Passive Hydrogen Maser Frequency and Time Standard

VCH-1006

Maintenance and service manual

411141.012 SM

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The present manual contains information about Passive Hydrogen Maser Frequency and Time Standard VCH-1006, its composition, main applications, principle of operation, basic configuration and technical maintenance.

It also gives the description of instrument specifications and information on adequate usage of the instrument according to its purpose.

Safety precaution

Before the instrument starts operating you must provide reliable instrument grounding. For that it is necessary to connect the ground terminal to the common ground. If the grounding of the instrument is performed with the help of net cable conductor and a plug with grounding contact, then it is vital to plug it in the socket before any other connections are made.

Strength of the grounding terminal and conductors must be thoroughly fixed.

To avoid the influence of static electricity all instrument connections must be made only with the instrument being grounded.

1 Instrument description

1.1 Description and operation

1.1.1 Main applications

1.1.1.1 Passive Hydrogen Maser Frequency and Time Standard VCH-1006 is designed to be used as the high-stable signal source for time frequency measurements and for the application in reference measurement systems and telecommunications.

1.1.1.2 Main applications:

— time and frequency measurement equipment;
— metrology;
— scientific research measurements.

The instrument can be used as an integral part in automated measurement systems. The working and monitoring parameters of the instrument are accessible for read and write operations through the internal interface RS-232C.

The external view of the instrument is given in Fig. 1.1.

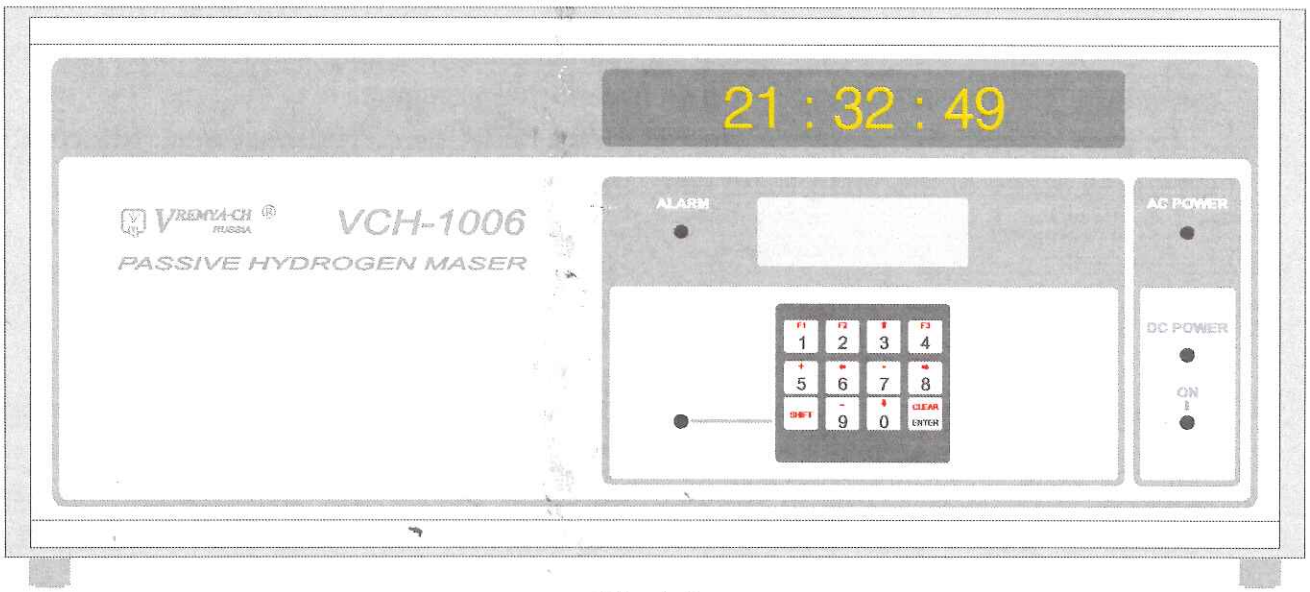


Fig.1.1.

1.1.1.3 Operating conditions:

— Power supply: (100 - 240) V AC with frequency (50 – 60) Hz
— Redundant power supply source $(+27\pm^{3}_{5})$ V
— Ambient temperature: +5 up to +40 °C
— Relative humidity: up to 80% at +25 °C
— Atmospheric pressure 84-106 kPa (630-795 mm Hg)
— DC magnetic field | 0 – 2 | Gauss

1.1.1.4 According to the demands to precautions and radio-electric protection the instrument meets the requirements of GOST (Federal Technical Requirement of Russia) No. 22261-94.

1.1.1.5 The instrument official name in the documents and when making order should be indicated as:

Passive Hydrogen Maser Frequency and Time Standard VCH-1006 411141.012TY

1.1.2 Product specifications

1.1.2.1 The main metrological specifications of the instrument are given in table 1.1.

Table 1.1

Type	Nominal value	Max. deviation or accuracy	Note
1. Output signals frequency	1 Hz 2,048 MHz 5 MHz 10 MHz 100 MHz	$\pm5\times10^{-13}$ (factory calibration)	
2. Output sinusoidal signal voltage value 5 MHz, 10 MHz, 100 MHz	1 V	±0,2	RMS at 50 Ohm load
3. Parameters of pulse signals **1 Hz:** Amplitude not less than Pulse duration Rising edge time **2,048 MHz**: Pulse form Amplitude	 2,5V 15±5 μs 10 ns meander 1,5–2,8 V		 At 50 Ohm load At 75 Ohm load
4. Output signal 5 MHz frequency instability (Allan variance) at time average : 1 s 10 s 100 s 1000 s 1 hour 1 day		 7×10^{-13} 3×10^{-13} 7×10^{-14} 3×10^{-14} 2×10^{-14} 5×10^{-15}	 excluding environment effects
5. Relative frequency reproducibility		1×10^{-13}	
6. Frequency accuracy		Less $\pm3\times10^{-13}$ Less $\pm1\times10^{-12}$	due to environment for one year operation

Type	Nominal value	Max. deviation or accuracy	Note
7. Frequency corrector Resolution Retuning range	 1×10^{-15} 1×10^{-10}		
8. External time scale synchronization pulse parameters period duration, not les than amplitude, not less than synchronization accuracy	 1 s 1 μs 2,5 V	 ±50 ns	 Positive polarity At 50 Ohm load
11.Harmonic distortion in 5 MHz output signal not more than	 - 30 dB		
12.SSB phase noise spectral density, not more than 10 Hz 100 Hz 1 kHz 10 kHz	 -125 dB/Hz -140 dB/Hz -150 dB/Hz -155 dB/Hz		

1.1.2.2 Instrument provides the following indications:

— Current time in hours, minutes, seconds;

— Monitoring functions;

— Control functions;

1.1.2.3 Instrument also provides operation mode programming, manually through front panel keyboard or remotely through the interface RS-232C.

1.1.2.4 The instrument provides its specifications after 8 hours warm-up time.

1.1.2.5 Power supply: AC-line: (100 – 240) V, (50- 60) Hz or redundant DC power supply $(27\pm^{3}_{5})$ V.

1.1.2.6 Standard power consumption at nominal voltage is not more than 80 W (AC), and is not more than 70 W (DC).

1.1.2.7 Normal and utmost operation conditions must correspond with those given in the table 1.2.

Table 1.2

Operating conditions	Operation temperature	Humidity	Atmospheric pressure	External magnetic field
Normal	+20±5 °C (with allowed fluctuations not more than ±0,5°C)	30-80 % at temperature up to +25 °C	84-106 kPa (630-795 mm Hg)	|0 – 2| Gauss in any direction (with allowed fluctuations not more than ± 0,05Gauss)
Utmost (non-operating)	from –30 up to +50°C	80 % at temperature +25 °C	12 kPa (90 mm Hg)	±10 Gauss

1.1.2.8 The instrument preserves its specifications given in Sections 1.1.2.1 – 1.1.2.3 when provided operating conditions described in Section 1.1.1.3. Specifications are preserved after the instrument's being in utmost conditions with the following storage in operating or normal conditions during 8 hours.

1.1.2.9 The instrument provides continuous non-stop operation in operating conditions with all specifications preserved.

1.1.2.10 In case the instrument was switched off for the time period not more than 3 months it can be switched on without any external pumping devices and with specifications preserved.

1.1.2.11 Life time of the instrument is not less than 10 years. Resource – not less than 27000 hours.

1.1.2.12 Size - 200×470×513 mm.

1.1.2.13 Weight - not more than 31 kg.

1.1.3 Product composition

1.1.3.1 The instrument composition is given in Table 1.3.

Table 1.3

Type	Designation	Quantity
1. Frequency and time standard VCH-1006	411141.012	1
1. Accessory kit: a) Power cable 220V; b) Cable for source 27 V; c) RS-232C Cable d) RF adapters e) Fuse link f) Fuse link	 SCZ-1R 685650.030 685670.026 434541.007 3,15A-250V 481.304TY 5A-250V 481.304TY	 1 1 1 2 4 2
2. Packing case		1
3. CD with software and documentation	411141.012 CD	1

1.1.4 Basic configuration and operation

1.1.4.1 The instrument is executed within the case of size 200×470×513 mm. The top and the bottom of the case have easy-removable covers with ventilation holes. The left half of the case contains physical part of the instrument with high-frequency oscillator. The front part of the right half of the case has the indication unit and control unit, hydrogen source, interface of hydrogen quantum discriminator, high-voltage supply unit, pressure sensor, beam stabilizer, power supply unit, batteries. Behind these units there is a cross-board, which is connected to the inserted blocks: power supply unit, pulse signals source, central processor, FLL processor, interrogation signal unit, reference signals source and receiver. The panels with the inserted blocks with output connectors form the back panel of the instrument.

To provide the possible instrument repair there is a free access to the instrument's units and blocks through top and bottom covers. The units can be easily removed due to the use of removable and inserted blocks.

1.1.4.2 Hydrogen frequency and time standard VCH-1006 belongs to the sort of hydrogen standard of passive type. The block-diagram in the Fig. 1.2 represents the instrument principle of operation.

VCH-1006 principle of operation is based on quartz oscillator frequency lock to the frequency line of hydrogen atom emission of the discriminator. The influence of the discriminator RF-cavity frequency fluctuations on emission line is eliminated by RF-cavity frequency adjustment to quartz oscillator frequency. As discriminator energy level, emitted by hydrogen atoms, is less than the sum of loss energy, FM excitation

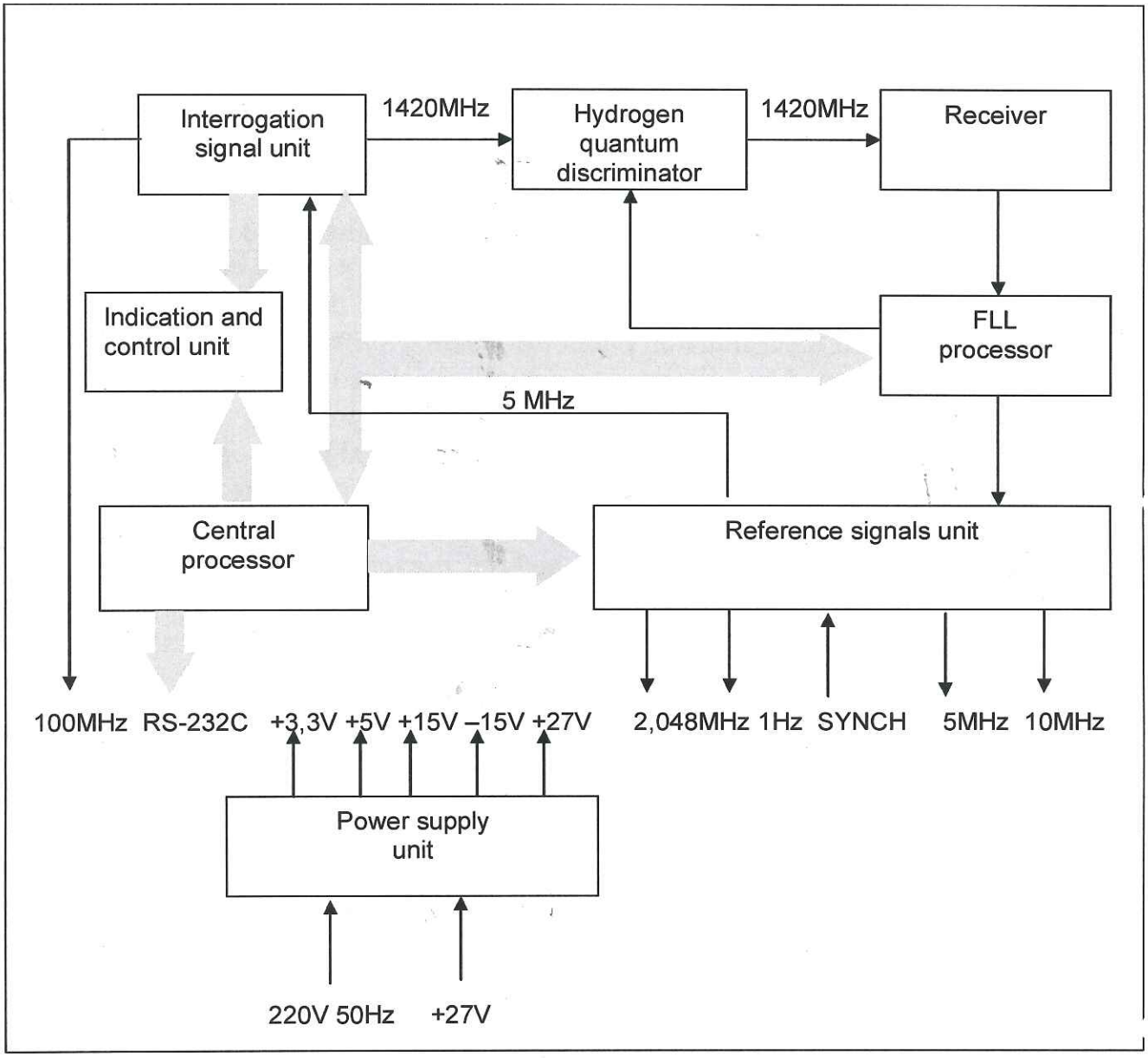
signal is introduced into discriminator cavity to provide spectral line indication and frequency adjustment. This FM interrogation signal is formed in the interrogation signal unit, which is controlled by FLL processor. The FM interrogation signal is formed by mixing the frequency modulated signal of 20,405 MHz $\pm$ 12.6 kHz with the 14^{th} harmonic of 100 MHz signal. The interrogation signal with frequency 1420,405 MHz is separated directly in the discriminator cavity.

Due to the interaction of the FM interrogation signal with atom line and resonator cavity it is converted into AM signal. The rounding phase and amplitude of this signal provide information about quartz oscillator frequency deviation from hydrogen atom emission line frequency and about cavity frequency deviation from quartz oscillator frequency. From discriminator outlet AM signal passes to the receiver, where it is amplified, converted and detected. From the receiver outlet the signal passes to FLL processor, where it is processed. The processor produces signals to control the frequency of quartz oscillator, which is in reference signals source, and to control the frequency of discriminator cavity and also performs the auto tuning (adjustment) of their frequencies to the frequency of hydrogen atoms spectrum line.

When power supply 220 V is switched off, the instrument automatically switches to the external power supply source +27 V, preserving its operating characteristics.

If the external power supply is switched off, internal batteries provide the instrument operation, with specifications preserved, for the time period not less than 10 minutes.

Fig.1.2 VCH-1006 block-diagram



1.1.5 Shipping marks

1.1.5.1 The instrument serial number and year of production are indicated at the rear panel of the instrument.
1.1.5.2 All elements and constituent parts of the instrument are marked in accordance with position signs in the list of components of circuit diagrams.
1.1.5.3 Customer shipping container must be labeled with the instrument name.

1.1.6 Packing

The insterument should be packed into a special packing case. Before that the instrument is put into polyethylene cover with celicagel according to GOST 3956. Accessory kit is also packed into the polyethylene cover and a cartone box. Inside the box the instrument must be enveloped with technical wadding (according to GOST 5679) or with crimped cartone of T-type according to GOST 7376.
Technical and shipping documentation must be packed into polyethylene covers according to GOST 10354.

1.2 Description and operation of the main parts of the instruments

1.2.1 Hydrogen quantum discriminator
Hydrogen quantum discriminator is used for FM excitation signal conversion into AM signal, which contains information about deviation of quartz oscillator frequency from reference line of the atomic transition. Discriminator consists of the following units:

— physical part,
— HFO,
— hydrogen source,
— thermal control unit,
— purifier current stabilizer,
— pressure sensor.

1.2.2 Indication and control unit
Time indication is carried out at LED seven-segment indicator. Messages, menu and control information are shown at the 4-string liquid-crystal display. The block is directly connected to the keyboard, which enables interactive dialogue between the instrument and the User.

1.2.3 Interface of hydrogen quantum discriminator

Interface of hydrogen quantum discriminator represents a complete unit within the structure of frequency standard VCH-1006 and is used to provide connection between central processor and electronic units of quantum discriminator.

Interface of hydrogen quantum discriminator provides the control and monitoring functions of quantum hydrogen discriminator operating with the central processor unit of the instrument

1.2.4 Central Processor

Central processor unit is based on the DSP TMS320VC5402. It realizes data acquisition of the states of all blocks of hydrogen frequency standard, provides the switch ON/OFF procedures of the instrument blocks (ion pump, hydrogen source, high frequency oscillator (HFO). Central processor is controlled by keyboard from the front panel or through RS-232C interface.

1.2.5 Reference signals unit

Reference signals unit contains the voltage controlled 5 MHz precision crystal oscillator and is used to form the instrument output signals (1Hz, 2,048MHz, 5MHz and 10MHz), as well as signals, which are used for the instrument units and blocks operation. 5 MHz crystal oscillator is adjusted to the hydrogen emission line. Another part of this device is the frequency divider 100MHz→1Hz which is intended to form 1 PPS time scale output signal. Time scale 1Hz signal may be synchronized with external 1 PPS signal. The same microcircuit synthesizes 2048 kHz pulse signal intended for clock synchronization in telecommunications.

1.2.6 FLL processor

FLL processor is based on signal processor TMS320VC5402. It is used to process the frequency misstuning signal, which come from the Receiver. The misstuning signal with frequency 12.6 kHz goes to ADC (analog digital converter) and then to microprocessor, which performs its digital processing (filtration, synchronous detection and accumulation). This processor produces control signals for 5 MHz crystal oscillator and discriminator cavity, adjusting them to the spectrum line of hydrogen atoms. Besides FLL processor controls the digital synthesizer 20,405MHz located in interrogation signal unit.

1.2.7 Receiver

Receiver is intended for amplification and frequency conversion of the signal coming from the hydrogen quantum discriminator and to detect AM misstuning signal 12.6 kHz. The receiver consists of low noise preamplifier 1,42 GHz, double balance mixer and IF wide band amplifier. SAW local oscillator 1440 MHz is used as heterodyne. At the output of the receiver there is the amplitude detector and selective amplifier 25.2 kHz (2^{nd} harmonic) for FLL indication.

1.2.8 Interrogation signal unit

Interrogation signal unit is used to form the interrogation signal for hydrogen quantum discriminator.

5MHz signal from reference signals source comes to the input of frequency multiplier 5-100MHz. 100MHz is divided into two ways: one of them goes to the rear panel as the output signal and the other one mixes on the diode with frequency modulated 20,405 MHz signal of digital synthesizer (AD9852AST) and enters the quantum discriminator as the interrogation signal.

1.2.9 Power supply unit

Power supply unit provides all units of the instrument with necessary voltage and current. It is divided into three blocks: AC/DC power converter (~100-240V→+27V), internal batteries and secondary power supply unit. Secondary power supply unit contains the DC/DC converter +27V →+27V, which stabilizes either external input voltage $+27\pm^{3}_{5}$ V or internal batteries voltage. On board there are power sources: +27V→ +3,3V, +27V→ +5V, +27V→ +15V, +27V→ -15V.

2 Maintenance

2.1 Working restrictions

2.1.1 Power supply:

— AC power (100 – 240) V; (50 –60) Hz,

— DC power $+27\pm^{3}_{5}$ V.

2.1.2 Operation conditions:

— Operating temperature range from +5 up to +40 °C;

— Relative humidity up to 80% at temperature +25 °C;

— Avoid magnetic field with fluctuation amplitude more than 10 Gauss;

— Avoid vibration influence on the instrument.

2.2 Preparation for operation

2.2.1 Sequence of the product external view inspection

While inspecting the external view of the instrument make sure that:
- there are no visible mechanical defects;
- if the external surfaces of the instrument, connectors, terminals and sockets are clean;
- connecting cables and converters are in good condition;
- during operation all ventilation holes in the instrument cover must be open, not hide by other objects.

2.2.2 Switches, connectors and indicators of the instrument.

The descriptions of switches, connectors and indicators of the instrument are given in the Table 2.1.

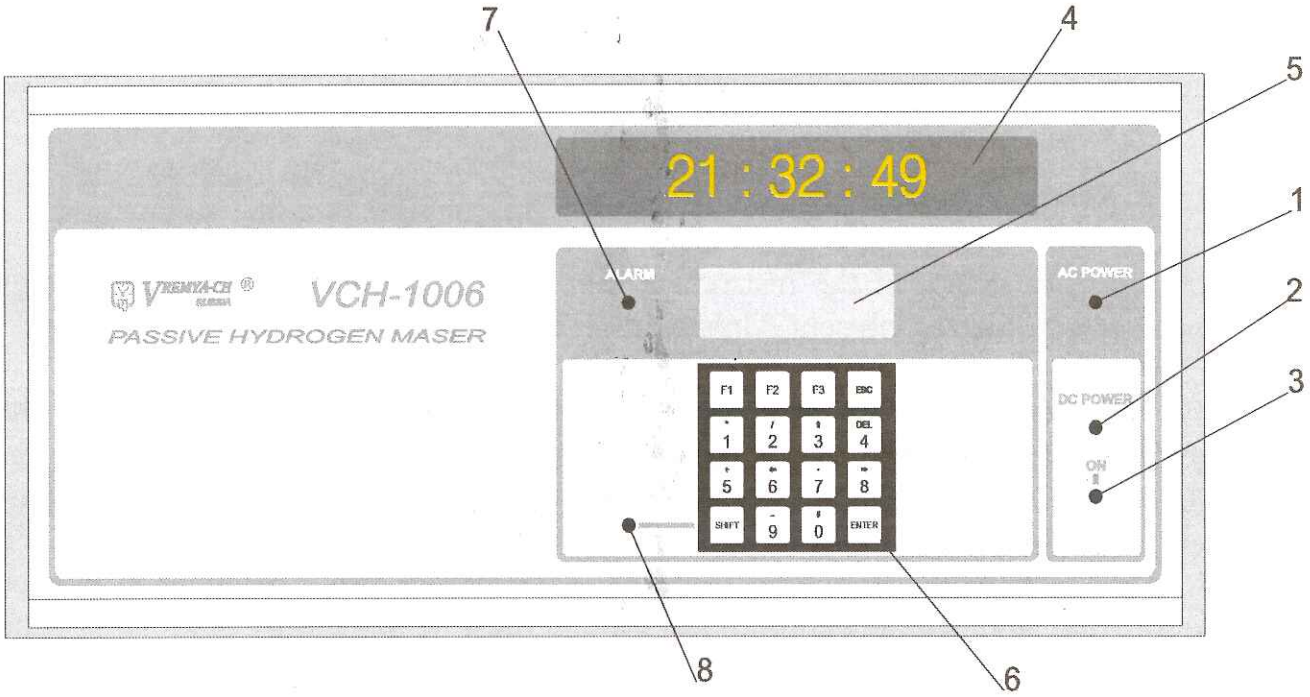
Their positions are shown in Fig. 2.1. and Fig 2.2

Table 2.1

Positions in Fig2.1	Means of control or connectors designation	Description
1	AC POWER	Indicator of the instrument operation from AC line
2	DC POWER	Indicator of external battery presence
3	ON	Indicator of the instrument operation
4		Digital indicator of current time in hours, minutes and seconds
5		LCD display showing current data of the instrument state, operating modes and parameters
6		Keyboard to control and adjust the instrument operating modes and to diagnose the instrument state
7	ALARM	Indicator of instrument malfunctions (see VCH-1006 User Guide 411141.012UG)
8		Indicator of keyboard register change
9	~220V 50Hz 80VA	AC line power connector
10	3AF, 3AF	Fuse links into AC line 100 - 240V
11	ACCUM ON	Toggle ON/OFF the internal battery
12		Indicators of the internal voltages presence
13	DC POWER ON	Toggle ON /OFF an external battery
14	5AF	Fuse link into DC power line +27 V
15	==27 B	Connector – external battery connection (pin1 +, pin4 -)

Positions in Fig2.1	Means of control or connectors designation	Description
16	ERROR	Connector – alarm signal output: Log "0"- when error (see VCH-1006 User Guide 411141.012UG)
17	CHECK	Connector – information output in "CHECK" mode (is used by manufacturer for regulation)
18	RS-232	Connector – serial interface RS-232C
19	100 MHz	Connector – output signal 100 MHz
20	5 MHz-1, 5 MHz-2	Connectors – output signal 5 MHz
21	10 MHz	Connector – output signal 10 MHz
22	2.048 MHz	Connector – output signal 2,048 MHz
23	1 PPS EXT	Connector – input signal 1 Hz for time scale synchronization
24	1 PPS	Connectors – output signal 1 Hz
25	LF	Connector – receiver detector output signal (is used by manufacturer for regulation)
26	IF	Connector – receiver IF output signal (is used by manufacturer for regulation)
27		Ground terminal

Fig.2.1



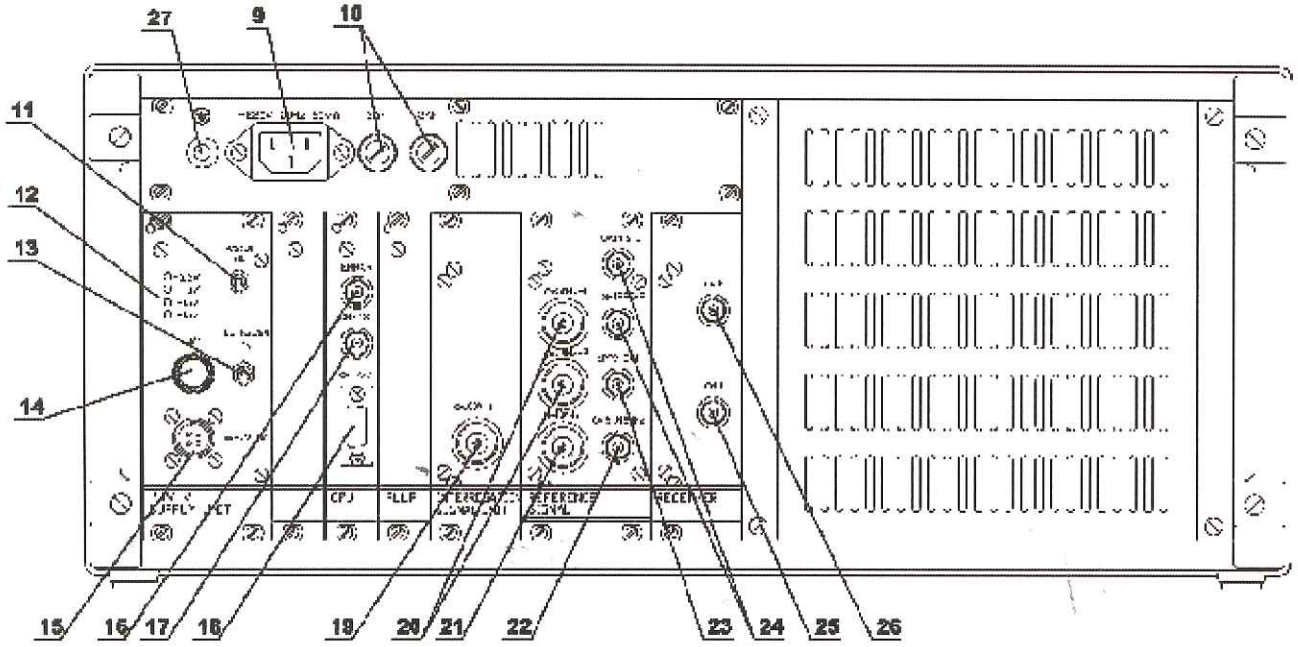


Fig.2.2

2.2.3 Before Switching ON!

2.2.3.1 It is recommended that this maintenance manual (point 2.2.3) must be read prior to operation of the instrument.

2.2.3.2 Check the reliability of the instrument ground connection.

2.2.3.3 If the conditions of the instrument storage or transportation were different from those of operating conditions, before starting the operation it is necessary to keep the instrument in operating conditions not less than 8 hours.

2.3 Recommendations on usage

2.3.1 Safety requirements

2.3.1.1 The safety of the instrument maintenance is provided by performing of the requirements of the present Maintenance and service manual point 2.2.1 and GOST 12997.

2.3.1.2 Net cable of the instrument must have grounding conductor and a plug with grounding contact. The use of net cable without grounding conductor is also possible but in this case the instrument case must be grounded with the help of grounding terminal, mounted in the back panel of the instrument.

2.3.1.3 Instrument grounding must be made before the instrument is connected to power line, and disconnection of the ground must be made only after the instrument is disconnected from power line.

2.3.2 Instrument operation

2.3.2.1 Operation of the instrument is performed in accordance with "H-maser frequency and time standard VCH-1006, User Guide 411141.012UG".

3 Technical service

3.1 General recommendations

3.1.1 The reliability of the instrument operation depends on qualified and adequate technical service. Ordinary technical service means periodical prompt monitoring of the instrument technical state by checking of all instrument-operating parameters.

3.2 Precautions

3.2.1 When performing the instrument technical maintenance it is strongly recommended to take safety precautions given in point 2.3.1 of the present Manual.
3.2.2 All the external circuits of the instrument (except the input 220 V AC) have voltage less than 30 V and are not dangerous.

3.3 Procedure of technical maintenance of the instruments

3.3.1 To be sure in the instrument operation prompt periodical diagnostic of instrument technical state is required.
3.3.2 During the normal operation the instrument performs full self-diagnostic automatically. In case of malfunction or significant detour of any operating parameters, ALARM indicator is lighted and the description of the malfunction message appears on the display.
3.3.3 While the instrument is stored it is necessary to perform the procedures of technical maintenance described in the item 6.

4 Instrument verification

4.1 The instrument verification is performed in accordance with THE INSTRUCTION "Hydrogen frequency and time standard VCH-1006" (Verification Methodic), developed by the "State Certification and Test Center"
4.2 The interval between performance verification is 1 year.

5 Repair

5.1 If the instrument does not meets its technical specifications or if there are some other reasons, which make impossible the instrument operation and usage according to its applications, the instrument must be directed for repair.
5.2 The instrument repair must be performed only by the instructed personnel, who were specially prepared for that at the place of the instrument exploitation or at the company-manufacture workshop.
5.3 So far as the instrument contains the power supply voltage 3,5 kV, the repair must be performed only by qualified personnel, who has already been instructed on it and has the access to work with 3,5 kV voltage.

6 Storage

6.1 The instrument must be stored in the heated apartment with ambient temperature from 0°C up to +50°C and humidity not more than 80% at temperature 25°C.
6.2 The storage apartment must be clean from dust, acid and alkali vapor and from other harmful admixtures that may cause corrosion.
6.3 Periodically (once in three months) the instrument must be unpacked. Then connect it to the AC line outlet to drive ion pumps of the discriminator. After the instrument is switched ON, enter main menu and chose item "Check". In the appeared submenu "Maser" chose item "Ipmp" and check the HV source current. In 30 minutes after switching ON of the instrument current must not exceed 50 mcA. In case the current is higher than 50 mcA the instrument must be directed for repair.

7 Transportation

7.1 Before transportation takes place the instrument must be packed into the packing case.
7.2 The instrument can be transported by any means of transportation.
7.3 Transportation conditions must correspond with those of the instrument operation conditions and must not contrary to the utmost operation conditions, indicated in Table 1.2.
7.4 Places used for the instrument transportation (ship hold or car body) must not have leftovers of coal, cement, chemicals etc.
7.5 When airway transportation is used the instrument must be located in normal pressure cabin.

Appendix - RS232C interface commands description

A1. Introduction

The VCH-1006 interface protocol is based on the transmission of binary packets of information between the personal computer and the device. A computer always requests the information of the standard (send a command). Each request packet (command) includes an identification code (1 byte, representing 2 hexadecimal digits) that identifies the meaning and format of the data that follows. Each request packet begins with control characters (01hex). The computer resets the CTS line of the RS-232C interface during transmission of first byte of the command and sets it again in former state after that. The next bytes of command are sent at normal state of CTS line.

A2. Reading of measured parameters

The computer sends the command of 5 bytes length. First byte is sent at low level of CTS line of RS-232C interface. Byte sequence and its numerical values are shown in Table A1.

Table A1.

Byte Number	Value (hex)
0	01
1	41
2	00
3	00
4	00

As a reply the standard VCH-1006 must send sequence in 189 bytes length, which represents current state of the instrument. Some parameters are the real physical values, measured as analogue parameters, the other ones represent current state of digital systems of the instrument. To obtain real physical values the analogue parameters should be multiplied by the corresponding coefficients. The all analogue values are represented by two bytes in two's complement code. The earliest byte in sequence represents the least significant bits (LSB), the next – most significant bits (MSB). Parameters of the instrument and corresponding bytes positions are given in Table A2, where the third column represents the coefficient for analogue value if it is necessary.

Table A2.

Bytes position	Represented value	Conversion coefficient, if necessary
1-3	Reserved	
4,5	Accumulator voltage	0.016336
6,7	External power source voltage	0.03055

8,9	Internal DC/DC converter +27/+27 V	0.016277
10,11	Voltage of power source +15 V	0.01645
12,13	Voltage of power source -15 V	0.01645
14,15	Voltage of power source +5 V	0.0158
16,17	Voltage of power source +3.3 V	0.0155
18,19	Voltage of AC/DC converter ~220/+27 V	0.01642
20,21	Level of signal 5 MHz #1, V, RMS	0.0024414
22,23	Level of signal 5 MHz #2, V, RMS	0.0024414
24,25	Level of internal signal 5 MHz, V, RMS	0.0024414
26,27	Level of signal 10 MHz, V, RMS	0.0024414
28,29	Level of signal source 100 MHz, V, RMS	0.0024414
30-33	Reserved	
34,35	Level of frequency synthesizer signal 20.40575168 MHz, V, RMS	0.0024414
36,37	Receiver IF level, V, RMS	0.0024414
38-41	Reserved	
42,43	Pump voltage, kV	0.0024414
44,45	Pump current, uA	0.24414
46,47	Purifier voltage, B	0.0024414
48,49	Purifier current, A	0.0024414
50,51	Reserved	
52,53	HFO current, A	0.0024414
54,55	HFO voltage, V	0.0161132
56,57	Voltage of discharge sensor output, V	0.0024414
58,59	Voltage of side cavity oven, V	0.024414
60,61	Voltage of bottom cavity oven, V	0.024414
62,63	Voltage of molecular	0.024414

	hydrogen source oven, V	
64,65	Pressure in molecular hydrogen source, atm	Calculated by formula P=A*0.0149755+2, where A is the value, composed from bytes 64,65
66,67	Reserved	
68-127	Reserved for digital thermostats	
128,129	Auxiliary information of the FLL system	
130	The low-order nibble contains value of 15-th sign of fractional frequency correction code	
131-133	Auxiliary information of the FLL system	
134,135	Output of second harmonic digital detector of the FLL system	
136-147	Auxiliary information of the FLL system	
148,149	DAC code of the auxiliary control voltage of the cavity (the FLL system)	
150,151	DAC code of the auxiliary control voltage of the quartz oscillator (the FLL system)	
152,153	DAC code of fine tuning of the cavity (the FLL system)	
154,155	DAC code of fine tuning of the quartz oscillator (the FLL system)	
156,157	Fractional frequency correction code with precision of 10e-14	

	(four significant digits from 1e-11 to 1e-14)	
158-163	Auxiliary information of FLL system	
164-189	Reserved for digital thermostating system	

A3. Reading of current status

This command gets binary code, which represents state of separate systems. Bits set to 1 inform about malfunction of instrument units or warn that some parameters got out of normal operation tolerance limits. Status word interpretation corresponds to diagnostic messages description given in paragraph 2.6. of User guide 411141.012UG To get the status word it's necessary to send 4-bytes command to VCH-1006. The first byte is to be sent at low level of RS-232C interface CTS line. Values of bytes of the command are given in Table A3.

Table A3

Byte number	Value (hex)
0	01
1	42
2	10
3	27

After the command is sent the instrument should return to computer data of 131-bytes length. Bytes 9 - 12 represent status 32-bits word as shown in Table A3:

Table A3

Byte	Byte 9		Byte 8		Byte 11		Byte 10	
Bit of byte	7	0	7	0	7	0	7	0
Bit of status word	31	24	23	16	15	8	7	0

Correspondence set to 1 bits and diagnostic messages described in paragraph 2.6. User guide is shown in Table A5.

Table A5

Bit set to 1	Malfunction, current state of instrument, or a parameter, which got out of tolerance limits	Diagnostic message and its number in p.2.6. of User guide
0	Quartz oscillator is not tuned on hydrogen spectral line	1) No synchronization
1	Level of signal 100 MHz	13) FLL 100M/20M level

2	Level of synthesizer signal 20.40575168 MHz	13) FLL 100M/20M level
3	Receiver IF level	15) FLL IF-level
4	Level of second harmonic detector output of FLL system	14) FLL D2h-level
5	FLL processor link error	17) FLLP Unit link
6	Reserved	
7	Voltage or current of pump out of tolerance limits	3) Pump Unit
8	Pump switched off	6) Pump Unit off
9	Voltage or current of purifier out of tolerance limits	4) Purifier Unit
10	Purifier switched off	7) Purifier Unit off
11	Voltage or current of HFO out of tolerance limits	5) HFO Unit
12	HFO switched off	8) HFO Unit off
13	Pressure of molecular hydrogen source out of tolerance limits	18) H2 source
14	Voltage of cavity ovens	9) Cavity Thermostats
15	Reserved	
16	Low level of 5/10 MHz signal in SRS unit	12) Signals Unit
17	1 PPS #1 signal is absent	12) Signals Unit
18	1 PPS #2 signal is absent	12) Signals Unit
19	2.048 MHz signal is absent	12) Signals Unit
20	Internal 1 PPS clock is absent	12) Signals Unit
21	Low level of ~220/27 V AC/DC converter	10) Power Unit
22	Low level of 27/27 V DC/DC converter	10) Power Unit
23	Low level of one of +15V/-15V/+5V/+3.3V power sources	10) Power Unit
24	Reserved	
25	Manual control on instrument	19) User's control
26	DAC overflow of cavity or quartz oscillator tuning	16) FLL DAC overflow

	loop	
27	Discharge of accumulator	11) Acc. Discharged
28	Instrument works from internal accumulators	See p.2.7 of User guide
29	Reserved	
30	Reserved	
31	H-line searching	2) H-line searching...

29.10	16.10.	12.10.07			
			1	2	3
			Qstat	Crystal oscillator fine tuning DAC code	between 0 and 65535, normal operation tolerance value - between 1000 and 65000
			R1h	Cavity detuning	between -8191 and +8191, if normal operation - between -3000 and +3000
			Q1h	Crystal oscillator detuning	between -8191 and +8191, if normal operation - between -3000 and +3000
			F	Frequency synthesizer code	Tolerance values between 0 and 99999e-15
-5955	-5914	-7438	D2h	Output of second harmonic detector of FLL processor	between -8191 and +8191, while normal operation – between -8191 and –1000
			Pumping	Synthesizer DAC code, determining signal 20.40575168 MHz output voltage	Tolerance value – between 20 and 4095, is set in the process of tuning
			ModIndx	Synthesizer phase modulation index code	Tolerance value – between 3500 and 5500, is set in the process of tuning
			kRez	Relative gain of cavity loop, defined as 2^{kRez}	Tolerance value – between 0 and 15, is set in the process of adjustment
			kQtz	Relative gain of crystal oscillator loop, defined as 2^{kQtz}	Tolerance value – between 0 and 15, is set in the process of adjustment
			P_QTZ	Number of points on synthesizer phase modulation period	Constant value - 12
			Phi	Relative phase shift code of synchronous detector	Is set automatically in the process of adjustment, tolerance value is between 0 and P_QTZ-1
			Cor	Correction code of synchronous detector reference signal	Is set automatically in the process of adjustment, tolerance value is between -49 and +49
			DDSerr	Synthesizer error counter	Has a permanent value by

30132	30044	27825	Cav
32390	32498	32702	Qtz

Table 1. List of inspected parameters in groups "Parameters" and "Thermostats"

29.10	16.10	12.10.07	1	2	3
			Parameter	***Description***	***Tolerance limits***
		26.9	Uacc	Built in accumulator voltage (in 411141.012 only)	21.5 - 32V
		2 0,69	Uext	External DC source voltage	22 - 32 V (411141.012) 36 – 72 V (411141.014)
		27,9	U+27	Internal converter +27 V voltage	24 - 30 V
		1T13	U+15	Converter +15 V voltage	13 - 18 V
✓		-14,8	U-15	Converter -15 V voltage	-13.5 - -18 V
		5.0T	U+5	Converter +5 V voltage	4.5 - 5.5 V
		3,27	U+3.3	Converter +3.3 V voltage	3 - 3.5 V
			Uac/dc	Converter ~220/+27 V voltage	23.5 - 30 V
1,30	1. 30	1,49	U5M1	Voltage of 5 MHz output sinusoidal signal, put on the rear panel and marked as "5MHz-1"	0.5 - 2 V RMS
1.01	1.01	1.01	U5M2	Voltage of 5 MHz output sinusoidal signal, put on the rear panel and marked as "5MHz-2"	0.5 - 2 V RMS
0.693	0.69T	0.693	U5M3	Internal 5 MHz sinusoidal signal voltage, used as a reference for synthesizer and interrogation signal unit	0.5 - 2 V RMS
0.996	0.99	0.99	U10M	Voltage of 10 MHz output sinusoidal signal, put on the rear panel and marked as "10MHz"	0.5 - 2 V RMS
2,60	2,60	2.65	U100M	Output voltage of multiplier 5-100 MHz	0.5 - 5 V RMS
4,34	4,34	4,34	U20.405	Frequency synthesizer 20.40575168 MHz output voltage	0.25 - 5 V RMS
1,44	142	2,27	Uif	Intermediate frequency output signal level	0.5 - 5 V RMS
1.94	1,90	2,09	U2h	Second harmonic signal level	0.5 - 5 V RMS

1PPS Impuls gemessen am Messplatz
Tor 27. 3V in 50 Ω, Auslösepegel ~ 5us
Pulsbreite 10 µs.

synchronisiert mit 1PPS CJ (TN 7)

29.10.	14.10	12.10.07	1	2	3
3,50	3,50	3,50	Upump	Ion pump supply voltage	2.5 - 4 kV
4,88	4,88	4,88	Ipump	Ion pump current	0 - 50 μA
1.03	1.02	1,02	Upur	Power voltage of molecular hydrogen purifier	0.5 - 2 V
0.607	0.605	0,61	Ipur	Purifier current	0.35 - 0.9 V
27.1	27.1	27,1	Uhfo	HFO power voltage	24.5 - 27 V
0.559	0.555	0,556	Ihfo	HFO current	0.3 - 0.7A
3.16	3.16	3,18	Udisch	Voltage on the output of discharge brightness sensor in discharge bulb	0.8 - 4.8 V
			CPUtemp	Temperature of the central processor board	20°C - 60°C
7,54	7,49	7,32	Side	Voltage on the heater of discriminator cavity side surface	5 - 15 V
7,42	7,44	7,37	Bottom	Voltage on the heater of discriminator cavity bottom	5 - 15 V
10.5	10.4	10.4	Hydr	Voltage on the heater of molecular hydrogen source	5 - 15 V
8.51	8.9	9.03	Pressure	Molecular hydrogen pressure in the source	1.5 - 14 atm

Table 2. List of inspected parameters in group "FLL system"

29.10

1875	1875	1875

1	2	3
Parameter	***Description***	***Inspected parameters, comments***
Rctl	Cavity rough tuning DAC code (control)	between 0 and 4095; 4095 - if normal operation
Qctl	Crystal oscillator rough tuning DAC code (control)	between 0 and 4095; is set in the process of working point search
Rstat	Cavity fine tuning DAC code	between 0 and 65535; normal operation tolerance value - between 1000 and 65000

27825 Cav ✓
32702 Qtz

7

15.10.07. F-Level H7: 47 800e-15
$y\{UTC(PTB) - H7\} \approx 1,8 \cdot 10^{-13}$ + 1 900
49 700

+800
190
47990
06:35 UTC
11:49 UTC

falsch!

12.11.07: Frequenz alt: 47990 e-15
+ 2380
50370

20.11. 50370 e-15
- 1430
48.940