Rubidium frequency standard

CH1-1022/2

Operation manual

RUGA.411653.011 RE

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CONTENTS

This operation manual gives an insight into CH1-1022/2 rubidium frequency standard (hereinafter refered to as the “instrument”) structure and functioning and contains description of instrument specifications, operating principle, design, setting-up and operation procedures, packing, storage and transportation conditions along with instrument performance testing methods.

Manufacturer constantly works on improvement of its product and reserves the right to introduce minor changes into instrument design which do not affect its performance.

1 Instrument description and operating principle

1.1 Purpose

1.1.1 CH1-1022/2 rubidium frequency standard is designed to be used in frequency and time measurement instrumentation, navigation and radio communication systems along with telecom networks as a source of highly stable signals. This small-sized light-weighted instrument with low power demand and fast operating mode access time is well-suited for various mobile radio-technical systems and complexes. The instrument has a function of automatic frequency control in response to 1 Hz external signal received from GPS/GLONASS/BeiDou satellite navigation systems (disciplined frequency standard function).

1.1.2 The instrument is available in one of the following options:

Option A: basic one with a standard set of features;

Option AB: instrument with enhanced short-term output signal frequency stability;

Option AC: instrument with low phase noise level in 10 MHz output signal spectrum.

Example of instrument designation entry to be used for reference in various documents and when drawing up an order:

Rubidium frequency standard CH1-1022/2AC RUGA.411653.011 TU.

Instrument overall and connection dimensions are shown in Fig. 1.1.

Fig. 1.1: Overall and connection dimensions
of CH1-1022/2 rubidium frequency standard.

1.2 Operating conditions

1.2.1 Instrument normal and operational conditions are presented in Table 1.1.

Table 1.1

Operational conditions	Temperature, °C	Relative humidity, %	Atmospheric pressure, kPa (mmHg)	Supply voltage, V
Normal	+ 20 ± 2	30–80	84–106 (630–795)	⎓ 18 ± 0,2
Operational	from - 30 to + 60 (*)	30–90	60–106,7 (500–800)	⎓ (17,0–22,0)
Limiting	from - 40 to + 70 (*)	30–90	60–106,7 (460–800)	⎓ (16,5–24,0)

(*) Instrument baseplate temperature should not fall outside the specified limits under any operational conditions. To stay within the operating temperature range it is necessary to ensure efficient heat removal from the instrument baseplate.

NOTE: The manufacturer does not recommend a long operation of the device under the limiting conditions and does not guarantee performance when more than one of table 1.1 factors have reached the limiting values.

Limiting condition of the instrument transportation:

– ambient air temperature: -55 to +70°C;

– relative humidity: up to 95% at 30°C.

1.2.2 The instrument retains its properties within the norms, specified in subsections 1.4.1-1.4.14, under normal conditions and after staying in limiting condition of transportation as well provided that thereafter the instrument is held under normal or operational conditions within 2 hours.

1.3 Instruments set contents

Instruments delivery set contents are presented in Table 1.2.

Table 1.2

Name, type	Designation	Quantity	Note
1 CH1-1022/2 rubidium frequency standard	RUGA.411653.011	1	
2 DB-9F connector	—	1	
3 CD with application software	RUGA.411653.011 MD	1	
4 Operation manual	RUGA.411653.011 RE	1	
5 Pack	RUGA.411915.121	1	

1.4 Specifications

Guaranteed properties are those properties for which tolerances or limiting values have been defined. Values without tolerances are given for reference only.

1.4.1 Rated frequency of the output signal is 10 MHz.

1.4.2 Relative error of 10 MHz output signal frequency does not exceed:

$\pm 2 \cdot 10^{-11}$ at product release;

$\pm 6 \cdot 10^{-10}$ in the calibration interval.

1.4.3 Frequency retrace for switching-on to switching-on (after 24 hours after power-on) does not exceed $5 \cdot 10^{-11}$.

1.4.4 Frequency drift per month (after 72 hours of continuous operation after power-on) does not exceed $\pm 5 \cdot 10^{-11}$.

1.4.5 Relative frequency error for 1 day in a sync mode by external 1pps signal, at range $\pm 1 \cdot 10^{-11}$.

1.4.6 Short-term stability (Allan variance) does not exceed:

$3 \cdot 10^{-11}$ ($1 \cdot 10^{-11}$ for AB option) over an averaging time of 1 s;

$1 \cdot 10^{-11}$ ($3 \cdot 10^{-12}$ for AB option) over an averaging time of 10 s;

$3 \cdot 10^{-12}$ ($1 \cdot 10^{-12}$ for AB option) over an averaging time of 100 s.

1.4.7 Relative frequency variation of the output signal within the operating temperature range of -40 to +70°C does not exceed $\pm 5 \cdot 10^{-10}$.

1.4.8 Relative frequency variation of the output signal in the event of supply voltage change by 1 V within the permissible voltage range does not exceed $1 \cdot 10^{-11}$.

1.4.9 Digital frequency tuning range for the output signal lies within $\pm 1 \cdot 10^{-8}$ with the step of $1 \cdot 10^{-12}$ (± 9999 steps).

1.4.10 The effective value of the output signal voltage at the connected load of (50±2) Ω lies within (0.6-1.2) V.

1.4.11 Warm-up time to the output signal relative frequency error within $\pm 1 \cdot 10^{-9}$ does not exceed:

5 min at the ambient air temperature of +25°C;

20 min at the ambient air temperature of -40°C.

1.4.12 Harmonic suppression in the output signal spectrum is not less than 30 dB.

1.4.13 Nonharmonic spurious in 10 Hz to 10 kHz range is not less then 100 dB.

1.4.14 SSB phase noise spectral density does not exceed:

- 80 dB/Hz at 1 Hz;
- 90 dB/Hz at 10 kHz;
- 130 dB/Hz at (85 ± 3) Hz;
- 140 dB/Hz (145 dB/Hz for AC option) at 1 kHz;
- 145 dB/Hz (150 dB/Hz for AC option) at 10 kHz.

1.4.15 The instrument allows for generation of a pulse chain with the following parameters:

– pulse repetition period: 1 s;
– pulse polarity: positive;
– pulse width: (12-20) µs;
– pulse rise time: max. 5 ns between levels 0.1 and 0.9 at load capacitance 10 pF;
– pulse amplitude in accordance with the output specifications LVTTL33 and LVCMOS33 of JEDEC JESD8C.01 standard.

1.4.16 The instrument provides synchronization of generated 1 pps chain by external time scale pulses with the following parameters:

– pulse repetition period: 1 s;
– pulse polarity: positive;
– pulse width: min. 4 µs;
– pulse rise time: max. 0.1 µs;
– pulse amplitude: min 2.5 V at the load of 150 Ω.

The resulting synchronization error lies within ±0.1 µs.

1.4.17 The instrument ensures data interchange with an external control device via RS-232C serial interface with the following parameters:

– data transmission rate: 115200 bit/s;
– data interchange format: 8 data bits, 1 stop bit, no parity check, no flow control.

Formats of control commands and replies are given in the Appendix.

1.4.18 The instrument provides a + (13.0-20.0) V DC voltage signal at the “Lock indicator” pin if it quits the lock mode.

1.4.19 The instrument provides a + (9.0-15.0) V DC voltage signal at the “Lamp indicator” pin in the spectral source ignition mode.

1.4.20 The instrument reaches its stated performance (except for cases given in subsections 4.4.3, 4.4.4 and 4.4.5) under normal conditions listed in specifications upon expiry of operating mode set-up time, i.e. 2 hours from power-on.

1.4.21 The instrument retains its performance capabilities even if used round-the-clock under operating conditions.

Note: continuous operation time does not include the operating mode set-up time.

1.4.22 The instrument retains its performance capabilities under normal conditions listed in specifications when powered from a DC current source with the following parameters: voltage + (16.5-24.0) V, max. pulse amplitude 100 mV.

1.4.23 Under normal operating conditions instrument power consumption from the power supply source does not exceed:

30 W in warm-up mode;

16 W in steady-state mode.

1.4.24 MTBF (T_0) is not less than 40000 hours.

1.4.25 Gamma-percentile service life is not less than 10000 hours at the confidence level of 95%.

1.4.26 Gamma-percentile lifetime is not less than 15 years at the confidence level of 95%.

1.4.27 Gamma-percentile shelf life at the confidence level of 95% is not less than 10 years when stored in heated premises and 6 years when stored in unheated premises respectively.

1.4.28 Average recovery time does not exceed 6 hours.

1.4.29 Probability of zero hidden failures within the 12-month calibration interval is not less than 0.95 at an average utilization factor of 0.1.

1.4.30 Instrument dimensions in mm and weight values in kg are given in Table 1.3.

Table 1.3

Instrument name and type	Unpacked		In a standard pack	
	mm	kg	mm	kg
CH1-1022/2 rubidium frequency standard	100 x 40 x 80 (*)	max 0.65	245 x 180 x 80	max 1.0

(*) Excluding protrusions of screws.

1.5 Instrument structure and functioning

1.5.1 CH1-1022/2 frequency standard consists of a magnetic shield functioning as the instrument casing, a discriminator, a control board, a multiplier board and frequency- locked loop board. Main components of the instrument are located on printed-circuit boards. The discriminator accommodated inside of an additional magnetic shield consists of a resonator with absorption cell, an optical pumping light source, a photo converter and thermostat elements such as heating elements and temperature sensors.

1.5.2 CH1-1022/2 frequency standard is designed as a fundamental-mode circuit based on the double radio-optical resonance effect in rubidium atoms, in case of which frequency of the VCXO is adjusted by a narrow atom absorption spectral line.

Instrument short-term frequency stability is defined by quality parameter of quantum discriminator and stability of crystal oscillator and corresponds to the size of order $(1-3)\cdot 10^{-11}/\sqrt{\tau}$ over an averaging time of τ = (1-100) s. Long-term frequency instability characterized by systemic variations of instrument frequency over a period of one month gets comparable with stability of rubidium atom resonance frequency at the level of $(1\text{-}5)\cdot 10^{-11}$, i.e. by (2-3) orders better than in case of a “free” (non-locked) crystal oscillator.

1.5.3 Simplified block diagram given in Fig. 1.2 is used to explain the instrument’s principle of operation. 10 MHz crystal oscillator signal enters high-frequency part of the frequency-locked loop system where it is subjected to low-frequency phase modulation and multiplication up to the f_{mult} frequency.

f_{mult} frequency signal enters the discriminator where it is subjected to further frequency multiplication up to the value close to f_0 frequency of rubidium atom resonance transition line.

As soon as multiplied frequency of the crystal oscillator matches the f_0 atomic transition frequency the discriminator generates a $U_{error}(t)$ signal which frequency is a multiple of phase modulation frequency. The first harmonic voltage of this $U_{error}(t)$ signal is proportional to frequency deviation and the phase contains information on the frequency difference sign.

$U_{error}(t)$ discriminator signal enters low-frequency part of the frequency-locked loop system, where $U_{control}$ voltage is generated which is used to control crystal oscillator frequency. In lock mode frequency of the crystal oscillator is supported so that $U_{error}(t)$ voltage is kept to the minimum while $U_{2\Omega}(t)$ signal second harmonic voltage reaches its maximum.

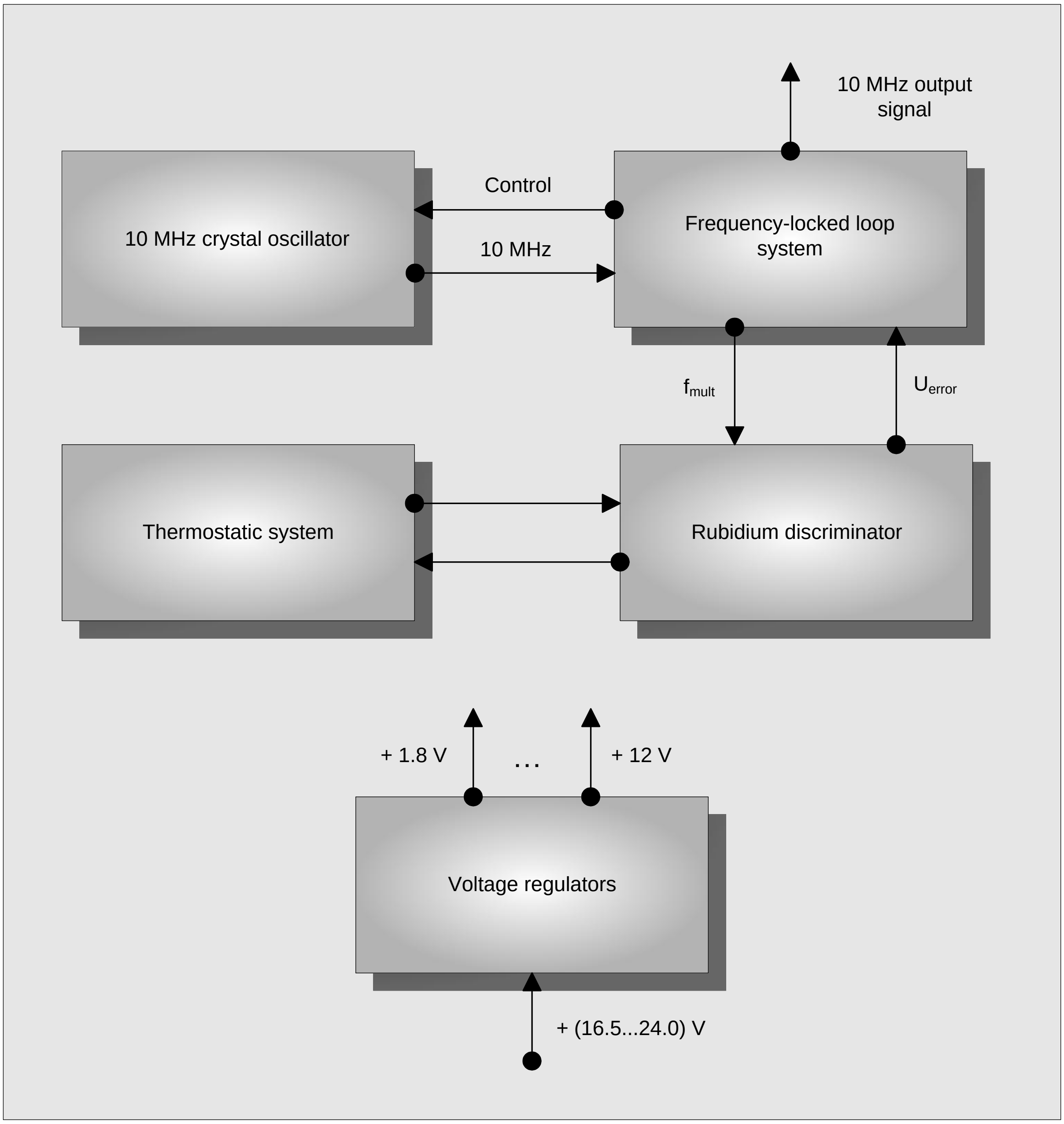

Fig. 1.2: Simplified block diagram of the CH1-1022/2 frequency standard.

1.6 Description and functioning of instrument components

1.6.1 Detail block diagram of the CH1-1022/2 frequency standard is given on Fig. 1.3.

Frequency multiplier consists of a frequency multiplier itself and a buffer amplifier. Pre-amplifier, selective amplifier, modulator, synchronous detector and integrator are located on the frequency-locked loop board. Amplifier and search circuit provide for automatic search and capture of crystal oscillator frequency via an atomic resonance signal at power on. Lamp ignition control circuit is intended for switching of optical pumping light source operation modes inside of the discriminator.

1.6.2 Discriminator consists of a microwave resonator with absorption cell, an optical pumping light source, a temperature sensor, a thermostat heating element and a magnetic winding. Heating element, temperature sensor and magnetic winding are located on the microwave resonator. Microwave resonator with optical pumping light source is mounted inside of the magnetic shield. Light detector and multiplier diode are accommodated in the microwave resonator.

1.6.3 Control unit provides for generation of secondary voltages required for instrument operation, heater winding control in the discriminator, optical pumping light source operation management and generation of stable current for magnetic winding.

1.6.4 Frequency-locked loop board performs amplification, filtering, detecting and formation of the control voltage for tuning of crystal oscillator in the standard frequency-locked loop system.

1.6.5 PLL-based frequency multiplier with a power amplifier at the output operates for microwave resonator multiplier diode which is used to generate the required multiplied signal harmonic.

1.6.6 Module of tying integrated into the frequency multiplier is intended for generation of a 1 pps chain from the 10 MHz crystal oscillator signal, measurement of time shift between generated pulses and external time scale pulses, and based on the results of these measurements calculation of frequency corrections and change of the multiplier frequency by a value required for the corresponding change of instrument frequency.

Besides, microcontroller of the module of frequency tying acquires telemetric data (photocurrent, crystal oscillator control voltage, error signal voltage) from oscillator units and transmits them by proper commands through the integrated RS-232C interface. This interface is also used to receive commands for change of instrument frequency and direct requests for time measurements data and data on applied corrections.

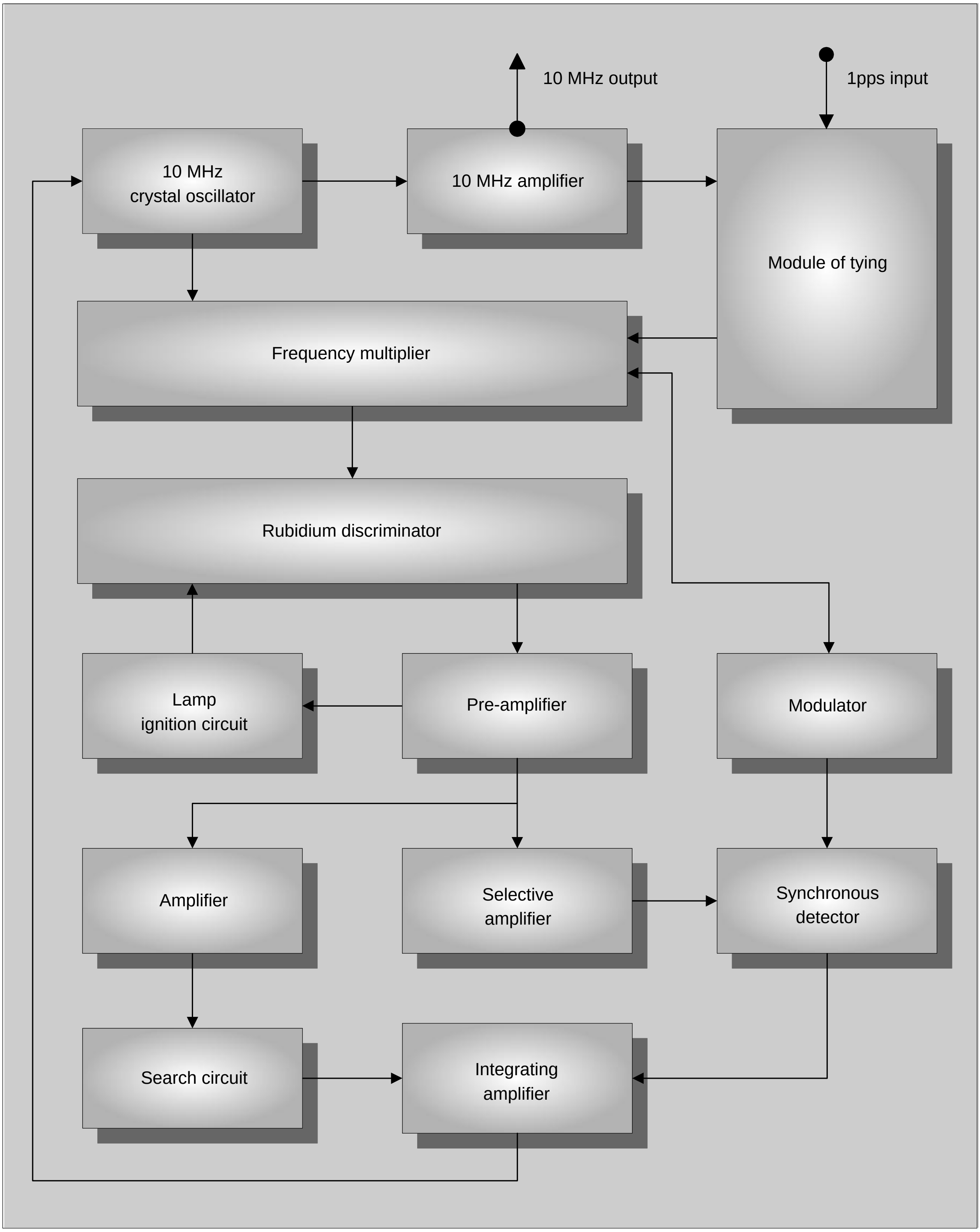

Fig. 1.3: Block diagram of the CH1-1022/2 rubidium frequency standard.

2 Setting-up procedure

2.1 Operating restrictions

2.1.1 Do not place the instrument near sources of strong electric and magnetic fields such as constant and electric magnets, transformers and high current switching devices. Strong magnetic fields may lead to magnetization of rubidium discriminator shields and as result uncontrolled shift of the output signal frequency.

2.2 Instrument unpacking and repacking

2.2.1 Unpack the instrument as follows:

– if the instrument is supplied in an additional shipping crate, open the crate and remove the packing list. Remove cardboard dampers and pull the instrument box out of the shipping crate;

– open the pack and remove the instrument from a polyethylene bag;

– open the bag with operational documentation and remove its contents;

– remove the bag with accessories and open it.

2.2.2 Prior to transportation pack the instrument as follows:

– put the instrument into a polyethylene bag and glue up the free end with adhesive tape; put the bag into the box;

– put accessories into a polyethylene bag and glue up the free end with adhesive tape; put the bag into the box pocket;

– put operational documentation into a polyethylene bag and glue up the free end with adhesive tape; put the bag into the box;

– put cardboard dampers into the shipping crate and lay the instrument box down onto dampers;

– make sure that the instrument cannot move freely inside the pack. If necessary fill the free space using corrugated cardboard;

– put the packing list onto upper spacer under watertight lining of the shipping crate upper cover;

– fix upper cover of the shipping crate and seal it.

2.3 Installation procedure

2.3.1 Prior to use visually inspect the instrument as follows:

– check integrity of seals;

– make sure there are no visible mechanical damages;

– check for cleanliness of instrument outer surfaces, jacks and connectors.

2.3.2 Check for instrument completeness in accordance with section 1.3 of this manual.

2.3.3 Position the instrument at the workplace providing for operational comfort and proper natural ventilation conditions. Take measures to ensure efficient heat removal from the instrument baseplate. Do not allow the instrument baseplate temperature to fall outside the limits specified in Table 1.1.

2.3.4 If the instrument is to be used as an integrated component of any other unit, tighten it on the base of the unit using mounting holes at the bottom of the instrument casing by M3 screws **with the maximum length of (5.0 + L) mm**, where L is the base thickness of the respective radio-technical device.

2.4 Setting-up procedure

2.4.1 Read this operation manual carefully before starting to use the instrument.

2.4.2 After long-term storage visually inspect the instrument, run it and check the metrological parameters in accordance with section 4 of this manual. If the instrument has been used under limiting conditions prior to power-on hold it under normal conditions within 2 hours.

2.4.3 Mount the connecting cable using DB-9F connector from the instrument delivery set in accordance with Table 3.2 or expansion board RUGA.468350.005 (supplied as an option).

2.4.4 Connect the cable to the interface of the respective radio-technical device, as a part of which CH1-1022/2 frequency standard will be operated.

2.4.5 The instrument will be powered by an external constant voltage source with the following parameters: voltage +(16.5-24.0) V, max. voltage ripple 100 mV, switching-on current up to 2 A in warm-up mode and 0.9 A in operational mode. The power supply must provide a monotone voltage rise on switching on and monotone voltage decrease on switching off. Voltage surges and voltage dips are not allowed in this case.

CAUTION! Operational temperature of the instrument baseplate should not exceed 70°C.

3 Operation procedure

3.1 Safety precautions to be taken during instrument operation

3.1.1 Supply voltage may be applied only if all external supply, control and indication circuits are connected to the instrument.

3.2 Control, connection and indication elements

3.2.1 CH1-1022/2 rubidium frequency standard is designed either for continuous round-the-clock operation in standalone mode or in session mode with subsequent power-off.

Instrument frequency may be controlled both in manual and remote modes.

3.2.2 Location of instrument controls and connectors is shown in Fig. 3.1. Function of instrument controls and connectors with the respective marking is given in Table 3.1.

Table 3.1

Position in Fig. 6.1	Marking	Function
1	«⊖> 10 MHz»	RF Connector. 10 MHz sine wave signal output.
2		“Frequency adjustment” potentiometer slot.
3		LF connector. Instrument power supply, performance control, remote frequency control.

Function of LF connector pins with the respective marking on the instrument nameplate is given in Table 3.2.

Table 3.2

Pin number	Marking	Function
1	“Power supply +(16.5-24) V”	Positive terminal of the instrument power supply source +(16.5-24) V.
2	“Ground”	Ground input. Negative terminal of the instrument power supply source.
3	“Lock indicator” (failure)	Indication of instrument functional capability. Voltage levels: (0-0.4) V for operational mode; +(13.0-20.0) V for non-operational mode.
4	“Lamp indicator”	Spectral lamp control. Voltage levels: (0-0.4) V for operational mode; +(9.0-15.0) V for non-operational mode.
5	“1pps in”	External time scale signal output.
6	“1pps out”	Signal output for time tags generated by the instrument and characterized by the repetition period of 1 s.
7	“RxD (RS-232C)”	RS-232C interface data reception line.
8		Not used.
9	“TxD (RS-232C)”	RS-232C interface data transmission line.

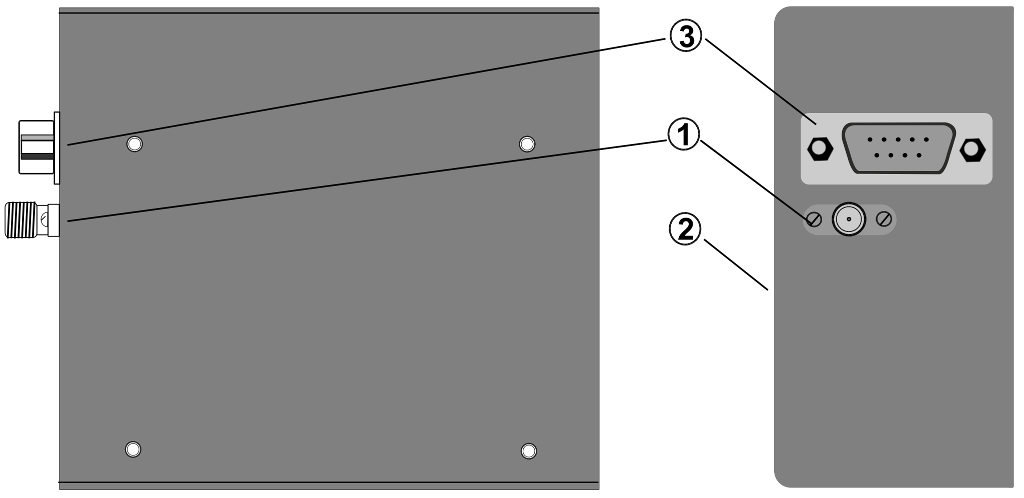

Fig. 3.1: Location of CH1-1022/2 rubidium frequency standard controls and connectors.

3.3 Preparation for measurements

3.3.1 Make sure that operational conditions of the instrument match those specified in Table 1.1.

3.3.2. Functional check of the instrument will be run by measurement of voltage values on LF connector pins 3 and 4 and their comparison with values given in Table 3.2.

Immediately after instrument power-on +(9.0-15.0) V constant voltage on low-frequency connector pin 4 induces absence of HF discharge in spectral lamp. As soon as the HF discharge in spectral lamp occurs (in 1-2 min after instrument power-on) voltage level on pin 4 drops down to (0-0.4) V.

After instrument power-on constant voltage on low-frequency connector pin 3 settles at +(13.0-20.0) V inducing absence of atomic resonance signal and instrument unreadiness to measurements. Under normal conditions in 5 min after power-on voltage level on pin 3 drops down to (0-0.4) V which is indicative of the normal instrument operation.

CAUTION! If in 5 min after power-on voltage level on pin 3 under normal conditions does not drop down to (0-0.4) V or if voltage level on pin 3 during continuous operation periodically reaches +(13.0-20.0) V, this may be a symptom of instrument malfunction.

3.4 Conduct of measurements

3.4.1 Switch power to the instrument.

3.4.2 Warm-up the instrument as long as necessary. Remember that the warm-up time increases along with decline of temperature and drop of supply voltage. Then the instrument may be used as a reference source. To ensure high accuracy of measurements the instrument should be warmed-up within 2 hours.

3.4.3 The instrument is equipped with a digital parameter management and control (monitoring) system. This means that at any time you can obtain comprehensive data on instrument state and change its frequency by sending the respective command via instrument interface (list of commands and replies is given in the Appendix). To this end you can use our software recorded on a CD (/Soft directory) being part of the instrument delivery set. This software which does not need installation and may be run directly from the CD or copied to the PC hard drive offers all the functional capabilities available to the end user.

3.4.4 The instrument allows you to change the output signal frequency within the range of $\pm 1 \cdot 10^{-8}$ with step of $1 \cdot 10^{-12}$. For this purpose, the instrument makes use of a frequency register four decimal digits in length with a sign (± 9999 increments). At product release zero value is entered into the frequency register and max. instrument frequency deviation is set to $\pm 2 \cdot 10^{-11}$ of rated value by changing the discriminator magnetic field magnitude via a potentiometer (pos. 2 in Fig. 3.1). You may change the instrument output signal frequency for your own needs by entering a corresponding value into the frequency register. Remember that the least-significant digit value corresponds to relative deviation of $1 \cdot 10^{-12}$. We do not recommend using the discriminator magnetic field setting potentiometer to change the instrument output signal outside of calibration procedure (subsection 4.3.4.1).

3.4.5 The instrument generates a pulse (time tag) chain with the repetition period of 1 s on low-frequency connector pin 3 (pos. 3 in Fig. 3.1). This chain is automatically synchronized with a similar external chain fed to pin 5 of the same connector. Synchronization error equals to ± 100 ns. As long as the external signal is available time shift of generated and external tags will be automatically maintained within the range of ± 1 µs. You can restore tag timing at any moment by routing the respective command via instrument interface.

3.4.6 The instrument comes with the disciplined frequency standard function, i.e. it is capable of automatic frequency adjustment of the 10 MHz output signal by a pulse signal (time tag) with the repetition period of 1 s fed to low-frequency connector pin 5. If external 1pps signal source is represented by a GPS/GLONASS/BeiDou satellite navigation system receiver, then instrument frequency will be set equal to value of one of the common international frequency standards depending on receiver settings. You can also give the 1 s signal from a higher level frequency and time standard and make use of this tool for frequency calibration of your instrument. The process of instrument frequency adjustment to the frequency of external standard via a time tag signal is known as “tying” and the mode of operation is called the “sync mode”. Tying process begins immediately after instrument warm-up provided that the external time tag signal is available on low-frequency connector pin 5. During this process time shifts between generated by the instrument and external time tags are measured and used for calculation of frequency corrections. Upon completion of measurement cycle and achievement of required accuracy corrections are automatically entered into the instrument frequency register. Thus, in the process of tying contents of the frequency register will constantly change compensating for variations of instrument frequency under the influence of various factors.

3.4.7 It is common knowledge that the time tag signal supplied by a satellite navigation system receiver may assume different stability depending on reception conditions, number of visible satellites along with settings and quality of the receiver. Besides, the navigation system signal may be deteriorated intentionally. In these circumstances time to get the information with the required degree of accuracy will increase significantly. The instrument is equipped with a system providing for dynamic evaluation of external time tag signal stability. This system automatically expands measurement cycle duration (time interval between consecutive frequency corrections) in case of time tag stability decrease and vice versa. Minimum time to the first frequency correction makes up approximately 40 min if time tags have been received directly from a high-stability frequency and time standard. Should the stability be at a very low level as manifested by drop-out of pulses and significant time deviations the tying process may not complete successfully. Frequency corrections made in the tying process are stored in the instrument memory till power-off. The instrument memorises last 250 values which may be displayed by routing the respective command via instrument interface. When the instrument is de-energized these values get lost but the frequency register state is kept in instrument’s non-volatile memory and is restored at the next power-on.

4 Instrument performance testing

4.1 Operations and means of testing

When running check-up perform operations and use testing means specified in Table 4.1.

Table 4.1

Operation name	Number of calibration procedure step	Recommended calibration instrument (name, type)	Basic specifications of the calibration instrument
1	2	3	4
1 Visual inspection	4.3.2		
2 Functional check of the instrument	4.3.3	Universal voltmeter V7-38	Voltage measurement range 0 to 20 V Error ± 1%
3 Check of instrument metrological parameters:	4.3.4		
- relative error of 10 MHz output signal frequency	4.3.4.1	VCH-1008 hydrogen frequency and time standard CHK7-1011 frequency comparator	Frequency instability in 10 s: $2 \cdot 10^{-13}$ Measurement error in 10 s: $\pm 5 \cdot 10^{-13}$
- frequency drift per month	4.3.4.2	VCH-1008 hydrogen frequency and time standard CHK7-1011 frequency comparator	Frequency instability in 1 day: $4 \cdot 10^{-15}$ Measurement error in 10 s: $\pm 5 \cdot 10^{-13}$
- relative frequency error for 1 day in a sync mode by external 1pps signal	4.3.4.3	VCH-1008 hydrogen frequency and time standard CHK7-1011 frequency comparator	Frequency instability in 1 day: $4 \cdot 10^{-15}$ Measurement error in 10 s: $\pm 5 \cdot 10^{-13}$

Продолжение таблицы 4.1

1	2	3	4
- short-term stability (Allan variance) in 1 s, 10 s and 100 s	4.3.4.4	VCH-1008 hydrogen frequency and time standard CHK7-1011 frequency comparator	Frequency instability in 1 s: $5{\cdot}10^{-13}$ in 10 s: $2{\cdot}10^{-13}$ in 100 s: $5{\cdot}10^{-14}$ Measurement error in 1 s: $\pm 2{\cdot}10^{-12}$ in 10 s: $\pm 5{\cdot}10^{-13}$
- the effective value of the output signal voltage	4.3.4.5	Digital millivoltmeter V3-52/1	Voltage range: 3 mV to 300 V, error: ± 4%

Note:

You may use other measuring instruments to check frequency standard performance with the required degree of accuracy.

4.2 Testing conditions and preparation for testing

4.2.1 Observe the following test performance conditions:

– ambient air temperature, °C ..……………. +(20 ± 2);

– relative humidity, % ……………. 30–80;

– atmospheric pressure, kPa (mmHg) ………… 84-106 (630-795);

– supply voltage, V …………………………… +(18,0 ± 0,2).

4.2.2 Prepare the instrument for testing in accordance with sections 2.4 and 3.3 of this manual.

4.3 Testing

4.3.1 Tests are performed in accordance with the check-list and the sequence of operations specified in Table 4.1.

4.3.2 Visual inspection is carried out to ascertain compliance with the following requirements:

– instrument completeness according to Table 1.2;

– instrument appearance according to subsection 2.3.1 requirements;

– instrument nameplate marking according to Table 3.2.

Defect instruments will be discarded and sent in for repair.

4.3.3 Functional check of the instrument and evaluation of its operability are performed in accordance with subsection 3.3.2 of this manual. Failed instruments will be discarded and sent in for repair.

4.3.4 Check of instrument metrological parameters

4.3.4.1 Relative error of 10 MHz output signal frequency is defined when the instrument is connected according to the diagram shown in Fig. 4.1.

For this purpose, CHK7-1011 frequency comparator is used with the following measurement parameter values: time of measurings 10 s, cycle length 200 s, data source - signal with frequency 10 MHz. Zero value is entered into the frequency register of the instrument under check. Thereafter the average relative difference between frequencies of instrument and VCH-1008 frequency and time standard is measured.

Test results are considered acceptable if the obtained relative frequency error at product release does not fall outside of $\pm 2 \cdot 10^{-11}$ limit.

In case of unacceptable results instrument frequency should be corrected by “frequency adjustment” potentiometer (pos. 2 in Fig. 3.1) till attainment of the required relative frequency error whereafter measurements will be taken once again following the abovementioned procedure.

4.3.4.2 Frequency drift per month is determined when the instrument is connected according to the diagram shown in Fig. 4.1.

For this purpose, CHK7-1011 frequency comparator is used with the following measurement parameter values: time of measurings 3600 s, cycle length 1000 s, data source - signal with frequency 10 MHz.

Measurements are taken on expiry 72 hours after instrument power-on within 11 days.

Measurements are taken hour by hour and average relative difference of frequency values in 1 day is calculated by the following formula:

$$\frac{\overline{\Delta f}}{f_0} = \frac{\sum_{i=1}^{24} \frac{\Delta f_i}{f_o}}{24}.$$

The frequency drift per day (ν) is calculated based on measurement results of instrument and VCH-1008 frequency and time standard average relative difference of frequency values for each day by the following formula:

$$\nu = \frac{6}{n(n-1)} \cdot \sum_{i=1}^{n} \left(\frac{2i}{n+1} - 1 \right) \cdot \frac{\overline{\Delta f_i}}{f_o},$$

where n is the number of days spent for conduct of measurements,

$\frac{\overline{\Delta f_i}}{f_0}$ is average relative difference of frequency values on the i^{th} day.

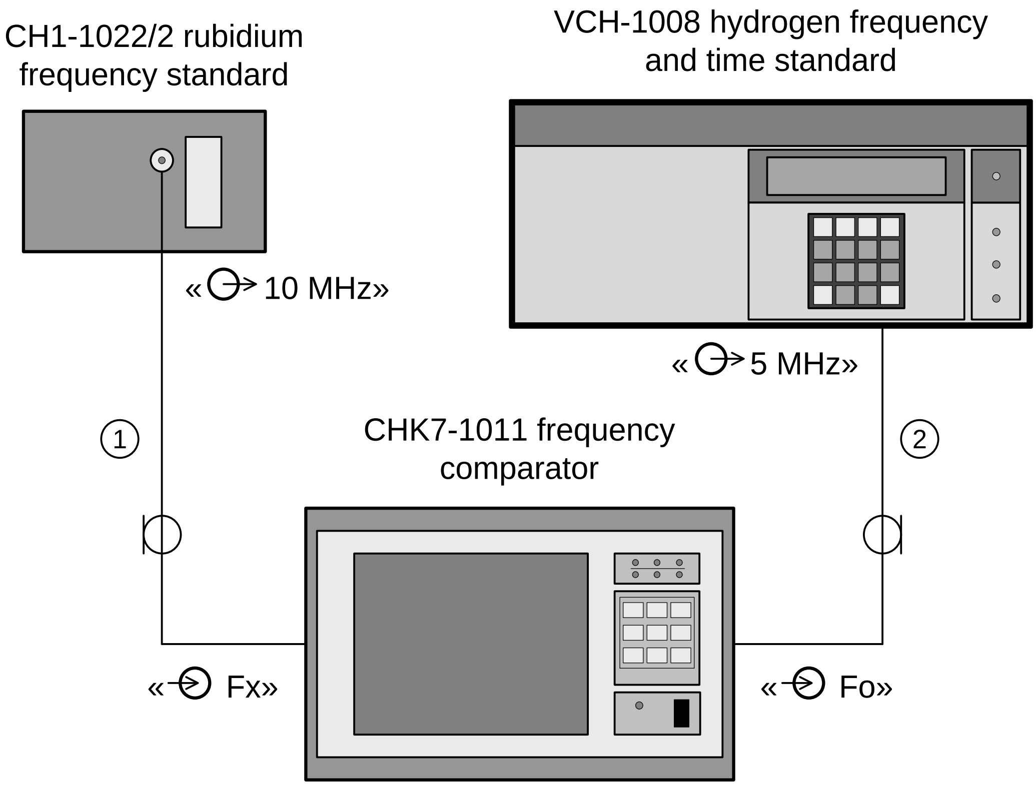

Fig. 4.1: Instrument connection diagram used to determine relative error of output signal frequency, frequency drift per month and Allan variance in 1 s, 10 s and 100 s.

1. HF cable RUGA.685671.363. Part of the CH1-1022/2 delivery set.
2. HF cable RUGA.685661.003-01. Part of the CHK7-1011 delivery set.

Frequency drift per month (ν_{month}) is determined based on measurement results of frequency drift per day (ν) in accordance with the following expression: $\nu_{month} = 30\,\nu$.

Test results are considered acceptable if the obtained frequency drift per month does not fall outside $\pm\ 5{,}0 \cdot 10^{-11}$ limit.

In case of unacceptable results measurements will be taken over a period of up to 30 days.

4.3.4.3 Relative frequency error for 1 day in a sync mode by external 1pps signal is determined when the instrument is connected according to the diagram shown in Fig. 4.2.

Measurements are taken on expiry 24 hours after instrument power-on within 11 days.

Average relative frequency error values are determined day by day following the procedure given in subsection 4.3.4.2.

Test results are considered acceptable if obtained relative frequency error values do not fall outside of $\pm\ 1 \cdot 10^{-11}$ limit.

4.3.4.4 Allan variance in 1 s, 10 s and 100 s is determined when the instrument is connected according to the diagram shown in Fig. 4.1.

For this purpose, CHK7-1011 frequency comparator is used with the following measurement parameter values: time of measurings 1 s, cycle length 2000 s, data source - signal with frequency 10 MHz.

Test results are considered acceptable if obtained Allan variance values do not fall outside the limits specified in subsection 1.4.6.

4.3.4.5 The effective value of the output signal voltage is determined by measurement of instrument HF connector (pos. 1 in Fig. 3.1) voltage with V3-52/1 millivoltmeter at the connected load of 50 Ω.

Test results are considered acceptable if the obtained output signal voltage value lies within (0.6-1.2) V.

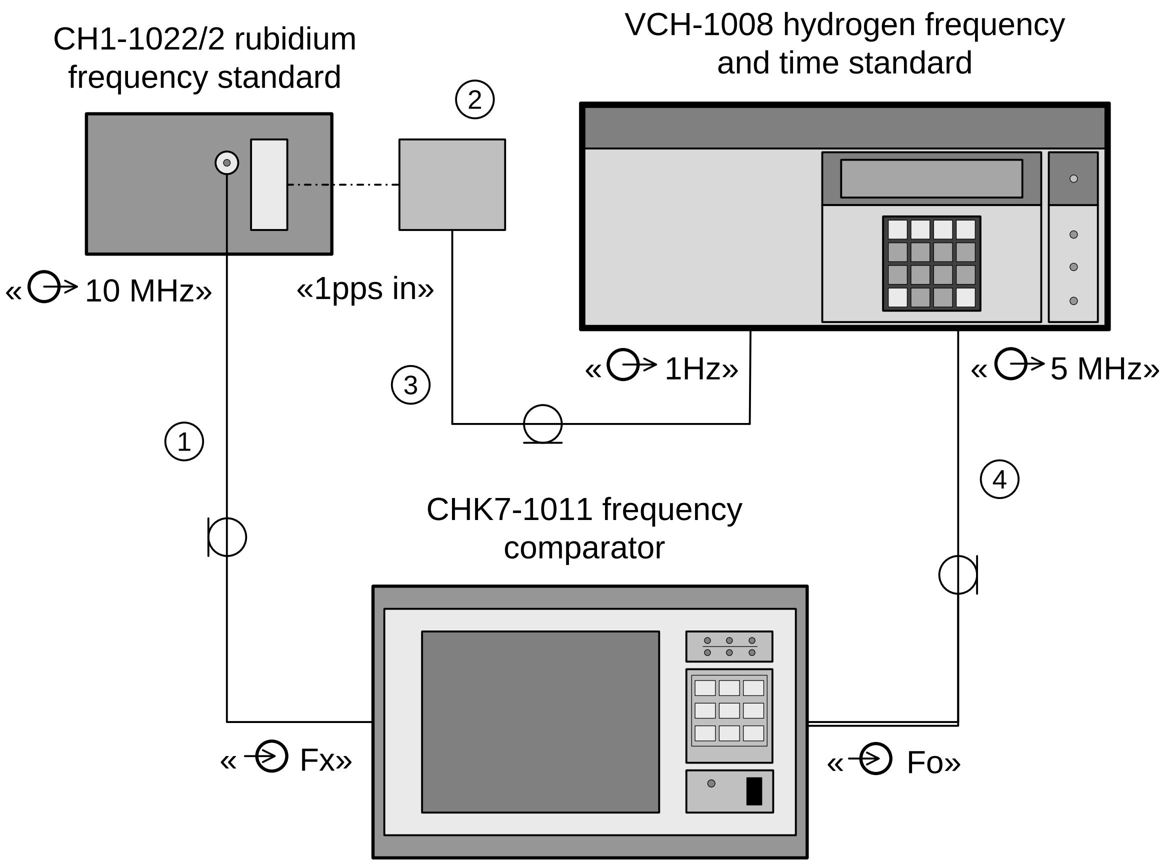

Fig. 4.2: Instrument connection diagram used to determine relative frequency error for 1 day.

1. HF cable RUGA.685671.363. Part of the CH1-1022/2 delivery set.
2. Expansion board RUGA.468350.005 (supplied as an option).
3. HF cable RUGA.685671.363 (supplied as an option).
4. HF cable RUGA.685661.003-01. Part of the CHK7-1011 delivery set.

5 Storage

5.1 The instrument should be packaged and kept at the rack in closed storage room with no dust, toxic, alkaline and other aggressive air pollutants at an ambient air temperature of 0 to +70°C and relative humidity of 80% at the temperature of 25°C. Short-term (up to ten days) storage of the instrument at an ambient air temperature of -55 to +70°C and relative humidity of up to 95% is considered as acceptable.

6 Transportation

6.1 The packaged instrument may be shipped by any means of transport at an ambient air temperature of -55 to +70°C and relative humidity of up to 95% at the temperature of 30°C.

6.2 During transportation the instrument should be protected against atmospheric precipitation and dust penetration.

6.3 Prior to transportation the instrument is packed in accordance with section 2 of this manual.

Appendix

Format of control commands and replies generated during
data exchange with external control device

Table A.1

Item No.	Command code	Reply	Command description
1	**Azxxxx**	**F_zxxxx<CR>**	**Absolute.** Entry of command-containing code directly into the instrument frequency register. Reply returns a new state of the frequency register.
2	**Czxxxx**	**F_zxxxx<CR>**	**Correction.** Change of instrument frequency register state by value of the command-containing code. Reply returns a new state of the frequency register.
3	**D**	**D_*xxx<CR>**	**Dump.** Request of the last measurement value. Asterisk character in the third reply position means that this measurement value has not been updated since the previous request.
4	**d**	**d_zxxxx_…zxxxx<CR>**	**dump.** Request of the current correction array.
5	**R**	**R_!<CR>**	**Reset.** Reset (nulling) of the current array of complete corrections.
6	**E**	**E_zxxxx_zxxxx_xxxx<CR>**	**Evaluation.** Request of the previous (first field) and preliminary evaluation of the next (second field) frequency correction based on current measurement array. The third field contains the number of elements (length) within the current measurement array.
7	**f**	**F_zxxxx<CR>**	**frequency.** Request of instrument frequency register current state.
8	**n**	**N_xxx<CR>**	**number.** Request of instrument serial number.
9	**S**	**S_!<CR> / S_?<CR>**	**Synchronization.** Synchronization of instrument time tag with the external time tag. If there is no external time tag signal synchronization will be cancelled and message **S_?<CR>** will be returned.

Table A.1 (continued)

Item No.	Command code	Reply	Command description
10	**t**	**t_zxx<CR>**	**temperature.** Request of interior instrument temperature. Reply returns a temperature value in Celsius degrees.
11	**V**	**V_xx_xx_xx_xx_bbbbbbb<CR>**	**Value.** Request of instrument controlled parameter values. Reply given in percents of the maximum value returns error signal voltage, crystal oscillator control voltage, thermostat voltage, light current and seven bit parameters: lamp state (1 - light off; 0 - light on), FLL state (1 - no lock; 0 - lock), PLL state (1 - failure; 0 - normal), availability of external time tag (1 - no; 0 - yes), frequency tying(1 - non-complete; 0 - complete), debugging mode (1 - off, 0 - on), temperature compensation system (1 - off, 0 - on). For all bit parameters zero value means normal operation.
12	**W**	**W_xxx_xxx.x<CR>**	**Work.** Scanning of instrument "in use time" counter. Reply returns counter data with the accuracy of up to one tenth of an hour.
13	**v**	**v_xx.xx.xxxx<CR>**	**version.** Request of the microcode software version number (release date).

Note: All messages are transmitted and received in ASCII characters,

where "_" is space character (20h);

z is space character or minus sign;

x is number from 0 to 9;

b is binary parameter (0 or 1);

<CR> is carriage return character (0Dh).