



**HIGH VOLTAGE
NANOSECOND PULSE GENERATORS
NPG30P11 and NPG30N11**

USER MANUAL

v. 1.0

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WHAT ARE IN THE PACKAGE

The package includes all you need to set up the equipment and start the experiments with the discharge:

- ✓ NPG30P11 (NPG30N11) HV pulse generator (hereinafter "generator");
- ✓ Power supply cable;
- ✓ 5 meters in length HV output coaxial cable with NPG30-M connector;
- ✓ 2 ml of silicone grease for the HV connectors.

What you may need more:

- ✓ Oscilloscope with 500 MHz bandwidth and 5 Gsa/s or more;
- ✓ Tektronix© P6015A probe for pulse voltage measurement;
- ✓ Megaimpulse© CS-10/500 current shunt for pulse current measurement;
- ✓ Megaimpulse© RC30 resistive coupler for the incident and reflected pulse energy measurement, as well as voltage and current waveforms on the load;
- ✓ BNC-to-BNC cable for the connection to the external triggering source;
- ✓ BNC-to-BNC cable for registering the SYNC OUT pulse.



Fig.1. General view of NPG30P11 HV nanosecond pulse generator.

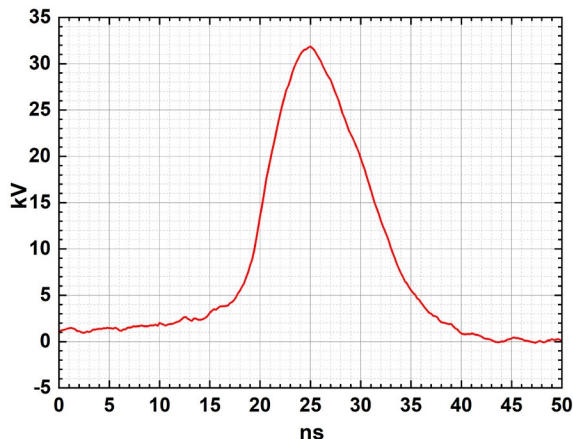


Fig.2. Typical output pulse waveform on matched 75 Ohm load at max amplitude.

SAFETY MANUAL

Electrical safety

- NPG30P11 (NPG30N11) pulse generator is a high voltage equipment. Please be careful, and operate qualified personnel only.
- The electric shock, strong electromagnetic interference, and damage to the generator or other equipment are possible in a case of improper operation.
- The grounding of the equipment is obligatory using a three-terminal power supply cable and wall outlet and/or grounding the shell of HV output connector/output coaxial cable braid.
- Turning on the generator without the HV output coaxial cable is strongly prohibited. The electrical arcing on the open connector will damage it and the output circuit of the generator. Please use our special HV coaxial cable/connector only. The cable length should be 5 meters or more.
- Please turn off the generator before connecting to or disconnecting from the load. Connect or disconnect any external triggering or measurement equipment while the HV system of the generator is switched OFF by the HV ON/HV OFF button.

Operation safety

- Please read this manual before using the generator.
- Make sure that all the cables are applicable and not damaged. The HV connectors on the rear panel and coaxial cable should be clean, and the insulator parts of both connectors should be covered by thin silicone grease. This grease eliminates the air gap between mated connectors and prevents unwanted discharge inside.
- To avoid shorts, please keep metal parts like clips, screws, and staples away from the generator.
- The generator is designed for operation in normal laboratory conditions. Please avoid dust, humidity, and temperature extremes. Do not place the generator in any place where it may become wet.
- Place the generator on a stable surface.
- If you encounter any technical problems with the generator, please contact Megaimpulse Ltd. Do not try to repair the generator by yourself.

TECHNICAL SPECIFICATION

Output pulse amplitude (typical)	smooth adjustable from 15 kV to 30 kV on matched 75 Ohm load; up to 60kV on the open cable and discharge reactor
Output impedance	75 Ohm
Output connector	NPG30, special HV coaxial type connector
Output cable	5m coaxial cable with 75 Ohm impedance, outer diameter 9.6 mm
Pulse polarity	positive for NPG30P11 negative for NPG30N11
Pulse rise time	< 5 ns (fast part of the output pulse)
Pulse width (FWHM)	11 ns ... 12 ns, fixed
Pulse energy	smooth adjustable from 30 mJ to 120 mJ
Peak pulse power	up to 12 MW
Operation modes	continuous, burst, single pulse modes; internal and external triggering
Continuous mode repetition rates	from 1 Hz to 1 kHz (internal triggering) from single pulse to 1 kHz (external triggering)
Burst mode repetition rates; number of pulses per burst	up to 50 kHz; up to 1000 pulses per burst / per second
External triggering	BNC-type connector, +2.4 V ... +5 V amplitude
Internal generator delay	~ 1.2 μ s
Jitter RMS (typical)	1 ns
Output pulse monitoring	BNC-type connector, +5V amplitude
Power supply	AC 110-230V, 50-60 Hz
Size	250 x 362 x 144 mm ³
Weight (without cables)	8.5 kg

FRONT VIEW

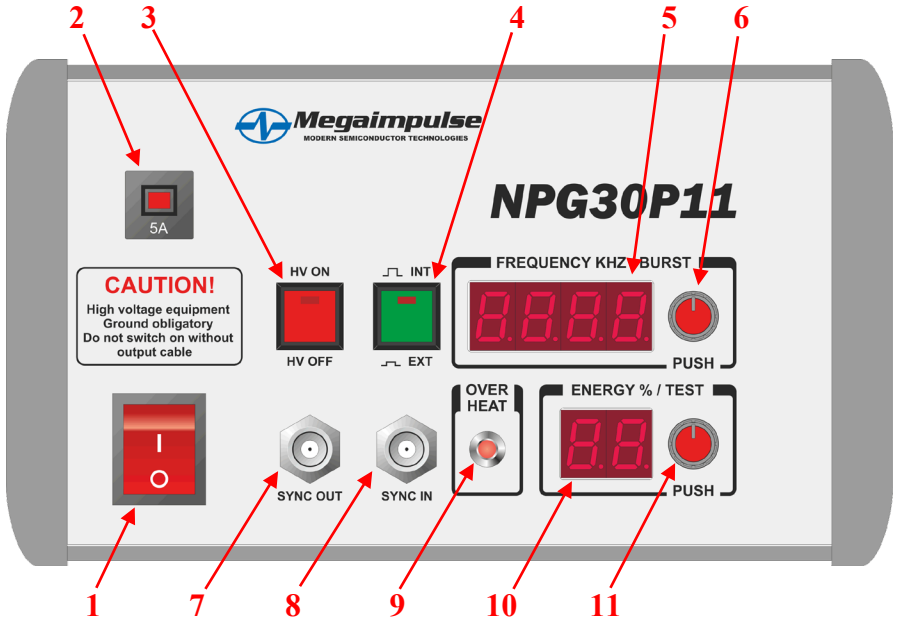


Fig.3. Front panel control elements.

- 1 – Power supply ON/OFF toggle switch
- 2 – Electronic fuse
- 3 – High voltage ON/OFF push button with ON state LED indicator
- 4 – Internal/external triggering push button with LED indicator
- 5 – Frequency and number of pulses per burst/second 4-digit display
- 6 – Frequency and number of pulses per burst regulation knob with push button
- 7 – BNC-type SYNC OUT connector
- 8 – BNC-type SYNC IN connector
- 9 – Overheat LED indicator
- 10 – Output pulse energy 2-digit display
- 11 – Output pulse energy regulation knob with push button

The HV output connector, main power supply connector, and the fans inlets/outlets are located on the rear panel.

BASIC OPERATION PRINCIPLES

The generator is a powerful and smart device. In spite of its compact size and small number of control elements, it implements a lot of operation regimes and high output power according to user demands. Please read this manual carefully to familiarize yourself with the basic operation principles.

- The generator has open and short load protection as well as overheating protection. However, it is strongly prohibited to switch on the generator without an HV output cable or if it is shorter than 5 meters in length.

The generator can operate in a single pulse, continuous, and burst operation modes, as well as internal or external triggering. The generator's control system provides quartz-stabilized pulse sequences for continuous and burst operation in the internal triggering mode and prevents improper operation in case of external triggering. The complete lists of the preset frequencies and preset number of pulses per burst/second are shown in Appendix A.

- In all operation modes, the minimum pulse-to-pulse interval is limited to 20 μ s, which corresponds to 50 kHz repetition rate. The maximum number of pulses per second is limited to 1000. Therefore, the maximum frequency in continuous mode is 1 kHz, and higher repetition rates are available in a burst mode only. It is recommended to set 100 pulses per burst or less because the amplitude of the following pulses becomes lower at high rates.


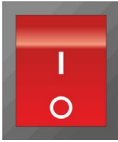



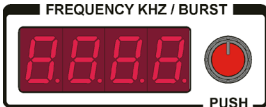
The following operation parameters can be set by the front panel controls:

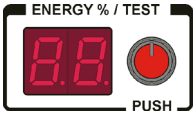



- FREQUENCY from 1 Hz to 50 kHz, the default value is 100 Hz;
- NUMBER OF PULSES per burst/second from 1 to 1000, the default value is 1000;
- PULSE ENERGY from 30% to 99%, the default value is 50%.

The continuous mode is activated if the set frequency in Hz is lower than or equal to the set number of pulses. Otherwise, the burst mode is chosen automatically. The period of bursts is fixed to one second. So, the FREQUENCY parameter sets the pulse-to-pulse interval, while the NUMBER OF PULSES sets the burst length or number of pulses followed by a pause up to the next burst.

- The FREQUENCY and NUMBER OF PULSES parameters work as limits for the external triggering pulses. Therefore, FREQUENCY sets the maximum external pulse frequency (minimum pulse-to-pulse interval), and NUMBER OF PULSES sets the maximum number of pulses per second. So, the generator's control system prevents overloading and damage to the generator in case of improper external triggering.

FRONT AND REAR PANELS IN DETAIL

	<p>NPG30-type HV coaxial connector on the rear panel. Firmly attach the HV output cable before turning on the generator. The recommended torque for the cable connector nut is 10 N×m. The HV connectors should be clean, and insulating parts covered by thin silicone grease. This grease fills the gap, eliminates air, and prevents unwanted arcing or glow discharge inside.</p>
	<p>Main power supply ON/OFF toggle switch.</p>
	<p>Electronic fuse. The red button should be pressed down.</p>
<p>HV ON</p>  <p>HV OFF</p>	<p>Non-latched push button which enables the HV output pulses. The red LED on the button lights on when the HV system is activated and ready for triggering. HV system is set to OFF state at the powering on, overheating, or in the TRIGGERING TEST mode.</p>
	<p>Latched push button toggles internal and external triggering modes. The upper state indicates the internal triggering mode, the red LED on the button lights on, and immediate triggering occurs when the HV system is activated by the HV ON/HV OFF button. Press the button to activate the external triggering mode. The LED is off when no external triggering pulses and 1 Hz blinks when they are applied and successful triggering occurs.</p>
	<p>The FREQUENCY and NUMBER OF PULSES parameters are indicated on a four-digit LED display and set by the control knob with a push button. The FREQUENCY is indicated in kHz with a decimal dot. For example, 1 Hz is indicated as 0.001; 50 kHz is indicated as 050.0. Press down the control knob to click and hold for one second to switch to NUMBER OF PULSES regime. The LED display blinks and indicates the NUMBER OF PULSES without a digital dot. For example, 1 pulse setting is indicated as 0001; 1000 pulses setting is indicated as 1000. Press down</p>

	<p>the control knob and hold for one second again to switch back to the FREQUENCY mode. The preset frequencies and number of pulses are shown in Appendix A.</p>
	<p>The PULSE ENERGY parameter is indicated on a two-digit LED display and set by the control knob with a push button. The energy can be set from 30% to 99% with a 1% step. This LED display is always on in the idle or continuous operation modes. It blinks in a burst mode, the durations of on and off states correspond to the duty cycle. Press down the control knob to click and hold for one second to switch into the TRIGGERING TEST mode. The HV ON/HV OFF button is blocked in this mode; the LED display shows 00, which means zero output power; the triggering sequence from an internal or external source goes to the SYNC OUT connector. This mode allows us to check the triggering sequence without applying HV pulses to the load. Press down the control knob and hold for one second again to switch back into the PULSE ENERGY mode.</p>
	<p>If the temperature exceeds the safe level, then the OVERHEAT LED lights on and the generator stops the operation. It may occur due to too high ambient temperature, obstacles to the airflow, or after a long-time operation at a high amplitude and high repetition rate. The HV system is blocked in case of overheating. Please keep the generator in idle mode and allow cooling by the fans for several minutes. The generator will return to normal operation automatically when the temperature decreases. Press the HV ON/HV OFF button again to continue the operation.</p>
 <p>SYNC IN</p>	<p>BNC-type input connector for the external triggering pulses. The pulse amplitude should be +2.4V ... +5V and the pulse width should be 1 μs or more. The external synchronization mode is activated by pressing down the INT/EXT green push button.</p>
 <p>SYNC OUT</p>	<p>BNC-type output connector for SYNC OUT pulses. The front edge of the SYNC OUT pulse precedes the HV output pulse by $\sim 1.2\mu$s. SYNC OUT pulse width is 400 ns and the amplitude is 5V.</p>

PUTTING INTO OPERATION

- ➔ Please follow strictly the described steps. It will help to prevent damage to the generator, other equipment, and personnel injury.

Step 1.

Unpack the generator and check the presence in the package of the following items:

- NPG30P11 (NPG30N11) generator;
- power supply cable;
- 5 m HV output coaxial cable.

Step 2.

Set up the generator. Ground it obligatory by using a three-terminal power supply cable and/or by grounding the HV output coaxial cable braid.

Step 3.

Check the HV connectors on the rear panel of the generator and on the HV coaxial cable. Both connectors should be clean and insulating parts covered by thin silicone grease. Clean the connectors with alcohol and/or cotton buds if necessary. After cleaning, apply a drop of silicone grease before mating the connectors. The grease fills the possible air gap between connectors and eliminates glow discharge inside.

Attach the cable connector to the generator's rear panel connector. The tight and firm contact of the connectors is very important for reliable operation. Even a small air gap between the connectors may result in a glow discharge, arcing, and damage to the equipment.

The following procedure is recommended for the firm and tight connection:

1. Align both connectors.
2. Hold the generator with one hand to prevent moving and press the cable connector with another hand toward the generator's connector.
3. Screw the cable connector nut by hand, usually one or two turns. Do not rotate the cable connector body.
4. Press the cable connector toward the generator's connector again.
5. Again, screw the cable connector nut one or two turns.
6. Repeat steps 4 and 5 up to tight contact. Finally, screw the cable connector nut firmly by hands or gently with a wrench. Do not apply excessive force to the wrench. The recommended torque is 10 N×m.

After the first testing of the generator, it is highly recommended to check whether the tight contact was attained. Unscrew the cable connector. There should be no ozone or burnt smell from the connectors or any burnt traces.

Please do not connect/disconnect the HV output cable many times to prevent the connectors from wearing and contamination. Silicone grease has been already applied to both connectors at the factory. It remains inside the connector pair for a long time and prevents the discharge inside.

Step 4.

Connect the HV output cable to the load by soldering the cable central wire to the HV electrode of the load and solder/screw the load ground electrode to the screw and nut on the cable ground clamp. The Teflon cone prevents the arcing between the central wire and the ground (cable braid) across the cable solid PE insulator (See Fig.4). If necessary, the additional wires can be used for the connection to the load, but please keep the length of these wires as short as possible.

- The wires more than 10 cm between the load and the coaxial cable have excessive stray inductance, distort the pulse waveform significantly, and result in reducing the pulse amplitude on the load.



Fig.4. The load side connection: the HV central wire of the coaxial cable (1) in solid PE insulator (2), the Teflon cone insulator (3) which prevents unwanted arcing, and the ground contact (4), i.e. screw and nut on the clamp connected to the coaxial cable braid.

- The length of the HV output coaxial cable is 5 meters. Significantly shorter output cable may result in damage to the generator.

Step 5.

Connect the power supply cable to the wall power outlet.

Power on the generator by the toggle switch on the front panel. The LED indicators should light on and the cooling fans should start.

Step 6.

Check the internal triggering mode. The INT/EXT green latched button should be in upper state, and the red LED on it should light on.

Set the required frequency, number of pulses per second/per burst, and percent of the max pulse energy by the knobs. It is clever to start the experiments with low operation parameters, which helps to prevent or minimize possible damage to the equipment in case of any fault.

Press the HV ON/HV OFF push button. The red LED on the button should light on, and the HV output pulses should be generated. Adjust the amplitude and the frequency by the corresponding knobs as necessary.

Step 7.

Always stop the operation with the HV ON/HV OFF push button, and only after that turn off the generator by the power switch. The temperature of the generator's components becomes high after a long-time operation at a high pulse amplitude and frequency. Allow the idle mode to cool down with the fans for several minutes before turning it off.

TRIGGERING THE GENERATOR

The generator can operate in continuous and burst modes in both internal and external triggering as well as single pulse mode.

Internal triggering mode

The upper position of the INT/EXT green latched push button indicates the internal triggering mode. The red LED on the button should light on continuously. It is possible to set continuous or burst operations in this mode. The repetition rate is adjusted from 1 Hz to 50 kHz by the FREQUENCY knob. The number of pulses per burst is set from 1 to 1000 by the same knob after one second of pressing down. The burst operation is chosen automatically if the set number of pulses is less than the set frequency in Hz. The complete lists of preset frequencies and number of pulses are presented in Appendix A.

External triggering mode

Press down the INT/EXT green latched button to set the external triggering mode. The red LED on the button lights off and blinks with 1 Hz frequency when the external triggering pulses are applied to the BNC-type SYNC IN connector. The recommended triggering pulse amplitude is +2.4V ... +5V @ 50 Ohm input impedance. The delay between the triggering pulse front and the HV output pulse (internal generator delay) is 1.2 μ s or less. Typical jitter (RMS) is about 1 ns.

- The maximum allowable pulse repetition rate and number of pulses per second are limited by set FREQUENCY and NUMBER OF PULSES parameters. Please set the required values of these parameters by the FREQUENCY knob.

External triggering burst enable mode

Each short external triggering pulse, i.e. 20 μ s or less, generates a single HV output pulse, of course, if it is not blocked by the set parameters. In addition, a long-duration triggering pulse generates a burst with the repetition rate set by the FREQUENCY parameter and the burst length determined by the triggering pulse width (see Fig.5). So, the external triggering pulse works as an enable signal. The HV pulses are generated continuously while the triggering pulse level is high. This is the simplest way to get externally triggered burst mode.

- The single pulse mode is possible for the external triggering only.

Triggering test mode

Click and hold for one second the PULSE ENERGY knob to activate the TRIGGERING TEST mode. The HV ON/HV OFF button is blocked in this mode; two-digits LED display shows **00**, which means zero output power; triggering sequence from internal or external source goes to SYNC OUT connector. This mode allows to test the triggering and see the exact triggering sequence without HV output pulses generation. Click and hold the PULSE ENERGY knob for one second again to switch back from this mode to normal operation.

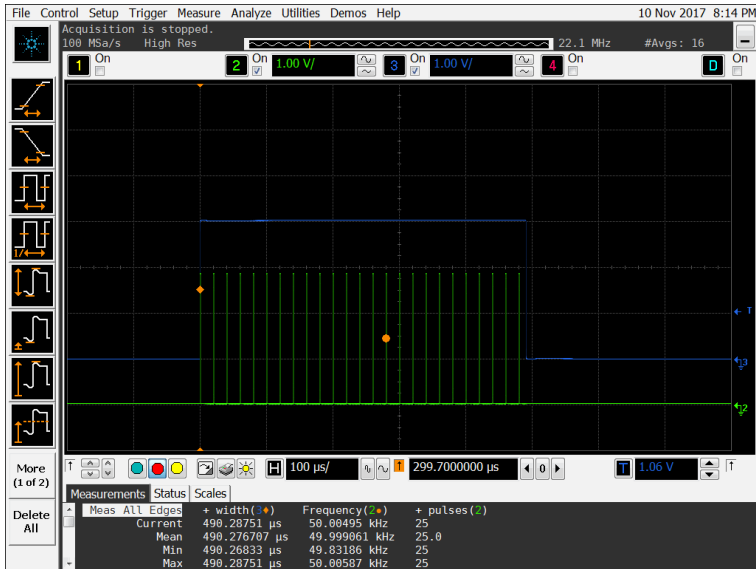


Fig.5. External triggering burst enable mode. The FREQUENCY parameter (50 kHz) sets the repetition rate of the output pulses, SYNC OUT (CH2, green line). The burst length, i.e. 25 pulses, is determined by SYNC IN pulse width (CH3, blue line), which works as an enable signal.

SYNC OUT PULSE

The generator has a front panel BNC-type connector for the SYNC OUT pulse which is synchronized with the HV output pulse. The SYNC OUT pulse amplitude is 3 V on 50 Ohm load and 5 V on high impedance load, the pulse width is 400 ns. The delay between a rising edge of the SYNC OUT pulse and the HV output pulse is 1.2 μ s or less.

The oscillogram of the SYNC OUT pulse is shown in Fig.6. The HV output pulse with a few nanoseconds rise time is a source of strong interference. Therefore, one can see the noise on the oscillogram at the moment of the HV output pulse generation.

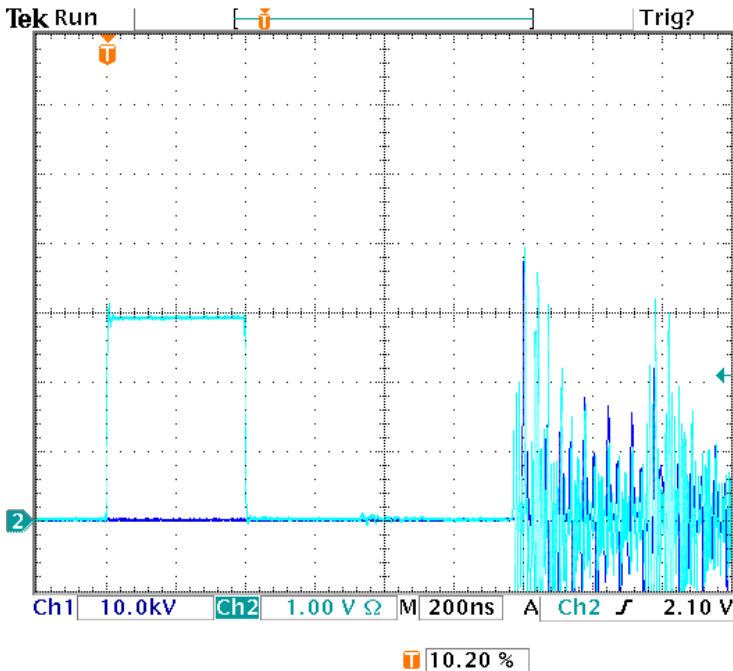


Fig.6. The oscillogram of SYNC OUT pulse (Channel 2, cyan line). The pulse amplitude is 3 V on 50 Ohm load and 5 V on high impedance load, the pulse width is 400 ns. The delay between a rising edge of the SYNC OUT pulse and the HV output pulse is 1.2 μ s or less.

OVERHEATING PROTECTION

The generator has overheating protection system. If the generator operates for a long time with high amplitude and high repetition rate and/or at a high ambient temperature, then it may be overheated. OVERHEAT LED lights on in this case, and the generator stops the operation. The HV system is switched off automatically and the HV ON/HV OFF push button is disabled. Please keep the generator in idle mode for several minutes and allow the fans to cool it down. OVERHEAT LED lights off when the temperature decreases down to the safe limit. The generator is ready for the operation again.

ELECTRONIC FUSE

The 5-ampere electronic fuse on the front panel is used for protection. The red button on the fuse should be in a pressed-down position which allows the power supply of the generator.

WARRANTY

Please see your sales agreement to determine the warranty period and terms. The generator has warranty seals.

- ➔ Removing the warranty seals terminates the warranty.

Appendix A.

A list of preset values for the frequency is presented in Table 1. One can set any of them in the internal triggering mode. More than 1 kHz frequencies are available in a burst mode only.

Table 1.

Frequency	4 digits display	Frequency	4 digits display
1 Hz	0.001	1 kHz	001.0
2 Hz	0.002	1.5 kHz	001.5
3 Hz	0.003	2 kHz	002.0
4 Hz	0.004	2.5 kHz	002.5
5 Hz	0.005	3 kHz	003.0
6 Hz	0.006	3.5 kHz	003.5
7 Hz	0.007	4 kHz	004.0
8 Hz	0.008	4.5 kHz	004.5
9 Hz	0.009	5 kHz	005.0
10 Hz	0.010	5.5 kHz	005.5
20 Hz	0.020	6 kHz	006.0
30 Hz	0.030	6.5 kHz	006.5
40 Hz	0.040	7 kHz	007.0
50 Hz	0.050	7.5 kHz	007.5
60 Hz	0.060	8 kHz	008.0
70 Hz	0.070	8.5 kHz	008.5
80 Hz	0.080	9 kHz	009.0
90 Hz	0.090	9.5 kHz	009.5
100 Hz *)	0.100	10 kHz	010.0
200 Hz	0.200	15 kHz	015.0
300 Hz	0.300	20 kHz	020.0
400 Hz	0.400	25 kHz	025.0
500 Hz	0.500	30 kHz	030.0
600 Hz	0.600	35 kHz	035.0
700 Hz	0.700	40 kHz	040.0
800 Hz	0.800	45 kHz	045.0
900 Hz	0.900	50 kHz	050.0

*) The default value of 100 Hz is set at power on the generator.

A list of preset values for the number of pulses per burst or per second is presented in Table 2. The 4-digit display flashes at 1 Hz frequency, while displaying the set value of the number of pulses.

Table 2.

Number of pulses	4 digits display	Number of pulses	4 digits display
1	0001	60	0060
2	0002	70	0070
3	0003	80	0080
4	0004	90	0090
5	0005	100	0100
6	0006	200	0200
7	0007	300	0300
8	0008	400	0400
9	0009	500	0500
10	0010	600	0600
20	0020	700	0700
30	0030	800	0800
40	0040	900	0900
50	0050	1000 *)	1000

*) The default value of 1000 pulses is set at power on the generator.