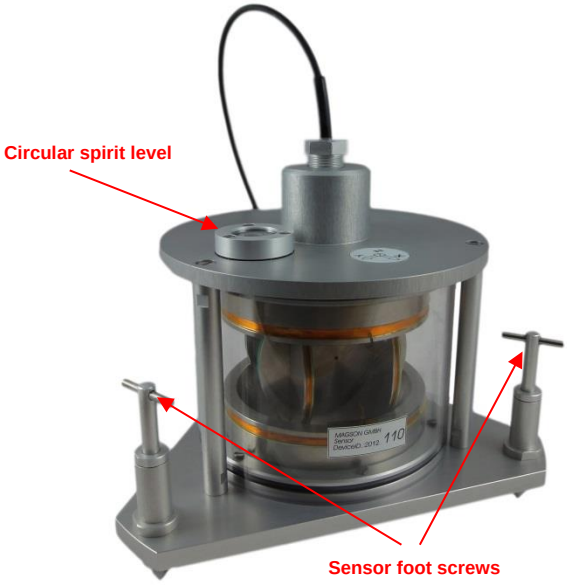
2.1 Mini sensor

Sensor construction:	Self-supporting Helmholtz coil system
Sensor size:	H: 40 mm, Cover ∅: 50 mm, Socket ∅: 67 mm
Sensor weight:	105 g
Noise:	<20 pT/√Hz (typical 15 pT/√Hz) at 1Hz
Expansion coefficient of feedback system:	17,5 ppm/°C +/- 1,5 ppm/°C
Long-term stability:	<10 nT/year
Orientation:	Orthogonal system (X, Y, Z)

2.2 Titanium sensor

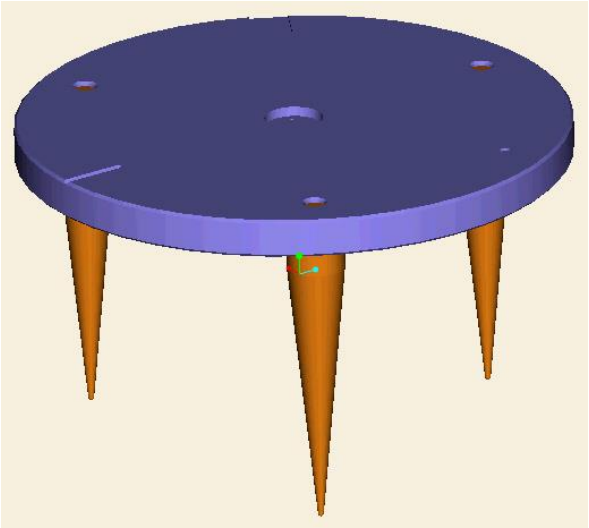
The support material for the feedback coil system is titanium to realize high mechanical and thermal stability.

Sensor size:	H: 25 cm, Cover ∅: 12 cm
Sensor weight:	2.5 kg
Dimensions of the sensor housing:	H:25cm , Cover ∅: 27cm
Total weight of the sensor and housing:	5.5 kg
Noise:	<20 pT/√Hz (typical 15 pT/√Hz) at 1 Hz
Thermal expansion coefficient	11 ppm/°C
Long-term stability:	<10 nT/year
Orientation:	Orthogonal system (X, Y, Z)



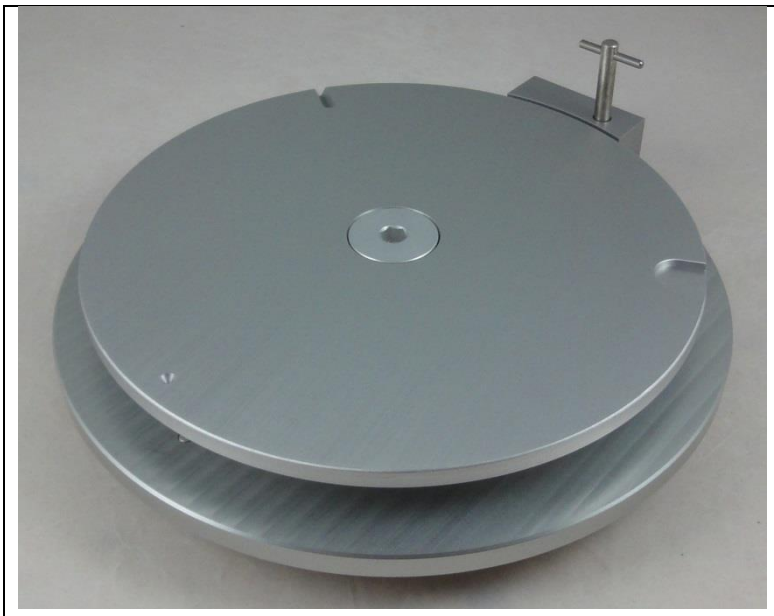
2.2.1 Field tripod

The field tripod allows a stable sensor installation under field conditions.
The three legs have to be pressed into the ground. The circular spirit level shall be used for a draft horizontal adjustment.
The tripod surface has a countersink, a groove and a flat area to pick up the sensor foot screws.

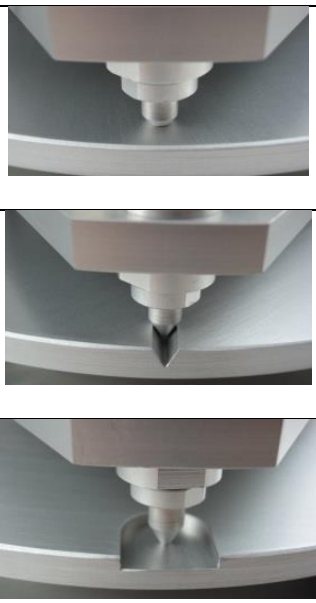


2.2.2 Rotation unit

The rotation adapter, installed between field tripod and sensor, makes the precise adjustment of the sensor axis to the magnetic field direction possible.
The transmission ratio is 1800: 1, five rotations on the screw turn the sensor for one degree. The horizontal adjustment can be done by leveling of the three foot screws under observation of the circular spirit level on the top side of the sensor. The fine adjustment into the meridian has to be done by the sensor adapter rotation screw until the data output for the Y component By is approximately zero.



Sensor rotation unit



Sensor feet bearing in countersink, groove and plane

2.2.3 Waterproofing

The titanium sensor is assembled between two aluminum plates inside a polycarbonate tube. Water sealing is realized by O rings between tube and aluminum plates as well as by seals of the pass through of the sensor cable. Note that the sensor is not suitable for permanent under water operation. The water sealing is only made for protection against water in an emergency case (heavy rain).

3 Overview of user interfaces

The software controlling of the magnetometer has a modular architecture. The main application software is responsible for controlling the measurement process, getting data on hardware level and storing them on the SD card. There are different user interfaces to access the application software and each of them has different possibilities to control the magnetometer. The following chapter gives an overview.

3.1.1 Touch screen

- Direct control via magnetometer electronics (no PC connection needed)
- Information on
  - Magnetometer time (format: HH:MM:SS)
  - Synchronization status
  - Magnetic field components
  - Absolute value of magnetic field
  - Difference of magnetic field components and absolute values (only in the 2 sensor version)
  - SD card memory status
  - CPU usage
  - GPS position
  - Electronics temperature
  - Sensor temperature
  - Inclination (optional)
  - Rotary encoder angle (optional)
  - Log messages
  - Sampling rate
  - Synchronization mode
- View files on SD card
- Graphical presentation of
  - Magnetic field components
  - Absolute value of magnetic field
  - Difference of magnetic field components and absolute values (only in the 2 sensor version)

  as absolute or variation plot with zoom function
- Visualization interval is 1 second
- Actions and settings
  - Shut down device
  - Manually triggered measurement
  - Switch on/off data recording
  - Choose between ASCII or binary data recording
  - Switch on/off automatic screen blanking
  - Switch on/off data output via serial interface
  - Set magnetometer date and time (format: dd.mm.yyyy hh:mm:ss)
  - Change synchronization mode
  - Set sampling rate
  - Enable heating controllers and change temperature setpoints (optional)
  - Change network settings
  - Establish a support connection to the manufacturer
  - Delete files

3.1.2 Serial interface

- Output of
  - Magnetometer time (format: seconds since 1.1.1970)
  - Magnetic field components
  - Electronics temperature
  - Sensor temperature
  - Inclination (optional)
  - Rotary encoder angle (optional)
  - Binary status word
  - SD card memory status notifications
  - Log messages

  in ASCII format and with a maximum data rate of 10 Hz
- Actions and settings
  - Shut down device
  - Manually triggered measurement
  - Switch on/off data recording
  - Choose between ASCII or binary data recording
  - Switch on/off automatic screen blanking
  - Switch on/off data output via serial interface
  - Change GPS data recording scheme (continuous with 1Hz or on position change)
  - Set magnetometer date and time (format: seconds since 1.1.1970)
  - Change synchronization mode
  - Set sampling rate
  - Enable heating controllers and change temperature setpoints (optional)

3.1.3 Network services

The network services grant device control via network (LAN) or internet.

3.1.3.1 FTP server

- Access to data stored on SD card (download, delete, rename)

3.1.3.2 Website

- Information on
  - Magnetometer time (Format: hh:mm:ss)
  - Local PC time (Format: dd.mm.yy hh:mm:ss)
  - Synchronization status
  - Magnetic field components
  - Absolute value of magnetic field
  - SD card memory status
  - GPS position
  - Electronics temperature
  - Sensor temperature
  - Inclination (optional)
  - Rotary encoder angle (optional)
  - Log messages
  - Sampling rate
  - Synchronizations mode
  - Heating controller status (optional)

- Browse files on SD card
- Display of information on versions of software components
- Graphical presentation of
  - Magnetic field components
  - Absolute value of magnetic field
  - Difference of magnetic field components and absolute values (only in the 2 sensor version)
  - Electronics temperature
  - Sensor temperature
  - Inclination (optional)
  - Rotary encoder angle (optional)
  - Heating controller setpoints and control variables (optional)
    in 3x3 plot windows, where the data series can be assigned arbitrarily
- Visualization interval is 2 seconds
- Actions and settings
  - Manually triggered measurement
  - Switch on/off data recording
  - Choose between ASCII or binary data recording
  - Switch on/off automatic screen blanking
  - Switch on/off data output via serial interface
  - Change GPS data recording scheme (continuous with 1Hz or on position change)
  - Set magnetometer date and time via a calendar
  - Change synchronization mode
  - Set sampling rate
  - Enable heating controllers and change temperature setpoints (optional)
  - Download and delete files

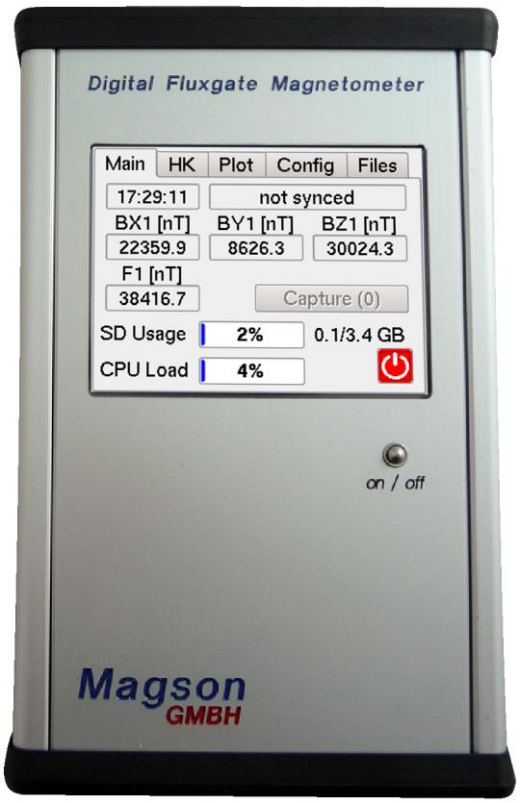
3.1.3.3 Socket connections

- In order to receive data and to command the device, the user has to write the client software. Magson provides a basic sample program (see appendix chapter 11.3).
- With socket connections data can be received at full data rate and in real time.
- The device can handle 5 socket connections simultaneously
- Socket connections provide full control of settings, all available actions and grant access to all information and measurement values. Downloading or deleting files from the internal SD card is not possible.

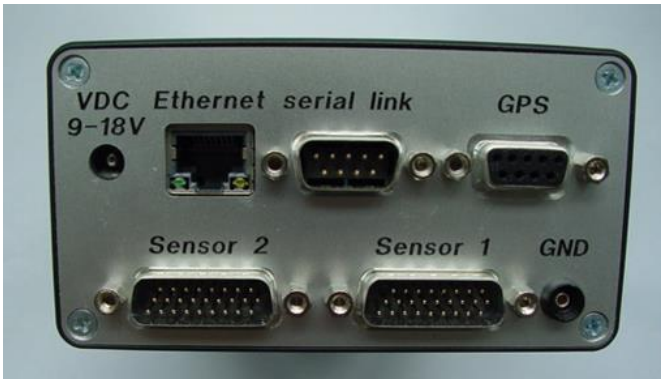
3.1.3.4 Maintenance

In case the device is connected to the internet, Magson can provide software updates or support with device problems. Chapter 7.4.1 shows how a support connection to Magson is established. Contact Magson (office@magson.de) if you need support.

4 Connectors and control



Controller top side



Controller back side. Two sensors

The touch screen and power button is on the top side of the controller while the back side covers all device connectors.

- Power supply (“VDC”, low voltage connector 2.5 mm)
- One or two sensor connectors depending on the magnetometer version (“Sensor1/Sensor2”, HD-26p)
- One connector for the GPS receiver (“GPS”, Sub-D-9s)
- Serial RS232 connector (”serial link”) or combined serial RS232 and rotary encoder (“Enc”), (Sub-D-9p)
- One Ethernet connector for the network connection (“Ethernet”, RJ45)
- Optional: connector for rotary encoder (“Enc”, Lemo 0B series 6 pins female)

4.1 Connector pin assignment

“VDC“

Pin	Function
inner	+Vin (9-18V)
outer	GND

”GPS”

Pin	Function
1	3.3V
2	GPS-TX
3	GPS-RX
4	1PPS
5	GND

“Ethernet“

Pin	Function
1	TD+
2	TD-
3	RD+
4	GND
5	GND
6	RD-
7	GND
8	GND

"Enc"

Pin	Function
1	GND (Enc)
2	RX (RS232)
3	TX (RS232)
4	Data (Enc)
5	GND (RS232)
6	Clk (Enc)
7	$\overline{\text{Data}}$ (Enc)
8	$\overline{\text{Clk}}$ (Enc)
9	5V(Enc)

“serial link“

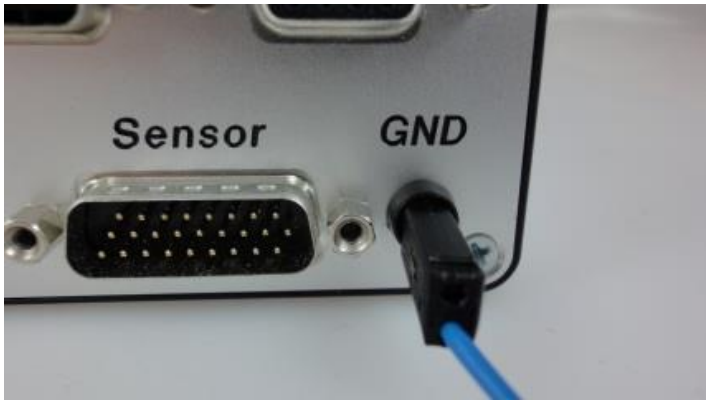
Pin	Function
2	RX
3	TX
5	GND

“sensor 1“ or “sensor 2”

Pin	Function
1	Excitation
2	Temp. sensor
4	Feedback Z
5	Feedback Y
6	Feedback X
7	Secondary Z
8	Secondary Y
9	Secondary X
10	Excitation Shield
11	Heater return
12	Heater
13	Heater Shield
15	+V Tilt (5V)
16	GND Tilt
17	Tilt X
18	Tilt Y
19	Excitation return
20	Temp. sensor return
21	Feedback Z return
22	Feedback Y return
23	Feedback X return
24	Secondary Z return
25	Secondary Y return
26	Secondary X return

5 Switching the device on and off

The magnetometer needs a DC power supply of 9.5 V-18 V. It can be run with the provided 12 V power supply unit or alternatively with a 12 V battery.
For proper operation the instrument needs a ground reference. To ensure this, connect the GND connector to main's safety ground or to another ground reference.



Ground connection

A voltage of at least 9.5 V is required in order to start the device. In case the operating voltage drops below 8.65 V, a warning message will be shown. The voltage has to rise to a normal level within 5 minutes, otherwise the system will end the measurement process and perform a controlled system shutdown. Whenever the operating voltage drops below 8.55 V the magnetometer is switched off immediately. In that case a loss of data is possible.

To start the device, connect the power supply to the VDC connector and press the on/off switch on the front side of the controller. The magnetometer will start and the boot process will be displayed on the touch screen. When the boot process is completed the graphical user interface (GUI) will be loaded.
In order to assure a controlled system shutdown, use the power button on the touch screen, send the corresponding command, or press the on/off button on the front side for more than 2 seconds until the message “System Shutdown initiated” is displayed.
Pressing the on/off button for more than 6 seconds or disconnecting the device from the power supply will lead to an uncontrolled system shutdown. In this case system errors or data losses can occur. Please execute an uncontrolled shutdown only if the system does not respond to any user input.

6 Device features

This chapter describes basic functions of the magnetometer, system features and settings. Most of the features and settings can be accessed via multiple user interfaces.

6.1 Sampling

The magnetic field and housekeeping (HK) values like temperatures or inclination (optional) are generated internally with 100 Hz (200 Hz optional). Depending on the chosen sampling rate of 1 Hz, 10 Hz and 50 Hz, values will be created by averaging the 100 Hz (200 Hz) values.
Except for the FTP server, all user interfaces have read/write access on the sampling rate.

6.2 Timestamp and synchronization

After switching the device on, the magnetometer time will be set to the value of the internal real time clock (RTC). The RTC is buffered by a battery, so the time is not lost when power is turned off. The backup battery has to be replaced after 1-2 years (see chapter 11.2).
Depending on the synchronization mode, the RTC and magnetometer time will be set to the GPS

time. RTC and magnetometer time can also be adjusted by the user via all user interfaces except the FTP server.
The magnetometer time will be counted forward with the time basis of data generation.

6.2.1 Synchronization mode

The synchronization mode determines when the connected GPS receiver will be activated to synchronize the RTC and magnetometer time. The different synchronization modes offer the possibility to choose between lower power consumption ("Sync Once" / "Sync Periodic") and higher time precession ("Sync Always"). At the moment of synchronization, a data gap is possible (except for the mode “Sync Always”). Following synchronization modes are available:

- **Sync Off** – Synchronization is switched off.
- **Sync Once** – Synchronization will be activated immediately but only once.
- **Sync Periodic** – Synchronization occurs once a day. The synchronization time (default: midnight) is determined by the Magson GmbH but can be changed if necessary.
- **Sync Always** – The device runs synchronously with the 1PPS (1 Hz) signal of the GPS receiver. Magnetometer and RTC time will be updated every 10 seconds.

The synchronization mode can be controlled by the user via all user interfaces except the FTP server.

6.2.2 Synchronization status

- **Not synced** – Magnetometer has not been synchronized since the last system start.
- **Syncing…** – Synchronization is in progress.
- **Synced** – Synchronization has been completed.

The status of synchronization can be controlled by the user via all user interfaces except the FTP server.

6.3 Position

The GPS position (latitude, longitude) will be displayed in degrees. Positive values represent the northern and eastern hemisphere. Negative values stand for the southern and western hemisphere.
The position will be updated with each synchronization process (see chapter 6.2). If the synchronization mode “Sync always” is activated, there are two settings on when the position update happens. If continuous GPS logging is enabled (can be done via the touch screen or the webpage) then the position is updated every second. If continuous GPS logging is disabled, then the position will be updated if the difference between the current and the last position is greater than 0.00005°. Additionally, the position can be requested per command via a socket connection or the serial interface.

6.4 Capture function

The capture function is used to record single shots of measurement values. It can be accessed per command or via the touch screen. One data set consists of a timestamp, the magnetic field components, the GPS position (see chapter 6.3), electronics and sensor temperatures, the inclination (optional) and the rotary encoder angle (optional). The file format will be explained in chapter 6.4.6.5. For example, the capture function can be used to capture measurement values on

different positions. The capture function is independent from the continuous recording of measurement values. It can also be used when logging is turned off.

Activating the capture function will create an empty capture file. Its name is composed of the current date and time (see chapter 6.4.5). Activation and deactivation of the capture function can be controlled via all user interfaces except the FTP server. The current status of the capture function can be accessed the same way.

The measurement values are averaged depending on the sampling rate. The number of collected data sets is indicated by the capture counter, which is accessible from all user interfaces except the FTP server.

After completing the measurement, the capture function should be deactivated to close the capture file and reset the capture counter to zero.

6.4.1 SD card

For data storage, an internal SD card is used. It cannot be removed. FTP server, touch screen and Website grant access to the data stored on the SD card. The following operations are possible:

user interface	download	delete	rename
Touch screen	-	●	-
Serial interface	-	-	-
FTP	●	●	●
Website	●	●	-
Socket connection	-	-	-

6.4.2 SD logging

Changing the “SD logging” setting will activate or deactivate data recording.
Except for the FTP server, all user interfaces have read/write access to this setting.

6.4.3 Log binary

To store data in a binary format, the “log binary” setting must be activated. GPS files, information files and capture files will always be stored in ASCII format. If “log binary” is deactivated, all data will be stored in ASCII format.
Except for the FTP server, all user interfaces have read/write access to this setting.

6.4.4 SD card memory status

In case that the free disk space on the SD card drops below 15 MB, the warning “Disk space runs low” will be displayed. In that case it is recommended to download and delete data from the SD card to free memory. If the free disk space is less than 5 MB, the SD card will be declared full (message “Disk full, logging stopped”) and the data recording is stopped. After that, data recording won't restart automatically even if memory is freed. It has to be reactivated by the setting “SD logging”.
The SD card memory status will be updated every 60 seconds. It will be written to all user interfaces except the FTP server and can also be requested by a command.

6.4.5 File names and types

The measurement values and additional information will be stored in different files on the SD card. The file extension consists of one letter and three numbers. The letter represents the file type and the numbers correspond to the device number. The file name is composed of the current date and time and has the form yyMMddhhmmss.

Placeholder	Meaning
yy	Year
MM	Month
dd	Day
hh	Hour
mm	Minute
ss	Second

Each placeholder has two characters. The date and time, which will be used for the file name, depend on the file type.

There are the following file types:

A: Measurement value file with magnetic field and HK data in ASCII format. The file name is equal to the timestamp of the first measured value inside the file.
A new file is created:
- When data recording in ASCII format is activated (see chapter 6.4.2)
- When data recording is active and the file format is changed from binary to ASCII (see chapter 6.4.3)
- Every hour (to prevent large files, which are hard to handle)
- When data recording is active and the sampling rate is changed (see chapter 6.1)
- When data recording is active and the time is adjusted (see chapter 6.2)

B: Measurement value file with magnetic field and HK data in binary format. The file name is equal to the timestamp of the first measured value inside the file.
A new file is created:
- When data recording in binary format is activated (see chapter 6.4.2)
- When data recording is active and the file format is changed from ASCII to binary (see chapter 6.4.3)
- Every hour (to prevent large files, which are hard to handle)
- When data recording is active and the sampling rate is changed (see chapter 6.1)
- When data recording is active and the time is adjusted (see chapter 6.2)

I: Information file in ASCII format. It is generated simultaneously with each measurement value file (file type A/B). The file contains the sampling rate and calibration values, which are used to generate the measurement values. The file name is identical to the corresponding measurement value file.

G: GPS data file in ASCII format. It is generated when the magnetometer has been synchronized successfully. If the mode “Sync-Always” is active, the GPS data is updated continuously every second or when the position has changed depending on the setting “continuous GPS logging” (see chapter 6.3). The file name is identical to the corresponding measurement value file.

C: Capture data file in ASCII format. The file name corresponds to the time of activating the capture function (see chapter 6.4).

Example:

The file 110812110000.A103 is a measurement value file in ASCII format of the device with the number 103. The first value was recorded on 12/08/2011 at 11:00:00.

6.4.6 File formats

6.4.6.1 Measurement value file in ASCII format

Each line is terminated with CR LF (0x0D 0x0A) and contains the following values (from left to right):

Position	Content	Exists only in a magnetometer with
left	Timestamp in seconds since 1.1.1970 (UTC)	
…	Magnetic field component X sensor 1 [nT]	
…	Magnetic field component Y sensor 1 [nT]	
…	Magnetic field component Z sensor 1 [nT]	
…	Magnetic field component X sensor 2 [nT]	2 magnetic field sensors
…	Magnetic field component Y sensor 2 [nT]	
…	Magnetic field component Z sensor 2 [nT]	
…	Electronics temperature [°C]	
…	Sensor 1 temperature [°C]	
…	Sensor 2 temperature [°C]	2 magnetic field sensors
…	Tilt X sensor 1 [°]	inclinometer option
…	Tilt Y sensor 1 [°]	
…	Tilt X sensor 2 [°]	2 magnetic field sensors and inclinometer option
…	Tilt Y sensor 2 [°]	
…	Rotary encoder angle [°]	rotary encoder option
right	Status word (see chapter 11.1)	

6.4.6.2 Measurement value file in binary format

Binary data are saved in Little-Endian format. A data set contains the following values:

Byte	Content	Format	Exists only in magnetometers with
first	Timestamp in seconds since 1.1.1970 (UTC)	32 Bit long	
…	Magnetic field component X sensor 1 [nT]	32 Bit float	
…	Magnetic field component Y sensor 1 [nT]	32 Bit float	
…	Magnetic field component Z sensor 1 [nT]	32 Bit float	
…	Magnetic field component X sensor 2 [nT]	32 Bit float	2 magnetic field sensors
…	Magnetic field component Y sensor 2 [nT]	32 Bit float	
…	Magnetic field component Z sensor 2 [nT]	32 Bit float	
…	Electronics temperature [°C]	32 Bit float	
…	Sensor 1 temperature [°C]	32 Bit float	
…	Sensor 2 temperature [°C]	32 Bit float	2 magnetic field sensors
…	Tilt X sensor 1 [°]	32 Bit float	inclinometer option
…	Tilt Y sensor 1 [°]	32 Bit float	
…	Tilt X sensor 2 [°]	32 Bit float	2 magnetic field sensors and inclinometer option
…	Tilt Y sensor 2 [°]	32 Bit float	
…	Rotary encoder angle [°]	32 Bit float	rotary encoder option
last	Status word (see chapter 11.1)	32 Bit long	

6.4.6.3 Information file

The information file contains the encoded sampling rate (see sampling rate command in chapter 8.2.1) and the calibration parameters. With these parameters and the information about the internal calculations (see chapter 11.4), the measurement values can be transformed to uncalibrated values.

6.4.6.4 GPS file

Each line is terminated with CR LF (0x0D 0x0A) and contains the following values:

Column	Content
1	Timestamp in seconds since 1.1.1970 (UTC)
2	Latitude [°] (see chapter 6.3)
3	Longitude [°] (see chapter 6.3)

6.4.6.5 Capture file

Each line is terminated with CR LF (0x0D 0x0A) and contains the following values (from left to right):

Position	Content	Exists only in magnetometers with
left	Year	
…	Month	
…	Day	
…	Hour	
…	Minute	
…	Second	
…	Latitude [°] (see chapter 6.3)	
…	Longitude [°] (see chapter 6.3)	
…	Magnetic field component X sensor 1 [nT]	
…	Magnetic field component Y sensor 1 [nT]	
…	Magnetic field component Z sensor 1 [nT]	
…	Magnetic field component X sensor 2 [nT]	2 magnetic field sensors
…	Magnetic field component Y sensor 2 [nT]	
…	Magnetic field component Z sensor 2 [nT]	
…	Electronics temperature [°C]	
…	Sensor 1 temperature [°C]	
…	Sensor 2 temperature [°C]	2 magnetic field sensors
…	Tilt X sensor 1 [°]	inclinometer option
…	Tilt Y sensor 1 [°]	
…	Tilt X sensor 2 [°]	2 magnetic field sensors and inclinometer option
…	Tilt Y sensor 2 [°]	
…	Rotary encoder angle [°]	rotary encoder option
right	Status word (see chapter 11.1)	

6.4.7 SD card data capacity

The amount of recorded data and the maximum recording duration depend on the sampling rate and the device configuration. For the following calculation, only measurement values will be taken into account. GPS data, information data and capture data will not be considered.
The device configuration is determined by the parameters D, T and R which represent:

Device with 1 sensor: D=0
Device with 2 sensors: D=1

Device without inclinometer: T=0
Device with inclinometer: T=1

Device without rotary encoder: R=0
Device with rotary encoder: R=1

fs: sampling rate in [Hz]

6.4.7.1 Data recording in ASCII format

Data rate (r) in [bytes/s]: r = fs * [67 + D*37 + T*16*(D+1) + R*8]

Example:

On a device with 2 magnetic field sensors, without inclinometers and rotary encoder and a sampling rate of 100 Hz
100 * [67 + 1*37 + 0*16*(1+1) + 0*8] = 10400 bytes of data are generated every second.

A one hour file of measurement values has a size of:
3600 s * 10400 byte/s = 37440000 byte ≈ 35.7 Mbyte

A 4GB SD card has ≈3.37GB (3625598976 byte) of free disk space. After a recording duration of 3625598976 byte / 10400 byte*s^{-1} = 348615 s = 96.8 hours ≈ 4 days, the SD card would run out of free disk space.

6.4.7.2 Data recording in binary format

Data rate (r) in [bytes/s]: r = fs * [28 + D*16 + T*8*(D+1) + R*4]

Example:

On a device with 2 magnetic field sensors, without inclinometers and rotary encoder and a sampling rate of 100 Hz
100 * [28 + 1*16 + 0*8*(1+1) + 0*4] = 4400 bytes of data are generated every second.

A one hour file of measurement values has a size of:
3600 s * 4400 byte/s = 15840000 byte ≈ 15.1 Mbyte

A 4GB SD card has ≈3.37GB (3625598976 byte) of free disk space. After a recording duration of 3625598976 byte / 4400 byte*s^{-1} = 824000 s = 228.9 hours ≈ 9.5 days, the SD card would run out of free disk space.

6.5 Log messages

In case of functional errors or critical system states (e.g. the SD card runs out of free disk space or the supply voltage drops below a minimum value), the magnetometer displays log messages via the user interfaces. The messages are displayed in text form (touch screen, website) or as encoded log numbers (serial interface, socket connections). Some log messages contain data. For example the time until system shutdown inside the message “Battery voltage low”. Additionally, these messages will be stored in a system-wide log file which can only be accessed by the company Magson.
The following table summarizes the possible messages of the application software:

Log number	Log data	Meaning
0	-	“user.mag” file could not be opened
1	-	“dev_id.mag” file could not be opened
2	-	“cal.mag file” could not be opened
3	-	“config.mag” file could not be opened
4	-	Allocation of Cmd-Buffer space failed
5	-	Allocation of Magdatraw-Buffer space failed
6	-	Mag-Char-Device could not be opened
7	-	Cmd-Fifo could not be created
8	-	DB-Fifo could not be created
9	-	WS-Fifo could not be created
10	-	QT-Fifo could not be created
11	-	Cmd-Fifo could not be opened
12	ERRNO	Cmd-Fifo could not be read
13	-	Socket could not be opened
14	-	Socket settings could not be set
15	ERRNO	Socket could not be bound
16	ERRNO	Socket listening failed
17	ERRNO	Socket write failed
18	ERRNO	Socket read failed
19	-	Square wave of RTC could not be switch on
20	-	Device ID mismatch
21	File-Identifier	Temporary data file could not be opened
22	-	Serial interface read failed
23	Data type	Unknown data type
24	-	Watchdog-Timeout occurred
25	-	SD card is full, logging stopped
26	-	SD card is nearly full
27	Counter	Battery voltage low, Counter: seconds to automatic system shutdown
28	Fifo-Level	FPGA-Fifo-level
29	-	FPGA-Fifo full -> data loss
30	-	RTC has been set -> data loss

The user interfaces website and touch screen can create additional interface specific warnings, which will be displayed in text form.

6.6 Deactivation of data output on the serial interface

With the setting "serial TX", the data output on the serial interface can be enabled or disabled. Except for the FTP server, all user interfaces have read/write access to this setting. The data input will not be deactivated and all commands can still be received.

6.7 Automatic screen blanking

When the automatic screen blanking function is activated, the display and its backlight are switched off after 5 minutes. The function reduces the power consumption and increases the operating time while the device is running on batteries.
Tap the touch screen to reactivate the display. The touch screen still remains disabled for one more second, to prevent faulty operations. The display will stay lightened and the touch screen active when the automatic screen blanking function is deactivated.

6.8 Continuous GPS data logging

The setting “cont. GPS logging” is used to control the GPS logging scheme. If it is activated and valid GPS messages are received from the GPS, the data is updated every second. If “cont. GPS logging” is not activated, the GPS data is updated if the position (latitude or longitude) changes more then 0.000005° in respect to the last value.

6.9 Heaters (optional)

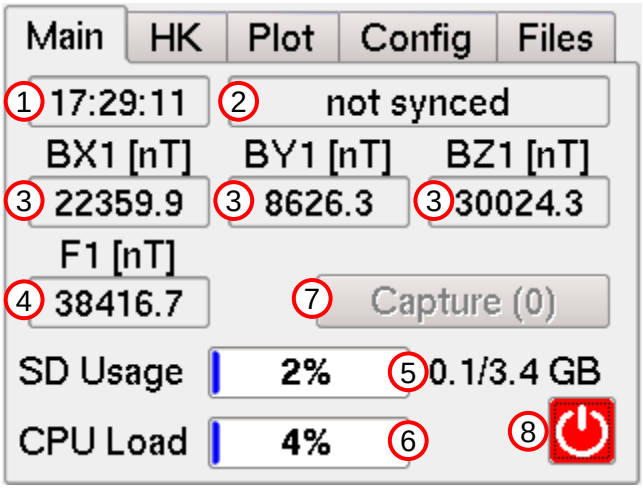
Optionally the magnetometer is equipped with electronics and sensor heaters to decrease its temperature dependency.
The heaters are controlled by digital PID controllers which can be accessed through all interfaces except the FTP server.
The temperature setpoints and the heater activation can be varied separately for electronics and sensor heaters. If the magnetometer is equipped with two sensors, the sensor heater setpoint and activation setting will be applied to both sensor PID controllers.
Via a socket connection or the website it is also possible to watch the PID controller output (controlled variable) which is refreshed every 10 seconds.

7 Touch screen with graphical user interface

The device can be controlled via the touch screen without having any connection to a computer. The touch screen displays all magnetic field components and HK values. The display will be refreshed every second. The displayed values are generated by decimation from the averaged values. To increase the clarity, the measured values are displayed in different tabs.

7.1 Tab “Main”

The main tab presents the most important measurement values.



1 **Timestamp** of the current measurement vector (see chapter 6.2)

2 **Synchronization status** (see chapter 6.2.2)

3 **Magnetic field vector**
The magnetic field vector shows the X-, Y- and Z- component of the current magnetic field in nanotesla.
If the magnetometer is equipped with 2 magnetic field sensors, the displayed sensor can be altered in the config tab (see chapter 7.4 point 7). Three options can be chosen, sensor 1 (BX1/BY1/BZ1), sensor 2 (BX2/BY2/BZ2) or the difference between the sensors (dBX/dBY/dBZ).

4 **Absolute field** in nanotesla
If the magnetometer is equipped with 2 magnetic field sensors, the displayed sensor can be altered in the config tab (see chapter 7.4 point 7). Three options are available, sensor 1 (F1), sensor 2 (F2) or the difference between the sensors (dF).

5 **SD usage**
The SD usage bar shows the amount of currently used SD card space in percent. Next to the bar, the values of currently used and overall available disk space are listed (see chapter 6.4.4).

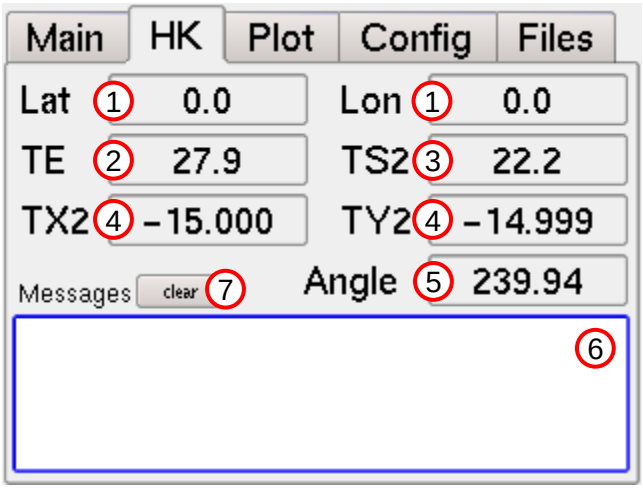
6 **CPU load**
This bar shows the mean value of current CPU load in percent.

⑦ **Capture** (see chapter 6.4)
This button will be enabled when the capture function is activated. By pressing the capture button, the current measurement values will be written into a capture file on the SD card. The number on the button represents the capture counter, which shows the number of data vectors inside the capture file.

⑧ **Off** (see chapter 5)
After pressing the power button, a popup dialog with the question “Do you really want to shut down?” is shown. Confirm with “Yes” to initiate a controlled system shutdown, or press “No” to close the popup dialog and cancel the shutdown process.

7.2 Tab ”HK“

The HK (housekeeping) tab displays values like temperatures, GPS position, log messages and inclination (optional).



① **GPS position** (see chapter 6.3)

② **Electronics temperature** (°C)

③ **Sensor temperature** (°C)
If the magnetometer is equipped with 2 magnetic field sensors, the displayed sensor temperature can be altered in the config tab (see chapter 7.4 point 7). Three options are available, sensor 1 (TS1), sensor 2 (TS2) or the difference between the sensors (dTS).

④ **Inclination** (°)
This value only exists, if a device with inclinometer option is ordered.
If the magnetometer is equipped with 2 magnetic field sensors, the displayed inclination can be altered in the config tab (see chapter 7.4 point 7). Three options are available, sensor 1 (TX1/TY1), sensor 2 (TX2/TY2) or the difference between the sensor inclinations (dTX/dTY).

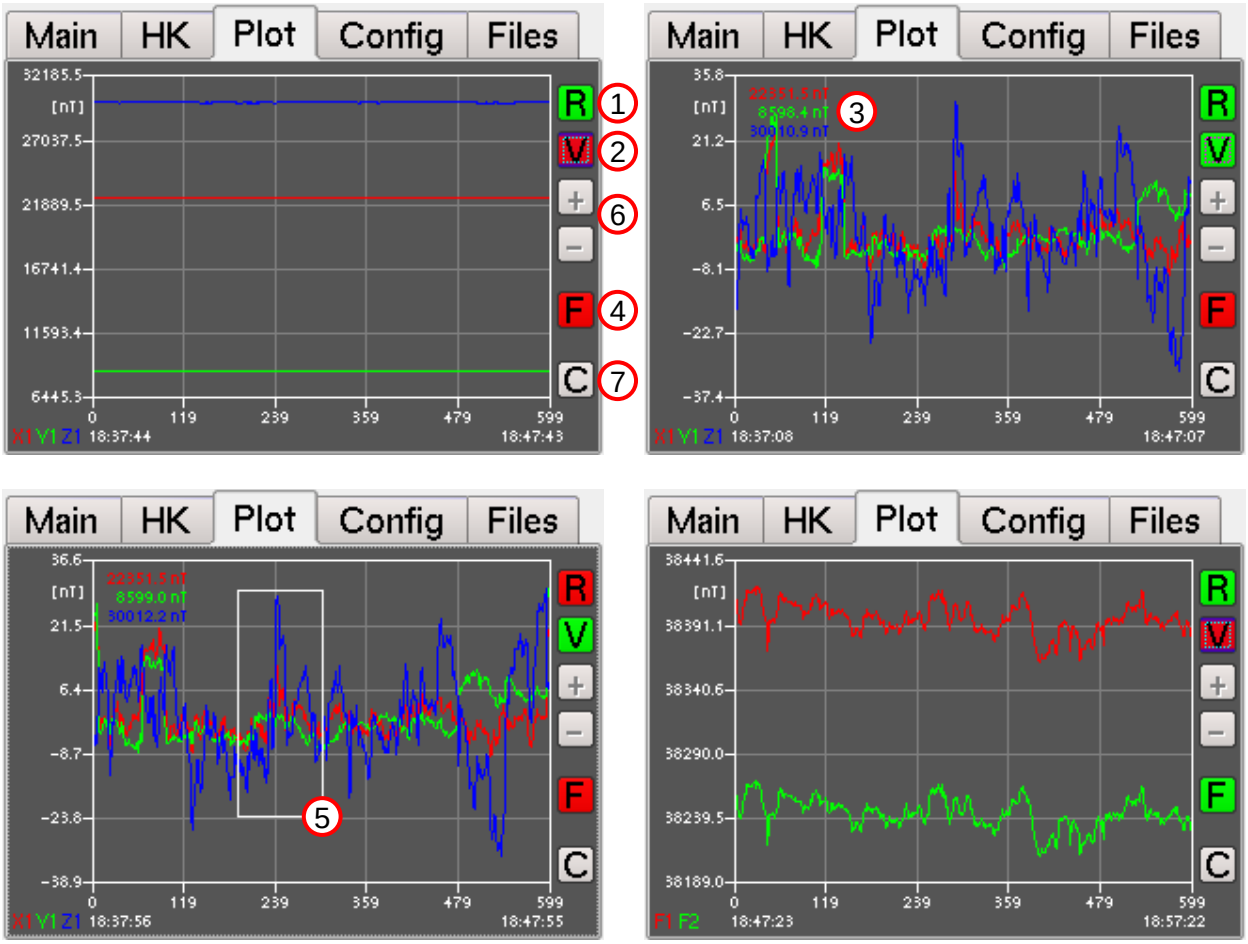
⑤ **Rotary encoder angle** (°)
This value only exists, if a device with rotary encoder option is ordered.

6 **Log messages** (see chapter 6.5)
Each message consists of an index number, a timestamp (if available), the source of the message in square brackets and a message text. If the number of messages exceeds the available display space, a scroll bar will be shown to ensure that all messages can be accessed.
The message box can store up to 512 entries. If there are more than 512 messages, the oldest messages are deleted.

7 **Clear**
This button clears the message box.

7.3 Tab ”Plot“

In this tab, the magnetic field components or the absolute field are displayed graphically.
The X-Axis is scaled to 600 seconds = 10 minutes and cannot be changed. Below this axis, the timestamps of the current (rightmost) and the oldest vector (leftmost) is displayed. The Y-Axis is scaled automatically.



1 **Run/Stop**
The run/stop button starts or stops plotting of measurement values. The color of the button indicates the status (green=running, red=stopped). All values which arrive while plotting is off will not be lost. It will appear if plotting is started again. Stopping the visualization is needed for zooming.

② **Variation**

The variation mode is used to visualize variations of the magnetic field components, which normally have significant offsets. If the variation mode is active (color of the button is green), the mean values of the curves are subtracted. The subtracted mean values will be displayed in the upper left corner of the plot window ③. If the color of the button is red, the variation mode is disabled.

④ **Absolute field**

This button is used to switch between the visualization of the magnetic field components (button is red) and the absolute field (button is green).
If the magnetometer is equipped with 2 magnetic field sensors, the displayed values can be altered in the config tab (see chapter 7.4 point 7). Three options are available, values from sensor 1, values from sensor 2 or the difference between the sensor values. The possible options are:

Config tab	Color	Displayed values
Show S1	Red	Magnetic field components of sensor 1
Show S2		Magnetic field components of sensor 2
Show Diff		Difference between magnetic field components of sensor 1 and sensor 2 (Bxyz1-Bxyz2)
Show S1	Green	Absolute field of sensor 1
Show S2		Absolute field of sensor 2
Show Diff		Difference between absolute fields of sensor 1 and sensor 2 (F1-F2)

⑤ **Zoom**

To use the zoom function, the visualization of magnetic field values must be stopped with the run/stop button ①. The zoom area is selected by drawing a rectangle. If the touch screen is released, the zoom operation is performed on the selected area.

⑥ **Zoom forward/backward**

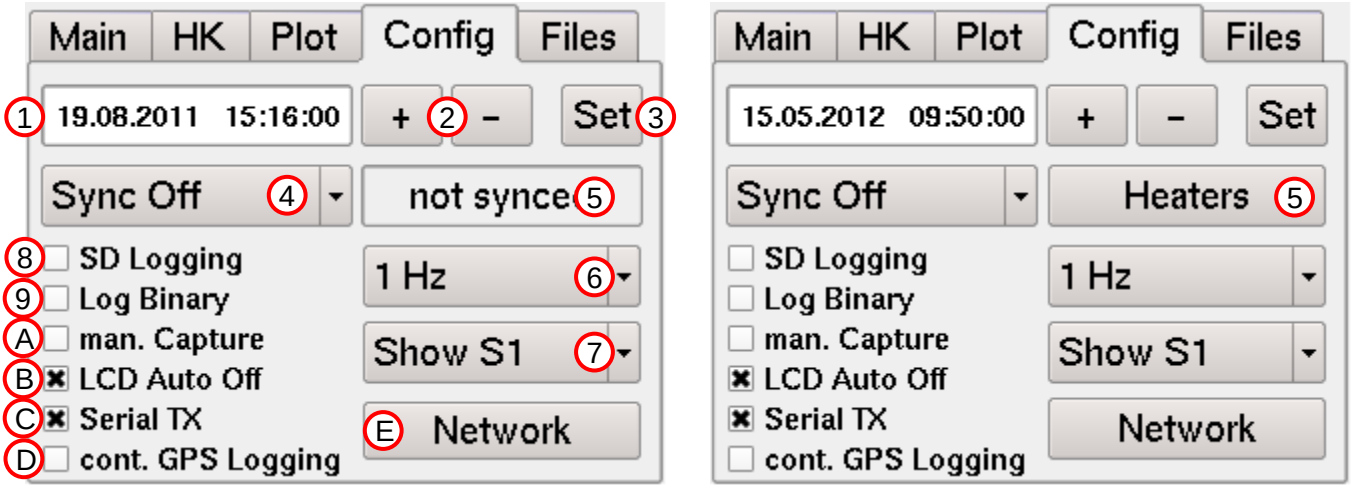
Every zoom level is stored in a zoom history.
The buttons "+" and "-" are used to step through this history. If there is no previous entry in the zoom history (fully zoomed out), the minus button is disabled. The plus button will become active after zooming out using the minus button. It can be used to reload the next bigger zoom level from the history.

⑦ **Clear**

The button is used to clear the plot window and to reset the scaling of the Y-axis. This is useful when big disturbances (for instance from moving the sensor) increase the scaling of the Y-axis to a level, where field variations are no longer recognizable. Otherwise the user has to wait until the disturbances run out of the screen.

7.4 Tab "Config"

The config tab displays the current configuration of the magnetometer. It is also used to change the configuration.



(1)(2) **Change date and time**
Every time the config tab is selected, the input box is initialized with the current magnetometer time (exception: seconds are set to zero). The values can be changed by placing the cursor at the corresponding position of the input box (1) and pressing the plus or minus button (2).

(3) **Set**
By pressing this button, the time of magnetometer and RTC is set to the value of the input field (1) (see chapter 6.2).

(4) **Synchronization mode** (see chapter 6.2.1)
This button shows the current setting of synchronization mode. Pressing the button will open a pull-down menu where the mode can be changed.

(5) **Synchronization status / Heaters**
At this position normally the synchronization status is shown (see chapter 6.2.2). If the magnetometer is equipped with heaters, a button to open the heater settings dialog (see chapter 7.4.2) is placed there instead.

(6) **Sampling rate** (see chapter 6.1)
This button shows the current setting of the sampling rate. Pressing the button will open a pull-down menu where the sampling rate can be changed.

(7) **Sensor**
This button only exists for a magnetometer equipped with two magnetic field sensors. Pressing the button will open a pull-down menu where the user can select whether measurements from sensor 1, sensor 2 or the differences should be displayed.

8 **SD logging** (see chapter 6.4.2)
Activates or deactivates data recording on the SD card and shows the current status of this setting.

9 **Log binary** (see chapter 6.4.3)
Changes the data recording format between binary and ASCII and displays the current status of this setting.

A **Man. Capture** (see chapter 6.4)
Activates or deactivates the manual capture function and displays the current status of this setting.

B **LCD auto off** (see chapter 6.7)
Activates or deactivates the automatic screen blanking function and displays the current status of this setting.

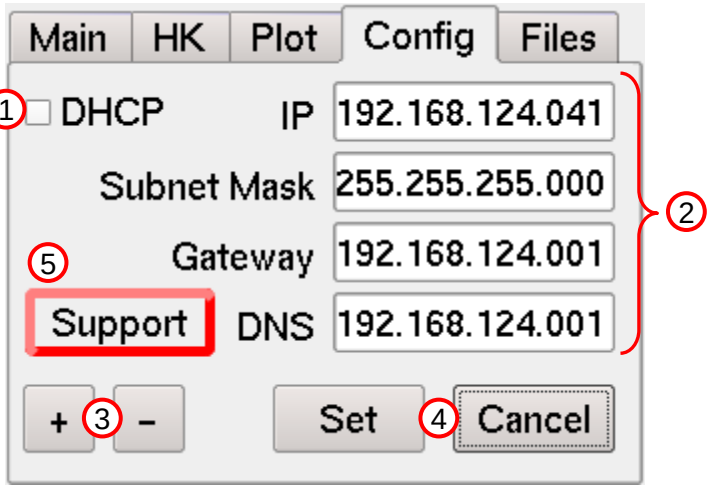
C **Serial TX**
Activates or deactivates the data output on the serial interface and displays the current status of this setting.

D **Continuous GPS Logging**
If activated the GPS data is updated every second. If not the GPS data is updated if the difference to the previous position (latitude or longitude) is more than 0.000005°.

E **Network**
Displays a dialog where network settings can be made
(see chapter 7.4.1).

7.4.1 Network settings

The dialog is used to set up the network parameters. After enabling this dialog by pressing the button "Network" in the config tab (see chapter 7.4), the current configuration is loaded from the magnetometer and displayed.



① **DHCP**
When the DHCP option is enabled, the magnetometer is configured for automatic network setup. It's important that the network, which is connected to the magnetometer, provides a DHCP server. If the DHCP option is disabled, all network parameters can be adjusted manually.

② **IP address / subnet mask / gateway address / DNS server address**
This four input boxes are used to adjust the network parameters manually. To change an octet, place the cursor on it and use the plus and minus buttons ③ for increasing or decreasing the value.
By holding these buttons longer than one second the value is changed by 10 instead of 1.

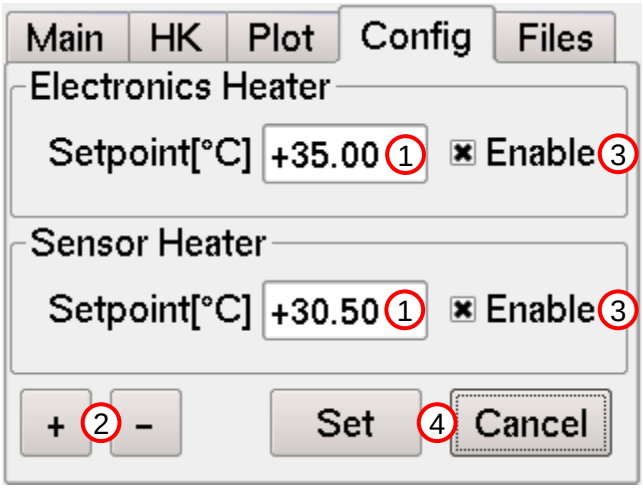
④ **Set/Cancel**
With the button "Set", the network settings will be applied. The button "Cancel" should be used to discard changes. After pressing one of these buttons, the network dialog is closed.

⑤ **Support**
With the button "Support", a secure connection to Magson can be established to give the manufacturer access to the magnetometer to help with trouble shooting or to update the software of the device. The color of the frame around the button shows the connection state. If the button is pressed while the connection is established, then the connection will be terminated. Contact Magson (office@magson.de) if you need support.

- red: No connection to Magson
- yellow: Connecting to Magson
- green: Connection to Magson established

7.4.2 Heater settings (optional)

The dialog is used to set up the heating controllers. After enabling this dialog by pressing the button "Heaters" in the config tab (see chapter 7.4), the current configuration is loaded from the magnetometer and displayed. If two sensors are connected to the magnetometer, the sensor heater settings will be applied to both of them.



① **Setpoints of electronics and sensor heaters**
To change the setpoint temperature, place the cursor before or behind the decimal point and use the plus and minus buttons ② for increasing or decreasing the integer or

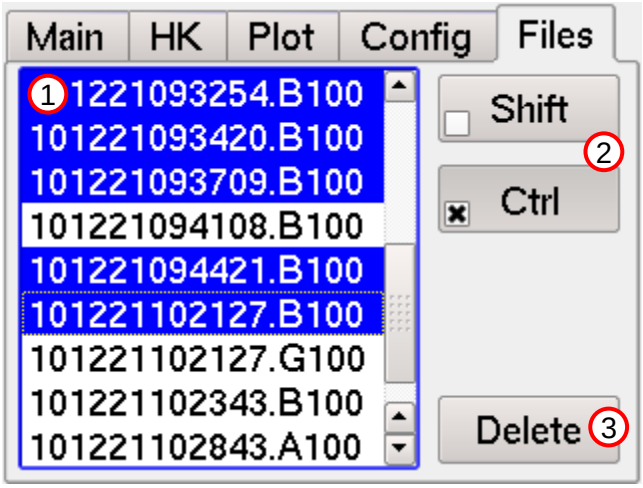
fractional part.
By holding the plus or minus button longer than one second the value is changed by 2 instead of 1.

④ **Enable**
Activates or deactivates the heating controller of electronics and/or sensor.

④ **Set/Cancel**
With the button "Set", the heating controller settings will be applied. The button "Cancel" should be used to discard changes. After pressing one of these buttons, the heater settings dialog is closed.

7.5 Tab ”Files“

This tab is used for viewing or deleting files from the SD card.



The list ① displays all files of the types A, B, C, G and I which are stored on the SD card. It will be refreshed when the tab "Files" was selected. If there are lots of files, this may take a moment. The file which is currently written to the SD card is not shown in the list. To delete files, select the files from the list, press the button “Delete” ③ and confirm the popup message “Do you really want to delete files” with “yes”. In order to select multiple files use the “Shift” and “Ctrl” buttons ②. They are used similarly to the corresponding keys on a normal PC keyboard. "Shift" has the higher priority, if both buttons are activated at the same time.

Examples:

Mark a block of consecutive files:
1. Mark 1st file of the block („Shift“ and „Ctrl“ must be disabled)
2. Activate „Shift“
3. Mark the last file of the block (use the scroll bar if needed)

Mark multiple not consecutive files (for example 1st, 3rd and 5th):
1. Mark 1st file („Shift“ and „Ctrl“ must be disabled)
2. Activate „Ctrl“
3. Mark 3rd and 5th file

Mark multiple not consecutive blocks of files (for example 3rd to 10th and 20th to 30th):

1. Mark 3rd file („Shift“ and „Ctrl“ must be disabled)
2. Activate „Shift“
3. Mark 10th file
4. Activate „Ctrl“ and disable “Shift”
5. Mark 20th file
6. Activate „Shift“
7. Mark 30th file

Restart selection:

- Disable „Ctrl“ and “Shift”
- Mark 1st file of the new selection
- Continue as described in the other examples

8 Serial interface

To communicate via the serial interface, the following parameters have to be set:

Parameter	Value
Baud rate	38400
Data bits	8
Parity	none
Stop bits	1

8.1 Data

The output format of data on the serial interface is identical to the file format of ASCII measurement files (see chapter 6.4.6.1). The output data rate is limited to 10 Hz. If a higher sampling rate is selected, data is generated by decimation from the averaged values.

8.2 Commanding

All commands have to be sent in ASCII format. Every command consists of a command type, a command address and command data. The three values are separated by a space character and have to be terminated by a line break (<CR><LF>). In most terminal programs a line break is sent by pressing the enter key.

Command format: TYPE <space> ADDRESS <space> DATA <CR><LF>

The next chapter (8.2.1) contains a list of all commands. Only commands of type 0 are important for the user. The other command types are only used for startup and debugging purposes. Commands are divided into "set" commands which will be used to change configuration parameters and "get" commands which request data from the device. “Set” commands start at address 0 (0x0000),”get” commands at address 4096 (0x1000).
All command addresses in the following list which are marked as reserved are either unused or used only for startup and debugging purposes. These commands should not be used by the user.

8.2.1 List of commands

Type	Addr.	Name	Data	Description
0	0	Sampling rate	0 → 100 Hz 1 → 50 Hz 2 → 10 Hz 3 → 1 Hz	see chapter 6.1
	1	SD logging	0 → deactivated 1 → activated	see chapter 6.4.2
	2	Sync mode	0 → Sync OFF 1 → Sync Once 2 → Sync Periodic 3 → Sync Always	see chapter 6.2.1
	3	Log binary	0 → ASCII 1 → Binary	see chapter 6.4.3
	4	Serial TX	0 → deactivated 1 → activated	see chapter 6.6
	5	LCD Auto off	0 → LCD screen blanking after 5 minutes 1 → LCD always on	see chapter 6.7
	6	Shutdown	don't care (e.g. zero)	initiates a controlled shutdown
	7	Set date/time	seconds since 1.1.1970	Sets magnetometer and RTC time
	8	Capture enabled	0 → activated 1 → deactivated	see chapter 6.4
	9	Capture sample	don't care (e.g. zero)	see chapter 6.4
	10	Setpoint HeaterE	Temperature in 10^{-3} °C (e.g. 23432 -> 23.432°C)	optional: Electronics heating controller setpoint see chapter 6.9
	11	Setpoint HeaterS	Temperature in 10^{-3} °C	optional: Sensor heating controller setpoint see chapter 6.9
	12	Heater Enable	Bit1: HeaterE enable Bit0: HeaterS enable	
	13	Continuous GPS Logging	0 → on position change 1 → continuous (every second)	see chapter 6.3
	14 ... 4095	reserved		
	4096	Get position	don't care (e.g. zero)	Requests the GPS position (see chapter 6.3)
	4097	Get SD info	don't care (e.g. zero)	Requests the SD card memory status
	4098 … 4351	reserved		
1	reserved			
2				
3				
4				

Examples:

0 0 2<CR><LF> → sets the sampling rate to 10 Hz
0 1 1<CR><LF> → activates data recording on SD card
0 6 0<CR><LF> → performs a controlled system shutdown
0 7 1313608105<CR><LF> → sets magnetometer and RTC time to 17.08.2011 19:08:25

9 Network services

9.1 FTP server

A FTP connection grants access to files which are stored on the SD card. Files can be downloaded, renamed or deleted. To establish a FTP connection, the current IP address of the magnetometer is required. It is displayed in the network settings dialog on the touch screen (see chapter 7.4.1). Additionally a FTP user name and a password are needed.

FTP user name: **ftpuser**
FTP password: **fluxgate**

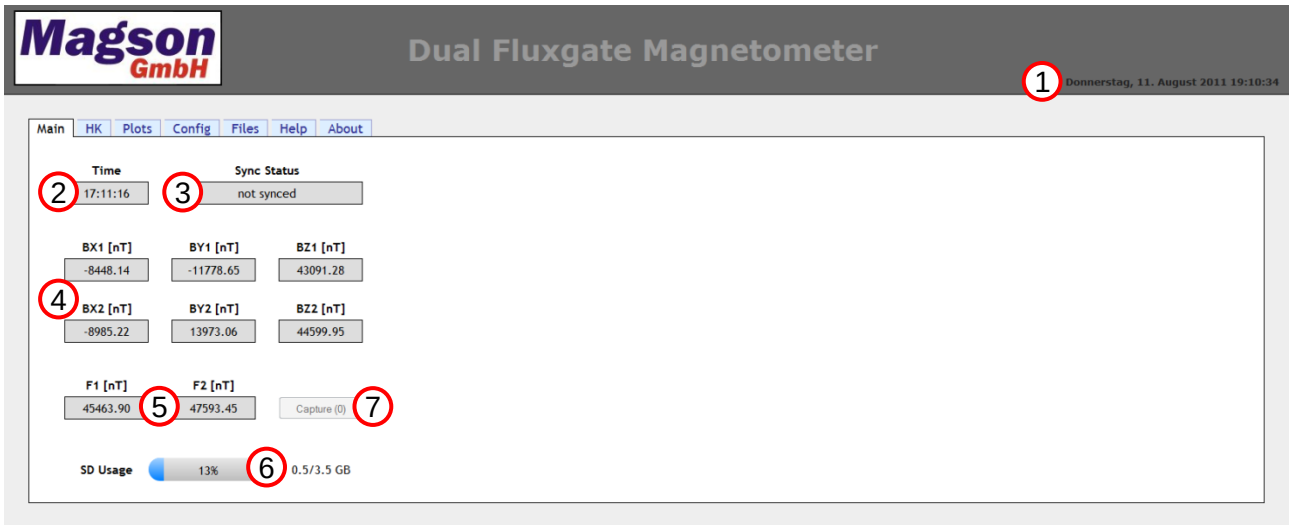
If any problems occur with the FTP connection, it is recommended to run the FTP client in passive mode.

9.2 Website

The magnetometer offers a website which displays all measurement values in a numerical and graphical form. It can also be used to change the magnetometer configuration. To access the website, enter the current IP address of the magnetometer (see chapter 7.4.1) into the address bar of your browser. The website is divided into different tabs just like the GUI of the touch screen. Furthermore, it grants access to the SD card for downloading or deleting files. The update rate is 2 seconds, which is realized by decimation of the averaged values.

9.2.1 Tab “Main”

The main tab presents the most important measurement values.



1 **Time and date (local)**
Local time and date of the PC, from which the website is accessed.

2 **Timestamp** of the current measurement vector (see chapter 6.2)

3 **Synchronization status** (see chapter 6.2.2)

④ **Magnetic field vector**
The magnetic field vector shows the X-, Y- and Z- component of the current magnetic field vector in nanotesla.
If the magnetometer is equipped with 2 magnetic field sensors, also the magnetic field vector of the second sensor (Bxyz2) will be shown.

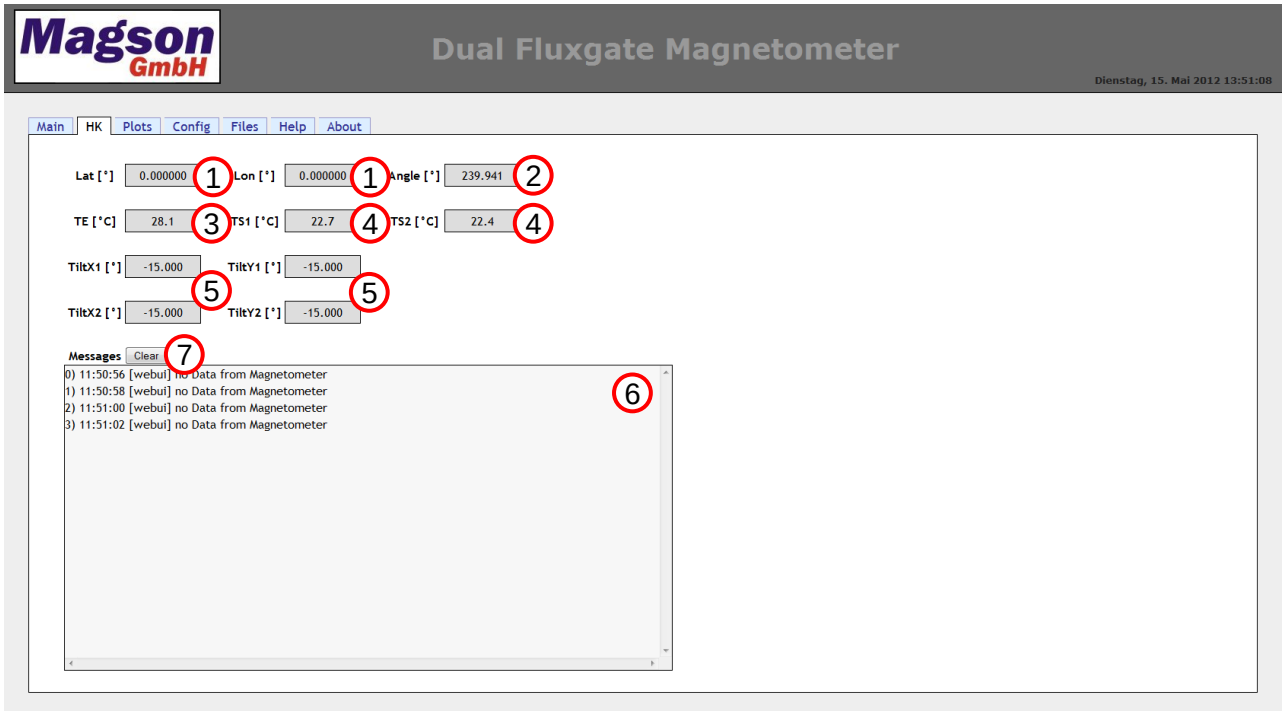
⑤ **Absolute field** in nanotesla
If the magnetometer is equipped with 2 magnetic field sensors, also the absolute field value of the second sensor (F2) will be shown.

⑥ **SD usage**
The SD usage bar shows the amount of currently used SD card space in percent.
Next to the bar, the values of currently used and overall available disk space are listed (see chapter 6.4.4).

⑦ **Capture** (see chapter 6.4)
This button will be enabled when the capture function is activated. By pressing the capture button, the current measurement values will be written into a capture file on the SD card. The number on the button represents the capture counter, which shows the number of data vectors inside the capture file.

9.2.2 Tab “HK”

The HK (housekeeping) tab displays values like temperatures, GPS position, log messages, inclination (optional) and rotation angle (optional).



① **GPS position** (see chapter 6.3)

② **Rotary encoder angle** (°)
This value only exists, if a device with rotary encoder option is ordered.

③ **Electronics temperature** (°C)

④ **Sensor temperature** (°C)
If the magnetometer is equipped with 2 magnetic field sensors, also the temperature of the second sensor (TS2) will be shown.

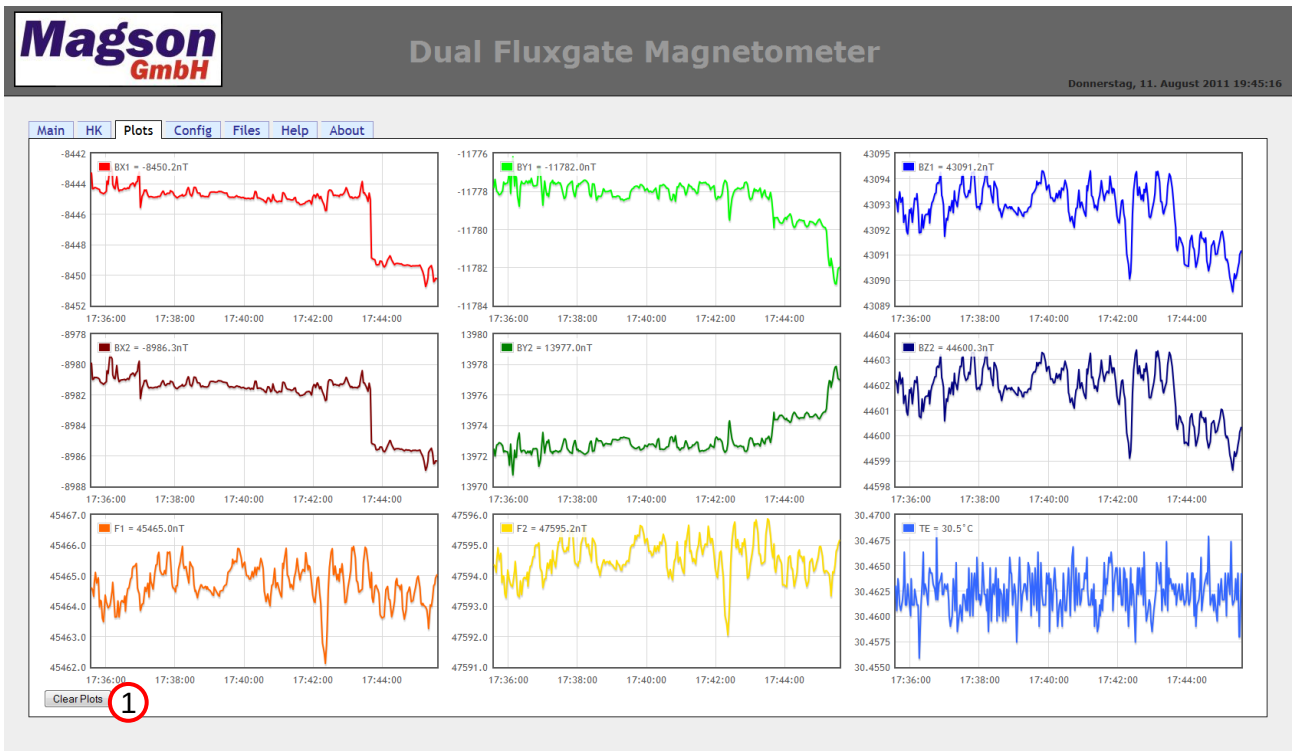
⑤ **Inclination** (°)
This value only exists, if a device with inclinometer option is ordered.
If the magnetometer is equipped with 2 magnetic field sensors, also the inclination of the second sensor (TiltX2, TiltY2) will be shown.

⑥ **Log messages** (see chapter 6.5)
Each message consists of an index number, a timestamp (if available), the source of the message in square brackets and a message text. If the number of messages exceeds the available display space, a scroll bar will be shown to ensure that all messages can be accessed.

⑦ **Clear**
This button clears the message box.

9.2.3 Tab "Plots"

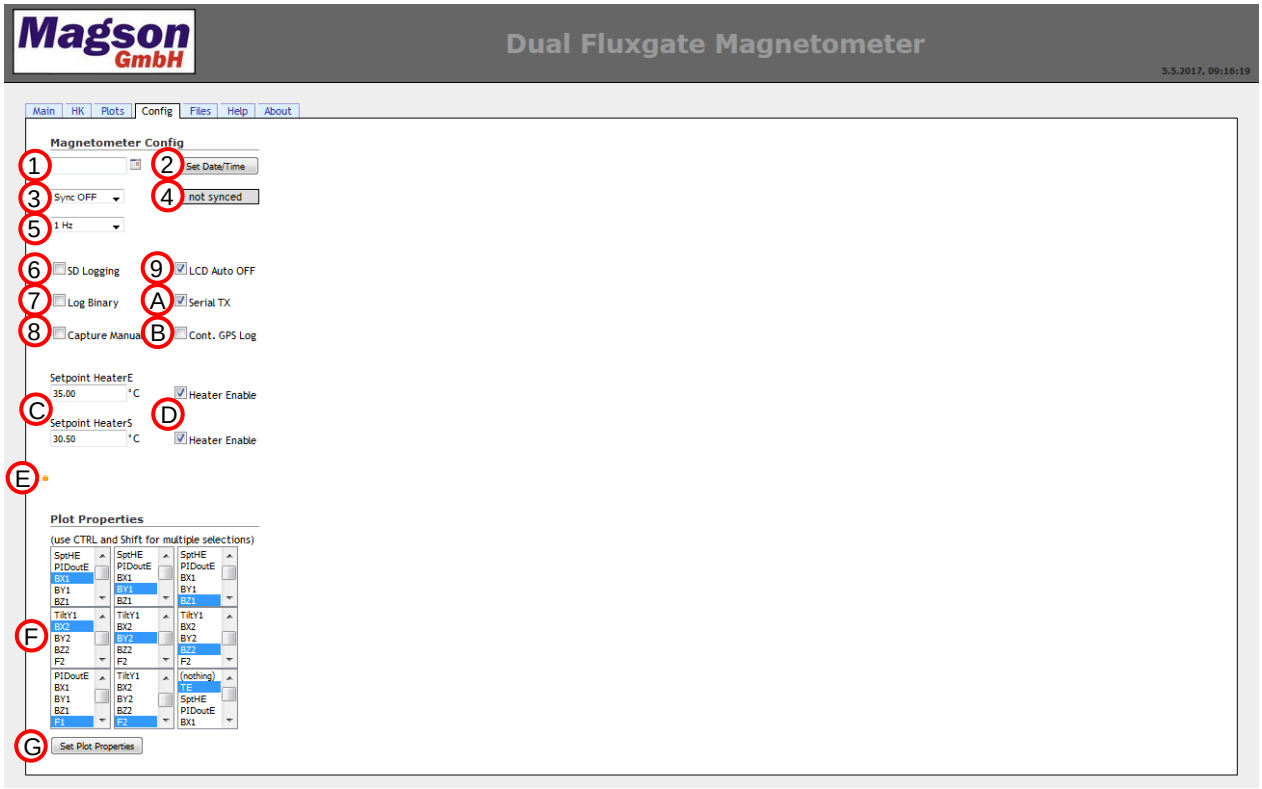
In this tab, all measured values (magnetic field components, absolute fields, differences and HK values) can be displayed graphically.
The X-Axis is scaled to 600 seconds = 10 minutes and cannot be changed, the Y-Axis is scaled automatically.
In the config tab, data series can be assigned to certain plot windows. It is also possible to assign multiple data series to one plot window.



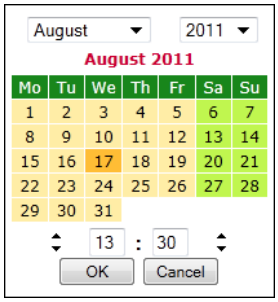
① **Clear**
The button is used to clear the plot windows and to reset the scaling of the Y-axes. This is useful when big disturbances (for instance from moving the sensor) increase the scaling of the Y-axes to a level, where field variations are no longer recognizable. Otherwise the user has to wait until the disturbances run out of the plot windows.

9.2.4 Tab "Config"

The config tab displays the current configuration of the magnetometer. It is also used to change the configuration.



① **Select date/time**
Date and time can be chosen from a calendar. The calendar appears when the calendar button or the date/time box is clicked.



If the calendar opens, its time is initialized with the local time of the PC. The pull-down menus at the top of the calendar are used to adjust month and year. The day of month can be selected by clicking on it inside the calendar widget. The chosen day will be highlighted green.
Hour and Minute can be adjusted by typing into the input boxes at the bottom of the calendar or via the arrows beside these boxes. By clicking the OK button, the chosen date and time is transferred into the config tab (the magnetometer and RTC time will not be changed yet). To close the calendar widget without applying date and time, use the Cancel button.

② **Set Date/Time**
By pressing this button, the time of the magnetometer and the RTC is set to the value which was chosen via the calendar (see chapter 6.2).

③ **Synchronization mode** (see chapter 6.2.1)
This button shows the current setting of synchronization mode. Pressing the button will open a pull-down menu where the mode can be changed.

④ **Synchronization status** (see chapter 6.2.2)

⑤ **Sampling rate** (see chapter 6.1)
This button shows the current setting of the sampling rate. Pressing the button will open a pull-down menu where the sampling rate can be changed.

⑥ **SD logging** (see chapter 6.4.2)
Activates or deactivates data recording on the SD card and shows the current status of this setting.

⑦ **Log binary** (see chapter 6.4.3)
Changes the data recording format between binary and ASCII and displays the current status of this setting.

⑧ **Man. capture** (see chapter 6.4)
Activates or deactivates the manual capture function and displays the current status of this setting.

⑨ **LCD Auto off** (see chapter 6.7)
Activates or deactivates the automatic screen blanking function and displays the current status of this setting.

Ⓐ **Serial TX**
Activates or deactivates the data output on the serial interface and displays the current status of this setting.

Ⓑ **Continuous GPS Logging**
If activated the GPS data is updated every second. If not the GPS data is updated if the difference to the previous position (latitude or longitude) is more than 0.000005°.

Ⓒ **Setpoint HeaterE / HeaterS**
This fields show the actual value of electronics and sensor heating controller setpoint.
The value can be changed by clicking into the desired field. That will open a popup input dialog for entering the new value. Use “Ok” button to apply the new value or “Cancel” button to discard changes.

Ⓓ **Enable HeaterE / HeaterS**
Activates or deactivates the heating controller of electronics and/or sensor heater and displays the current status of these settings.

Ⓔ

Administrator area (password protected)

(F)(G) Plot configuration

The nine select boxes (F) are used to configure, which data series are displayed in the plot windows. The arrangement of these boxes is identical to the arrangement of the plot windows. For example, the selected data series in the upper right box will be displayed in the upper right plot window. Multiple selections can be done by using the Shift and Ctrl keys. Choosing the option "nothing" will hide the corresponding plot window.

The button “Set plot properties” (G) is used to apply the plot settings.

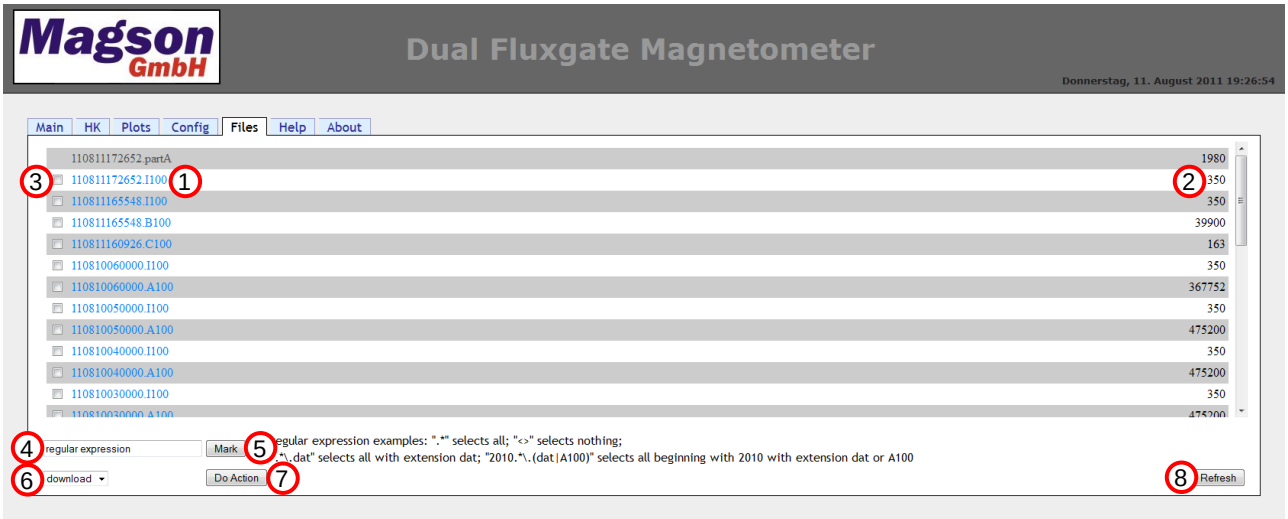
Series name	Meaning
TE	Electronics temperature [°C]
SptHE	Setpoint temperature of electronics heating controller [°C]
PIDoutE	Output (controlled variable) of electronics heating controller [%]
BX1	Magnetic field sensor 1 component X [nT]
BY1	Magnetic field sensor 1 component Y [nT]
BZ1	Magnetic field sensor 1 component Z [nT]
F1	Absolute value of magnetic field of sensor 1 [nT]
TS1	Temperature sensor 1 [°C]
SptHS	Setpoint temperature of sensor heating controllers [°C]
PIDoutS1	Output (controlled variable) of sensor 1 heating controller [%]
TiltX1	Inclination sensor 1 component X [°]
TiltY1	Inclination sensor 1 component Y [°]
BX2	Magnetic field sensor 2 component X [nT]
BY2	Magnetic field sensor 2 component Y [nT]
BZ2	Magnetic field sensor 2 component Z [nT]
F2	Absolute value of magnetic field of sensor 2 [nT]
TS2	Temperature sensor 2 [°C]
PIDoutS2	Output (controlled variable) of sensor 2 heating controller [%]
DiffBX	Magnetic field difference of component X (BX1 – BX2) [nT]
DiffBY	Magnetic field difference of component Y (BY1 – BY2) [nT]
DiffBZ	Magnetic field difference of component Z (BZ1 – BZ2) [nT]
TiltX2	Inclination sensor 2 component X [°]
TiltY2	Inclination sensor 2 component Y [°]
Angle	Rotary encoder angle [°]

only in dual sensor configuration

optional

9.2.5 Tab “Files”

The files tab can be used to browse through the SD card, download files or delete them.
All files with the file extension “part” (grayed out files) are currently recorded and cannot be downloaded or deleted by the user.



① **Links to single files**
Each filename in the list (except part files) is a link. By clicking the link, a dialog is opened where the user can choose between downloading and opening the file.

② **File size** (byte)

③④⑤ **File selection**
To download or delete multiple files, they must be marked. This can be done via the check boxes ③ directly in front of the file names or with regular expressions. If a regular expression should be used, enter it into the input box ④ and click the "Mark" button ⑤. Some simple examples of regular expressions are:

Regular expression	Selection
.*	All files
<>	No file
.*\.A102	All files with the extension A102
110817.*\.(A102|G102)	All files beginning with 110817 and have the extension A102 or G102 (measurement value files and GPS files of the day 17.08.2011 recorded on the device 102) – see chapter 6.4.5

⑥⑦ **Download and delete files**

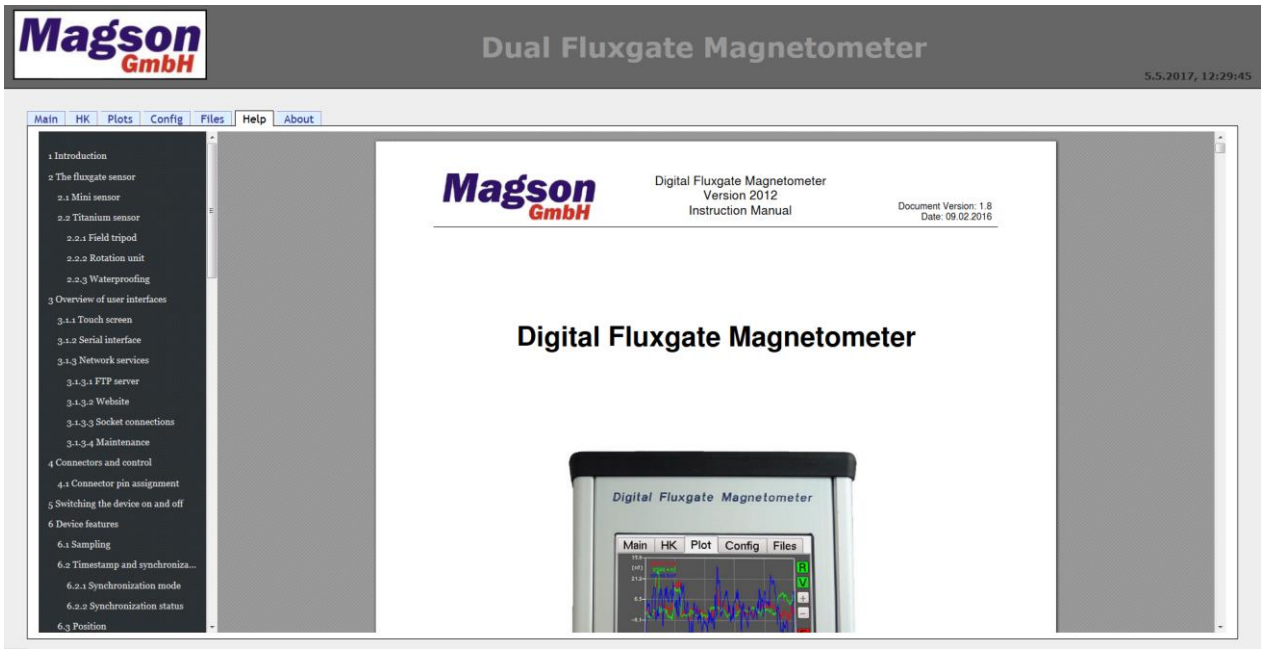
The select box ⑥ determines which action will be performed on selected files by clicking the “Do action” button ⑦. Possible actions are:

- ”Download“– downloads the selected files as tar-archive. A dialog will pop up, which is used to select the download destination or a program to open the file.
- ”Delete“– deletes the selected files. A dialog will pop up to confirm the deletion process.

⑧ **Refresh file list**
Clicking the button “Refresh” or the tab “Files” will update the file list.

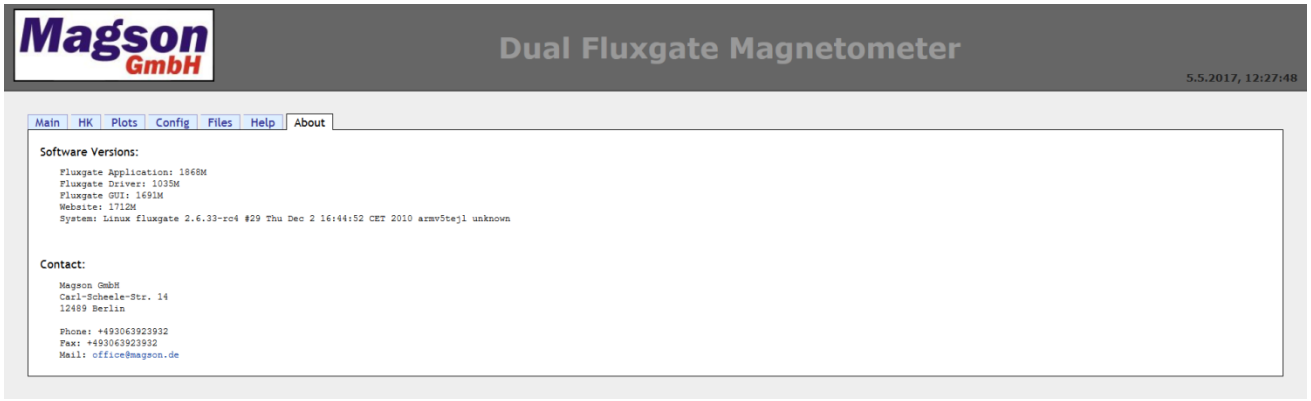
9.2.6 Tab “Help”

In the tab “Help” this instruction manual can be found.



9.2.7 Tab “About”

The tab “About” shows the version of software components and a contact address.



9.3 Socket connections

Socket connections can be used for a bidirectional communication over a TCP network. It is possible to send commands and to receive data with the full sampling rate. The device can handle up to 5 socket connections simultaneously. To establish a socket connection, the current IP address of the magnetometer and the port number is needed. The IP address will be shown on the network settings dialog in the tab "Config" on the touch screen (see chapter 7.4.1). The port number is

Port number: 12345

In order to receive data and to command the device, the user has to write the client software. Magson provides a basic sample program (see chapter 11.3).

9.3.1 Data

Data is sent using as a structure which differs slightly on magnetometers with one or two sensors.

Magnetometer (1 sensor)	Magnetometer (2 sensors)

struct mag_data_struct
{
long Data Type;
long l[3];
float f[11];
};
	struct mag_data_struct
	{
	long DataType;
	long l[3];
	float f[14];
	};

The structure has three members:

- Data type (4 byte),
- An array of long integer numbers (3*4byte=12byte)
- An array of floating point numbers (11*4byte=44byte respectively 14*4byte=56byte).

The content of the arrays l[] and f[] differs depending on the data type. Optional or unused array cells may have uninitialized values.
The following 7 data types are possible:

Data type	Number	Content of array l and f
TYPE_DAT	1	Magnetometer measurement values
TYPE_REP	2	Reply to commands of type 1 or 3 (see chapter 8.2.1)
TYPE_POS	3	GPS position
TYPE_SDS	4	SD card memory status
TYPE_LOG	5	Log message
TYPE_CCN	6	Capture counter
TYPE_HTS	7	Heater status (optional)

9.3.1.1 Data type TYPE_DAT

A structure of type TYPE_DAT contains measurement values and will be sent with the selected sampling rate.

Structure element	Magnetometer with 1 sensor
DataType	TYPE_DAT (1)
l[0]	Timestamp in sec since 1.1.1970 (UTC)
l[1]	Magnetometer status word (see chapter 11.1)
f[0]	Sensor temperature [°C]
f[1]	Electronics temperature [°C]
f[2]	Inclination X sensor 1 [°] (optional)
f[3]	Inclination Y sensor 1 [°] (optional)
f[6]	Rotary encoder angle [°] (optional)
f[8]	Magnetic field X component [nT]
f[9]	Magnetic field Y component [nT]
f[10]	Magnetic field Z component [nT]

Structure element	Magnetometer with 2 sensors
DataType	TYPE_DAT (1)
l[0]	Timestamp in sec since 1.1.1970 (UTC)
l[1]	Magnetometer status word (see chapter 11.1)
f[0]	Sensor 1 temperature [°C]
f[1]	Electronics temperature [°C]
f[2]	Inclination X sensor 1 [°] (optional)
f[3]	Inclination Y sensor 1 [°] (optional)
f[4]	Inclination X sensor 2 [°] (optional)
f[5]	Inclination Y sensor 2 [°] (optional)
f[6]	Rotary encoder angle [°] (optional)
f[7]	Sensor 2 temperature [°C]
f[8]	Magnetic field X component sensor 1 [nT]
f[9]	Magnetic field Y component sensor 1 [nT]
f[10]	Magnetic field Z component sensor 1 [nT]
f[11]	Magnetic field X component sensor 2 [nT]
f[12]	Magnetic field Y component sensor 2 [nT]
f[13]	Magnetic field Z component sensor 2 [nT]

9.3.1.2 Data type TYPE_REP

A structure of type TYPE_REP contains a reply to a previously sent command of type 1 or 3 (see chapter 8.2.1). This data type is not important for the user, because commands of type 1 and 3 are only used for startup and debugging purposes.

Structure element	Meaning
DataType	TYPE_REP (2)
l[0]	Timestamp in sec since 1.1.1970 (UTC)
l[1]	Receiver
l[2]	Reply data

9.3.1.3 Data type TYPE_POS

A Structure of type TYPE_POS contains the GPS position. It will be sent depending on the synchronization mode (see chapter 6.3) or after a request command.

Structure element	Meaning
DataType	TYPE_POS (3)
l[0]	Timestamp in sec since 1.1.1970 (UTC)
f[0]	Latitude [°]
f[1]	Longitude [°]

9.3.1.4 Data type TYPE_SDS

A Structure of type TYPE_SDS contains information on the currently used and the overall available disk space on the SD card. The structure will be sent each minute and after a request command.

Structure element	Meaning
DataType	TYPE_SDS (4)
l[0]	Timestamp in sec since 1.1.1970 (UTC)
f[0]	Overall available disk space [MByte]
f[1]	Used disk space [MByte]

9.3.1.5 Data type TYPE_LOG

A Structure of type TYPE_LOG contains a log message (see chapter 6.5).

Structure element	Meaning
DataType	TYPE_LOG (5)
l[0]	Timestamp in sec since 1.1.1970 (UTC)
l[1]	Log number
l[2]	Log data

9.3.1.6 Data type TYPE_CCN

A structure of type TYPE_CNN contains the capture counter, which represents the number of values in the capture file. The structure is sent when a new value was written into the capture file or when the capture function was disabled (see chapter 6.4).

Structure element	Meaning
DataType	TYPE_CCN (6)
l[0]	Timestamp in sec since 1.1.1970 (UTC)
l[1]	Capture counter

9.3.1.7 Data type TYPE_HTS (optional)

A Structure of type TYPE_HTS contains status information of the heating controllers. It will be sent every second.

Structure element	Meaning
DataType	TYPE_HTS (7)
l[0]	Timestamp in sec since 1.1.1970 (UTC)
l[1]	Bit1: Electronics heating controller enabled(1) / disabled(0) Bit0: Sensor heating controller enabled(1) / disabled(0)
f[0]	Setpoint electronics heater [°C]
f[1]	Setpoint sensor heater [°C]
f[2]	Electronics heater controller output (controlled variable) [0..100%]
f[3]	Sensor 1 heater controller output (controlled variable) [0..100%]
f[4]	Sensor 2 heater controller output (controlled variable) [0..100%] ➔ only on devices with 2 sensors

9.3.2 Commanding

Sending commands via a socket connection is identical to sending commands over the serial connection (see chapter 8.2).

10 Technical data

10.1 Electronics box drawing

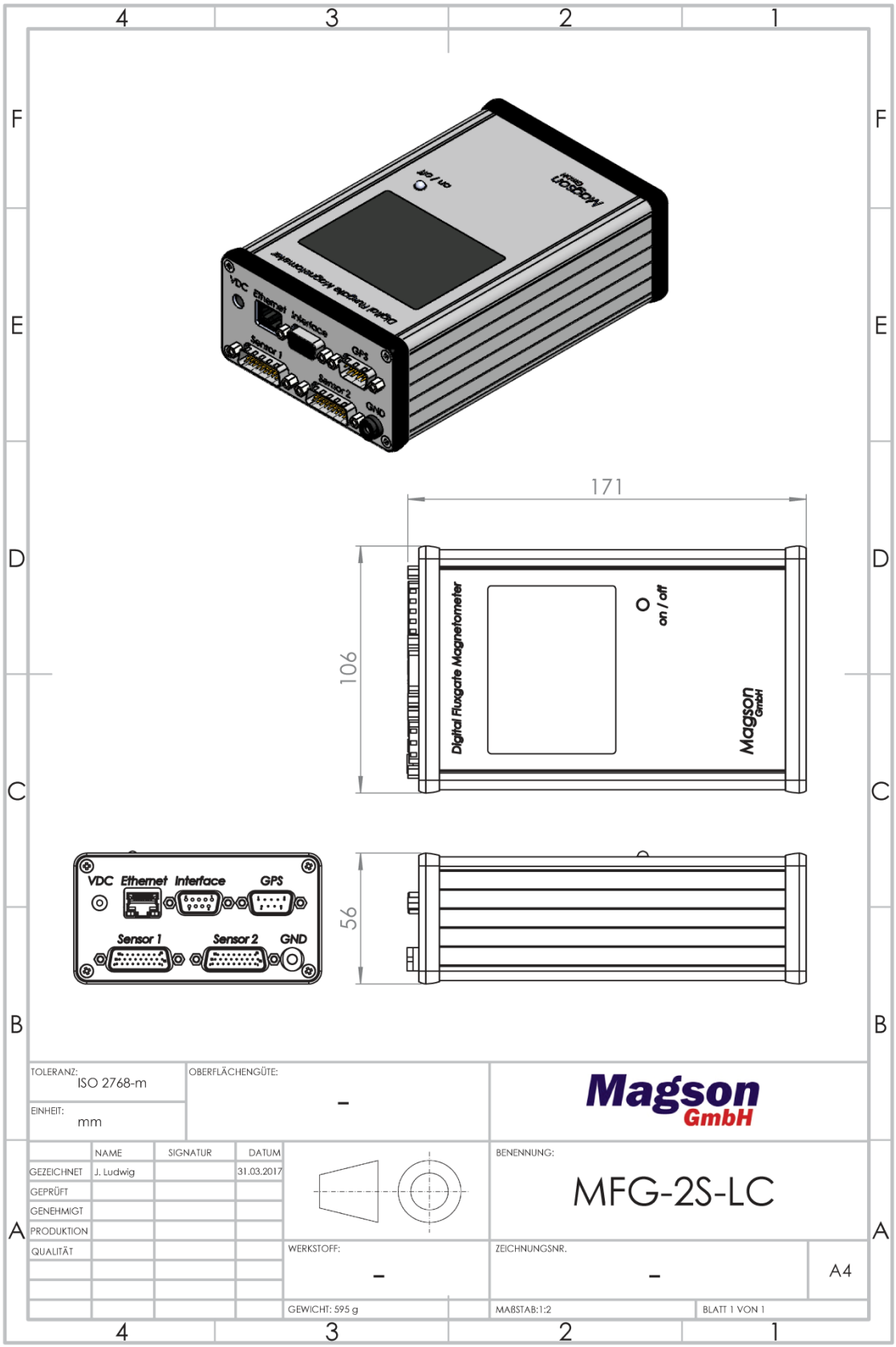


Figure 1: Electronics box drawing

10.2 Mini Sensor drawing

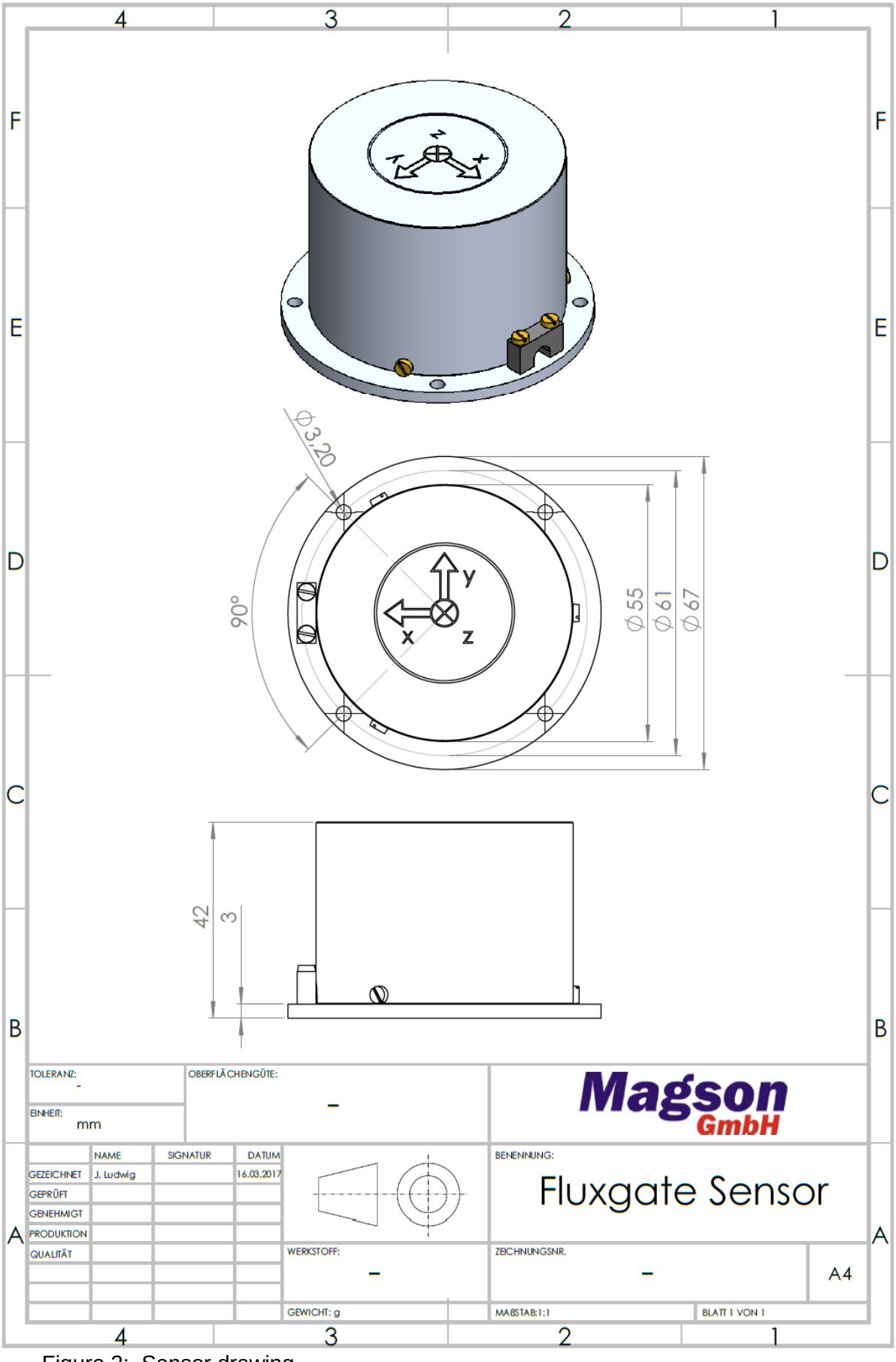


Figure 2: Sensor drawing

10.3 Inclinometer drawing

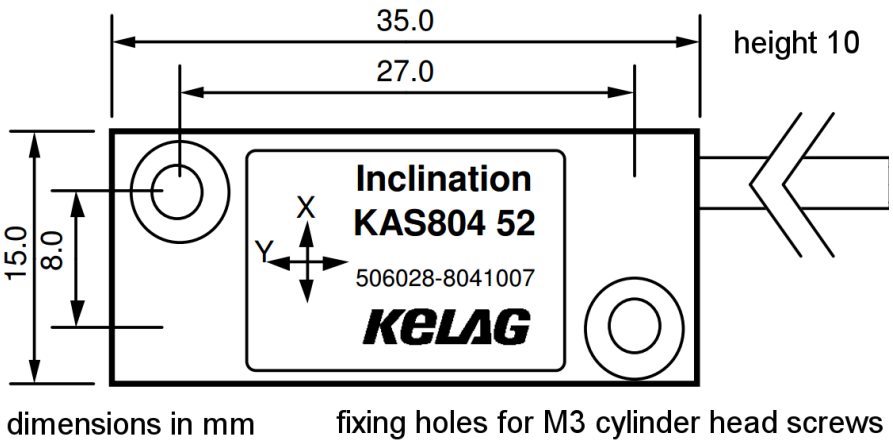


Figure 3: Inclinometer drawing

10.4 Specifications

Mini Sensor:		
Construction		Self-supporting Helmholtz coil system
Sensor size:		H: 42 mm, Cover ∅: 55 mm, Socket ∅: 67 mm
Sensor weight:		105 g
Titanium sensor:		
Sensor size:		H:11cm, Cover ∅: 12cm
Sensor weight:		2.5 Kg
Dimensions of the sensor housing:		H:25 cm ∅: 27 cm
Total weight of the sensor and housing:		5.5 Kg
Electronics:		
Electronics size:		171 mm x 106 mm x 56 mm
Electronics weight:		565 g
Noise:		<20 pT/√Hz (typical 10pT/√Hz) at 1 Hz
Long-term stability:		<10 nT/year
Orientation:		Orthogonal system (X, Y, Z)
Resolution:		10 pT
Measurement range:		±100000 nT
User interfaces:		Touch screen, serial interface, FTP, website, socket connections
Sampling rate:		Selectable: 100 Hz, 50 Hz, 10 Hz and 1 Hz or 200 Hz, 100 Hz, 10 Hz and 1 Hz (optional)
Data format:		ASCII / binary
Disk space:		4 GByte (32 GByte maximum)
Operating voltage:		9.5 V-18 V, power supply should be referenced to ground
Power consumption at 12V:		
Minimum:		1.4 W (1 Sensor, Touch screen off, GPS off, no Network cable plugged in)
Maximum:		2.7 W (2 Sensors, Touch screen on, GPS on, Network cable plugged in)
Max. Heater Power at 12V:		Per sensor: ~4.5 W Electronics: ~6 W
Backup battery type:		CR 2032
Additional options:		Inclinometer, rotary encoder, heaters, 200 Hz version

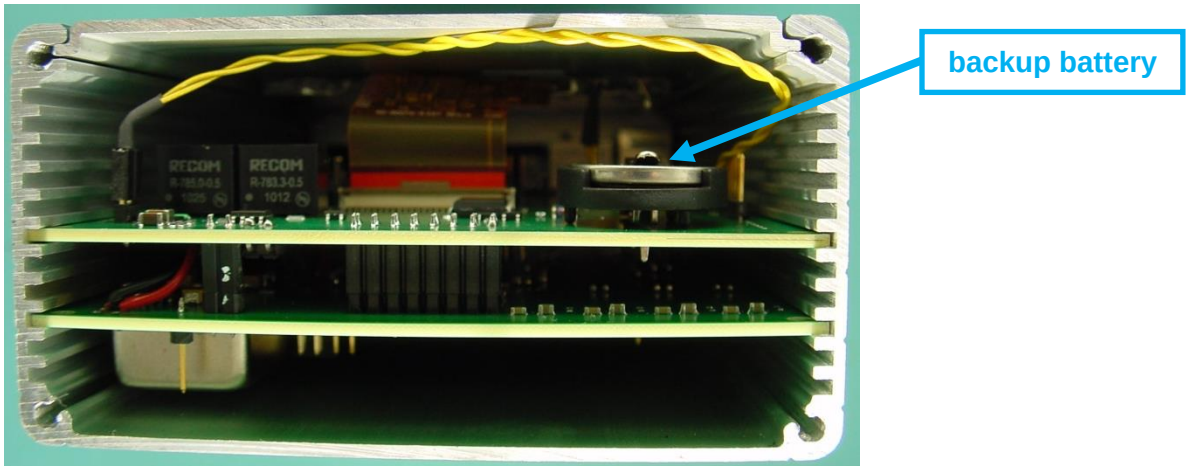
11 Appendix

11.1 Status word

Bit	Meaning
0	Excitation: off (0) / on (1)
1	Findphase: inactive (0) / active (1)
2	Sensor2 Heater: off (0) / on (1)
3	Sensor1 Heater: off (0) / on (1)
4	Electronics Heater: off (0) / on (1)
5	Clock Source: GPS or RTC (0) / FPGA internal (1)
6	NewSecond (GPS 1PPS marker)
7	FPGA data FIFO empty (1) / not empty (0)
8	FPGA data FIFO full (1) / not full (0)
9-14	FPGA data FIFO level
15	Reserved
16	Logging: off (0) / on (1)
17	1Hz Source: RTC (0) / GPS (1)
18	Serial TX: off (0) / on (1)
19	Data file format: ASCII (0) / binary (1)
20-21	Sync mode: Off (0) / Once (1) / Periodic (2) / Always (3)
22-23	Sync status: not Synced (0) /Syncing (1) / Synced (2)
24	LCD screen blanking: LCD is switched off after 5min (0) / LCD always on (1)
25-26	Sampling rate index: 100Hz (0) / 50Hz (1) / 10Hz (2) / 1Hz(3) for 100Hz version 200Hz (0) / 100Hz (1) / 10Hz (2) / 1Hz(3) for 200Hz version
27-28	Reserved
29	Manual capture: deactivated(0) / activated(1)
30	LSB output: inactive (0) / active (1)
31	GPS logging: on position change (0) / continuously every second (1)

11.2 Replacing the RTC backup battery

To replace the backup battery, remove the cover plate from the front side of the electronics box (opposite to the backside with the connectors) which is fixed with four screws.
Remove the old battery using tweezers (or similar). To insert the new battery (type is CR2032), use only fingers or plastic tweezers, to avoid discharging.
The picture shows the position of the battery socket.



11.3 Sample program for socket communication

The sample program demonstrates the socket communication of a magnetometer equipped with two sensors. It is designed for compilation on Microsoft Windows and was tested with the compiler MinGW. The library winsock32 must be added to the development environment. The program expects two command line parameters, the magnetometer IP address, which is displayed in the network settings dialog on the touch screen (see chapter 7.4.1), and the port number 12345.
To send commands, enter the command type, the command address and the command data separated by space characters and terminated by the enter key.

Example command to change the sampling rate to 1Hz:

0<space>0<space>3<enter>

```
#include <stdio.h>
#include <winsock.h>
#include <conio.h>

#define TYPE_DAT              1
#define TYPE_REP              2
#define TYPE_POS              3
#define TYPE_SDS              4
#define TYPE_LOG              5
#define TYPE_CCN              6
#define TYPE_HTS              7

#define TYPE_DAT_L_TIMESTAMP  0
#define TYPE_DAT_L_STATUS     1
#define TYPE_DAT_F_TS1        0
#define TYPE_DAT_F_TE         1
#define TYPE_DAT_F_TS2        7
#define TYPE_DAT_F_BX1        8
#define TYPE_DAT_F_BY1        9
#define TYPE_DAT_F_BZ1        10
#define TYPE_DAT_F_BX2        11
#define TYPE_DAT_F_BY2        12
#define TYPE_DAT_F_BZ2        13

#define TYPE_REP_L_TIMESTAMP  0
#define TYPE_REP_L_REPDEST    1
#define TYPE_REP_L_REPDATA    2

#define TYPE_POS_L_TIMESTAMP  0
#define TYPE_POS_F_LAT        0
#define TYPE_POS_F_LON        1

#define TYPE_SDS_L_TIMESTAMP  0
#define TYPE_SDS_F_CARDSIZE   0
#define TYPE_SDS_F_CARDUSAGE  1

#define TYPE_LOG_L_TIMESTAMP  0
#define TYPE_LOG_L_LOGNO      1
#define TYPE_LOG_L_LOGDATA    2

#define TYPE_CCN_L_TIMESTAMP  0
#define TYPE_CCN_L_COUNTER    1

#define TYPE_HTS_L_TIMESTAMP  0
#define TYPE_HTS_L_ENABLE     1
#define TYPE_HTS_F_SETPOINTE  0
#define TYPE_HTS_F_SETPOINTS  1
#define TYPE_HTS_F_PIDOUTE    2
#define TYPE_HTS_F_PIDOUTS1   3
#define TYPE_HTS_F_PIDOUTS2   4

#define ESC    27
#define LF     10
#define CR     13

#define MAXCMDLENGTH   64
```

```
struct mag_data_struct
{
   Long DataType;
   long l[3];
   float f[14];
};

int main(int argc, char *argv[])
{
   int sock; /* Socket descriptor */
   struct sockaddr_in  ServAddr; /* Server address */
   unsigned short ServPort; /* Server port */
   char *servIP; /* Server IP address (dotted quad) */
   int bytesread; /* Bytes read in single recv() */
   WSADATA wsaData;
   char key=0;
   char command[MAXCMDLENGTH+2];
   int  EXIT=0;
   int  charcnt=0;
   struct mag_data_struct magdat;

   if (argc != 3) /* Test for correct number of arguments */
   {
      fprintf(stderr, "Usage: %s <Server IP> <Port>\n", argv[0]);
      return -1;
   }

   servIP = argv[1]; /* First arg: server IP address (dotted quad) */
   ServPort = atoi(argv[2]); /* Use given port, if any */

   if (WSAStartup(MAKEWORD(2, 0), &wsaData) != 0)
   {
      fprintf(stderr,"WSAStartup() failed");
      return -2;
   }

   /* Create a reliable, stream socket using TCP */
   if ((sock = socket(PF_INET, SOCK_STREAM, IPPROTO_TCP)) < 0)
   {
      fprintf(stderr,"socket() failed");
      return -3;
   }

   /* Construct the server address structure */
   memset(&ServAddr, 0, sizeof(ServAddr)); /* Zero out structure */
   ServAddr.sin_family = AF_INET; /* Internet address family */
   ServAddr.sin_addr.s_addr = inet_addr(servIP); /* Server IP address */
   ServAddr.sin_port = htons(ServPort); /* Server port */

   /* Establish the connection to the server */
   if (connect(sock, (struct sockaddr *) &ServAddr, sizeof(ServAddr)) < 0)
   {
      fprintf(stderr,"connect() failed");
      return -4;
   }

   do
   {
      while (_kbhit()) /*Check Keyboard Input */
      {
         key=_getch();

         switch (key)
         {
            case ESC:
               EXIT=1;
               break;
            case CR:
            case LF:
               command[charcnt]=LF;
               command[charcnt+1]='\0';
               printf("\nSend %s\n",command);
               if (send (sock, command, strlen(command),0) != (signed int)strlen(command))
               {
                  fprintf(stderr,"send() failed");
                  return -5;
```

```
                }
                charcnt=0;
                break;
            default:
                if (charcnt<MAXCMDLENGTH)
                {
                    command[charcnt]=key;
                    charcnt++;
                }
                else
                {
                    charcnt=0;
                }
                break;
        }
    }

    bytesread=recv(sock, (char *)&magdat, sizeof(magdat), 0);

    if (bytesread==sizeof(magdat))
    {
        switch (magdat.DataType)
        {
            case TYPE_DAT:
                printf( "%.2ld:%.2ld:%.2ld %9.2f %9.2f %9.2f"
                        "%9.2f %9.2f %9.2f %6.2f %6.2f %6.2f 0x%.8lx\n",
                        ((magdat.l[TYPE_DAT_L_TIMESTAMP]/3600)%24),
                        ((magdat.l[TYPE_DAT_L_TIMESTAMP]/60)%60),
                        (magdat.l[TYPE_DAT_L_TIMESTAMP]%60),
                        magdat.f[TYPE_DAT_F_BX1], magdat.f[TYPE_DAT_F_BY1], magdat.f[TYPE_DAT_F_BZ1],
                        magdat.f[TYPE_DAT_F_BX2], magdat.f[TYPE_DAT_F_BY2], magdat.f[TYPE_DAT_F_BZ2],
                        magdat.f[TYPE_DAT_F_TE], magdat.f[TYPE_DAT_F_TS1], magdat.f[TYPE_DAT_F_TS2],
                        magdat.l[TYPE_DAT_L_STATUS]);
                break;
            case TYPE_REP:
                printf("ReplyData: 0x%.8lx\n", magdat.l[TYPE_REP_L_REPDATA]);
                break;
            case TYPE_POS:
                printf("%10ld Lat:%10.5f Lon:%10.5f\n",
                        magdat.l[TYPE_POS_L_TIMESTAMP],
                        magdat.f[TYPE_POS_F_LAT], magdat.f[TYPE_POS_F_LON]);
                break;
            case TYPE_SDS:
                printf("%10ld Card Size: %10.3fMB, Card Usage:%10.3fMB, free disk space %10.3fMB\n",
                        magdat.l[TYPE_SDS_L_TIMESTAMP],
                        magdat.f[TYPE_SDS_F_CARDSIZE], magdat.f[TYPE_SDS_F_CARDUSAGE],
                        magdat.f[TYPE_SDS_F_CARDSIZE]-magdat.f[TYPE_SDS_F_CARDUSAGE]);
                break;
            case TYPE_LOG:
                printf("%10ld LogNo: %12ld LogData: %12ld\n",
                        magdat.l[TYPE_LOG_L_TIMESTAMP],
                        magdat.l[TYPE_LOG_L_LOGNO], magdat.l[TYPE_LOG_L_LOGDATA]);
                break;
            case TYPE_CCN:
                printf("%10ld Capture Counter %12ld\n",
                        magdat.l[TYPE_CCN_L_TIMESTAMP], magdat.l[TYPE_CCN_L_COUNTER]);
                break;
            case TYPE_HTS:
                printf("%10ld HeaterE: Ena=%d, Setpoint=%.3f, PIDout=%.1f%%;"
                        "HeaterS: Ena=%d, Setpoint=%.3f" "PIDoutS1=%.1f%%, PIDoutS2=%.1f%%\n",
                        magdat.l[TYPE_HTS_L_TIMESTAMP],
                        magdat.l[TYPE_HTS_L_ENABLE]>>1)&0x01, magdat.f[TYPE_HTS_F_SETPOINTE],
                        magdat.f[TYPE_HTS_F_PIDOUTE],
                        magdat.l[TYPE_HTS_L_ENABLE]&0x01, magdat.f[TYPE_HTS_F_SETPOINTS],
                        magdat.f[TYPE_HTS_F_PIDOUTS1], magdat.f[TYPE_HTS_F_PIDOUTS2]);
                break;
            default:
                printf("unknown DataType (%2ld)\n",   magdat.DataType);
                break;
        }
    }
} while ((bytesread>0)&&(!EXIT));

closesocket(sock);
WSACleanup();
return 0;
}
```

11.4 Calibration of magnetic field data

The magnetic field values are internally calibrated by the device. The values are calculated as follows:

BX = (bx - OFFSET_BX) * SCALE_BX

BY = (by - OFFSET_BY) * SCALE_BY
+ (bx - OFFSET_BX) * SCALE_BX * ORTH_BXY

BZ = (bz - OFFSET_BZ) * SCALE_BZ
+ (bx - OFFSET_BX) * SCALE_BX * ORTH_BXZ
+ (by - OFFSET_BY) * SCALE_BY * ORTH_BYZ

bx, by and bz are uncalibrated magnetic field components and BX, BY, BZ are calibrated magnetic field components.