



# **NPG30PN12, NPG30P12, and NPG30N12**

## **TWO-CHANNEL NANOSECOND PULSE GENERATORS WITH PRECISE CONTROL OF CHANNEL-TO-CHANNEL DELAY**

### **USER MANUAL**

v. 1.0

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## WHAT ARE IN THE PACKAGE

The package includes everything you need to set up the equipment and start experiments:

- ✓ NPG30PN12 (NPG30P12 or NPG30N12) HV pulse generator (hereinafter "generator");
- ✓ Power supply cable;
- ✓ Two 5-meter long output HV coaxial cables with attached NPG30-M connectors;
- ✓ 2 ml of silicone grease for lubricating HV connectors.

What you may need more:

- ✓ Oscilloscope with 500 MHz bandwidth and 5 GS/s or more;
- ✓ Tektronix© P6015A probe for the pulse voltage measurement;
- ✓ Megaimpulse© CS-10/500 current shunt for the pulse current measurement;
- ✓ Megaimpulse© RC30 resistive coupler for the incident and reflected pulse energy measurement, as well as measurement of the voltage and current waveforms on the load;

→ RC30 is "must-have" tool for measuring the channel-to-channel delay and precise synchronization the channels in differential mode.

- ✓ BNC-to-BNC cables for connection to the external triggering source;
- ✓ BNC-to-BNC cables for registering the SYNC OUT pulses.



Fig.1. General view of NPG30PN12 (the first channel has positive pulse polarity and the second channel has negative pulse polarity).

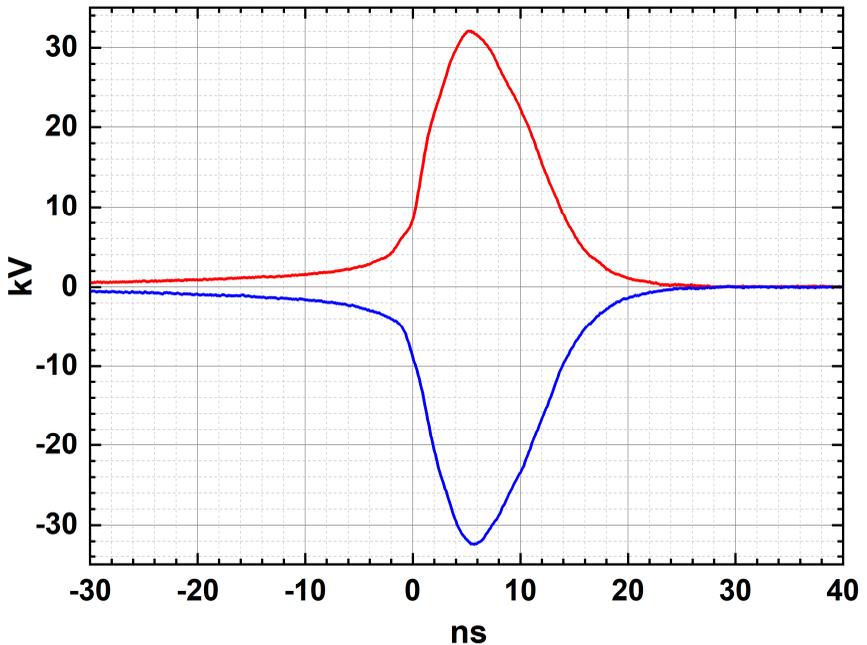


Fig.2. Typical output pulse waveforms of NPG30PN12 CH1 (positive, red line) and CH2 (negative, blue line) on matched 75 Ohm loads at set max pulse amplitude and zero channel-to-channel delay.

NPG30PN12, NPG30P12 and NPG30N12 are high-voltage nanosecond pulse generators with a precise, controllable delay between output channels. The delay can be smoothly adjusted within the range of -54 ns to +54 ns with 0.25 ns steps. The output channels are either positive polarity (NPG30P12), negative polarity (NPG30N12), or positive and negative polarities combined (NPG30PN12). Each channel can be turned on and off independently. Therefore, the generator can operate in CH1+CH2, CH1 only, and CH2 only modes.

The generators can operate with any type of the load including matched load, high-impedance load and discharge reactor.

NPG30PN12 allows to get up to 120 kV differential pulse voltage on a common floating load when both channels operate synchronously.

# SAFETY MANUAL

## Electrical safety

- The pulse generator is a high voltage equipment. Please be careful and operate with qualified personnel only.
- There is a risk of electric shock, strong electromagnetic interference, and damage to the generator or other electronic equipment in case of improper use.
- Do not switch on the generator without proper grounding. We recommend using a grounding cable and/or a three-terminal power supply outlet with a ground contact.
- It is strongly prohibited to switch on the generator without output coaxial cables. Electrical arcing on an open coaxial connector can damage it and the output circuit of the generator. Please use only our special high-voltage coaxial cables and connectors. High-voltage connectors must be kept clean and free of dust and dirt. Mating Teflon parts of connectors should be lubricated with silicone grease to eliminate air gaps inside.
- When adding or removing a generator to or from a system, ensure that the power supply ON/OFF switch is turned off before connecting or disconnecting the HV cables.
- Please connect or disconnect any equipment, toggle the generator from the internal to the external triggering mode or vice versa, only while the generator is in the high-voltage OFF state set by the HV ON/OFF switch.

## Operation safety

- Please read this manual before installing and using the generator.
- Before using the product, make sure that all cables are suitable and not damaged.
- To avoid a short circuit, please keep metal parts such as clips, screws, and staples away from the generator.
- The generator is designed to operate under normal laboratory conditions, avoiding dust, humidity and temperature extremes. Do not leave it in a wet place.
- Place the generator on a stable surface.
- If you encounter any technical problems with the generator, please contact Megaimpulse Ltd. Do not attempt to repair the generator yourself.

## TECHNICAL SPECIFICATION

Output pulse amplitude (typical)	smoothly adjustable from +/-19 kV to +/-30 kV on a matched 75 Ω load; up to +/-60 kV on an open cable and discharge reactor; up 120 kV differential pulse amplitude on a common load (NPG30PN12 only)
Output impedance	75 Ω
Output connectors	HV coaxial of special type
Output HV cables	coaxial 75 Ω impedance, 5m in length, 9.6 mm outer diameter
Number of channels	2
Pulse polarity	NPG30PN12: positive plus negative channels NPG30P12: both channels positive NPG30N12: both channels negative
Pulse rise time	< 5 ns, fixed (fast part of the output pulse)
Pulse width (FWHM)	10 ns, fixed
Pulse energy	smoothly adjustable from 48 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	from 1 Hz to 50 kHz; from 1 to 1000 pulses per burst / per second
Channel-to-channel delay	- 54 ns ... + 54 ns with 0.25 ns increments <sup>1)</sup>
Typical jitter of channel-to-channel delay	0.1 ns (RMS), 0.5 ns (peak-to-peak) <sup>2)</sup>
External triggering; SYNC IN connectors	+2.4 V ... +5 V @ 50 Ohm; BNC-type
Internal generator delay	approx. 600 ns from triggering to HV pulse
SYNC OUT pulses; connectors	+5V amplitude; BNC-type
Power supply	AC 110-230V, 50-60 Hz

Size	460 x 360 x 140 mm <sup>3</sup>
Weight (with cables)	14.7 kg

- 1) for internal triggering mode; in external triggering mode any channel-to-channel delay is possible;
- 2) the typical jitter(RMS) is 0.1 ns for matched or high impedance load; it may be increased up to a few ns for operation on discharge reactor(s).

## FRONT PANEL

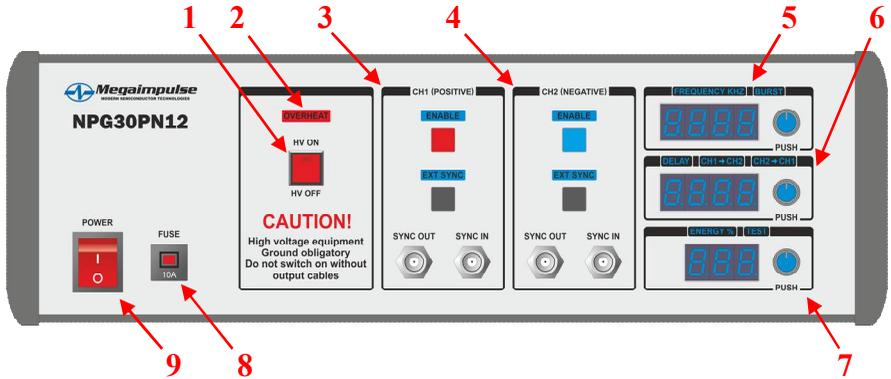


Fig.3. Front panel control elements:

- 1 – High voltage ON/OFF push button with ON state LED indicator
- 2 – Overheat LED indicator
- 3 – Channel 1 controls, including ENABLE button and LED indicator, EXT SYNC button and LED indicator, SYNC OUT and SYNC IN BNC-type connectors
- 4 – Channel 2 controls, including ENABLE button and LED indicator, EXT SYNC button and LED indicator, SYNC OUT and SYNC IN BNC-type connectors
- 5 – Frequency and number of pulses per burst / per second 4-digit display, FREQUENCY / BURST LED indicator and regulation knob with push button
- 6 – Delay 4-digit display, CH1 → CH2 / CH2 → CH1 delay modes LED indicator and regulation knob with push button
- 7 – Output pulse energy 3-digit display, ENERGY / TEST modes LED indicator and regulation knob with push button
- 8 – Electronic fuse
- 9 – Main power supply ON/OFF toggle switch

Two HV output connectors, 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 produces high voltage unipolar bell-like nanosecond pulses. The typical output pulse waveforms on a matched 75 Ohm load are shown in Fig. 2. The output pulse width, rise time, and polarity are fixed. The adjustable parameters are pulse energy (amplitude), frequency, number of pulses per burst, and channel-to-channel delay. The pulse energy, frequency and number of pulses per burst are common and set the pulse parameters for both channels. The front panel control elements are shown in Fig.3 and emphasized in the text by **bold red** color.

- ➔ The generator has open and short load protection as well as overheating protection. However, it is strongly prohibited to switch on the generator without output HV cables attached or if they are shorter than 5 meters.

HV ON/HV OFF button **1** activates/deactivates the HV system and allows the generation of HV pulses in the enabled channels. Red LED on the button lights on if the HV system is active. The generator can operate in a single pulse, continuous, and burst operation modes as well as internal or external triggering. Both channels can be enabled (CH1+CH2 by default), CH1 enabled only, or CH2 enabled only.

The generator's control system provides quartz-stabilized pulse sequences for continuous and burst operation in internal triggering mode and prevents improper triggering in external triggering mode. The currently set FREQUENCY and number of pulses per BURST are indicated on 4-digit display **5**. The set frequency is indicated in kHz with decimal dot; the number of pulses is indicated without dot. Push the knob **5** up to a click to toggle between them. The indicated parameter lights on. The complete lists of preset frequencies and preset number of pulses per burst / per second are shown in Appendix A.

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 activated automatically. The period of bursts is fixed to one second. So, the FREQUENCY parameter sets the pulse-to-pulse interval, while the BURST parameter sets the burst length (number of pulses followed by a pause until the next burst).

The external triggering pulses for each channel should be applied to the corresponding BNC SYNC IN connector. In case of successful triggering, the EXT SYNC indicators blink with 2 Hz frequency and confirm the triggering. Please see the External triggering section of the User Manual for more details.

Each channel triggering pulses go to the corresponding SYNC OUT BNC connector. The SYNC OUT triggering pulse precedes the HV output pulse by approximately 600 ns.

- In all operation modes, the minimum pulse-to-pulse interval is limited to 20  $\mu$ s, which corresponds to 50 kHz repetition rate. The maximum number of pulses per second in each channel 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 at 10 kHz and higher rates because the amplitude of the following pulses reduces. The FREQUENCY and BURST parameters work as limits for the external triggering pulses. Therefore, FREQUENCY sets the upper limit for the external pulse frequency (minimum pulse-to-pulse interval), and BURST 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.

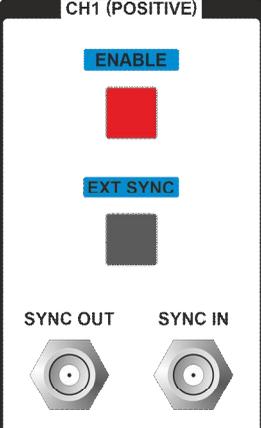
In the internal triggering mode, one of the channels operates as master, the another as slave (delayed). The delay of the slave channel relative to the master channel is set using knob **6** within -9.75 ns ... +54 ns with 0.25 ns increments, and the set delay (in nanoseconds) is indicated on a 4-digit LED display. CH1→CH2 LED lights on if CH1 is master. CH2→CH1 lights on if CH2 is master. The changing master/slave channels is possible by pressing knob **6**. If one of the channels is set to external triggering mode by the corresponding EXT SYNC button, then this channel becomes master. If both channels are set to external triggering mode, then both channels operate independently and 4-digit DELAY LED display lights off.

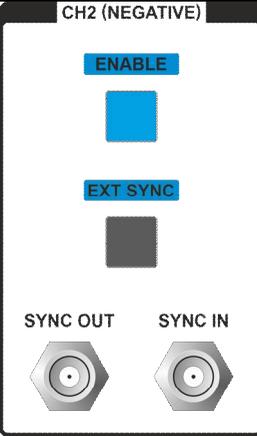
The output pulse energy can be set by knob **7** and is indicated in 3-digit display in percent of maximum level. Special TEST mode can be activated by pressing knob **7**. The HV output pulses are blocked for both channels in this mode, HV ON/HV OFF button **1** is deactivated, and display **7** indicates 00 value, which means zero output power. Therefore, it is possible to check the successful triggering of the generator and output pulses sequences on the SYNC OUT connectors without applying HV pulses to the load. Press knob **7** again to toggle to the normal operation regime.

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 / per second from 1 to 1000, the default value is 1000;
- The channel-to-channel DELAY from -9.75 ns to +54 ns, the default value is 0 ns;
- Pulse ENERGY from 40% to 100%, the default value is 50%.

## FRONT PANEL IN DETAIL

 <p style="text-align: center;">HV ON HV OFF</p>	<p>Non-latching push button, which toggles HV system ON and OFF. Red LED on the button lights on when the HV system is activated and ready for triggering by internal or external triggering pulses. HV system is set to OFF state when the generator is powered on and automatically toggles to OFF state in case of overheating or TEST mode activation.</p>
	<p>If the ambient temperature is high or the cooling is insufficient, then the internal temperature may exceed the safe level. OVERHEAT LED lights on, and the generator stops the operation. Please allow fans to cool it for several minutes. When the temperature decreases OVERHEAT LED lights off, and the generator returns to normal operation automatically. Press HV ON again to continue the operation.</p>
 <p style="text-align: center;">CH1 (POSITIVE)</p> <p style="text-align: center;">ENABLE</p> <p style="text-align: center;">EXT SYNC</p> <p style="text-align: center;">SYNC OUT      SYNC IN</p>	<p>Channel 1 controls, including ENABLE button and LED indicator, EXT SYNC button and LED indicator, SYNC OUT and SYNC IN BNC connectors. The ENABLE button enables/disables the HV pulses only. The channel control system is always triggered. Therefore, the disabled channel can be master, and, for example, in case of external triggering, the enabled slave channel may be delayed relative to the SYNC IN signal of the master channel.</p>

	<p>Channel 2 controls, including ENABLE button and LED indicator, EXT SYNC button and LED indicator, SYNC OUT and SYNC IN BNC connectors. The ENABLE button enables/disables the HV pulses only. The channel control system is always triggered. Therefore, the disabled channel can be master, and, for example, in case of external triggering, the enabled slave channel may be delayed relative to the SYNC IN signal of the master channel.</p>
	<p>Four-digit LED display and control knob with push-button, which sets FREQUENCY and number of pulses in a BURST. Push the knob up to a click to toggle between them. The light on LED indicator above the display shows the current mode. The FREQUENCY is indicated in kHz with a decimal dot. For example, 1 Hz is indicated as 0.001; 50 kHz is indicated as 50.0. The complete lists of the preset frequencies and number of pulses are shown in Appendix A.</p>
	<p>Four-digit LED display and control knob with push-button, which sets DELAY between master and slave channels. The delay is indicated in nanoseconds and can be adjusted from -9.75 ns to +54 ns with 0.25 ns steps. Push the knob up to a click to toggle the master/slave channels. CH1 is master when CH1→CH2 lights on, while CH2 is master when CH2→CH1 lights on. In case of one channel external triggering, this channel is set as master. In case of both channels external triggering, the delay module is deactivated and 4-digit display lights off.</p>

	<p>Three-digit LED display and control knob with push-button, which sets pulse ENERGY parameter. The energy can be adjusted from 40% to 100% with 1% step. Push the knob up to a click to switch into TEST mode. The LED indicator above the display shows the current mode. HV ON/HV OFF push button is blocked in the TEST mode. LED display shows 00, which means zero output power. Triggering sequences from the internal or external sources go to SYNC OUT connectors, which allows testing the successful triggering and the triggering sequence without applying HV pulses to the load. Push the knob again to toggle back to pulse ENERGY mode.</p>
<p><b>POWER</b></p> 	<p>Main power supply ON/OFF toggle switch.</p>
<p><b>FUSE</b></p> 	<p>Electronic fuse.</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:

- NPG30PN12 (NPG30P12, NPG30N12) generator;
- power supply cable;
- two 5 m HV coaxial cables.

### 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 and on the HV coaxial cables. All the connectors should be clean and insulating parts covered by 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 gap between connectors and eliminates the air and glow discharge inside.

Attach the cable connectors to the generator's rear panel connectors. 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.

Do not connect/disconnect the HV output cables many times to prevent the connectors 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 cables to the load by soldering the cables central wire to the HV load electrodes and solder/screw the ground load electrodes to the cables 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.

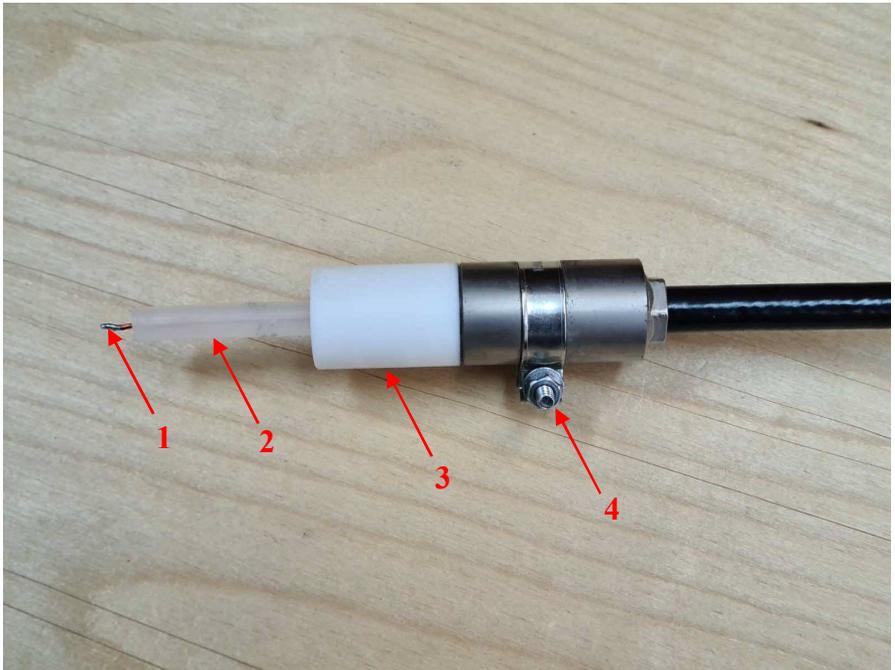


Fig.4. The load side connection: the HV central wire of the coaxial cable (1) in solid PE insulator (2), the Teflon cone insulator (3) which prevents unwanted arcing, and the ground contact (4), i.e. screw and nut on the clamp connected to the coaxial cable braid.

- The length of the HV output coaxial cables is 5 meters. Significantly shorter output cables 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 main power toggle switch **9** on the front panel. The LED indicators should light on and the cooling fans should start.

### Step 6.

At first, test the internal triggering mode. Both EXT SYNC indicators should light off. If necessary, press the EXT SYNC button(s).

Set by the knobs **5, 6, 7** the required frequency, number of pulses per second/per burst, delay, and pulse energy. 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 **1**. The red LED on the button should light on, and the HV output pulses should be generated. Adjust the frequency, channel-to-channel delay and amplitude by the corresponding knobs as necessary.

### Step 7.

Always stop the operation with the HV ON/HV OFF push button **1**, and only after that turn off the generator by the main power switch **9**. 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 for several minutes before turning off to cool the generator with the fans.

## EXTERNAL TRIGGERING

The external triggering mode is the most flexible. Some operation regimes can be realized only in this mode. For example, the single pulse mode and independent triggering of channels with different repetition rates, delays, and number of pulses in bursts. The external triggering mode can be set for one of the channels only. In this case, that channel becomes the master, and another (slave) channel is delayed relative to the master by the value set by **6**. If both channels are set to external triggering mode, then they operate independently; the delay module is deactivated and the 4-digit LED display **6** lights off.

The impedance of the SYNC IN inputs is 50 Ohm. Use 50-ohm coaxial cables with BNC connectors to feed the triggering pulses. The recommended amplitude of the triggering pulse is +5 V. The EXT SYNC indicator will blink at a frequency of 2 Hz if the channel has been triggered successfully by external pulses.

There are two possible external triggering modes: **external triggering**, in which each rising edge of the triggering pulse results in one output HV pulse, and **external burst enable** in which output HV pulses are generated continuously while the external triggering pulse is high.

### External triggering mode

The triggering pulse width should be less than 20  $\mu\text{s}$  (1  $\mu\text{s}$  is recommended) to activate this mode. Triggering occurs by the rising edge of SYNC IN pulse, and an HV pulse is generated after approximately 600 ns internal delay, of course, if the triggering is not blocked by the control system due to too high frequency or too many pulses in a second (see Fig.5).

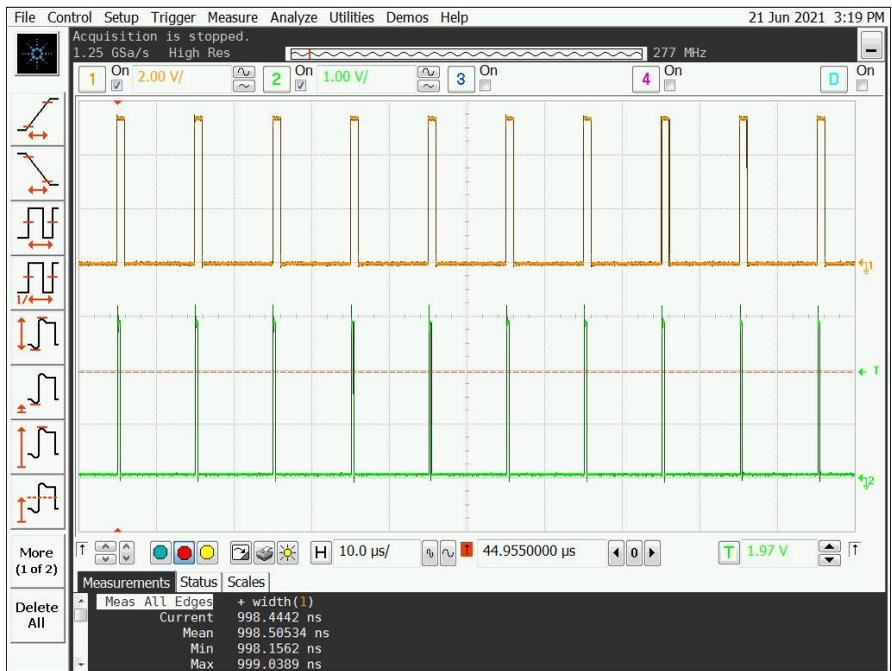


Fig.5. External triggering mode. Channel 1 (orange line) is the external triggering pulses applied to SYNC IN connector, Channel 2 (green line) is the SYNC OUT pulses. Each triggering pulse results in a single output HV pulse.

- The maximum allowable pulse frequency and the number of pulses within a burst are limited by the FREQUENCY and BURST parameters. Please set the required values using knob 5. After successful triggering, the control system blocks the next triggering for a period set by the FREQUENCY parameter. The control system counts the triggering events and blocks further triggering until the end of one-second interval if the number of pulses exceeds a set BURST parameter.

### External burst enable mode

The generator automatically switches to this mode if the external triggering pulse is long enough. The external triggering pulse fed to SYNC IN connector works as enable signal, and HV output pulses run continuously with the set FREQUENCY while the triggering pulse level is high. The other operation parameters are similar to the external triggering mode. As an example, the burst of five output pulses (Channel 2, green line) formed by a single triggering pulse (Channel 1, orange line) is shown in Fig.6.

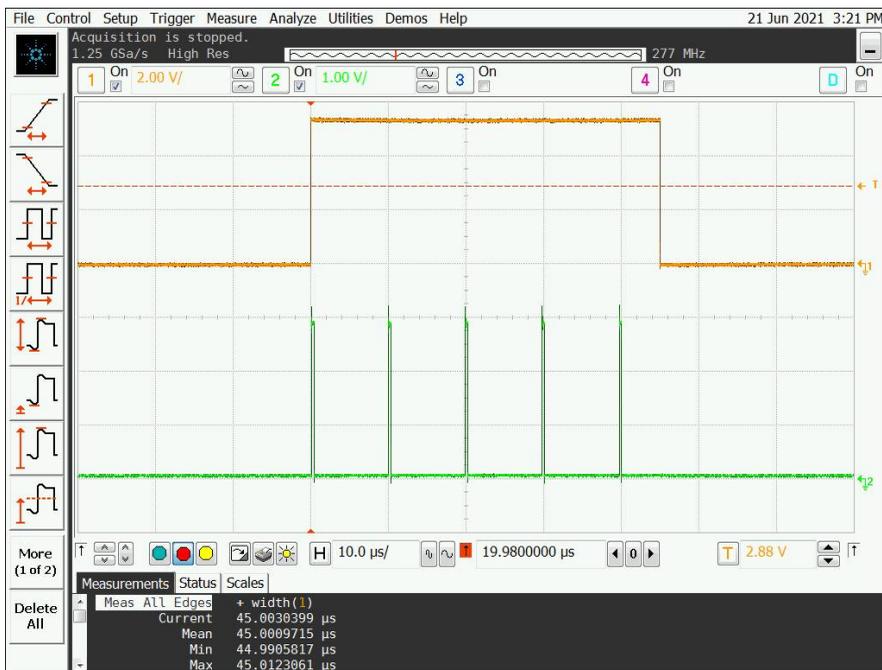


Fig.6. External burst enable mode. The burst of five output pulses (Channel 2, green line) is formed by a single triggering pulse (Channel 1, orange line).

## **ELECTRONIC FUSE**

The generator is equipped with 10A electronic fuse **8**. The fuse interrupts the power supply if there is short circuit or overload. Please turn off the main power toggle switch **9**, push the red button on the fuse and turn the generator back on. If the fuse breaks the power supply again, then please consult the manufacturer.

## **WARRANTY**

Please see your sales agreement to determine the warranty period and condition. The generator has warranty seals. Removing the warranty seals and unauthorized opening of the generator enclosure terminates the warranty.

## APPENDIX A

The preset frequencies which can be set in internal triggering mode are presented in Table 1. The frequencies above 1 kHz are available only in a burst mode. The set value of FREQUENCY works as a limit on the external pulse frequency.

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 when the generator is powered on.

2. The preset number of pulses in a burst in internal triggering mode. The period of bursts is fixed at one second. The set value of BURST works as a limit on number of pulses per second in external triggering mode.

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 when the generator is powered on.