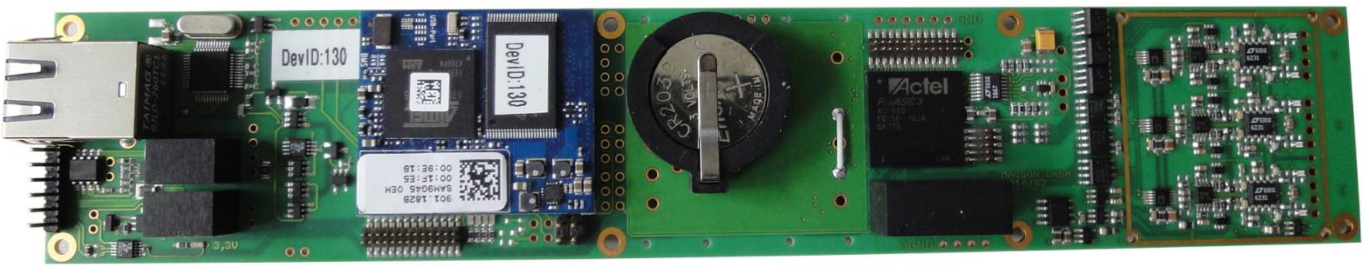
Self Potential Data Logger



Content

1 Preparing a Measurement

After connecting the supply voltage (batteries) for the first time, the device starts automatically. The voltage must be in the range of 5V…18V. The device is protected against reversed polarity of the supply voltage.
In the optional equipment variant with an atomic clock, neither the atomic clock nor the RTC are backed up by a backup battery. For this reason, the time information gets lost without an external power supply. After start up, the time starts counting from 01/01/1970 00:00:00 and any existing timetable is not processed.

<u>short explanation about it:</u>
The devices save some parameters that can be changed during operation on the internal SD card and load them after the start. These include the E-field gain, the data rate at which the E-field data is output over the network (socket connection) and the start mode (logging off, logging timetabled, logging on).
If the start mode is set to "Logging on", a device starts recording data immediately after start-up. If the start mode is set to “Logging off”, no data will be recorded.
In the "Logging timetabled" start mode (normal case), if an (old) timetable was available, the device would immediately start processing it and go into idle mode, since the first entry in the timetable would very likely be greater than 01.01.1970 (see 4.1).
Thus, one would no longer be able to switch on the device.
This is prevented by the fact that the start mode is automatically set from "Logging timetabled" to "Logging off" if the time at the start is less than 01/01/2000 23:23:59. This is the case after applying the supply voltage.

If the devices are already connected to the supply voltage and are in the idle state, they can be started by briefly connecting the Sync+ line to the GND line.
Starting a device takes about 15 seconds.

The data logger has a shutdown battery. It is used to easily control the measuring function of the devices via the input voltage. As already mentioned, the devices start automatically after applying the supply voltage and start recording if the start/stop mode was set to 2 (start) before switching off. With the shutdown battery, the devices can be switched off and a measurement stopped by simply switching off the supply voltage in addition to the standard variants using a timetable and commands. The battery takes over the power supply until the measurement is completed and the device is properly shut down. The shutdown battery is charged automatically via the supply voltage of the devices. This is indicated by a red LED on the charging electronics.

Transferring/editing the timetable and downloading/deleting the data is done via FTP connection (access data see 8.5.2). To set up the FTP connections, the devices must be connected to a router using a network cable and this must be connected to the PC.
After establishing the FTP connection, copy the timetable, which must have the file name timetable.selfpot, to the selfpot_bin folder on all devices. The structure of the timetable is described in Chapter 4.1. If necessary, old data files (in the selfpot_data folder) and the log files (logfile_0.log and logfile_1.log in the selfpot_bin folder) can also be deleted via the FTP connection.

To synchronize the atomic clocks of the devices, the sync cable, which connects the Sync+ and Sync- connections of all devices, must be connected in addition to the Ethernet (see 8.1). The SelfPotLogger_SocketClient software is used for this. The synchronization is started with the s key and the current PC time is sent to the devices.
It is also possible to set the devices to a specific time. After successful synchronization, the software displays the message >>>>>>>> Sync successful ! <<<<<<<< off.
Now you should check in Compare mode (see 3.1.2) whether the devices have the same time and are running synchronously.

By pressing the t key, a command is sent to all devices that sets the start mode to "timetabled". This re-reads the timetable and the devices start processing it. If the next entry in the timetable is more than 60s in the future (2*PRESTART_TIME), the devices now go into sleep mode.
The SelfPotLogger_SocketClient software is described in detail in Chapter 3.1.

Now all sync and network cables can be removed and the preparation of the devices is complete.

2 After the Measurement (Data evaluation)

After processing the timetable, the devices are in the idle state.
To start it again, the Sync+ line must be briefly connected to the GND line.
The data is downloaded/deleted via FTP connection (access data see 8.5.2). To set up the FTP connections, the devices must be connected to a router using a network cable and this must be connected to the PC.
The measurement data files are located in the selfpot_data folder on the SD card.

The SelfPotLogger_ConvertData software can be used to convert the data into ASCII format (see 3.2).
The binary files can also be used directly for data processing. Its structure is described in Chapter 4.2.

Before the devices are disconnected from the power supply (batteries), they should be put into sleep mode (shut down). This can be done by sending the command "Shutdown Request" (0 0 5 0) with the software SelfPotLogger_SocketClient (see 3.1.4). If the device is equipped with the shutdown battery, it is not necessary to shut it down before switching it off.

3 PC Software

3.1 SelfPotLogger_SocketClient

The SelfPotLogger_SocketClient console software communicates with the devices via a socket connection and performs several tasks. These include:

- Display of all measured values of a device
- Simultaneous display of time, E-field, magnetic field, housekeeping or atomic clock status of all connected devices
- Sending any commands to one or all connected devices
- Synchronizing the atomic clocks and setting the time

Before starting the software, the SelfPotLogger_SocketClient.cfg file, which is located in the same directory as the SelfPotLogger_SocketClient.exe, must be adjusted. In the file there is an entry for each connected device, here is an example:

```
106   192.168.124.106   S
107   192.168.124.107
108   192.168.124.108
122   192.168.124.41
```

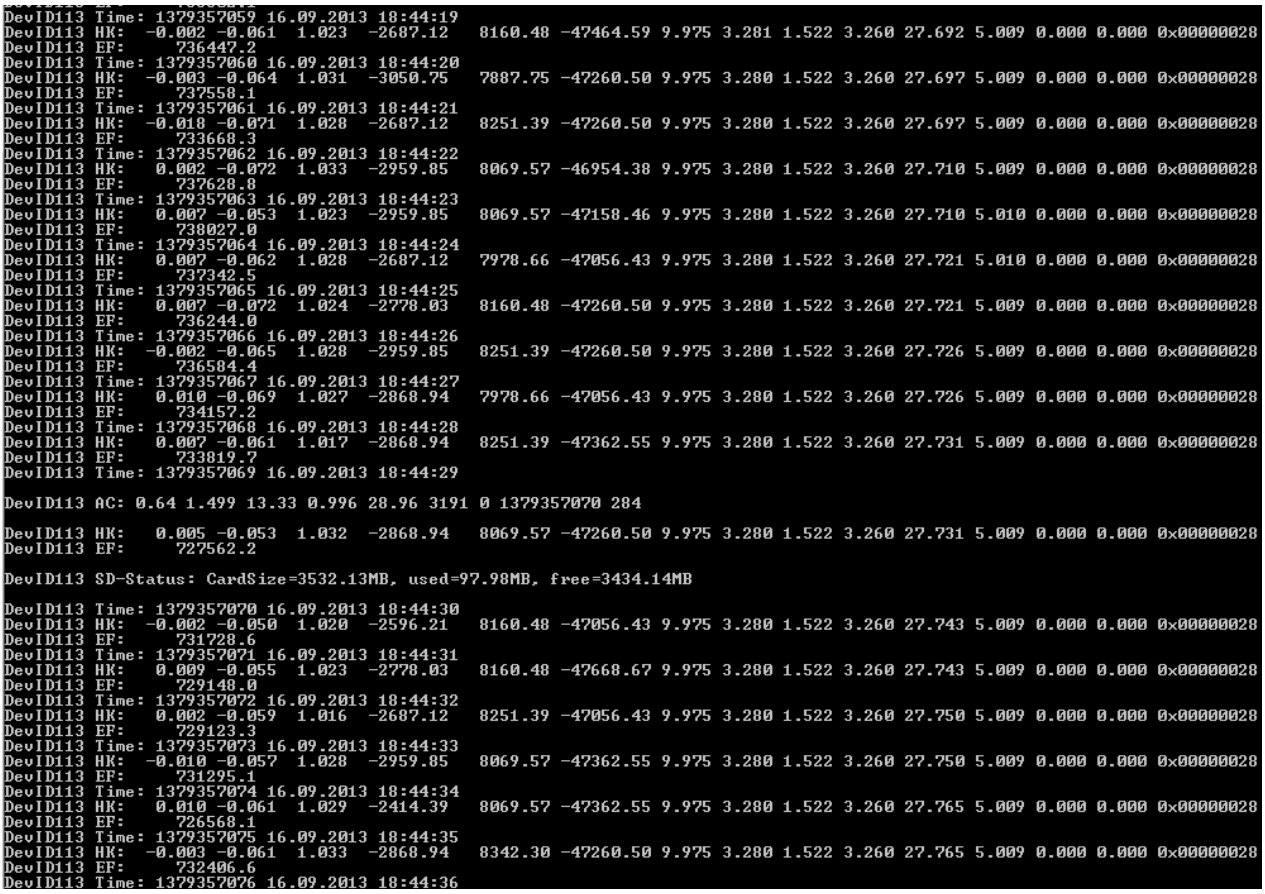
The 1st column contains the DeviceID and the 2nd column the IP address of the corresponding device. In the 3rd column there is a capital S after the device that is supposed to be the transmitter of the synchronization pulse. If none of the devices is to send a synchronization pulse because it is fed in externally by a GPS, for example, simply leave out the S. Values can be separated by spaces or tabs.

The SelfPotLogger_SocketClient software is controlled via the keyboard, the following keys are defined:

Taste	Funktion
ESC	terminates the software or aborts the entry of a command
s	synchronizes the atomic clocks and sets the time of the devices (see 3.1.3)
t	sets the start mode of all devices to timetabled, re-reads the timetable and starts processing it (see 3.1.6)
c	toggles between standard and compare mode (see 3.1.1 and 3.1.2)
h	stops the output of incoming data on the screen (see 3.1.5)
w	sends a command to one or all connected devices (see 3.1.4)
0…9	selects the device from whose data is displayed on the screen

3.1.1 Standard-Mode

After starting the software, it is in standard mode, in which all the data from a single device is displayed. With the keys 0 to 9 you can switch between the devices. 0 corresponds to the device from the 1st line of the SelfPotLogger_SocketClient.cfg file, 1 to the device from the 2nd line, etc.



```
DevID113 Time: 1379357059 16.09.2013 18:44:19
DevID113 HK:  -0.002 -0.061  1.023  -2687.12   8160.48 -47464.59 9.975 3.281 1.522 3.260 27.692 5.009 0.000 0.000 0x00000028
DevID113 EF:     736447.2
DevID113 Time: 1379357060 16.09.2013 18:44:20
DevID113 HK:  -0.003 -0.064  1.031  -3050.75   7887.75 -47260.50 9.975 3.280 1.522 3.260 27.697 5.009 0.000 0.000 0x00000028
DevID113 EF:     737558.1
DevID113 Time: 1379357061 16.09.2013 18:44:21
DevID113 HK:  -0.018 -0.071  1.028  -2687.12   8251.39 -47260.50 9.975 3.280 1.522 3.260 27.697 5.009 0.000 0.000 0x00000028
DevID113 EF:     733668.3
DevID113 Time: 1379357062 16.09.2013 18:44:22
DevID113 HK:   0.002 -0.072  1.033  -2959.85   8069.57 -46954.38 9.975 3.280 1.522 3.260 27.710 5.009 0.000 0.000 0x00000028
DevID113 EF:     737628.8
DevID113 Time: 1379357063 16.09.2013 18:44:23
DevID113 HK:   0.007 -0.053  1.023  -2959.85   8069.57 -47158.46 9.975 3.280 1.522 3.260 27.710 5.010 0.000 0.000 0x00000028
DevID113 EF:     738027.0
DevID113 Time: 1379357064 16.09.2013 18:44:24
DevID113 HK:   0.007 -0.062  1.028  -2687.12   7978.66 -47056.43 9.975 3.280 1.522 3.260 27.721 5.010 0.000 0.000 0x00000028
DevID113 EF:     737342.5
DevID113 Time: 1379357065 16.09.2013 18:44:25
DevID113 HK:   0.007 -0.072  1.024  -2778.03   8160.48 -47260.50 9.975 3.280 1.522 3.260 27.721 5.009 0.000 0.000 0x00000028
DevID113 EF:     736244.0
DevID113 Time: 1379357066 16.09.2013 18:44:26
DevID113 HK:  -0.002 -0.065  1.028  -2959.85   8251.39 -47260.50 9.975 3.280 1.522 3.260 27.726 5.009 0.000 0.000 0x00000028
DevID113 EF:     736584.4
DevID113 Time: 1379357067 16.09.2013 18:44:27
DevID113 HK:   0.010 -0.069  1.027  -2868.94   7978.66 -47056.43 9.975 3.280 1.522 3.260 27.726 5.009 0.000 0.000 0x00000028
DevID113 EF:     734157.2
DevID113 Time: 1379357068 16.09.2013 18:44:28
DevID113 HK:   0.007 -0.061  1.017  -2868.94   8251.39 -47362.55 9.975 3.280 1.522 3.260 27.731 5.009 0.000 0.000 0x00000028
DevID113 EF:     733819.7
DevID113 Time: 1379357069 16.09.2013 18:44:29

DevID113 AC: 0.64 1.499 13.33 0.996 28.96 3191 0 1379357070 284

DevID113 HK:   0.005 -0.053  1.032  -2868.94   8069.57 -47260.50 9.975 3.280 1.522 3.260 27.731 5.009 0.000 0.000 0x00000028
DevID113 EF:     727562.2

DevID113 SD-Status: CardSize=3532.13MB, used=97.98MB, free=3434.14MB

DevID113 Time: 1379357070 16.09.2013 18:44:30
DevID113 HK:  -0.002 -0.050  1.020  -2596.21   8160.48 -47056.43 9.975 3.280 1.522 3.260 27.743 5.009 0.000 0.000 0x00000028
DevID113 EF:     731728.6
DevID113 Time: 1379357071 16.09.2013 18:44:31
DevID113 HK:   0.009 -0.055  1.023  -2778.03   8160.48 -47668.67 9.975 3.280 1.522 3.260 27.743 5.009 0.000 0.000 0x00000028
DevID113 EF:     729148.0
DevID113 Time: 1379357072 16.09.2013 18:44:32
DevID113 HK:   0.002 -0.059  1.016  -2687.12   8251.39 -47056.43 9.975 3.280 1.522 3.260 27.750 5.009 0.000 0.000 0x00000028
DevID113 EF:     729123.3
DevID113 Time: 1379357073 16.09.2013 18:44:33
DevID113 HK:  -0.010 -0.057  1.028  -2959.85   8069.57 -47362.55 9.975 3.280 1.522 3.260 27.750 5.009 0.000 0.000 0x00000028
DevID113 EF:     731295.1
DevID113 Time: 1379357074 16.09.2013 18:44:34
DevID113 HK:   0.010 -0.061  1.029  -2414.39   8069.57 -47362.55 9.975 3.280 1.522 3.260 27.765 5.009 0.000 0.000 0x00000028
DevID113 EF:     726568.1
DevID113 Time: 1379357075 16.09.2013 18:44:35
DevID113 HK:  -0.003 -0.061  1.033  -2868.94   8342.30 -47260.50 9.975 3.280 1.522 3.260 27.765 5.009 0.000 0.000 0x00000028
DevID113 EF:     732406.6
DevID113 Time: 1379357076 16.09.2013 18:44:36
```

Fig 3-1: Output in standard mode

The following outputs are displayed (compare with socket data IDs, chapters 8.3.1 and 8.3.2):

```
DevID122 Time: 1332950285 28.03.2012 15:58:05
```

Unix timestamp   date and time

```
DevID122 EF:   10254.0 10249.3 10257.8
```

averaged E-Field values X Y Z (averaging corresponds to EFSockDataRate see 8.2) in µV

```
DevID106 HK: 0.015 0.045 1.088 7405.85 -19644.84 32616.23 6.928 3.266 1.523 3.267 30.922 7.200 0.000 0.000 0x00000008
```

Acceleration X Y Z   Magnetic feld X Y Z   VBatt $3.3V_{DIG}$ 1.5V $3.3V_{RTC}$ Temperature Aux1   Aux2   Aux3   Status(see 8.3.1.1)

```
DevID122 SD-Status: CardSize=7189.05MB, used=259.54MB, free=6929.52MB
```

total memory size   used memory   free memory

```
DevID122 Log message: 28.03.2012 15:58:05, Nr=009, Dat=0
```

date and time of log message   log number und date (see 8.4)

```
DevID106 AC: 0.74 1.557 14.66 0.996 34.00 2946 0 1332950429 21628
```

Atomuhr   laser current   TCXO voltage   heater power   DC level   tempe-rature   contrast   steer value   time stamp   time since lock

```
DevID122 Mag: 0.0740585 -0.1964484 0.3261623 26.978
```

magnetic field X Y Z   magnetic field sensor t

```
DevID122 network settings: IP=192.168.124.41 Mask=255.255.255.0 GW=192.168.124.1 DNS=192.168.124.1
```

IP-address   netzwork mask   gateway   name server address

3.1.2 Compare-Mode

The c key switches to the compare mode in which certain data from all connected devices can be compared.

```
DevID106 HK:   0.026  0.042  1.077  -7496.75 -19917.56 -32820.31 6.929 3.266 1.523 3.268 30.069 0x00000008
DevID106 EF:   16331011.0
DevID106 Time: 1332955007 28.03.2012 17:16:47

************************************************************
*                  What should be compared ?               *
************************************************************
* 0: Date and Time              1: E-Field                 *
* 2: Housekeeping & Status      3: Atomic Clock telemetry  *
************************************************************

Enter a number: 0


DevID109 Time: 1332955009 28.03.2012 17:16:49
DevID106 Time: 1332955009 28.03.2012 17:16:49
DevID107 Time: 1332955009 28.03.2012 17:16:49
DevID108 Time: 1332955009 28.03.2012 17:16:49

DevID108 Time: 1332955010 28.03.2012 17:16:50
DevID109 Time: 1332955010 28.03.2012 17:16:50
DevID106 Time: 1332955010 28.03.2012 17:16:50
DevID107 Time: 1332955010 28.03.2012 17:16:50

DevID106 Time: 1332955011 28.03.2012 17:16:51
DevID108 Time: 1332955011 28.03.2012 17:16:51
DevID107 Time: 1332955011 28.03.2012 17:16:51
DevID109 Time: 1332955011 28.03.2012 17:16:51
```

Fig 3-2: Output in Compare-Mode

After switching to compare mode, the software asks which data should be compared with each other. To do this, enter the corresponding number and press the Enter key. The displayed data has the same format as in standard mode (see 3.1.1). In compare mode, for example, it is easy to check whether all devices have the same time and are running synchronously. By pressing the c key again, you switch back to the standard mode.

3.1.3 Synchronisation and setting time

By pressing the s button, the connected devices are synchronized and the time is set. First, synchronization occurs, in which a device sends a sync signal, synchronizing its own atomic clock and the atomic clocks of the other devices. Which device sends the sync signal is specified in the SelfPotLogger_SocketClient.cfg file (see above). If the synchronization was successful, the devices send the log message LN_INF_AC_SYNC_SUCCESS (see 8.4). If the software has received this log message from all connected devices, the message
>>>>>>>> Sync successful ! <<<<<<<< is displayed.

```
Syncing and setting time ...

DevID107 Log message: 28.03.2012 17:42:33, Nr=017, Dat=3
DevID108 Log message: 28.03.2012 17:42:34, Nr=017, Dat=3
DevID109 Log message: 28.03.2012 17:42:34, Nr=017, Dat=3
DevID106 Log message: 28.03.2012 17:42:34, Nr=017, Dat=4
DevID106 Log message: 28.03.2012 17:42:35, Nr=020, Dat=0
DevID107 Log message: 28.03.2012 17:42:34, Nr=020, Dat=0
DevID108 Log message: 28.03.2012 17:42:35, Nr=020, Dat=0
DevID109 Log message: 28.03.2012 17:42:35, Nr=020, Dat=0

>>>>>>>> Sync successful ! <<<<<<<<<<


DevID106 Time: 1332956554 28.03.2012 17:42:34
DevID108 Time: 1332956554 28.03.2012 17:42:34
DevID109 Time: 1332956554 28.03.2012 17:42:34
DevID107 Time: 1332956553 28.03.2012 17:42:33

DevID107 Time: 1332956554 28.03.2012 17:42:34
DevID108 Log message: 28.03.2012 17:42:34, Nr=017, Dat=2
```

Fig 3-3: Output on synchronisation

After synchronization, the times of the devices are automatically set to the PC time.
For testing, it can make sense to send a fixed time and not the current PC time to the devices in order not always to have to adjust the timetable. This can be achieved by passing a Unix timestamp as a parameter when calling SelfPotLogger_SocketClient.exe.

SelfPotLogger_SocketClient.exe 1262304000
- ➔ sets the time of the devices to 01.01.2010 00:00:00

Tip: To convert time stamps into date/time and vice versa, you can use the
Use website http://www.gaijin.at/olsutc.php.

3.1.4 Send commands

Commands can be sent with the w key.

```
DevID108 Time: 1332957842 28.03.2012 18:04:02
DevID106 Time: 1332957842 28.03.2012 18:04:02
DevID109 Time: 1332957842 28.03.2012 18:04:02
DevID107 Time: 1332957842 28.03.2012 18:04:02

*****************************************************************
* A command has the format: DevID CMD_Destination CMD_ID CMD_Data *
* DevID=0 addresses all CSEMs.                                    *
*****************************************************************

Enter command: 106 0 2 1262304000

DevID106 Log message: 28.03.2012 18:04:54, Nr=017, Dat=2
DevID106 Log message: 01.01.2010 00:00:00, Nr=004, Dat=1262304000

DevID109 Time: 1332957895 28.03.2012 18:04:55
DevID106 Time: 1332957895 28.03.2012 18:04:55
DevID108 Time: 1332957895 28.03.2012 18:04:55
DevID107 Time: 1332957895 28.03.2012 18:04:55

DevID109 Time: 1332957896 28.03.2012 18:04:56
DevID106 Time: 1262304001 01.01.2010 00:00:01
DevID108 Time: 1332957896 28.03.2012 18:04:56
DevID107 Time: 1332957896 28.03.2012 18:04:56
```

Fig 3-4: Command input

After pressing w, the command is entered using 4 numbers separated by spaces.
The first number indicates the DevID of the device to which the command should be sent. If you enter 0 here, the command is sent to all connected devices.
The second number corresponds to the command target number, the third number to the command number and the fourth number to the command data (see 8.2).

For example, the command in Figure 3-4 sets the time of the device with the DevID 106 to 01/01/2010 00:00:00.

3.1.5 Stop display

The h key can be used to stop and restart the output of the data on the screen.

3.1.6 Start Timetable processing

By pressing the t key, a command is sent to all connected devices that sets the start mode to "timetabled". This means that the timetable file (see 4.1) is read in again and processing is started

Notice: The same can also be achieved by pressing the w key and enter command 0 0 1 1 (see 3.1.4).

3.2 SelfPotLogger_ConvertData

The SelfPotLogger_ConvertData software is used to convert the binary files located on the SD card in the selfpot_data directory into ASCII files.
If the binary files are read in directly by your own data processing software, SelfPotLogger_ConvertData can be used to check the correct extraction of the data.

When calling SelfPotLogger_ConvertData.exe, the binary file or files must be passed as a parameter. Wildcards are also allowed. Here are some examples of calls:

SelfPotLogger_ConvertData.exe 170801142000.B132

→ *converts only the file 170801142000.B132*

SelfPotLogger_ConvertData.exe 170801142000.B132 170801142500.B132 170801143000.B132

→ *converts the files 170801142000.B132,170801142500.B132 und 170801143000.B132*

SelfPotLogger_ConvertData.exe *.B132

→ *converts all files in the current directory (of the device with DevID 132)*

SelfPotLogger_ConvertData.exe 17080114*.B132

→ *converts all files generated on the 01.08.2017, between 14:00 and 15:00.*

The data is extracted into several ASCII files. These have the same file name as the binary files but a different file extension that describes the type of data.

*.ef1 -> E-Field data channel 1
*.ef2 -> E-Field data channel 2
*.ef3 -> E-Field data channel 3
*.hk -> Housekeeping data and status
*.ac -> Housekeeping data of the atomic clock
*.mag -> magnetic field data

The files contain the following values separated by spaces:

*.ef1 / *.ef2 / *.ef3

Column	Value
1	Unix time stamp (seconds since 01.01.1970 00:00:00)
2	E-Field (voltage in µV)

*.hk

Column	Value
1	Unix time stamp (seconds since 01.01.1970 00:00:00)
2	Acceleration X
3	Acceleration Y
4	Acceleration Z
5	Magnetic field X (last value if magnetic field data rate > 1Hz)
6	Magnetic field Y (last value if magnetic field data rate > 1Hz)
7	Magnetic field Z (last value if magnetic field data rate > 1Hz)
Column	**Value**
8	Supply- (Battery) voltage
9	digital 3.3V
10	1.5V FPGA Core-Spannung
11	3.3V Supply voltage of RTC and tomic clock
12	Temperature (of PCB)
13	Aux1
14	Aux2
15	Aux3
16	Status (binary coded, see 8.3.1.1)

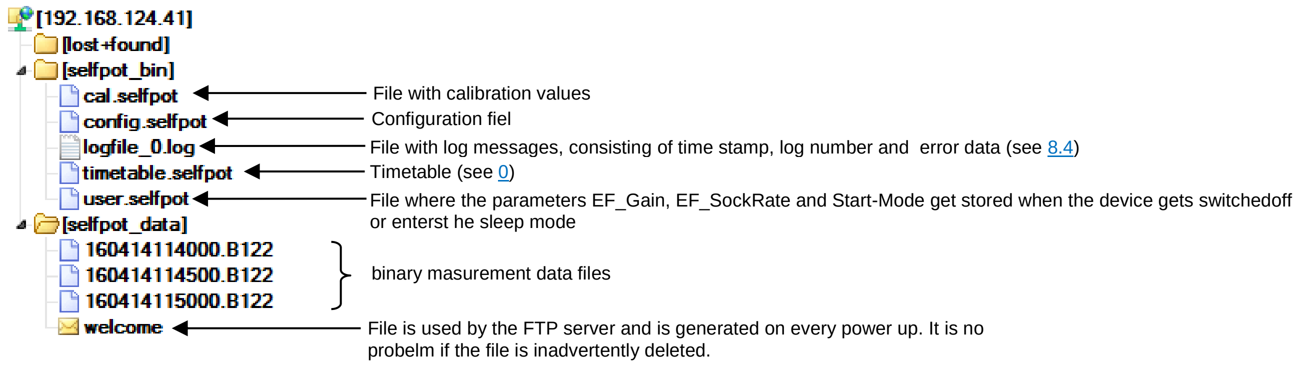
*.ac

Column	Value
1	Unix time stamp (seconds since 01.01.1970 00:00:00)
2	Laser current [mA]
3	TCXO voltage [V]
4	Heater power [mW]
5	DC signal level [V]
6	Temperature [°C]
7	Contrast
8	Steer valuet
9	Unix time stamp of atomic clock (seconds since 01.01.1970 00:00:00)
10	Time since first lock of the atomic

*.mag (optional, if external magnetometer is present)

Spalte	Wert
1	Unix time stamp (seconds since 01.01.1970 00:00:00)
2	Magnetic field X
3	Magnetic field Y
4	Magnetic field Z
5	Sensor temperature [°C]

4 Directories and files on SD card



4.1 Timetable

A timetable is a text file used to control when a device wakes up from sleep, records data, and goes back to sleep.
This is useful to save energy and storage space while no measurement data is required and thus increase the total runtime of the devices.
The timetable file is called timetable.selfpot and is located in the selfpot_bin folder on the SD card (see 4.1). It can be accessed via an FTP connection. The FTP access data can be found in Chapter 8.5.2.

<u>Example of an timetable</u>

```
#StartDay     Start HH:MM:SS     EndDay     End HH:MM:SS     Gain
26.           18:00:00           26.        18:05:00         0
26.           20:00:00           26.        20:05:00         21
26.           22:00:00           26.        22:05:00         42
27.           00:00:00           27.        00:05:00         63
```

A line beginning with # is a comment line and will be ignored by the device.
Every other line defines a measurement whose parameters are to be separated by spaces or tabs. Columns 1 and 2 indicate the day and time when the measurement begins, columns 3 and 4 indicate the day and time when the measurement ends. Column 5 specifies the gain setting with which the measurement is to be carried out. The gains of the 3 channels are to be combined as follows

Bit 5...4: Gain Channel 3 (0…3)
Bit 3...2: Gain Channel 2 (0…3)
Bit 1...0: Gain Channel 1 (0…3)

Example:

Channel 1: Gain=0 → binary "00"
Channel 2: Gain=1 → binary "01"
Channel 3: Gain=3 → binary "11"

→ Gain (binary) = "110100" → Gain (decimal) = **52** (measurement ranges see 8.6.1)

Due to the nature of the RTC used to wake up the device from sleep mode, the day on which the device starts/stops a measurement can be a maximum of one month in the future.
The device is always woken up by the RTC a little before the start of a measurement so that there is enough time to start the device. This time is specified in the config.selfpot file in the selfpot_bin folder with the PRESTART_TIME[sec] parameter and is 30s in the delivery state.
When a measurement is finished, the device goes back to sleep if the next measurement start is more than 2*PRESTART_TIME in the future.
After the last entry in the timetable has been processed, the device goes into idle mode and remains there.
In order to restart the device, it must either be disconnected from the supply voltage and reconnected, or the Sync+ line must be briefly connected to the GND line (see 8.1).

4.2 Binary measurement files

In the binary files, the readings are stored in consecutive pairs of data ID and data value. The file begins with an ID (1 byte) followed by the associated data. Then the next ID followed by the next data value and so on.
The assignment of data IDs and data, the data length and the format can be found in Chapter 8.3.1. The values are stored in "little endian" format.

Here a binary measurement file example (displayed in a Hex viewer):

ID: 1=Zeitstempel
Data: 0x570F8190=1460634000
= 14.04.2016 11:40:00 UTC

ID: 2 = E-Feld Channel 1
Data: 0x45FA2572
= 8004.6807 µV (float)

ID: 2 = E-Feld Channel 2
Data: 0x45FA8ED4
= 8017.8535 µV (float)

ID: 2 = E-Feld Channel 3
Data: 0x45FA2B87
= 8005.441 µV (float)

```
Offset(d)  00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19
00000000   01 90 81 0F 57 02 72 25 FA 45 1B D4 8E FA 45 1C 87 2B FA 45
00000020   02 CD C6 E0 45 1B 82 32 E1 45 1C 37 DB E0 45 02 A9 BD C6 45
00000040   1B B4 2C C7 45 1C 4A D0 C6 45 02 25 EF AB 45 1B 2C 63 AC 45
00000060   1C D5 F0 AB 45 02 41 7D 90 45 1B EB FD 90 45 1C 45 7C 90 45
                                    ...
00000000   09 75 A4 3E 41 0A 9A 47 52 40 0B 21 1E C2 3F 0C 1C ED 51 40
00000020   0D 9C 5C 42 43 0E 00 00 00 00 0F 00 00 00 00 10 00 00 00 00
00000040   02 54 BC 07 46 1B 62 F1 07 46 1C 0C C7 07 46 01 91 81 0F 57
00000060   02 1F 22 F7 45 1B 28 91 F7 45 1C 29 2A F7 45 02 9F BA DD 45
00000080   1B CD 19 DE 45 1C 63 CB DD 45 02 23 9F C3 45 1B D4 0A C4 45
```

ID: 9 = HK Battery
Data: 0x413EA475
= 11.915151 V (float)

ID: 10 = HK V33
Data: 0x4052479A
= 3.2856202 V (float)

ID: 11 = HK V15
Data: 0x3FC21E21
= 1.5165445 V (float)

The file names are structured as follows:

YYMMDDhhmmss.Bxxx

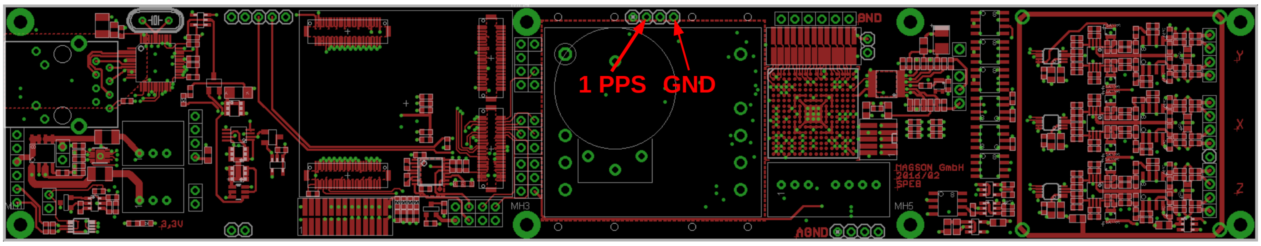
YY	Year
MM	Month
DD	Day
hh	Hour
mm	Minute
ss	Second
xxx	DevID

5 Trimming of the atomic clock

The accuracy of atomic clocks can be further improved by trimming.
If absolute accuracy is not required, one can proceed as follows.

First, one determines how the clocks of the different devices drift in relation to a particular device. To do this, the devices are first synchronized (see 3.1.3).
The time drift can be determined in different ways.

1. The time difference between the 1PPS signals of the atomic clocks is measured with an oscilloscope. This measurement is repeated e.g. 12 hours later.



2. A sinusoidal signal with a frequency of e.g. 100Hz is fed into the E-field inputs of all devices and the data is recorded e.g. over 12 hours with the devices. In order to reduce the amount of data, it is advisable to use a timetable that is configured, for example, so that one minute of data is recorded every hour. A sine is fitted to the data of the first and last measurement and the time differences are thus determined. The measurements in between can also be used to determine whether the drift is linear.

The second variant was used in a test with the devices DevID106 - DevID109 at room temperature. The device with the DevID 106 served as a reference. The sine fit delivered the following results:

1. measurement: t=1332771000 -> 26.03.2012 14:10:00

DevID	Phase angle [°]	Time [µs]	Amplitude [mV]	Frequency [Hz]	Offset [mV]
106	0	0	9,9526	99,9992	-0,4560
107	-0,0508	-1,4107	9,9522		-0,4694
108	-0,0389	-1,0804	9,9540		-0,4611
109	0,0037	0,1027	9,9556		-0,4719

last measurement: t=1332835499 -> 27.03.2012 08:04:59

DevID	Phase angle [°]	Time [µs]	Amplitude [mV]	Frequency [Hz]	Offset [mV]
106	0	0	9,9700	99,9993	-0,4351
107	0,2795	7,7644	9,9700		-0,4575
108	0,6747	18,7408	9,9717		-0,4514
109	-0,2490	-6,918	9,9721		-0,4577

Δt = 64499s (17,91 hours)

DevID	Time drift [µs]	Parts per 10^{-12}	Steer value
107	9,1751	142,251	142
108	19,8212	307,310	307
109	-7,0207	-108,850	-109

The setting of the trim (steer) value and other special functions of the atomic clock were not integrated into the software of the devices. In order to use this, you have to communicate directly with the atomic clock.

To do this, open two ssh connections, e.g. with the program Putty (access data see 8.5.3).

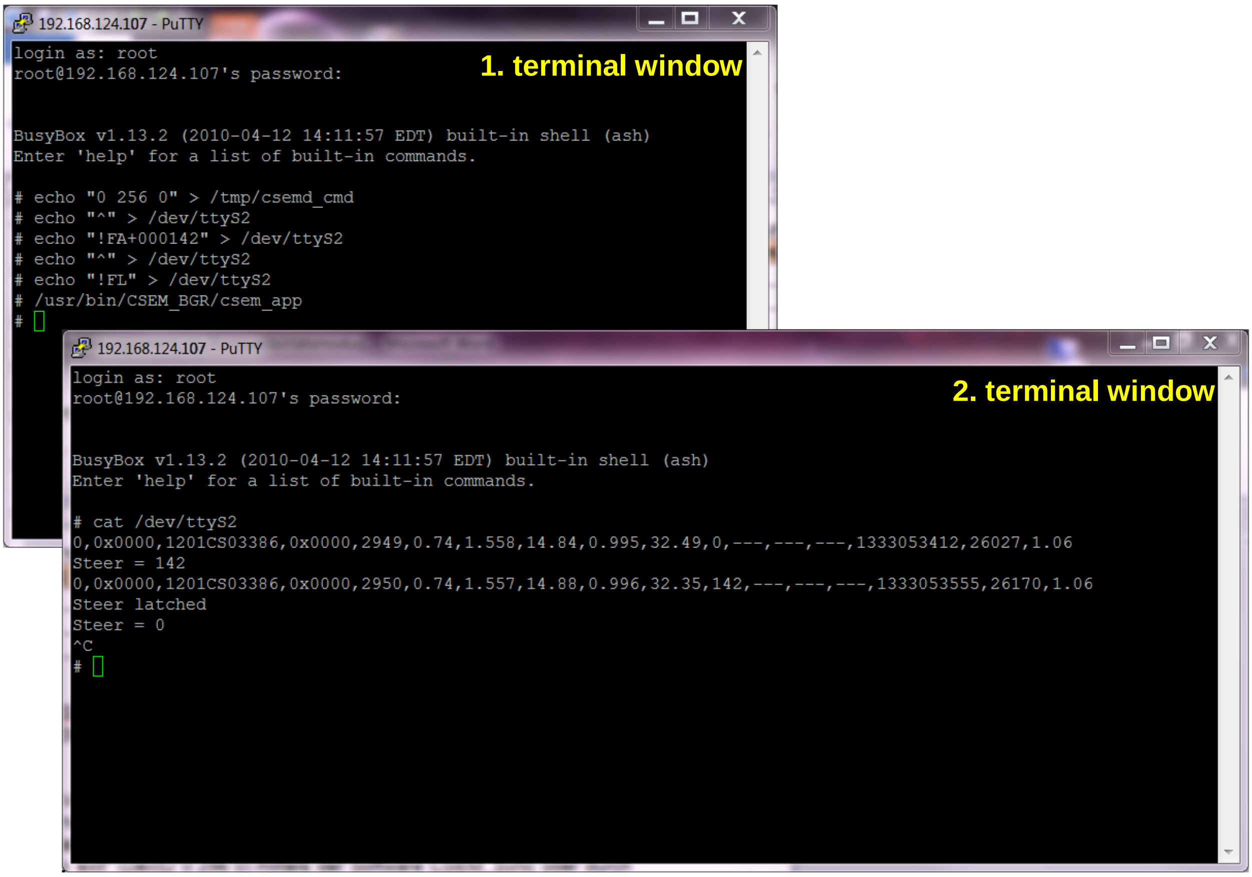


Fig 5-1: ssh terminal windows during communication with the atomic clock

Before you can communicate with the atomic clock, the device software must first be closed, as this also communicates with the atomic clock. This can be done by sending the command "selfpot_app exit" (for the device with DevID 106 e.g. 106 0 256 0) using the SelfPotLogger_SocketClient software (see 3.1.4) or by entering `echo "0 256 0" > /tmp/selfpotd_cmd` in the ssh terminal.
The second terminal window is used to display the atomic clock responses. Here you enter `cat /dev/ttyS2`.
Commands can now be sent to the atomic clock by entering `echo “command” > /dev/ttyS2`.
The actual `command` to the atomic clock is between the two quotation marks. A complete listing of all atomic clock commands and functions can be found in the User's Guide at https://www.microsemi.com/product-directory/clocks-frequency-references/3824-chip-scale-atomic-clock-csac#resources
To test the communication with the atomic clock, one can get the telemetry data with the command `echo “^“ > /dev/ttyS2`. These should now be displayed in the second terminal window. The 11th value corresponds to the steer value, which still has the value 0.
The atomic clock command !FA±xxxxxx is used to set the steer value. It is important that exactly 6 numbers (xxxxxx) follow the + or -. These correspond to the trim value in parts per 10-12 and are left-padded with zeros to 6 characters if necessary.
In the test measurement (see above), the drift for the device with DevID 107 was +142.251*10^{-12}.
The command to set the steer value for this is echo "!FA+000142" > /dev/ttyS2.
The atomic clock response to this command is Steer = 142. If the atomic clock telemetry data is queried again with `echo “^“ > /dev/ttyS2`, the steer value (11th value) should now be 142.
The trimming is now complete, but the set steer value would be lost if the supply voltage were disconnected. To prevent this, a latch command is sent (`echo "!FL" > /dev/ttyS2`), which

changes the calibration of the atomic clock based on the steer value and stores it in the internal non-volatile memory. After this command, the steer value has the value 0 again. The response of the atomic clock to the command is:

```
Steer latched
Steer = 0
```

In the second terminal window, the connection to the atomic clock is terminated by simultaneously pressing the `ctrl` and `c` keys. The device software can then be restarted by entering `/usr/bin/SelfPotLogger_Geomar/selfpot_app`.

6 Softwareupdate and Remote Support

The data loggers have a function that allows the customer to update the software. A software update is made available by Magson in the form of a file called "SoftwareUpdate". This file is placed in the selfpot_data directory using an FTP connection (access data can be found in Chapter 8.5.2) and the device is then restarted. Shutting down can be done by command (0 5 0) or by switching off the input voltage (if the device has a shutdown battery). To restart, the input voltage is then switched (off and) on again. The software update is then carried out during the start and the new software is started. The "SoftwareUpdate" file is automatically deleted from the SD card after the update.

The data logger has the "Remote Support" function for Magson support in the event of problems. The device establishes an encrypted connection to Magson, which Magson can use to remotely control and maintain it. For this, the data logger must be able to access the Internet. The connection to Magson is established with the command "0 262 1" and terminated again with the command "0 262 0".

7 Atomic Clock and RTC Options

The data loggers are usually equipped with a CSAC SA.45s atomic clock, which ensures a high time stability of 5×10^{-11} and enables time-synchronous measurements from different data loggers. At the customer's request, the logger can also be supplied without an atomic clock. The customer then has to procure and install the atomic clock himself.
Alternatively, the logger can also be supplied with a standard RTC DS3231. Although this is considerably cheaper than the atomic clock, it only has a time stability of 5×10^{-6}. Subsequent conversion from the RTC DS3231 to the CSAC SA.45s atomic clock is possible, but requires that the data logger be sent back to Magson.

8 Appendix

8.1 Connections

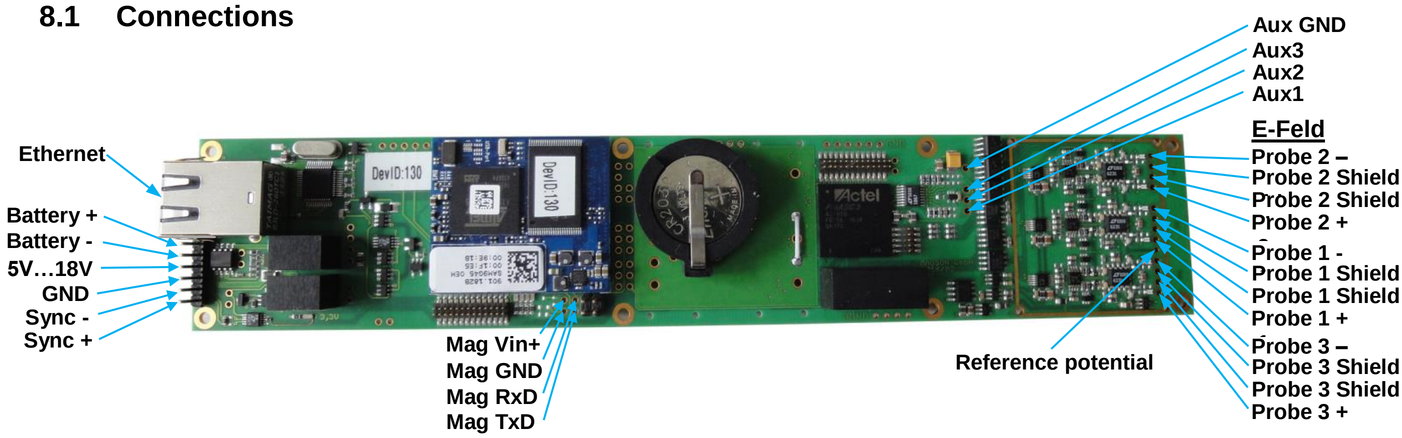


Fig. 8-1: Device connections

Ethernet Connector

Pin	Function
1	Tx+
2	Tx-
3	Rx+
6	Rx-

Fig. 8-2: Pin assignment Ethernet connector

8.2 Commands

CMD Destination No.	CMD Destination	CMD No.	CMD	CMD Data	Response	Comment
0	selfpot_app	0	EF Sock Data Rate	0=1Hz, 1=10Hz, 2=100Hz, 3=500Hz, 4=1kHz, 5=5kHz, 6=10kHz	no	
		1	Start Mode	0=Measurement Stop, 1=Start/Stop timetabled, 2=Measurement Start	no	if the mode is set to 1, then the timetable is re-read an gets executed
		2	Set Time	Unix Timestamp	no	
		3	Wait for Sync	dummy z.B. 0	no	
		4	Send Sync and wait for Sync	dummy z.B. 0	no	
		5	Shutdown Request	dummy z.B. 0	no	
		6	selfpot_app Restart	dummy z.B. 0	no	restarts the application (useful to re-read the config data)
		7	Set IP address	IP address z.B. 192.168.124.41 = 0xC0A87C29 = 3232267305	no	
		8	Set subnet mask	Network mask z.B. 255.255.255.0 = 0xFFFFFF00 = 4294967040	no	
		9	Set gateway address	Gateway address z.B. 192.168.124.1 = 0xC0A87C01 = 3232267265	no	
		10	Set DNS address	DNS address z.B. 192.168.124.1 = 0xC0A87C01 = 3232267265	no	
		11	Apply network settings	0: DHCP, 1: Manual (Apply setting of CMD 7-10)	no	
		256	selfpot_app exit	dummy e.g. 0	no	
		257	LSB Output	0=OFF, 1=ON	no	
		258	EF_SimData	0=normal E-Field data, 1=simulated E-Field data	no	
		259	selfpot_app SleepTime	0=no sleep, 1…=sleep time [µs]	no	
		260	Watchdog Enable	0=Watchdog disabled, 1=Watchdog enabled	no	Default: Watchdog enabled
		261	EF_Gain	Bit 5...4: Gain Channel 3 (0…3) Bit 3...2: Gain Channel 2 (0…3) Bit 1...0: Gain Channel 1 (0…3)	no	Measurement ranges see 8.6.1
		262	Remote Support	0: disconnect from Magson, 1:connect to Magson	no	sets up a support connection to Magson (Device needs internet connection)
		4096	GetSDStatus	dummy e.g. 0 (if the CMD was received from a socket, then the answer goes to the same socket; if the CMD was received from CMD_FIFO, then the answer goes to DBG_DATA_FIFO)	yes	Sends the SD card status
		4097	Get Network Settings	dummy e.g. 0 (if the CMD was received from a socket, then the answer goes to the same socket; if the CMD was received from CMD_FIFO, then the answer goes to DBG_DATA_FIFO)	yes	Sends the current network settings
1	FPGA immediately Read	FPGA SPI Adr	FPGA CMD	dummy e.g. 0 (if the CMD was received from a socket, then the answer goes to the same socket; if the CMD was received from CMD_FIFO, then the answer goes to DBG_DATA_FIFO)	yes	executes the CMD immediately

2	FPGA immediately Write	FPGA SPI Adr	FPGA CMD	SPI CMD Data	no	executes the CMD immediately
3	FPGA Read	FPGA SPI Adr	FPGA CMD	dummy e.g. 0 (if the CMD was received from a socket, then the answer goes to the same socket; if the CMD was received from CMD_FIFO, then the answer goes to DBG_DATA_FIFO)	yes	executes the CMD in ISR
4	FPGA Write	FPGA SPI Adr	FPGA CMD	SPI CMD Data	no	executes the CMD in ISR

8.3 Data IDs

8.3.1 Data IDs for sockets und fiels

ID (decimal)	Name	Data format	Comment	Rate / Frequency
1	Timestamp	long (4 Byte)	Unix Timestamp	1s
2	E-Field Data Channel 1	float (4 Byte)	scaling according config file (usually in µV)	10kHz
3	HK Acceleration X	float (4 Byte)	scaling according config file (usually in g)	1s
4	HK Acceleration Y	float (4 Byte)	scaling according config file (usually in g)	1s
5	HK Acceleration Z	float (4 Byte)	scaling according config file (usually in g)	1s
6	HK Magnetometer X	float (4 Byte)	scaling according config file (usually in nT)**	1s*
7	HK Magnetometer Y	float (4 Byte)	scaling according config file (usually in nT)**	1s*
8	HK Magnetometer Z	float (4 Byte)	scaling according config file (usually in nT)**	1s*
9	HK Vbattery	float (4 Byte)	scaling according config file (usually in V)	1s
10	HK V33	float (4 Byte)	scaling according config file (usually in V)	1s
11	HK V15	float (4 Byte)	scaling according config file (usually in V)	1s
12	HK V33RTC	float (4 Byte)	scaling according config file (usually in V)	1s
13	HK Temperature	float (4 Byte)	scaling according config file (usually in °C)	1s
14	HK Aux1	float (4 Byte)	additional HK channel, scaling according config file	
15	HK Aux2	float (4 Byte)	additional HK channel, scaling according config file	
16	HK Aux3	float (4 Byte)	additional HK channel, scaling according config file	
17	Status	long (4 Byte)	see 8.3.1.1	1s
18	AC_LaserCurrent	float (4 Byte)	in mA (typical 0.8-1.3)	60s
19	AC_TuneVoltage	float (4 Byte)	in V (0-2.5)	60s
20	AC_HeaterPower	float (4 Byte)	in mW (typical 15-25 at 25°C)	60s
21	AC_SignalLevel	float (4 Byte)	in V (typical ~1)	60s
22	AC_Temperature	float (4 Byte)	in °C (accuracy +/-2°C)	60s
23	AC_Contrast	long (4 Byte)	typical >2000 when locked and ~0 when unlocked	60s
24	AC_Steer	long (4 Byte)	in units per 10^{-12}	60s
25	AC_Time	long (4 Byte)	Unix time stamp	60s
26	AC_TimeSinceLock	long (4 Byte)	in seconds	60s
27	E-Field Data Channel 2	long (4 Byte)	scaling according config file (usually in µV)	10kHz
28	E-Field Data Channel 3	float (4 Byte)	scaling according config file (usually in µV))	10kHz
29	Magnetometer Temp.	float (4 Byte)	scaling according Applied Physics Magnetometer	10Hz

* 1s when using LSM303DLM, on Applied Physics magnetometer depending on magnetometer setting
** the Applied Physics magnetometer is not calibrated

8.3.1.1 Status

Bit Number	Meaning
31	RemoteSupport Status: 0=disconnected or connecting,1=connected
30…29	EF Gain Channel 3
28…27	EF Gain Channel 2
26…12	Atomic Clock Alarm (see 8.3.1.2)
11…8	Atomic Clock Status (see 8.3.1.3)
7	EF SimData (0=normal, 1=simulated)
6	LSB output (0=off, 1=on)
5…4	EF Gain Channel 1
3	Watchdog (0=off, 1=on)
2…1	Start-Mode
0	Logging (0=off, 1=on)

8.3.1.2 Atomic Clock Alarm

Status Bit Number	Alarm	Reason
26	Stack overflow (firmware error)	
25	Laser current High	> 2.3 mA
24	Laser current Low	< 0.5 mA
23	TCXO control voltage High	> 2.4 V
22	TCXO control voltage Low	< 0.1 V
21	uW Power control High	> 2.48 V
20	uW Power control Low	< 2 mV
19	Heater Power High	> 40.5 mW
18	Heater Power Low	< 50 mW
17	DC Light level High	> 2.48 V
16	DC Light level Low	< 200 mV
15	reserved	
14	Temperature Bridge Unbalanced	Bridge – Setpoint > +/- 2 mV
13	Synthesizer tuning at limit	Synthesizer detuned from calibration by > +30 kHz or < -15 kHz
12	Signal Contrast Low	Contrast < 1000

8.3.1.3 Atomic Clock Status

Wert	Bedeutung
0	Locked
1	Microwave Frequency Steering
2	Microwave Frequency Stabilization
3	Microwave Frequency Acquisition
4	Laser Power Acquisition
5	Laser Current Acquisition
6	Microwave Power Acquisition
7	Heater equilibration
8	Initial warm-up
9	Asleep (ULP mode only)

8.3.2 Data IDs for sockets

ID (decimal)	Name	Format	Remarks	Rate / Frequency
128	CMD Reply	short (2 Byte)		
129	SDCard Status	float[2] (8 Bytes)	float[0]=CardSize in MB, float[1]=CardUsed in MB	60s or on demand per CMD 0 4096 0

130	Log Message	struct log_struct	struct log_struct
			{
			long log_timestamp;
			char log_no;
			long log_data;
			};	

131	Network Settings	struct network_struct	struct network_struct
			{
			unsigned char Manual;
			unsigned int IP;
			unsigned int Mask;
			unsigned int Gateway;
			unsigned int DNS;
			};
				on demand per CMD
				0 4097 0

8.4 Log Messages

Log Number	Designator	Data
-45	LN_ERR_RD_NETSET	
-44	LN_ERR_MAG_OPEN	
-43	LN_ERR_AC_SYNC_ERROR	
-42	LN_ERR_AC_UKNOW_REP	
-41	LN_ERR_AC_TIMEOUT	
-40	LN_ERR_AC_OPEN	
-39	LN_ERR_FPGA_APBINTFLG	
-38	LN_ERR_FPGA_APBGNT	
-37	LN_ERR_FPGA_TSTAMP	
-36	LN_ERR_WRONG_LOGLEVEL	
-35	LN_ERR_ACCMAG_WR_DATA	SlaveAdr
-34	LN_ERR_ACCMAG_WR_SUBADR	SlaveAdr
-33	LN_ERR_ACCMAG_WR_SLAVEADR	SlaveAdr
-32	LN_ERR_WRITE_USER	
-31	LN_ERR_INVALID_DCMD	Deamon CMD
-30	LN_ERR_INVALID_CMDDEST	CMD Destination
-29	LN_ERR_SET_SYSTIME	
-28	LN_ERR_RTC_IOCTL	
-27	LN_ERR_OPEN_RTCDEV	
-26	LN_ERR_TRY_RTCOPEN	try counter
-25	LN_ERR_UNKN_DATID	received DataID
-24	LN_ERR_LOG_START_NOSPACE	
-23	LN_ERR_OPEN_TMPFILE	fid
-22	LN_ERR_DISK_FULL	
-21	LN_ERR_WATCHDOG	
-20	LN_ERR_MAP_MEM	
-19	LN_ERR_WRITING_SOCKET	errno
-18	LN_ERR_READ_SOCKET	errno
-17	LN_ERR_LISTEN_SOCKET	errno
-16	LN_ERR_BINDING_SOCKET	errno
-15	LN_ERR_SET_SOCKET_OPTIONS	
-14	LN_ERR_OPEN_SOCKET	
-13	LN_ERR_WRITING_DATFIFO	errno
-12	LN_ERR_READ_CMDFIFO	errno
-11	LN_ERR_OPEN_CMDFIFO	
-10	LN_ERR_CREATE_DATFIFO	
-9	LN_ERR_CREATE_CMDFIFO	
-8	LN_ERR_OPEN_SELFPOT_CHAR_DEV	
-7	LN_ERR_MALLOC_CSEMDATRAW	
-6	LN_ERR_MALLOC_CMDBUFFER	
-5	LN_ERR_MATCH_IDS	
-4	LN_ERR_READ_CONFIG	
-3	LN_ERR_READ_CAL	
-2	LN_ERR_READ_DEVID	
-1	LN_ERR_READ_USER	
0	LN_NO_LOG	
1	LN_INF_APP_START	
2	LN_INF_APP_END	
3	LN_INF_INIT_TIME	Time
4	LN_INF_SET_TIME	Time

Log Number	Designator	Error Data
5	LN_INF_TTREAD_RET	ReadTimetable return value (see 8.4.1)
6	LN_INF_INIT_COMPLETE	
7	LN_INF_DATFIFO_OPEN	
8	LN_INF_DATFIFO_CLOSE	
9	LN_INF_SOCKET_OPEN	Client Number
10	LN_INF_SOCKET_CLOSE	Client Number
11	LN_INF_MAN_SHDN	
12	LN_INF_LOW_BATTERY	battery low_cnt;
13	LN_INF_DISK_NEARLY_FULL	
14	LN_INF_LOG_START	
15	LN_INF_LOG_STOP	
16	LN_INF_SHDN_WAIT_RTCALM	
17	LN_INF_CMD_RCV	CMDDest<<16|CMD
18	LN_INF_SET_LOGLEVEL	loglevel
19	LN_INF_SET_EFGAIN	bit 5...4: EFGainCh3 bit 3…2: EFGainCh2 bit 1…0: EFGainCh1
20	LN_INF_AC_SYNC_SUCCESS	
21	LN_INF_APP_RESTART	
22	LN_INF_PWR_MISSING	
23	LN_INF_NETSET	0: DHCP, 1: Manual
24	LN_INF_SET_IP	IP address
25	LN_INF_SET_NETMASK	subnet mask
26	LN_INF_SET_GW	gateway address
27	LN_INF_SET_DNS	DNS address

8.4.1 Return value TTREAD (Log Number 5)

Return value	Bedeutung	Aktion
2	StartTime > CurrentTime+2*PRESTART_TIME -> RTC programmed to current StartTime	shutdown
1	StartTime > CurrentTime < CurrentTime+2*PRESTART_TIME, last Timetable entry -> Alarm Interrupt disabled	Start Logging at StartTime
0	StartTime > CurrentTime < CurrentTime+2*PRESTART_TIME -> RTC programmed to next StartTime	Start Logging at StartTime
-1	no Timetable present	Stay in timetabled Mode
-2	no StartTime > CurrentTime found	Stay in timetabled Mode
-3	StartTime > EndTime	Start Logging immediately
-4	Error on open RTC device	Start Logging immediately
-5	Error on setting RTC alarm time	Start Logging immediately
-6	Error on setting RTC alarm ON	Start Logging immediately
-7	CurrentTime < 1.1.2000 23:59:59 -> first startup	Logging = OFF

8.5 Access Data

8.5.1 IP-Addresses

When delivered, the devices have the IP address 192.168.124.DevID, e.g. 192.168.124.131 for the device with the device ID 131.
If required, the address can be changed as follows using commands from the SelfPotLogger_SocketClient program.

If you want the device to obtain the network settings automatically from a DHCP server, send the command 0 11 0. After the command has been sent, the network connection to the device is lost because its address has changed. You have to find out which address the device received from the DHCP server via the DHCP server.

For the manual configuration of the network parameters, these are sent with commands no. 7 to 10. The four address components of the IP addresses are encoded with the 4 bytes of the command data. The most significant byte corresponds to the left address component, the least significant byte to the right address component. The following example should illustrate this. The IP address should be set to 192.168.124.41. To do this, you convert the 4 address components into hexadecimal numbers and add them together. In this example, this results in 0xC0A87C29 which corresponds to 3232267305 (decimal). The command to set this IP address is then
0 7 3232267305.
The network settings are not changed at this point. The settings are only accepted when the command 0 11 1 is sent. The device should now be reachable under the new network address.

If something goes wrong when changing the network settings and the device can no longer be reached, you can also change the network settings by creating a file with the name `network.cfg` in the selfpot_bin folder on the SD card. The file must have the following content.

Manuel network setting: static IP-Adresse Network mask Gateway-Adresse DNS-Adresse
e.g..
static 192.168.124.41 255.255.255.0 192.168.124.1 192.168.124.1

Automatic network setting: dhcp

Since the SD card is formatted in the ext4 file system, writing to the card is only possible under Linux or with special software for Windows such as Ext2Fsd.

8.5.2 FTP

Server:	IP-Adresse (see 8.5.1)
Port:	Standard (21)
User name:	ftpuser
Password:	SelfPotLogger

In case of connection problems, the passive mode should be used.

8.5.3 SSH

Terminal access via an SSH connection is not normally required.

Server:	IP-Address (see 8.5.1)
Port:	Standard (22)

User access

User name:	ftpuser
Password:	SelfPotLogger

Root access

User name:	root
Password:	SelfPotLogger

8.5.4 Sockets

Server:	IP-Address (see 8.5.1)
Port:	12345

8.5.5 Web site

Browser address:	http://<IP-Address> (z.B. http://192.168.124.122 see 8.5.1)

8.6 Technical specifications

Parameter	**Value**
Supply voltage • Device can be switched on • Device reports under voltage • on under voltage the device switches off after • Device switches off immediately	5V … 18V 5V 4.61V 300 seconds 4.51V
Supply current at 12V supply voltage • Idle- / Sleep mode • Normal operation , no Ethernet connected • Normal operation, Ethernet connected	 ~ 16 mA (192 mW) ~ 147 mA (1.77 W) ~ 175 mA (2.1 W)
SD card • available memory space • max. logging timer	 29.25 GByte 58.14 hours
Socket connections	max. 5 simultaneously
Measurement range of the auxiliary housekeeping channels • AUX1 • AUX2 • AUX3	Pre-setting: 0 … 10 V (adaptable via resistor settings)

8.6.1 Measurement ranges

The four adjustable measuring ranges result from the combination of two amplifier stages, in each of which two different gains can be set.
The stage gains are set by resistors on the circuit board. The following amplifications have been implemented so far:

Version	Bit combination in command word see chap. 4.1 and 8.2		Amplification			Measurement range
	Bit 1	Bit 0	Stage2	Stage1	Total	
1	0	0	4.9	5.0	24.5	±167.1mV
	0	1	4.9	10.0	49.0	±83.6mV
	1	0	20.1	5.0	100.5	±40.8mV
	1	1	20.1	10.0	201.0	±20.4mV
2	0	0	9.8	2.5	24.5	±167.1mV
	0	1	9.8	245.0	2450.0	±1.678mV
	1	0	102.8	2.5	257.0	±159.4mV
	1	1	102.8	245.0	25186.0	±0.1626mV
3	0	0	0.83	1.2	1.00	±4096mV
	0	1	0.83	11.9	9.9	±413.7mV
	1	0	8.4	1.2	10.1	±405.5mV
	1	1	8.4	11.9	100.0	±40.96mV

Of the different variants, the following devices are currently in circulation:

Version	Device ID	Customer
1	Dev121	Geomar
	Dev122	Geomar
	Dev129	Geomar
	Dev134	Magson
2	Dev130	Geomar
3	Dev131	BGR
	Dev132	BGR