



# **ACTIVE HYDROGEN MASER**

**VCH-1003M**

**User Guide**

**411141.032 UG**

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## 1 Introduction

The program "Active Hydrogen Maser" (the Program) is designed to control the Active Hydrogen Maser (AHM) one of the following models: VCH-1003M, VCH-1003 Option LT and VCH-1003 Option L. The Program provides management of AHM, as well as reading, logging and viewing its parameters (current and for the specified time interval).

The Program requires Windows 7, 8, 10 or Linux operating system with kernel version 2.6.x or higher.

Communication between the computer, on which the Program is installed, and AHM is performed via COM port directly or via a LAN/RS-232 or USB/RS232 Converter. When using Converter, the relevant driver should be used.

Implemented features:

- AHM management (switch on/off, changing parameters);
- monitoring, maintaining and viewing parameters in the form of tables and graphs;
- copy data about AHM status to an FTP server for remote monitoring of the parameters.

## 2 Installation

### 2.1 Installation in Windows

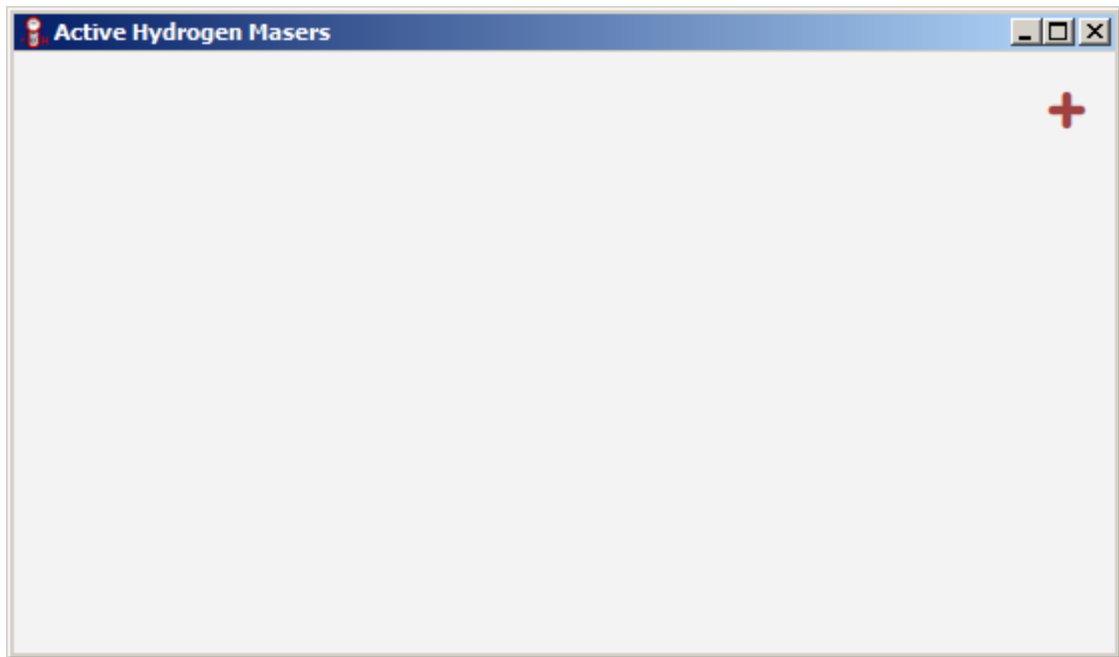
The Program can work under Windows 7, 8, 10. By default the software is installed from the CD/USB-drive (supplied with AHM). Run executable file from the root directory of the CD/USB-drive. The installer will create shortcut on the desktop and the corresponding item in the "Start" menu.

### 2.2 Installation in Linux

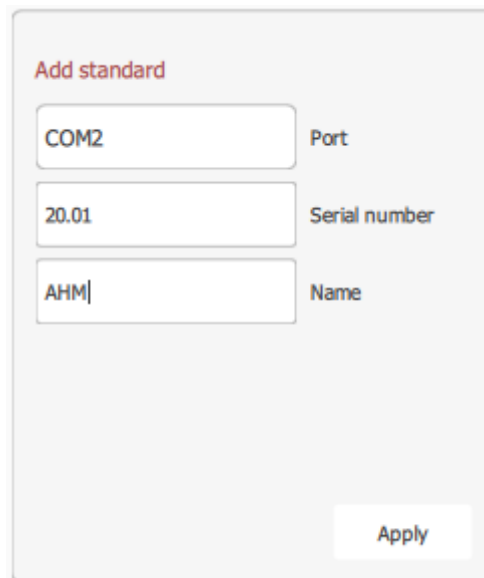
The Program can work with operating systems of the Linux family (the list of supported distributions <https://doc.qt.io/archives/qt-5.13/linux.html>). The software is installed from the CD/USB-drive (supplied with AHM) by default. To install on Ubuntu and Debian, run the command from the console "sudo dpkg -i (Program).deb". To install on OpenSUSE, RedHat and CentOS, run the command from the console "sudo rpm -i (Program).rpm". (Program) – name of the distribution's installation file. The Program will be installed in the folder "/opt/Progs/CH1-1003M".

### 3 Connecting AHM and starting work with the Program

When running the Program for the first time an empty window opens (Figure 3.1) with the option to add AHM. After clicking the "+" button, the selection window opens (Figure 3.2).



**Figure 3.1** – First launch of the Program

The image shows a dialog box titled "Add standard". It contains three text input fields arranged vertically. The first field is labeled "Port" and contains the text "COM2". The second field is labeled "Serial number" and contains the text "20.01". The third field is labeled "Name" and contains the text "AHM". At the bottom right of the dialog box, there is an "Apply" button.

**Figure 3.2** – Window for adding an AHM

When the window for adding an AHM opens, the Program automatically searches for available COM ports (including virtual COM-ports for RS-232/USB and RS-232/LAN converters).

**When using LAN/RS-232 Converter, simultaneous connection to the device from different computers is not allowed. Otherwise, data streams from different Programs may be mixed, that can lead to incorrect decoding the commands in the device!**

After entering the port name, a list of suggested options will appear (Figure 3.3).

Add standard

Port	Serial number	Name
COM1		
COM18		
COM19		
COM13		
COM15		

**Figure 3.3** – Entering the COM port

“Serial number” is a required field when adding a device.

After clicking the "Apply" button, the Program will try to establish a connection to the COM port. If the connection is successfully established, the main window with the AHM parameters will be opened (Figure 4.1).

When the Program is run next time, it attempts to connect to the previously selected COM-port, the COM-port number is stored in the ini-file in the Program folder (subfolder "config").

## 4 Interface and Program operation

Program interface displays the current AHM parameters (Figure 4.1). The parameters are divided into 6 blocks:

- 1) "PLL module. Power";
- 2) "PLL module. Basic parameters";
- 3) "CAT parameters";
- 4) "HG module. Power";
- 5) "HG module. Basic parameters";
- 6) "Oven".

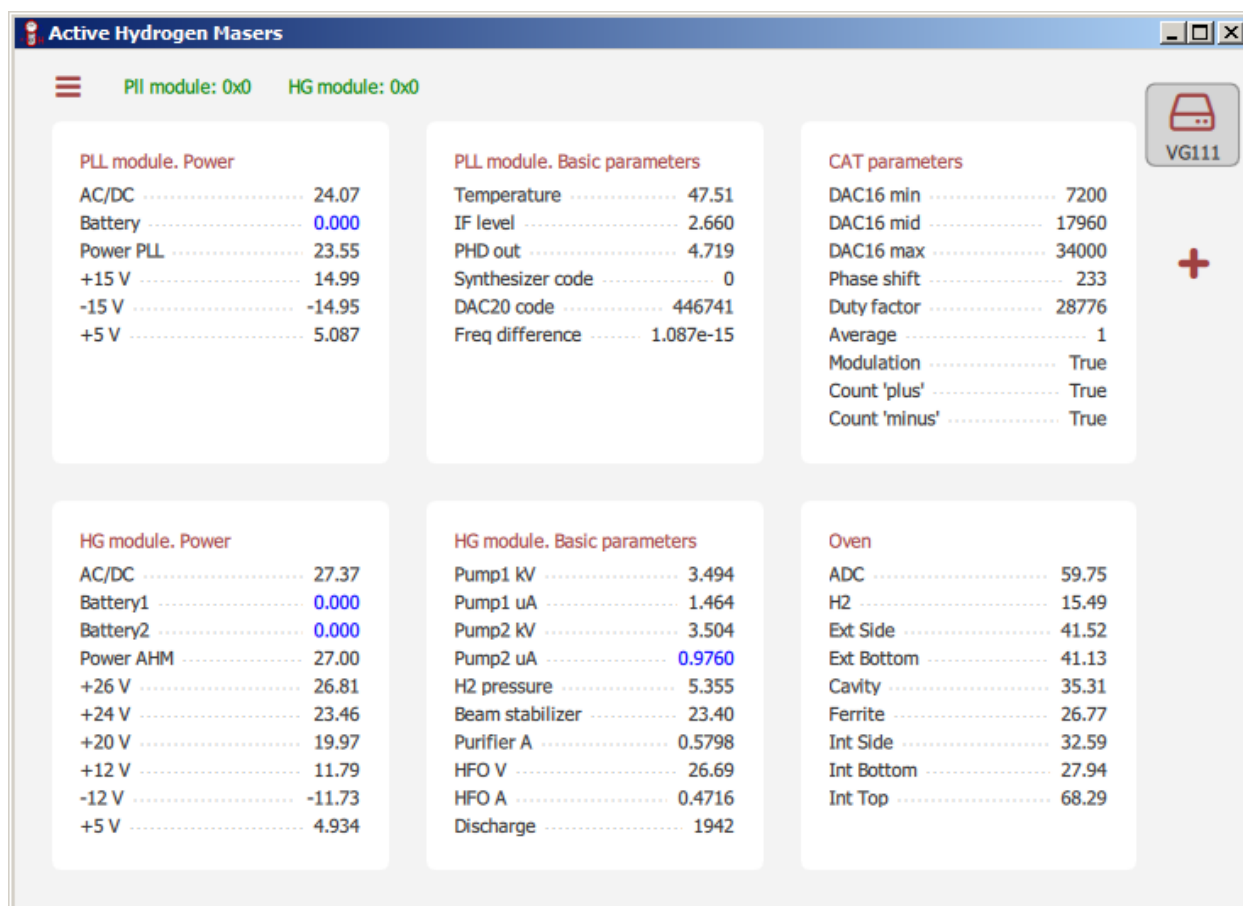


Figure 4.1 – Main window

The "PLL module. Power" block contains the following information:

- 1) "AC/DC" – the voltage on AC/DC converter output;
- 2) "Battery" – voltage of the external DC or battery backup applied to the PLL unit from the HG module;
- 3) "Power PLL" – power supply voltage of the PLL unit;
- 4) "+15 V" – the output voltage of the source +15 V;
- 5) "-15 V" – the output voltage of the source -15 V;
- 6) "+5 V" – the output voltage of the source +5 V.

The **"PLL module. Basic parameters"** block includes:

- 1) **"Temperature"** – PLL module temperature;
- 2) **"IF level"** – the intermediate frequency amplifier output voltage; gives the information about the receiver IF signal amplitude;
- 3) **"PHD out"** – the phase detector output; gives the information about the voltage applied to the VCO in the PLL;
- 4) **"Synthesizer code"** – standard output frequency code in relative units  $10^{-16}$ ;
- 5) **"DAC20 code"** – determines the tuning frequency of the maser cavity;
- 6) **"Frequency difference"** – frequency offset of the input signal with respect to the AHM signal measured at 100 s averaging time (indicating if 5/10/100 MHz signal is connected to the related input of the AHM, refer to the 411141.030-01OM);

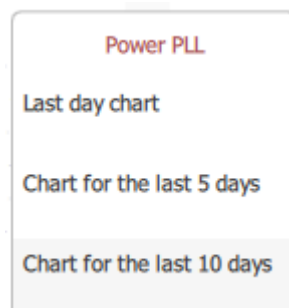
The **"HG module. Power"** block displays power supply voltage of HG module. If AHM is supplied with UPS unit the fields for DC inputs are named "Battery" and "UPS" instead of "Battery1" and "Battery2" (Figure 4.1).

The **"HG module. Basic parameters"** and **"Oven"** blocks displays information about work mode of HG module.

The **"CAT parameters"** block shows the set values of the cavity auto-tuning system parameters.

All the monitored parameters are displayed in the main window (Figure 4.1). The parameters values within nominal range are indicated in black. The values exceeding the nominal range are displayed in red, the values below the nominal range are in blue. The nominal range limits can be set in the Program settings (Figure 4.7).

Pressing the right mouse button on the parameter field causes the menu for selecting the history time interval to be opened (Figure 4.2). This menu allows to show a graph for the parameter for the selected time interval.

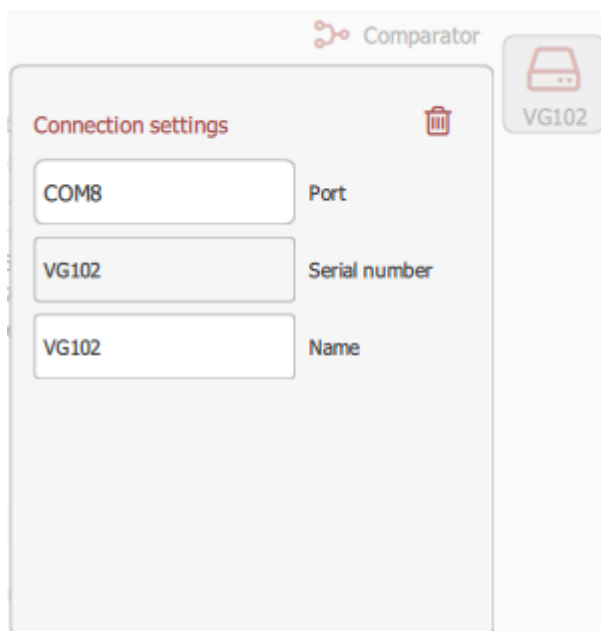


**Figure 4.2** – Menu for selecting the history time interval for the parameter "Power PLL"

After an interval has been selected in the menu (Figure 4.2) the parameter graph is displayed in the "Log Data" section, what is described in more details below (Figure 4.12).



The name of the added AHM is displayed in the right part of the main window of the Program. The right mouse button click on a list item, opens the window with connection settings (Figure 4.3).

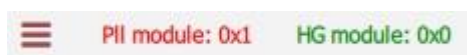


**Figure 4.3** – Frequency Standard connection settings window

The window displays the serial number of the AHM, the COM-port number, and the device name. The current port and name can be changed. The serial number can be set only while the connection is setting up (Figure 3.2). The button for deleting a device from the list of monitored AHMs is located in the upper-right corner of the window.

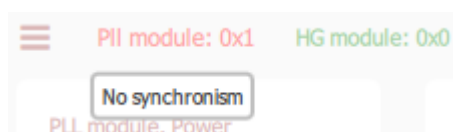
At the top of the screen (Figures 4.1, 4.4) the following items are displayed from left to right:

- 1) button to open the window for managing the AHM and Program settings (Section 4.1);
- 2) PLL module and HG module status fields;



**Figure 4.4** – Upper part of the main window of the Program

Normal operation of the PLL module and HG module is highlighted in green, and if there is an error, it will be indicated in red. If mouse cursor is located over the error code displayed in hexadecimal notation, a list of errors will appear (Figure 4.5).



**Figure 4.5** – Decoding the PLL module error code

The list of error codes for PLL module:


- 1) 0x0 – normal operation, no errors;
- 2) 0x01 – loss of lock (no synchronism);
- 3) 0x02 – no output signal 1 Hz;
- 4) 0x04 –synchronization error of 1 Hz output signal;
- 5) 0x08 – no power supply 220 V;
- 6) 0x40 – no connection with PLL module.

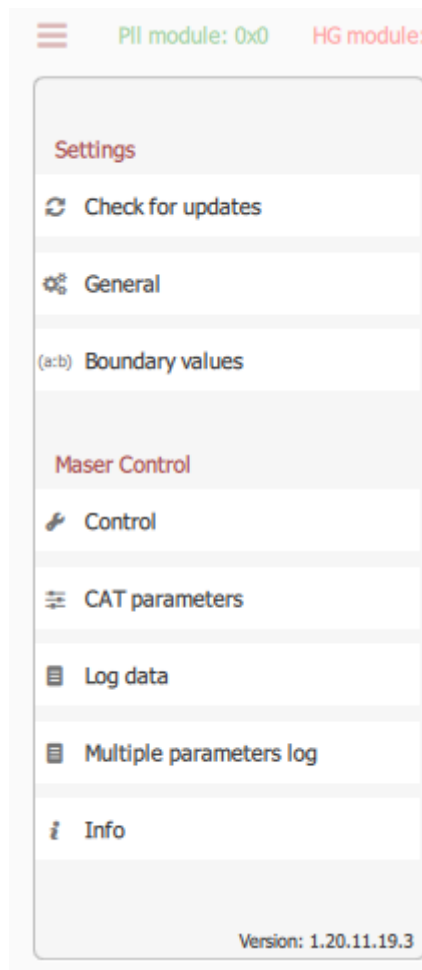
The codes of individual errors in the PLL module are summed up into a common error code.

The errors of HG module:

- 1) 0x0 – no errors;
- 2) 0x8 – no power 220 V, battery input is used;
- 3) 0x80 – no power.

#### 4.1 Settings and AHM Control

Figure 4.6 shows the menu of the main window of the Program. Click the icon  in the main window of the Program (Figure 4.1) to get to the menu.



**Figure 4.6** – Settings and Maser Control

Menu item "**Settings>Check for updates**" is optional and can be hidden in some versions of the software. The Program can be updated automatically by selecting this item, if connection to FTP-server <ftp.vremya-ch.com> is available.

Clicking the menu item "**Settings>General**" (Figure 4.6) opens the window shown in Figure 4.7. Here the following parameters can be set:

- 1) **"Request period"** – request period for Frequency Standard parameters update
- 2) **"Data logging period"** – period for saving current parameters to log file
- 3) **"Scale"** – the scale of the elements and text of the Program
- 4) **"Language"**
- 5) **"Time before the password is requested again"**

The changed values will be highlighted, and the button for saving changings will appear in the upper-right corner (Figures 4.7, 4.8).

The screenshot displays the 'Settings>General' window. On the left, a sidebar lists various settings categories: 'Settings' (with a sub-item 'Check for updates'), 'General' (which is currently selected and highlighted with a red bar), '(a:b) Boundary values', 'Maser Control', 'Control', 'CAT parameters', 'Log data', 'Multiple parameters log', and 'Info'. The main content area on the right is titled 'General' and contains several adjustable parameters. 'Request period' is set to 1 second. 'Data logging period' is set to 60 seconds, with a note indicating it's the time interval for saving results to a file. 'Time before the password is requested again' is set to 120 seconds. The 'Scale' is currently at 100%, with minus and plus buttons for adjustment. The 'Language' is set to 'English' with a dropdown arrow. At the bottom left of the window, the version number 'Version: 1.20.11.19.3' is displayed.

**Figure 4.7 – Settings>General**

Section	Parameter	Toggle	Min	Max
PLL module. Power	AC/DC	<input checked="" type="checkbox"/>	23.5	27.5
	Battery	<input checked="" type="checkbox"/>	22	30
	Power PLL	<input checked="" type="checkbox"/>	22	30
	+15 V	<input checked="" type="checkbox"/>	14	16
	-15 V	<input checked="" type="checkbox"/>	-16	-14
	+5 V	<input type="checkbox"/>	0	0
PLL module. Basic parameters	Temperature	<input checked="" type="checkbox"/>	5	50
	IF level	<input checked="" type="checkbox"/>	0.3	4
	PHD out	<input checked="" type="checkbox"/>	0	8

**Figure 4.8** – Boundary values – nominal range limits

In "**Boundary values**" menu item (Figure 4.6) the acceptable parameters limits can be set (Figure 4.8). The parameter in the main window of the Program is indicated in blue or red if its value is lower or higher than the corresponding limit.

**WARNING! The limit values are set during the adjustment process at the manufacture and must not be changed by the user.**

**To change maser parameters in the menu items "Control" and "CAT parameters" an authentication is required. Default username and password: user, 1. The procedure for changing the username and password is described in section 4.3.**

"**Control**" menu (Figure 4.9) contains the sections described below.

- 1) "**Mode**" is used for choosing how to turn on AHM. In "Auto" mode Frequency Standard modules are switched on automatically after required parameters have been normalized.

In "Manual" mode the next section "**HG power**" becomes available and user can switch on/off the modules. In manual mode user should check required AHM parameters before switching on the next module (see the section 6).

To extend the resource and to minimize the ensuing installation time the "Stand by" mode is realized. This mode enables the AHM to be partially shut down. Only ion pumps and the cavity temperature control are to be left on.


- 2) "**HG power**" contains control elements "**Pumps**", "**Beam**" and "**HFO**". This group becomes available if the manual mode is selected.

First, the "**Pumps**" element becomes available, to switch on/off ion pumps. After turning on the pumps, the "**Beam**" element becomes available, which turns on the beam of hydrogen. After hydrogen beam has been switched on the last element – "**HFO**" becomes available. Use this button to switch on high-frequency oscillator that provides dissociation of molecular hydrogen.

**WARNING! AHM blocks should be switched on in the order described in the section 6.1.**

- 3) "**Synthesizer code**" contains the field for entering the code of the frequency synthesizer. This is the six-digit number, which allows to adjust the standard output frequency to the nominal value within  $1 \times 10^{-10}$  range and with the resolution  $1 \times 10^{-16}$ .
- 4) "**Frequency drift compensation (per day)**" allows to set the daily frequency drift correction value.
- 5) "**Time scale synchronization**" allows to synchronize the AHM output signal 1 PPS to the external input signal 1 PPS.
- 6) "**Modulation**" contains two buttons that change the q-factor of the hydrogen emission line:
  - "**1 (Qmin)**" – reduced q-factor;
  - "**0 (Qmax)**" – maximum (normal) q-factor.

Q-factor modulation is only used for setting the correct parameters of the cavity auto-tuning system.

Values changed by user are highlighted. The buttons  on the right of the parameters are used to apply and set them to the AHM. To save and transmit all the values at once, click the button in the upper-right corner (Figure 4.9).

**Settings**

- General
- (a:b) Boundary values
- Maser Control**
- Control**
- CAT parameters
- Log data
- Multiple parameters log
- Info

**Control**

**Mode**  
Choose the way to turn on the maser. **Standby** is used to turn off the high-frequency generator and the beam without switching off the pumps and thermostats

☐ Auto ☒ Manual ☐ Standby

**HG power**  
**Pumps** - activates magnetic-discharge pumps; **Beam** allows to turn on the hydrogen beam; **HFO** is used to turn on a high-frequency generator that provides dissociation and excitation of molecular hydrogen;

☒ Pumps ☒ Beam ☒ HFO

**Synthesizer code**  
The **Synthesizer code** is used to correct the relative value of the AHM frequency

585000 1e-16

**Frequency drift compensation (per day)**

0

**Time scale synchronization**  
Adjust to external 1pps

1PPS output synchronization

**Modulation**

☐ 1 (Qmin) ☒ 0 (Qmax)

Version: 1.20.10.21

**Figure 4.9 – Control**

The "CAT parameters" menu item (Figure 4.10) is used for setting the parameters of the cavity auto-tuning system (CAT).

- 1) "**DAC20 code**" is the hexadecimal code of the 20-bit DAC from 0 to FFFFF. It determines the DAC output voltage applied to the cavity tuning varactor.
- 2) "**DAC16 min**", "**DAC16 mid**", "**DAC16 max**" are the decimal min, mid and max codes of the 16-bit DAC from 0 to 65535. They determine the DAC output voltage applied to the modulating cavity varactor.
- 3) Modulation parameters:
  - "**Phase shift**" in decimal from 0 to 1024;
  - "**Duty factor**" in decimal from 0 to 57344;

- **"Average"**, averaging factor, defining the time constant of the CAT system, in decimal from 0 to 255 (the averaging factor of 100 corresponds to a time constant approximately equal to one hour).
- 4) **"Modulation"** – enable or disable modulation. **"Count 'plus'"** and **"Count 'minus'"** buttons enables the cavity tuning.

**Settings**

- General
- (a:b) Boundary values
- Maser Control
- Control
- CAT parameters**
- Log data
- Multiple parameters log
- Info

Version: 1.20.10.21

**CAT parameters**

Current values

797529 DAC20 code

c2b59 DAC20 code. Initial value (hex)

DAC16 min, DAC16 mid and DAC16 max allow to set the minimum, average and maximum modulating voltages in range from 0 to 65535

0 DAC16 min

17960 DAC16 mid

34000 DAC16 max

Modulation parameters

Phase shift in decimal from 0 to 1024; Duty factor from 0 to 57344; Averaging factor from 0 to 255

233 Phase shift

28776 Duty factor

1 Average

Modulation

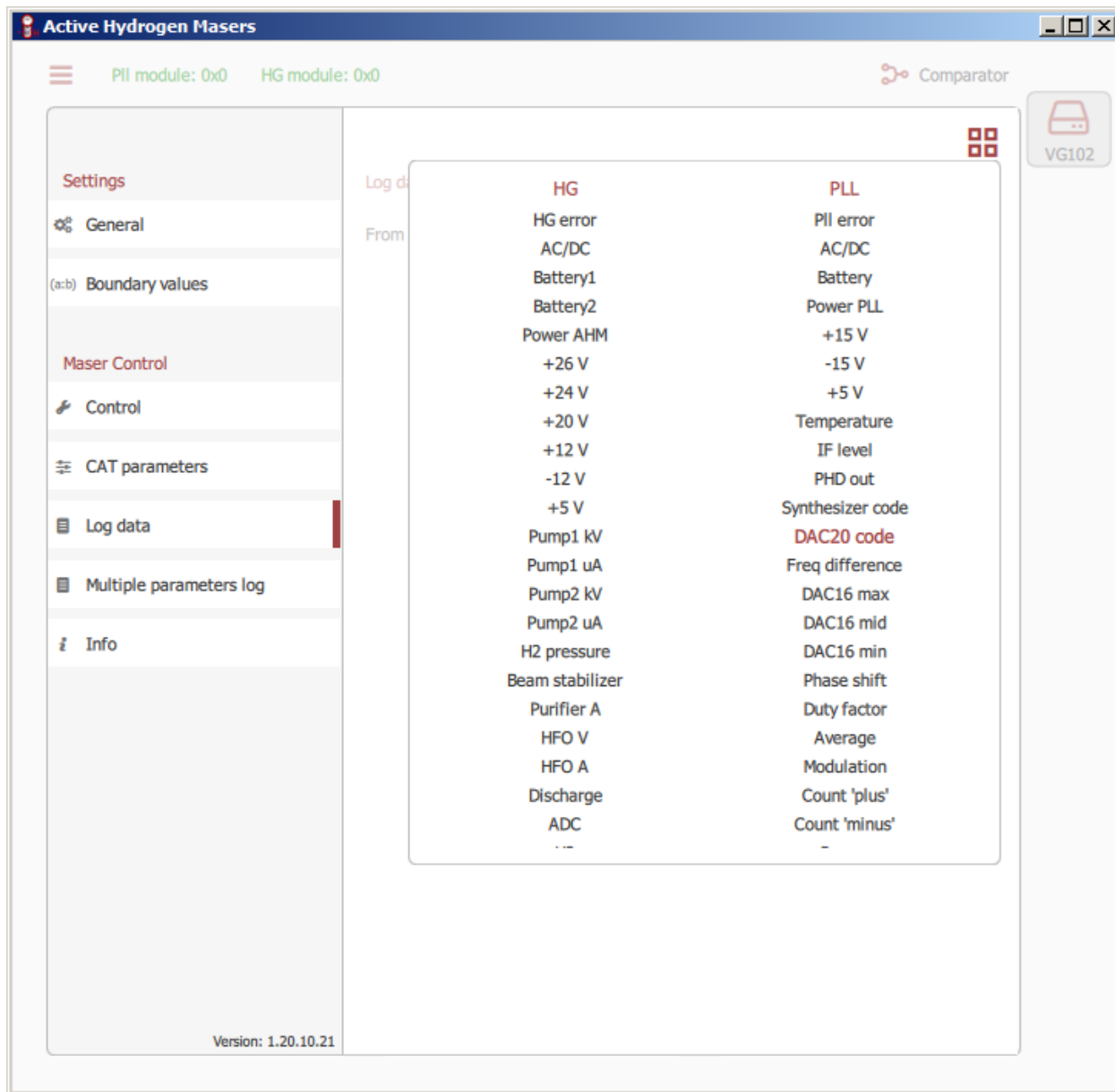
Count 'plus'

Count 'minus'

**Figure 4.10 – CAT parameters**

In the upper-right corner there are the buttons (from left to right): apply, read, write to file, read from file. By pressing the "Apply" button, the changes entered by the user are transmitted to the device. After clicking the "Read" button, the **"CAT Parameters"** panel will display the current values read from the device. Write/read to/from file allows storing and restoring parameter values in the configuration file on computer.

The **"Log data"** menu item (Figure 4.11) is used to display AHM parameters for the specified time interval. History is displayed in the form of a table (Figure 4.12) or a graph (Figure 4.14).

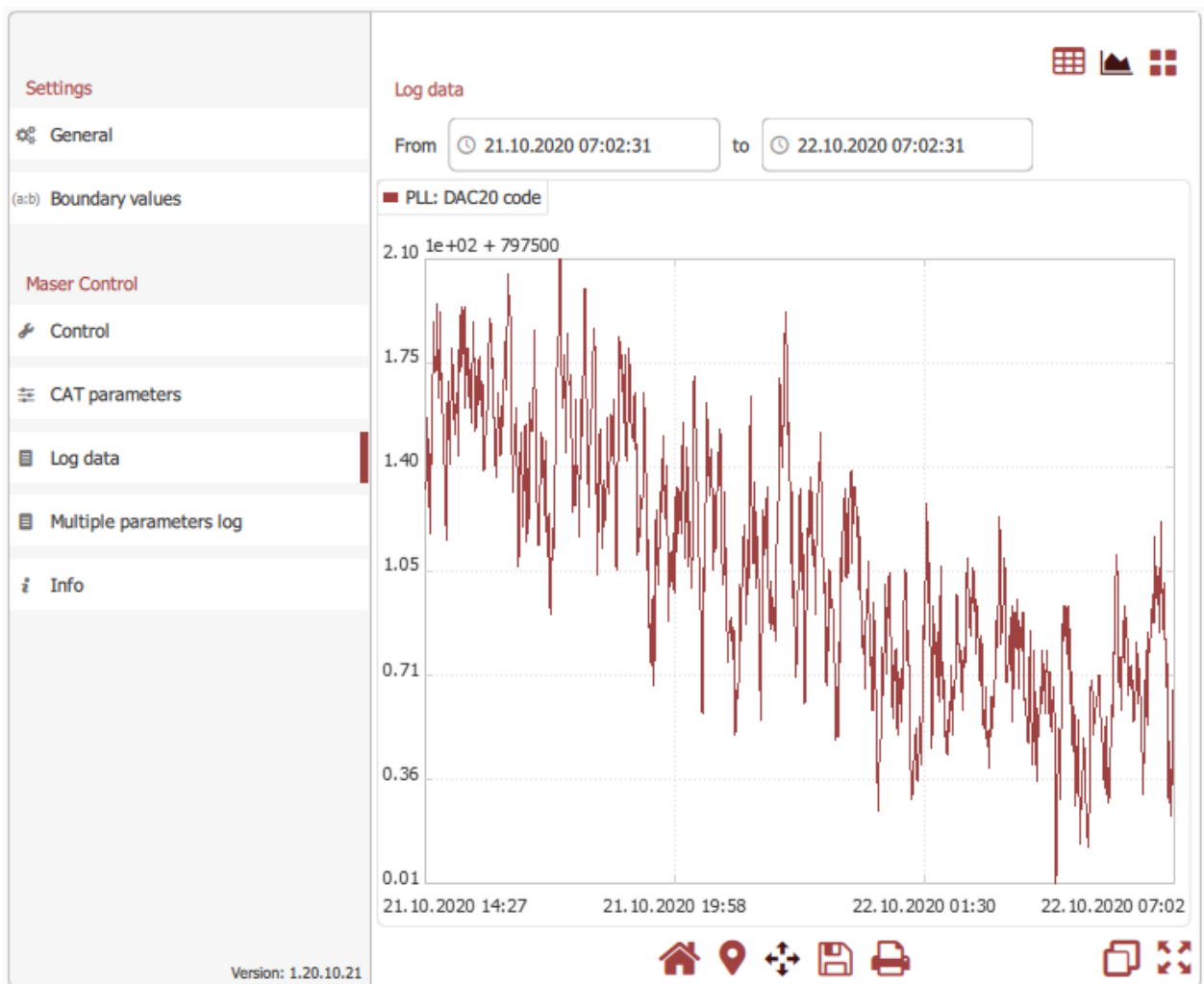


**Figure 4.11** – List of parameters

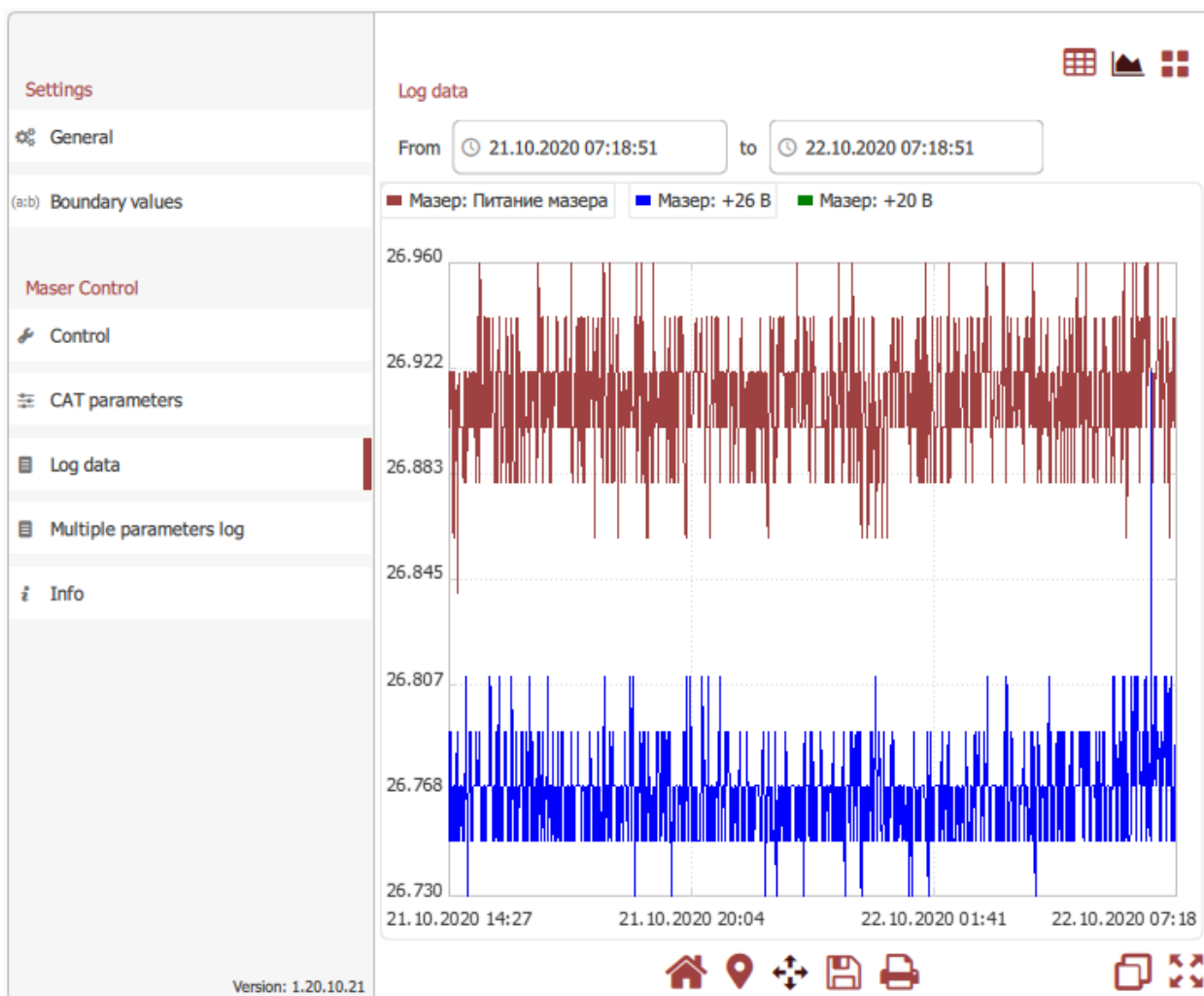
To open the list of the device parameters (Figure 4.11), hover the mouse cursor over the button in the upper-right corner. It causes the two-columns list of the HG module and PLL module parameters to be generated. If not all parameters fit on the screen, scroll them using the mouse wheel or the Page Up and Page Down buttons. Select a parameter using the cursor keys (up, down, left, and right), or using the mouse. Select several parameters (Figure 4.13).

In addition, set the start and finish dates for displaying data.





**Figure 4.12** – Frequency Standard parameter plot



**Figure 4.13** – Displaying several Frequency Standard parameters on a chart

Settings

General

(a:b) Boundary values

Maser Control

Control

CAT parameters

Log data

Multiple parameters log

Info

Version: 1.20.10.21



Log data

From 21.10.2020 07:24:59 to 22.10.2020 07:24:59

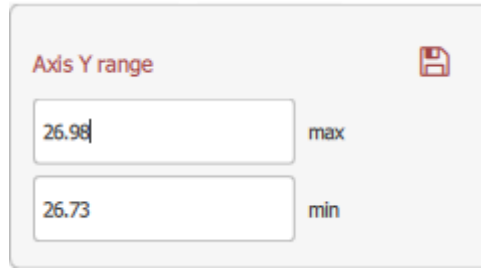
Date	HG: Power AHM	Date	HG: +26 V	Date	HG: +24 V
21.10.2020 14:27:13	26.92	21.10.2020 14:27:13	26.77	21.10.2020 14:27:13	23.46
21.10.2020 14:28:13	26.92	21.10.2020 14:28:13	26.75	21.10.2020 14:28:13	23.46
21.10.2020 14:29:13	26.9	21.10.2020 14:29:13	26.79	21.10.2020 14:29:13	23.46
21.10.2020 14:30:13	26.92	21.10.2020 14:30:13	26.79	21.10.2020 14:30:13	23.46
21.10.2020 14:31:13	26.92	21.10.2020 14:31:13	26.75	21.10.2020 14:31:13	23.46
21.10.2020 14:32:13	26.9	21.10.2020 14:32:13	26.75	21.10.2020 14:32:13	23.46
21.10.2020 14:33:13	26.92	21.10.2020 14:33:13	26.77	21.10.2020 14:33:13	23.46
21.10.2020 14:34:13	26.86	21.10.2020 14:34:13	26.75	21.10.2020 14:34:13	23.46
21.10.2020 14:35:13	26.92	21.10.2020 14:35:13	26.77	21.10.2020 14:35:13	23.46

Copy Paste

**Figure 4.14** – Displaying several Frequency Standard parameters in a table view

Click the button  display graph in a different window. Click the button  to extend the table or graph.


Double-click on the vertical axis of a graph opens a pop-up window for setting the axis range (Figure 4.15). Click on the horizontal axis, to set the averaging time interval in seconds (Figure 4.16).






**Figure 4.15 – Pop-up menu Axis Y range**

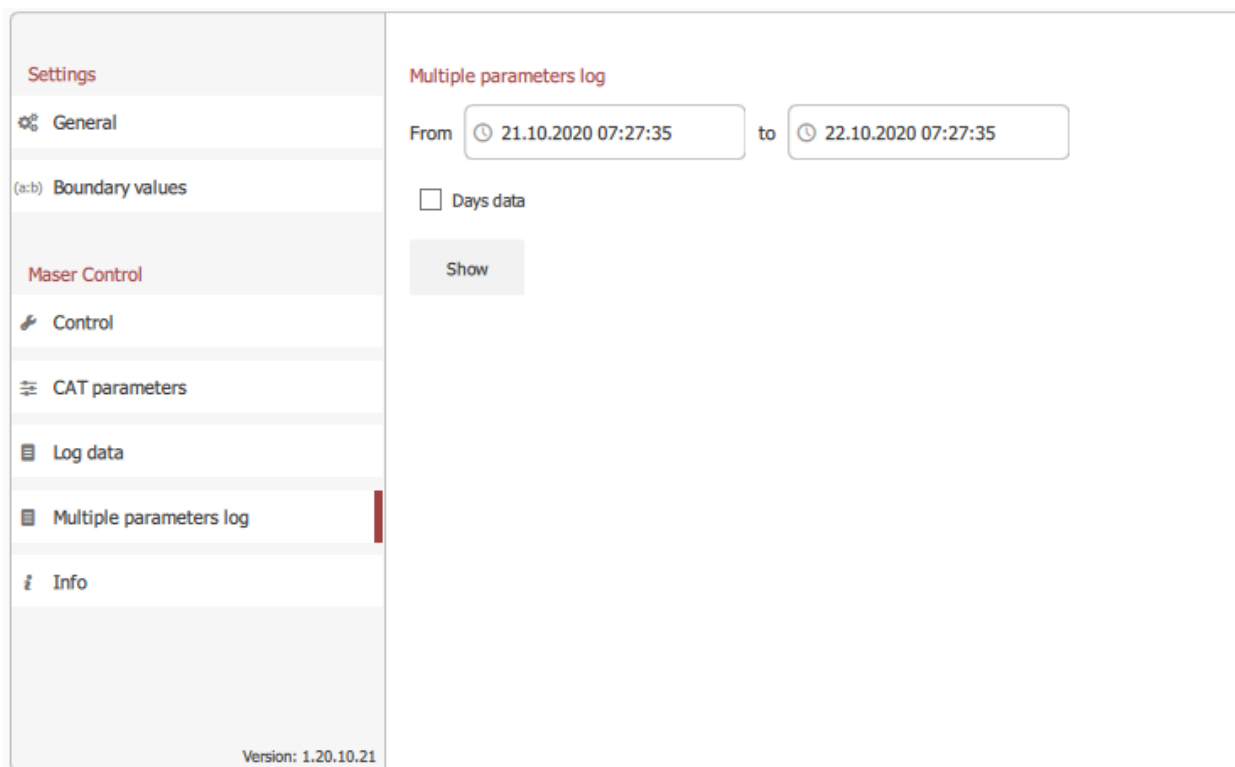


**Figure 4.16 – Pop-up menu Averaging Interval**

The graph contains a marker that appears after left mouse button click in the graph field. The horizontal and vertical values for the point are displayed in the upper-right corner of the window (Figure 4.22). The marker can be used to measure differences of the coordinates between two points on the graph. To do this, click the button , and then mark the first point by pressing left mouse button, then hold down the button and move the cursor to the second point where you can release the mouse button. The measured horizontal and vertical Delta values will be also displayed in the upper right corner of the window (Figure 4.23).

Click  to change the scale of the graph (right mouse button) or move it (left mouse button). Click the buttons:   to save the graph or print it.

To display a list of all parameters of the AHM for the specified time interval, select "**Multiple parameters log**" (Figure 4.17)



**Figure 4.17** – Multiple parameters log

To decimate values click on the "Days data" check box. After clicking the «**Show**» button, a new window with a table of parameters opens will be opened (Figure 4.18).

History							
	+26 V	+24 V	+20 V	+12 V	-12 V	+5 V	Pur
21.10.2020 14:27:13	26.77	23.46	19.95	11.79	-11.75	4.95	3
21.10.2020 14:28:13	26.75	23.46	20.01	11.79	-11.73	4.97	3
21.10.2020 14:29:13	26.79	23.46	19.99	11.79	-11.73	4.95	3
21.10.2020 14:30:13	26.79	23.46	19.97	11.79	-11.75	4.93	3
21.10.2020 14:31:13	26.75	23.46	19.99	11.79	-11.73	4.95	3
21.10.2020 14:32:13	26.75	23.46	19.99	11.79	-11.73	4.95	3
21.10.2020 14:33:13	26.77	23.46	19.97	11.79	-11.73	4.91	3
21.10.2020 14:34:13	26.75	23.46	19.95	11.79	-11.73	4.93	3
21.10.2020 14:35:13	26.77	23.46	19.99	11.79	-11.73	4.95	3
21.10.2020 14:36:13	26.77	23.46	19.97	11.79	-11.73	4.95	3
21.10.2020 14:37:13	26.75	23.46	19.97	11.79	-11.73	4.93	3
21.10.2020 14:38:13	26.77	23.44	19.97	11.79	-11.73	4.93	3
21.10.2020 14:39:13	26.79	23.46	19.99	11.79	-11.73	4.91	3

**Figure 4.18** – "History" window

User can select the parameter values needed and build a graph or save to a file. Select the values and click right mouse button to choose the necessary (Figure 4.19).

History							
	+26 V	+24 V	+20 V	+12 V	-12 V	+5 V	Pur
21.10.2020 14:27:13	26.77	23.46	19.95	11.79	-11.75	4.95	3
21.10.2020 14:28:13	26.75	23.46	20.01	11.79	-11.73	4.97	3
21.10.2020 14:29:13	26.79	23.46	19.99	11.79	-11.73	4.95	3
21.10.2020 14:30:13	26.79	23.46	19.97	11.79	-11.75	4.93	3
21.10.2020 14:31:13	26.75	23.46	19.99	11.79	-11.73	4.95	3
21.10.2020 14:32:13	26.75	23.46	19.99	11.79	-11.73	4.95	3
21.10.2020 14:33:13	26.77	23.46	19.97	11.79	-11.73	4.91	3
21.10.2020 14:34:13	26.75	23.46	19.95	11.79	-11.73	4.93	3
21.10.2020 14:35:13	26.77	23.46	19.99	11.79	-11.73	4.95	3
21.10.2020 14:36:13	26.77	23.46	19.97	11.79	-11.73	4.95	3
21.10.2020 14:37:13	26.75	23.46	19.97	11.79	-11.73	4.93	3
21.10.2020 14:38:13	26.77	23.44	19.97	11.79	-11.73	4.93	3
21.10.2020 14:39:13	26.79	23.46	19.99	11.79	-11.73	4.91	3

**Figure 4.19** – Selecting parameters

In the "Info" menu item (Figure 4.20) the following information is present: PLL and HG firmware versions, serial number of the AHM, COM port number and name of the device.

Settings	Info
General	Name: VG102
Boundary values	Serial number: VG102
Maser Control	Port: COM8
Control	PLL version: 02.07.05 Oct 1 2012
CAT parameters	HG version: 02.07.02.Oct 4 2012
Log data	
Multiple parameters log	
Info	

**Figure 4.20** – "Info" panel

## 4.2 Changing the user's password

User names and password hash codes are saved in the **passwords.ini** file in the subfolder **config** in the root folder of the Program. Default username and password: **user**, **1** respectively.

To change the **user**'s password, calculate the hash code using the MD5 algorithm (online services and free software is available in the Internet) for the new password and replace the old code with the new one in the corresponding line.

To change the username, it is enough to replace **user** with a new name. The name must be written in Latin letters.

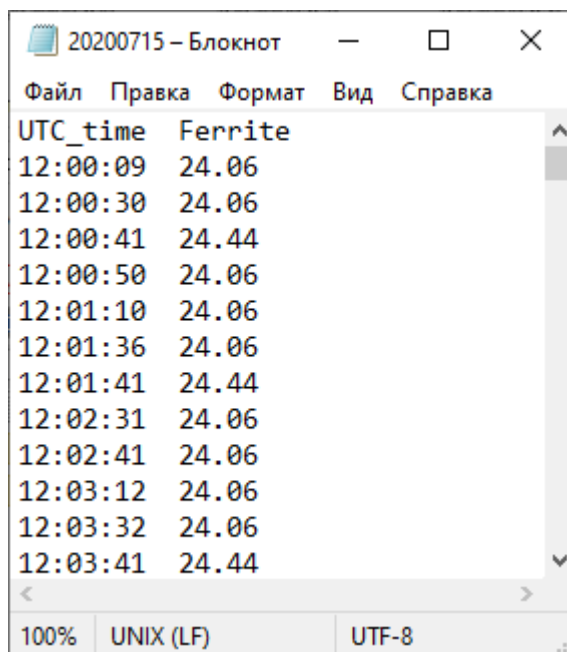
A new user can be created by adding a line of three elements separated by spaces: the user's priority (any number that is not used in this Program), the user's name in Latin letters, and the hash code for the password.

## 5 Output files

The Program saves all monitored parameters in its root folder.

The parameters are saved in the subfolder **Data** the folder named in the format **Name\_SN**, where Name is the specified AHM name and SN is the specified serial number (Figure 4.3). For each parameter, daily files are created in the folder with the parameter name. Parameter file does not have a file extension and it is named in the format YYYYMMDD, where YYYY – year, MM – month, DD – day.

Figure 5.1 shows an example of the file in ASCII format. The first column contains the measurement time corresponding to the time of the computer (converted to UTC) on which the Program is running. The second column contains the current value of the parameter.



The screenshot shows a Notepad window titled '20200715 - Блокнот'. The menu bar includes 'Файл', 'Правка', 'Формат', 'Вид', and 'Справка'. The text content is as follows:

UTC_time	Ferrite
12:00:09	24.06
12:00:30	24.06
12:00:41	24.44
12:00:50	24.06
12:01:10	24.06
12:01:36	24.06
12:01:41	24.44
12:02:31	24.06
12:02:41	24.06
12:03:12	24.06
12:03:32	24.06
12:03:41	24.44

At the bottom of the window, the status bar shows '100%', 'UNIX (LF)', and 'UTF-8'.

**Figure 5.1** – Example of file with parameter values

## 6 Instruction for use

### 6.1 Switching on the AHM

Connect the AHM to the computer (directly to COM-port or using USB/LAN to RS-232 Converter) and turn on the power of the AHM (refer to the Operations Manual). After that establish a connection with the Program (see Section 3).

#### Manual mode

After switching on the AHM power the temperature control system for the cavity and the VCO in the PLL module starts working. The warm-up time of the AHM (to meet the specification completely) is 10 days.

Open "**Control**" menu item of the Program (Figure 4.9) and follow these steps:

- Activate manual mode for turning on the Frequency Standard.
- Click the "**Pumps**" button to start-up ion pumps. Watch the "Pump1, 2" V and  $\mu\text{A}$  readings displayed in the main window of the Program.
- After the pump current reaches the upper limit (it is indicated by black color of the pump current indicators "**Pump 1,2 mkA**"), click the "**Beam**" button to turn on the purifier. Check the "Purifier A" reading.
- In ~30 minutes after the beam has been switched on, turn on the high-frequency oscillator to initiate the discharge that provides hydrogen dissociation ("**HFO**" button). Operation of the HFO is monitored by the voltage ("**HFO V**") and current ("**HFO A**") values. Discharge process is monitored by the sensor ("**Discharge**").

In 2 or 3 days after the maser has been powered on the cavity thermal control system will go into the normal operational state and the maser generation will appear. The PLL system locks the VCO. The cavity tuning system starts tuning the cavity to the hydrogen line emission frequency. In the next 7 days all the AHM parameters transient effects will be stabilized and output standard frequency will reach the nominal value.

The PLL system operation is monitored by the following parameters:

- Intermediate frequency level ("**IF level**"). The value of this voltage is proportional to the amplitude of the maser signal,
- the output voltage of the phase detector ("**PHD out**"). This is PLL voltage applied the VCO control input.

The AHM is ready to work after all controlled parameters have reached values within the set limits.



## Automatic mode

To turn the Frequency Standard on in automatic mode, you need to activate the mode "**Auto**" in the "**Control**" menu item (Figure 4.9) and wait till normal operation is indicated in the main window (green labels "**PLL module**" and "**HG module**").

### 6.2 Standby mode

If long transportation (with available power supply) or very long-term storage is planned but it is required the AHM to recover its frequency and stability for a few days the maser may be set to Standby mode or partially shut down. Only ion pumps and cavity thermal control system are left on. The PLL module is to be powered down as well. For more details refer to the Operations Manual.

### 6.3 Frequency correction

The initial setting of the standard frequency is made by the manufacturer. However, it may be necessary to make a correction. To do this, go to the "**Control**" menu item, then set the relative frequency value of the standard in the units of  $10^{-16}$  in the "Synthesizer code" field.

### 6.4 Correction of the frequency drift of the Frequency Standard

The Program allows to correct linear frequency drift of the Frequency Standard by automatic changing the code of the frequency synthesizer (minimal frequency step is  $10^{-16}$ ) with the period calculated from the daily frequency drift correction value entered by the user in the "**Control**" menu in the "**Frequency drift correction**" section. For example to compensate frequency drift  $+3.5 \times 10^{-16}$  per day, enter the value with the opposite sign: "-3.5e-16".

### 6.5 Time scale synchronization

To synchronize 1 PPS output signal of the Frequency Standard to an external 1 PPS signal, connect the reference 1 PPS signal to the 1 PPS input connector (see Operations Manual), then click the "**1PPS output synchronization**" button. The 1PPS output signal of the maser will be synchronized with 25 ns accuracy to the external signal.

## 7 Abbreviations

AHM – active hydrogen maser;  
CAT – cavity auto-tuning system;  
PLL – phase-locked loop;  
HG – hydrogen generator (maser);  
HFO – high frequency oscillator;  
IF – intermediate frequency;  
PHD – phase detector;  
DAC – digital to analog converter;  
VCO – voltage controlled oscillator;  
UPS – unperturbed power supply.