Low Power Nanosecond Pulser User's Manual (NSP Series)
Last Updated: October 2020

!!! Extreme Danger !!!

The energy levels, voltages, and/or currents used and generated by the power supply and pulser can be lethal. Supply and pulser should only be operated by qualified personnel. Do not attempt to operate the power supply and pulser unless the user has sufficient knowledge of the dangers and hazards of working with high voltage. Do not attempt to approach or touch any internal or external circuits or components that are connected or have been connected to the power supply and pulser. Be certain to discharge any stored energy that may be present before and/or after the power supply and pulser is used.

!!! Exposed High Voltage !!!

Lethal voltages are present and exposed at the rear high voltage input and output connections. Operate supply and pulser such that no contact between these connections and any human, equipment, and/or cable is guaranteed.

Critical Operational Warnings

Failure to follow these warnings can result in immediate and catastrophic failure of the Nanosecond Pulser (NSP). Such failure results in characteristic internal damage, and is not covered by the EHT warranty. If you have any questions regarding safe operation, please contact EHT for guidance prior to such operation.

1. **Never ground either high voltage output (*applies to floating units only*)**
   The NSP high voltage output is floating and must not be grounded either on its positive side, or its negative side. Grounding either output, especially at high voltage, generates internal corona that damages the NSP. Both direct and capacitive grounding must be avoided.

   Connecting a probe and oscilloscope to the output, even a differential probe, is effectively grounding the output at the location where the probe is clipped. Carefully read and understand the High Voltage Nanosecond Pulse Measurements document, which can be found at www.eagleharbortech.com/support prior to conducting any such measurements.

2. **Maintain load high voltage isolation and minimize stray capacitive coupling.**
   Stray capacitive coupling can cause significant issues that are not seen when operating with longer pulses and/or slower rise times. Therefore, stray capacitive coupling must always be minimized. In general, this involves keeping the HV output, leads, and load far from all grounded surfaces, cables, and other equipment. A 2” minimum clearance between the high voltage output and other components is recommended for the variants with output voltages of 20 kV or below, and 3” minimum for 30 kV variants.

3. **Always connect both output leads to the load**
   If only one of the two outputs is connected to the load, potentials will shift unpredictably and currents will flow through stray capacitive coupling rather than through the intended current path of the output leads. This can cause damage to the system.

4. **Do not block airflow.**
   The NSP has air intakes on the bottom and an exhaust fan on the back. The bottom vents draw in air from all around the unit. Unobstructed airflow is essential to keep internal components cool. Do not obstruct the airflow by placing other objects close to the sides of the NSP, behind the NSP, or underneath the NSP. Pulser failure and fire may result if these vents are blocked. If you smell burning during operation, immediately turn off the pulser.

5. **Do not open or modify the NSP chassis.**
   The NSP chassis should remain sealed at all times. There are components that operate at high voltage. Do not modify any part of the chassis from its original condition. Unsuitable modifications may result in safety hazards. Any modification or signs of tampering will void the warranty.

6. **Use the appropriate AC circuit for power.**
   The AC power must be within the voltage/frequency range printed on the NSP back panel just below the master power switch. The AC circuit must be grounded.

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1 Warranty

EHT warrants that all EHT Electronics Ltd. manufactured equipment will be free of any defect in materials or workmanship for the period of (1) year. The warranty is extended to customers and applies to all EHT manufactured equipment purchased, installed, and used for the purpose for which such equipment was originally designed. The above warranties cover only defects arising under normal use and do not include malfunctions or failures resulting from misuse, abuse, neglect, alteration, problems with electrical power, usage not in accordance with product instructions, acts of nature, or improper installation or repairs made by anyone other than EHT.

2 Patents

The Nanosecond Pulser product line is protected by one or more patents issued in the United States, and covered by one or more patent applications pending in the United States and elsewhere. A listing of these patents can be found at http://www.eagleharbortech.com/patents.

3 General Information

The NSP series of power supplies are nanosecond pulsers with an output voltage range of 0-30 kV, pulse widths of 20-500 ns, and pulse repetition frequencies up to 30 kHz. Each parameter is independently adjustable through a continuous range, although not all the maximum parameters may be reached simultaneously, depending on the load that is being driven. The NSP series units are designed to drive dielectric barrier discharges, pseudosparks, arcs, and other loads where impedance matching is challenging.

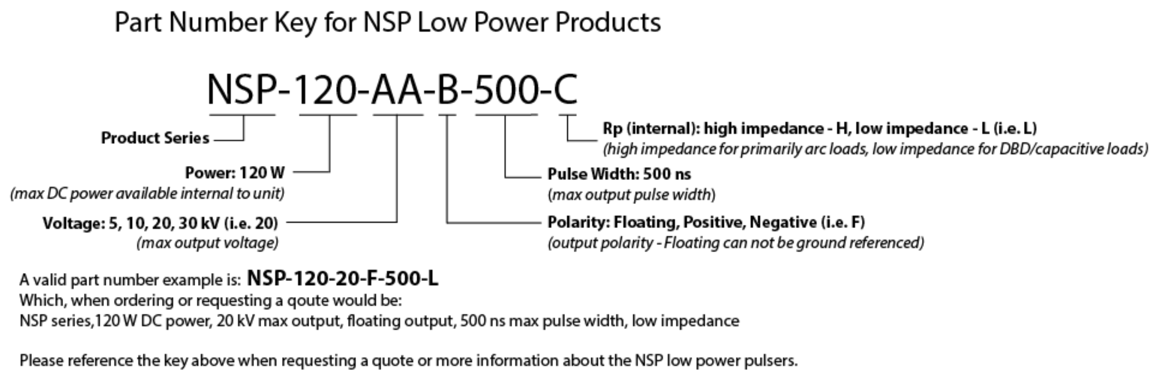
The NSP series comes with either a floating output or a grounded output. The floating output stage (on part numbers ending in –F) allows the user complete control over the current return path, minimizing EMI noise, and enhancing laboratory safety. EHT recommends using the floating configuration whenever possible. However, the floating output units may not be used with a grounded load. In applications where the load is grounded, the grounded output version of the NSP must be used. Grounded NSP power supplies come in both a positive polarity (part numbers ending in –P) and a negative polarity (part numbers ending in –N) output variant.

NSP series power supplies can be operated in three modes: free-running, triggered, and external. Free-running mode is useful when the NSP is being used as part of a standalone benchtop experiment, it will continuously output pulses of the specified pulse width and frequency. Triggered mode is useful for synchronization with other equipment – the pulse width is set by the front panel knobs, while the output is triggered remotely through a fiber-optically isolated input. Lastly, External mode allows full remote control, where both the pulse width and trigger timing are controlled by a user's signal generator or control system, which can be useful if pulse width must be modulated from pulse to pulse.

Figure 1. Photo of NSP-120-20-F

3.1 Specifications

The part numbering for the standard NSP series of power supplies is as follows:



The output voltage, rise time, and pulse width are load dependent. The stated rise times are measured into a high impedance load at the output connector.

Table 2. Nominal Specifications for 500 ns pulse width units.

Model	Voltage [kV]	Max Pulse Repetition Frequency [kHz]	Rise Time [ns]	Pulse Width [ns]	Output Impedance [Ω]
NSP-120-5	5	10	20	40-500	300
NSP-120-10	10	10	20	40-500	600
NSP-120-20	20	10	20	40-500	1200
NSP-120-30	30	3	50	50-500	2400

For updated specification tables, please refer to our website www.eagleharbortech.com under the Low-Power Nanosecond Pulsers section.

Additional Specifications:

Load Type: DBD, capacitive, resistive, arc, pseudospark
Input Power (*Specified at time of sale*): 110-120 VAC 50-60 Hz or 200-230 VAC 60 Hz
Dimensions: 21.5 cm × 31.8 cm × 36.2 cm (8.5" × 12.5" × 14.25 ")
Weight: 9.8 kg (21.6 lbs.)

3.2 Operational Space

The NSP voltage, pulse width, and pulse repetition frequency are all individually adjustable. For the load types indicated, the following figures show the accessible operating space.

- The minimum pulse width is measured at maximum output voltage, defined as the full width at half-maximum (FWHM). Shorter pulses are possible at voltages below the NSP's maximum output voltage.
- Simultaneous maximum for each specification is limited by both available power and by the load driven.
- If the user sets the operating parameters to a region outside the operating area, the NSP will self-protect by dropping the output voltage.

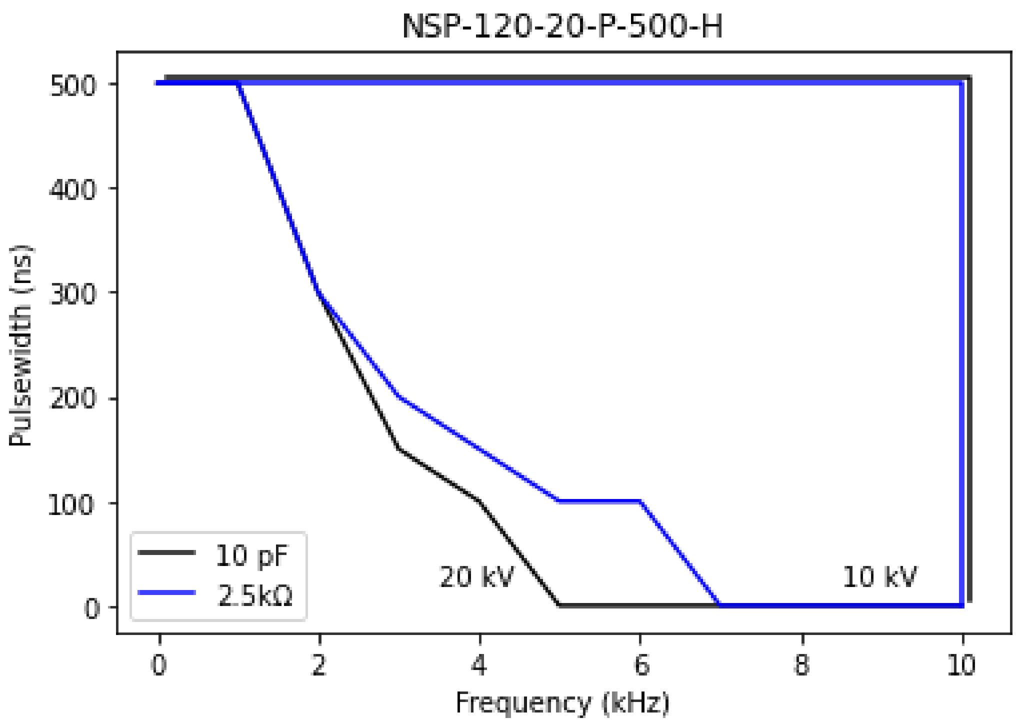


Figure 2. Available Operating Space for the NSP-120-20-P-500-H

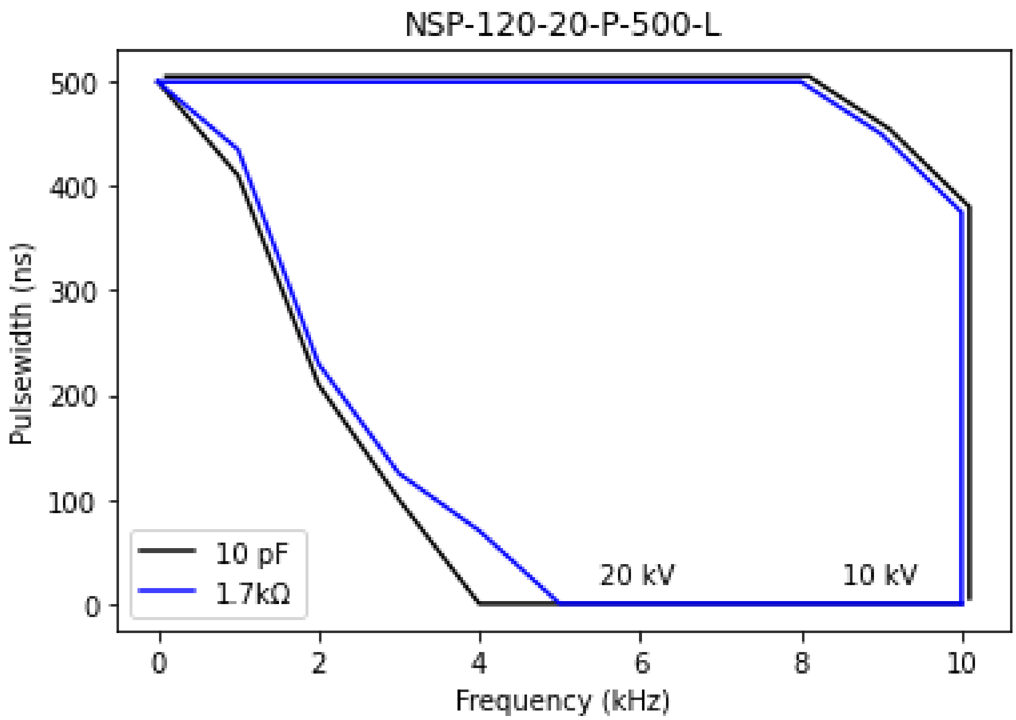


Figure 3. Available Operating Space for the NSP-120-20-P-500-L

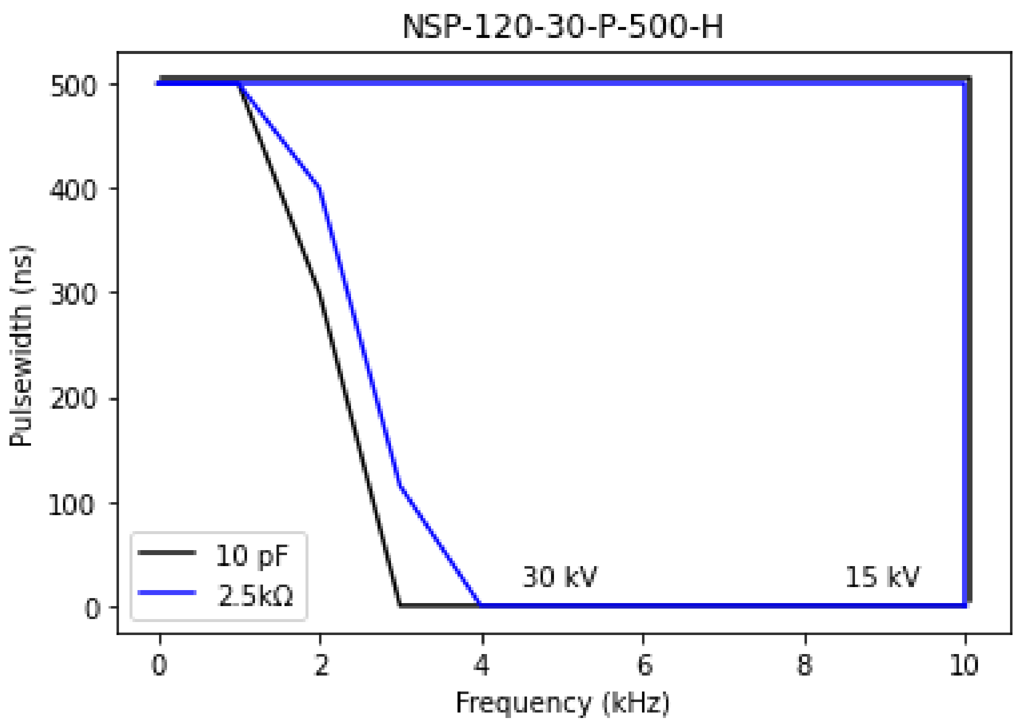


Figure 4. Available Operating Space for the NSP-120-30-P-500-H

3.3 Output Resistor Stage

All versions of the NSP series have an output resistor stage. The exact configuration and values of the resistors depends on the exact model of the NSP ordered, but they all contain a parallel output resistor (R_p) and a series output resistor (R_s).

The function of the parallel resistor is to provide the necessary minimum load to the HV pulse generator stage and to sink the current from the user provided load. For example, capacitive and DBD loads need to be discharged before they can be charged again. They also protect the NSP in the event that the load is left open or shorted.

The function of the series resistor is to limit the maximum output current, which protects the NSP in case the output is shorted or arcs.

3.3.1 Output Resistor Stage for Floating Units (-F)

Floating units contain a symmetric output resistor stage as shown in Figure 5. The effective output impedance of the NSP is 2 R_S. *Note that if your NSP was purchased prior to 2019, please contact the manufacturer for values.*

Pulser Model	R_S	R_P
NSP-120-5-F-500-L	71 Ω	5 kΩ
NSP-120-5-F-500-H	96 Ω	27 kΩ
NSP-120-10-F-500-L	284 Ω	1.5 kΩ
NSP-120-10-F-500-H	241 Ω	50 kΩ
NSP-120-20-F-500-L	998 Ω	49.5 kΩ
NSP-120-20-F-500-H	914 Ω	100 kΩ
NSP-120-30-F-500-L	2069 Ω	15 kΩ
NSP-120-30-F-500-H	1827 Ω	100 kΩ

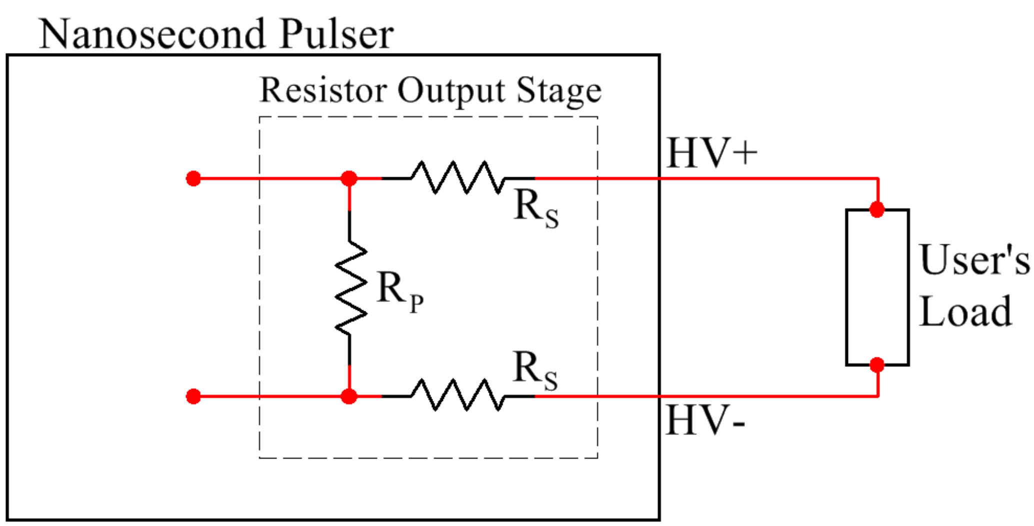


Figure 5. Resistive Output Stage for Floating Units

3.3.2 Output Resistor Stage for Grounded Units (-P and –N)

Grounded versions of the NSP contain an asymmetric resistive output stage as shown in Figure 6. The effective output impedance of the NSP is R_S. *Note that if your NSP was purchased prior to 2019, please contact the manufacturer for values.*

Pulser Model	R_S	R_P
NSP-120-5-P/N-500-L	71 Ω	5 kΩ
NSP-120-5-P/N-500-H	71 Ω	25 Ω
NSP-120-10-P/N-500-L	334 Ω	1.5 Ω
NSP-120-10-P/N-500-H	241 Ω	50 Ω
NSP-120-20-P/N-500-L	1035 Ω	4.95 kΩ
NSP-120-20-P/N-500-H	875 Ω	100 kΩ
NSP-120-30-P/N-500-L	2069 Ω	15 kΩ
NSP-120-30-P/N-500-H	1884 Ω	106 kΩ

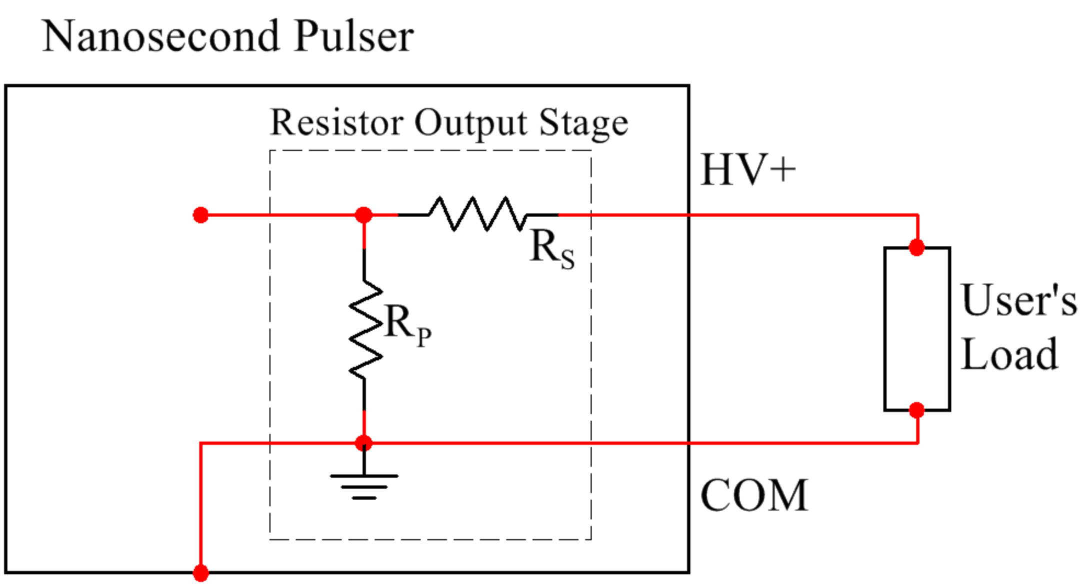


Figure 6. Resistive Output Stage for Grounded Units

4 Controls and Connectors

4.1 Front Panel

A description of the front panel controls, indicators, and connections is given below.

Figure 7. NSP-120-20-F Front Panel

1. **Power LED:** Green when AC power is switched on.

2. **HV On LED:** Red when the **HV Output** is enabled.

3. **Fault LED:** Red when the control electronics detects a fault.

4. **HV Output Switch:** When in the **Enable** position, the NSP will output high voltage pulses and the **Enable LED** and **HV On LED** will be illuminated.

5. **Mode Switch:** Switch to toggle between **Internal** and **External Mode**. The LED corresponding to the selected mode will be illuminated green.

6. **Single Pulse Button:** If the **Base Pulse Repetition Frequency Knob** is set to **Single Pulse**, this button will be illuminated red, and pressing it will fire a single pulse at the set pulse width and voltage. In other modes, this button does nothing.

7. **Pulse Width – Coarse Control:** In **Internal Mode**, this dial allows the user to adjust the output pulse width from 20 to 240 ns in increments of 20 ns, or from 50 to 500 ns in increments of 50 ns. In **External Mode**, this dial does nothing.

8. **Pulse Width – Fine Control:** In **Internal Mode**, this dial allows the user to adjust the output pulse width in increments of 2 or 5 ns. In **External Mode**, this dial does nothing.

9. **Pulse Repetition Frequency – Base Control:** In **Internal Mode**, this dial allows the user to control the base pulse repetition frequency. If the user wants to operate under the single shot mode, this knob must be dialed to **Single Pulse**. In **External Mode**, this dial does nothing.

10. **Pulse Repetition Frequency – Multiplier Control:** This dial allows the user to adjust the base pulse repetition frequency by set multiplicative factors. In **External Mode**, this dial does nothing.

11. **Voltage – Coarse Control:** This dial allows the user to adjust the output voltage in coarse increments.

12. **Voltage – Fine Control:** This dial allows the user to adjust the output voltage in fine increments.

13. **External Trigger Input (Optional):** When the **Mode Switch** is set to **External Mode**, both the pulse width and repetition frequency of the NSP is controlled by an external fiber optic input signal.

4.2 Back Panel

A description of the back panel controls, indicators, and connections is given below.

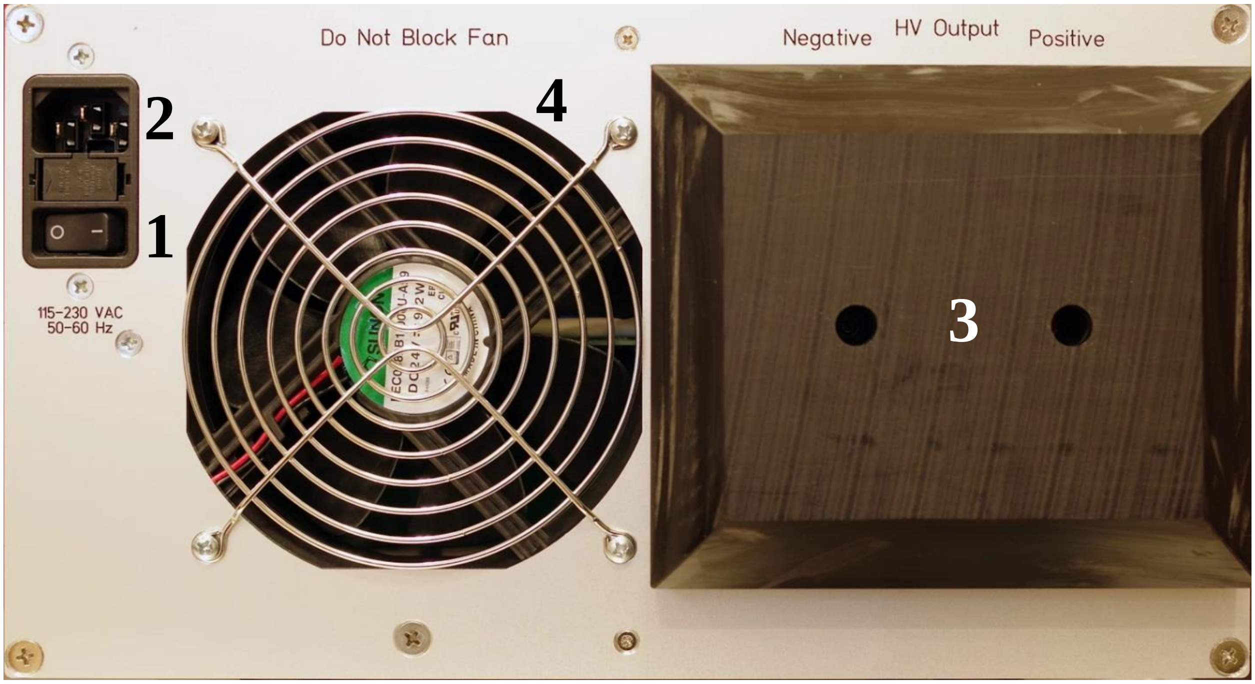


Figure 8. NSP-120-20-F Back Panel

1. **AC Switch:** Master power switch for the NSP.

2. **AC Power Receptacle:** A three prong (grounded) AC power cord should be plugged into the back panel of the NSP.

3. **HV Output Connectors:** The output load should be plugged into the positive and negative HV output terminals of the NSP using the provided positive/hot (red) and negative/ground (black) output cables. The output is at high voltage and the plastic block provides isolation.

4. **Exhaust Fan:** The exhaust fan cools the internal electronics.

5 Preparation for Use

5.1 Unpacking

Please verify that all items are present and inspect for damage during shipping.

1. EHT NSP series power supply
2. HV output cables, one red and one black
3. Standard AC power cord for the NSP
4. User’s manual

If the user ordered the option to control the NSP remotely, also find inside:

5. FT-1
6. Fiber optic cable
7. 5V adapter for FT-1

If any component is missing, contact Eagle Harbor Technologies, Inc. If the package appears to have been damaged during shipping, file a claim with the carrier. Retain the packing material for possible inspection and/or reshipment.

5.2 Operational Setup

1. Place the NSP on a bench near the load. Do not block the exhaust fan or the intake vents on the bottom side of the unit. If the exhaust fan or vents are blocked, the pulser may overheat.

2. If desired, flip up the front feet to tilt the face of the unit up.

3. Check the **AC Switch** is set to **Off (O)** and the **HV Output Switch** is set to **Disable**.

4. Plug in the AC power cord with a proper ground. It should provide AC power within the voltage/frequency range printed on the NSP back panel just below the master power switch.

5. To connect the load cables to the NSP:

    a. Loosen the two setscrews located on top of the black plastic block on the back of the NSP.
    b. The positive cable is marked in red, and the negative cable is marked in black.
    c. Insert the tip connector of the positive cable into the positive output terminal on the NSP.
    d. Insert the tip connector of the negative cable into the negative output terminal on the NSP.
    e. Check that both cables are inserted all the way into the black plastic output block until a hard stop is felt (the blue stopper rings on the cables should touch the block).
    f. Hand tighten the set screws (included) so that the cables cannot shake or move out of place.

6. Connect the load to the load cables. Always use both output connections. For floating units, the load must remain floating, *never tie either the positive or negative outputs to ground.*

6 Operation Instructions

The NSP may be operated in three different modes: Free-running, Triggered, and External. However, certain steps are common to all modes.

6.1 Turning on the NSP

1. Set **AC Switch** on the rear panel to **On**. The green **Power LED** will illuminate.

2. Select **Internal Mode** using the switch on the front panel if intended to operate in Free-running or Triggered mode. Select **External Mode** using the switch on the front panel if intended to operate in External mode. The LED for the associated mode will illuminate.

3. Set the voltage, pulse width, and pulse repetition frequency to desired values (see instructions below).

4. Set the **HV Output Switch** to **Enable**. The **HV On LED** will illuminate. In Free-Running mode, HV will now be present on the output, while in Triggered and External modes, the NSP is now ready to be remotely triggered.

5. Turn off the NSP when not in use. See instructions in section 6.2.

6.2 Turning off the NSP

The NSP should be turned off and the capacitive load returned to a safe state following use.

1. Set **HV Output Switch** to the **Disable** position. Standard HV safety protocol would also dictate setting the voltage, pulse width, and frequency knobs to their minimum settings.

2. Turn the **AC Switch** on the back panel to the **Off** position.

3. Following standard HV safety protocols, use a grounding stick to ensure that no residual energy resides at the end of the load cables of the NSP or on anything that was connected to the NSP.

6.3 Adjusting Output Voltage

The output voltage can be adjusted with the **Voltage – Coarse Control** and **Voltage – Fine Control**. Output voltage is load dependent.

The output voltage can be adjusted while the **HV Output Switch** is set to **Enable**.

1. Adjust **Voltage – Coarse Control** to the desired value.
2. Use the **Voltage – Fine Control** to fine-tune the desired value.

The total output voltage is the sum of the coarse and fine voltage settings. The nominal output voltage should be accurate to within +/- 5% of full scale. However, the repeatability of any given voltage setting should be much better. The output voltage is also load dependent and if the exact voltage is important, it should be directly measured at the load.

6.4 Free-running Mode Operation

In free running mode, the NSP will continuously output pulses as set by the pulse width, frequency, and voltage knobs on the front panel. To operate in Free-running mode, ensure that the Internal/External switch is set to “Internal”, and that the Base Pulse Repetition Frequency Knob is in any position except “Single/Trigger”.

6.4.1 Adjusting Pulse Width

Output pulse width depends on load, voltage, and temperature. The value set by the coarse and fine knobs is a nominal value, good to within 2 ns at the peak output voltage as measured into a 1 kΩ resistive load. At lower voltages, the pulses are slightly longer. If a precise pulse width must be dialed in to an exact number of nanoseconds, the user must measure the output waveform at their load. For a fixed load at a given temperature, the output pulse width will always be stable and repeatable.

The pulse width can be adjusted while the **HV Output Switch** is set to **Enable**.

1. Adjust the **Pulse Width – Coarse Control** to the desired value.
2. Use the **Pulse Width – Fine Control** to fine-tune the desired value.

The total output pulse width is the sum of the coarse and fine pulse width control settings.

6.4.2 Adjusting Pulse Repetition Frequency

The pulse repetition frequency can be adjusted with the **Pulse Repetition Frequency – Base Control** and **Pulse Repetition Frequency – Multiplier Control**.

- The output pulse repetition frequency is the product of the base pulse repetition frequency with the pulse repetition frequency multiplier.
- For example, if the base frequency is set to 2 kHz and the multiplier is set to x5, the output frequency will be 10 kHz.

The pulse repetition frequency can be adjusted while the **HV Output Switch** is set to **Enable**.

6.5 Triggered Mode Operation

Triggered mode operation allows synchronization with external systems while maintaining the pulse width settings on the front panel. Additionally, in this mode, the user can press the “Single Pulse” button to output a single pulse, useful for initial testing or setting up a new load or experiment. To operate in Triggered mode, ensure that the Internal/External Switch is set to “Internal”, and that the Base Pulse Repetition Frequency Knob is in the “Single/Trigger” position.

6.5.1 Single Pulse Button

Press the “Single Pulse” button to output a single pulse with the voltage and pulse width set on the front panel knobs.

6.5.2 Remote Trigger (Optional)

As an optional feature, the NSP can be remotely triggered. This allows for precision timing control and allows the NSP to be synchronized with other events in the user’s experiment/application. This can also be used to generate pre-defined bursts of shots, as needed by the user. In this mode, the pulse width and voltage is still set by the front panel knobs. While running in triggered mode, the user can operate up to

100 kHz. Images for droop of internal capacitor storage can be seen at the end of the document. If the user attempts to trigger the NSP at too high of a frequency, the internal control system will detect this and disable the output, lighting the “Fault” LED. To re-enable the output, cycle the “HV Output” switch off and then back on.

To provide noise immunity and safety, the external control input is fiber-optically coupled. EHT provides a fiber optic driver (FT-1) that is used to send the appropriate pulses to the NSP. See additional information about the FT-1 in section 7. Each rising edge of a signal going into the FT-1 will correspond to a single output pulse of the NSP. The width of the pulse going into the FT-1 is not relevant so long as it is longer than the minimum needed to trigger the FT-1. *EHT recommends using a pulse width in the range of 500 ns to trigger the FT-1 for Triggered Mode Operation of the NSP*.

1. Adjust the pulse width and voltage as described for Free-Running Mode, and freely trigger the NSP using an external control system or signal generator through the FT-1.

6.6 External Mode Operation (Optional)

As an optional feature, the NSP can be operated in **External Mode**, triggered by a user’s own control system or signal generator. Like the Triggered Mode, this allows for precision timing control, and allows the NSP to be synchronized with other events in the user’s experiment as well as pre-defined bursts of shots. Additionally, External Mode also allows the pulse width to be controlled remotely. This can be useful if the user has a system which requires pulse width modulation, or otherwise wants to control the pulse width remotely using their control system. The voltage is still controlled by the front panel knobs. To operate in External Mode, set the Internal/External switch to the “External” position.

External Mode operation still restricts the user to the same range of pulse widths and frequencies that are available in Free-Running Mode. Pulses that are too short will be automatically lengthened to the minimum pulse width. Pulses that are too long will be automatically shortened to the maximum pulse width. And pulses that come in at too high of a frequency will trigger a fault, shutting off the output. This fault can be reset by lowering the external input frequency and then cycling the **HV Output Switch** on the NSP front panel.

As with Triggered Mode, to provide noise immunity and safety, the external control input is fiber-optically coupled. EHT provides a fiber optic driver that is used to send the appropriate pulses to the NSP. See additional information about the FT-1 in section 7. Each rising edge of a signal going into the FT-1 will correspond to a single output pulse of the NSP.

The input pulse width given to the FT-1 does not map directly to the high voltage output pulse width, and the scaling is nonlinear. The user will need to measure their output waveform to dial in a particular pulse width. Figure 9 shows the nominal mapping between the input pulse width and the output pulse width, as measured into a resistive load.

1. Set the voltage using the front panel knobs, and freely trigger the NSP using an external control system or signal generator through the FT-1.

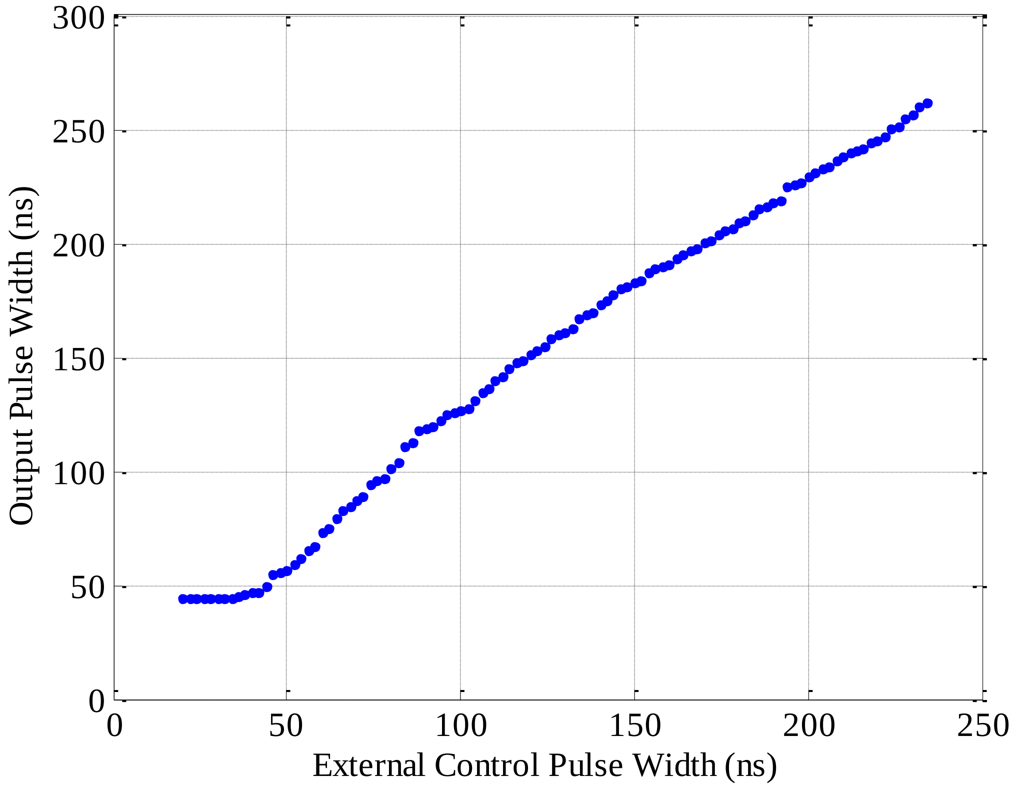


Figure 9. Input pulse width vs output pulse width for NSP-120-20-F

7 FT-1

The Fiber Transmitter FT-1 (shown in Figure 10) is used to provide signals from the user's signal generator or control system to trigger the NSP externally in Triggered or External mode.

The FT-1 is a single channel unit that has a 50 Ω terminated BNC input and a fiber optic output. The FT-1 requires a 5 V input gate signal from a source capable of driving the 50 Ω input load to 5 V. The FT-1 is powered by a 5 V/1 A power supply provided by EHT.

The input trigger signal must be a clean smooth trigger, with no overshoots or oscillations and have a rise time and fall time of less than 20 ns. Any noise spikes or oscillations on the input trigger may cause unwanted output trigger signals to be generated, leading to potential false triggering of and damage to the NSP. **Do not provide any signal to the FT-1 BNC input while the 5 V/1 A power supply is unplugged, as doing so could damage the internal electronics of the FT-1.**

The fiber optic output uses standard 2.2 mm jacketed plastic fiber. The fiber should be cut to length with a sharp razor (not wire cutters or scissors), and it should have a smooth, clean end. To connect a fiber optic cable to the Trigger Input on the NSP, loosen the black connector nut, insert the fiber all the way into the connector, then tighten the black connector nut. Make sure the fiber is fully inserted to avoid false/improper signaling. The user should feel an obvious stop as the fiber is fully inserted into the connector. Insert the other end of the fiber into the blue connector nut of the FT-1in the same fashion. Do not insert or remove fibers with AC power on. The fiber optic outputs have rise and fall times of less than 5 ns, with a jitter of less than 2 ns. The input-to-output delay is ~30 ns, plus any delay due to the length of the fiber optic cable. The FT-1 can provide output fiber gate pulses from 4 ns to DC.

More information about the FT-1 can be found at http://www.eagleharbortech.com/products-new/fiber-optic-isolators/ft-1/.

Figure 10. EHT Fiber Transmitter FT-1

8 Troubleshooting

8.1 General

Problem:
The rear panel **AC Switch** is turned to the **On (I)** position, but the fan does not turn on and none of the front panel LED indicators illuminate.

Solution:

- Ensure that the AC equipment cord included with the unit is receiving power and is firmly seated in the rear panel **AC Power Receptacle**.
- Ensure that the fuses in the rear panel **AC Power Receptacle** are intact. This can be accomplished by using two small flathead screwdrivers and pressing in the tabs on the left and right of the fuse drawer, located between the **AC Switch** and **AC Power Receptacle**.
- Otherwise, cease operation and contact Eagle Harbor Technologies immediately.

Problem:
The rear panel **AC Switch** is turned to the **On (I)** position and the front panel LED Power indicator illuminates, but the fan does not turn on.

Solution:
Cease operation and contact Eagle Harbor Technologies immediately. Operation of the unit without the cooling fan may result in catastrophic system failure.

Problem:
The voltage of the output pulse does not reach the desired/specified value.

Solution:

- Ensure that the front panel settings (if in **Internal Mode**) or the input pulse width (if in **External Mode**) are set such that the output is within the Operation Curve (see section 3.2 in this manual). If settings are such that the output exceeds the specified power rating for the unit, the voltage will collapse.
- Check the impedance ratio of the load impedance to output impedance (1 kΩ), as this will cause voltage division. For example, a 1 kΩ resistive load on the output of the supply will develop half of the output voltage due to this voltage division.
- If the pulse width is set to a short value, lengthen the pulse width. If this increases the voltage, this suggests the rise time inherent to the attached load is long and requires a longer output pulse to reach full voltage.

Problem:
Plasma discharge (DBD or arc) does not occur.

Solution:

- Measure the output voltage or current.
- If the output is shorted, no voltage will develop across the load, but the current will display a flattop current (~27 A at the full 20 kV front panel setting in the case of an NSP-120-20-N, for example) as dictated by the output impedance of the unit (745 Ω).
- If the output capacitance is too high, the pulse width may not be long enough to establish the voltage across the load. Increase the output pulse width.
- If the voltage waveform across the load is a clean flattop across the load and there is zero current during the flattop portion of the voltage trace, then the voltage is not high enough to break down the DBD/Arc at the current settings. Increase the supply output voltage.

8.2 Internal Mode

Problem:
The rear panel **AC Switch** is in the **On (I)** position and the front panel **HV Output Switch** in the **Enable** position, but there is no output pulse.

Solution:

- Ensure that the front panel Mode Switch is set to Internal Mode.
- If the Fault LED is illuminated, proceed with the Power Cycle Steps listed in section 8.4.
- If the Fault LED is not illuminated:
    - If the HV Output Switch was set to Enable when the rear panel AC Switch is switch to the On (I) position, cycle the HV Output Switch. If the unit receives AC power while the HV Output Switch is set to Enable, or if the HV Output Switch is turned to Enable too soon after the unit receives AC power, the HV output will be disabled as a safety precaution.
    - Ensure all knobs are in the intended positions.
    - Proceed with the Power Cycle Steps listed in section 8.4.

8.3 External Mode

Problem:
The rear panel **AC Switch** is in the **On (I)** position and the front panel **HV Output Switch** in the **Enable** position, but there is no output pulse despite a verified input pulse.

Solution:

- Ensure that the front panel **Mode Switch** is set to **External**.
- If the **Fault LED** is illuminated, then the unit has likely received an input pulse signal with a frequency higher than the maximum output frequency. Turn the **HV Output Switch** to **Disable** and ensure that the input frequency is less than the maximum output frequency.
- Ensure that the fiber optic cable is properly seated in the output of the FT-1 and in the external input of the NSP. See section 7 for more details.

Problem:
The rear panel **AC Switch** in the **On (I)** position and the front panel **HV Output Switch** in the **Enable** position, but the pulse width will not shorten as the input pulse width is reduced.

Solution:

- Ensure that the front panel **Mode Switch** is set to **External**.
- This is the minimum pulse width achievable by the unit, and internal protections have limited the output pulse to the value measured.

Problem:
The rear panel **AC Switch** in the **On (I)** position and the front panel **HV Output** switch in the **Enable** position, but the output pulse width will not lengthen as the input pulse width is lengthened.

Solution:

- Ensure that the front panel **Mode Switch** is set to **External Mode**.
- This is the maximum pulse width achievable by the unit, and internal protections have limited the output pulse to the value measured.
- Ensure that the fiber-optic output is illuminated with a faint red glow with the 5 VDC input is connected. If the unit emits a bright red glow with the input BNC disconnected, the FT-1 is damaged. Contact Eagle Harbor Technologies.
- Using the BNC input, send a 1-second on pulse to the FT-1 at 0.5 Hz, and visually ensure that the fiber optic output of the FT-1 turns oscillates from bright to dim at this frequency.
- Verify that the signal generator driving the FT-1 is outputting a clean signal. Connect the output of the signal generator across a 50 Ω resistor. Using an appropriate voltage, verify that the output voltage of the signal generator into this load is a clean square wave pulse with a flattop voltage of 5 V.

8.4 Power Cycle Steps

1. Ensure that the front panel **HV Output Switch** is in the **Disable** position.

2. Set the rear panel **AC Switch** to **Off (O)**.

3. Wait for approximately 30 seconds to allow internal capacitance to drain.

4. Set the rear panel **AC Switch** to **On (I)**.

5. If problem persists, conduct a Unit Functionality Test.

8.5 Unit Functionality Test

1. Ensure the front panel **HV Output Switch** is in the **Disable** position.

2. Ensure that the rear panel **AC Switch** is in the **Off (O)** position.

3. Using the provided HV output leads, ensure that they are well seated into the appropriate rear output ports and connect a verified resistive load between 2-4 kΩ.

4. Attach a differential voltage probe or current probe across this load to measure the load waveform, using a voltage divider if necessary. Ensure that the oscilloscope to which the probe is connected is both functional and that all settings required for measurement are at the appropriate levels. This includes the trigger level of the scope, which should be set to a level low enough such that the oscilloscope is triggered by the shot. In estimating this level, take into account the voltage division created by the 1 kΩ output resistance of the supply as well as any voltage divider used to make this measurement.

5. Using the front panel **Mode Switch**, put the unit in **Internal Mode**.

6. Turn the front panel knobs to the following settings:
   - **Pulse Width – Coarse**: 100 ns
   - **Pulse Width – Fine**: 10 ns
   - **Pulse Repetition Frequency – Base**: Single Shot
   - **Pulse Repetition Frequency – Multiplier**: 1x
   - **Voltage – Coarse**: Third position
   - **Voltage – Fine**: Fifth position

7. Using the rear panel **AC Switch**, turn the unit to the **On (I)** position, and ensure the fan turns on and the front panel **Power LED** illuminates. If the **Power LED** does not illuminate, contact Eagle Harbor Technologies. If the **HV On LED** or the **Fault LED** illuminates at this point, contact Eagle Harbor Technologies.

8. After having waited at least 2 seconds after turning on the rear panel **AC Switch**, turn the **HV Output Switch** to **Enable**, and ensure that the **HV On LED** illuminates. If it does not, contact Eagle Harbor Technologies.

9. Press the **Single Pulse Button**, and monitor the oscilloscope for an output pulse measurement.

10. If no output pulse is detected, turn the **Pulse Repetition Frequency – Base** knob to 2 Hz. If an output pulse is detected in this mode (every 0.5 seconds), but was not detected when set to **Single Pulse**, contact Eagle Harbor Technologies.

11. If no output pulse is detected, turn the **HV Output Switch** to **Off**, then turn the rear panel **AC Switch** to **Off (O)**. Ensure that all testing equipment (probes and oscilloscope) are set up correctly, and repeat steps 5-10. If no output pulse is detected after verifying measurement equipment, call Eagle Harbor Technologies for further support.

9 Appendix

For a detailed explanation of measuring fast high voltage pulses, see the *Nanosecond Pulse Measurement White Paper* at http://www.eagleharbortech.com/support. The following waveforms from the NSP were measured using:

- An isolated/floating Tektronix DPO 2024 Digital Phosphor Oscilloscope
- Pearson Current Monitor 6585 with 50 Ω terminator – 0.5 V/A
- Tektronix THDP0100 High Voltage Differential Probe, or
- Tektronix P6015A High Voltage Probe

Oscilloscope traces showing typical output waveforms of the NSP are shown below.

9.1 Internal Voltage Divider Waveforms

In this example, the High Voltage Differential Probe was connected across the middle resistor of R_p (voltage division ratio 1:4.5, not user accessible) with a high impedance load. In the next section, this will be compared to a capacitive voltage divider output. These traces illustrate the output waveforms that a user can expect to see when driving high impedance loads.

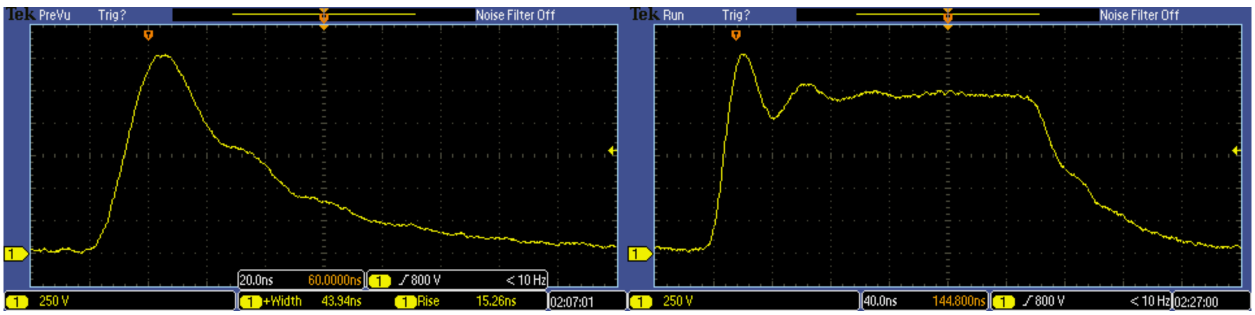


Figure 11. Minimum (left) and maximum pulse widths at 5 kV.

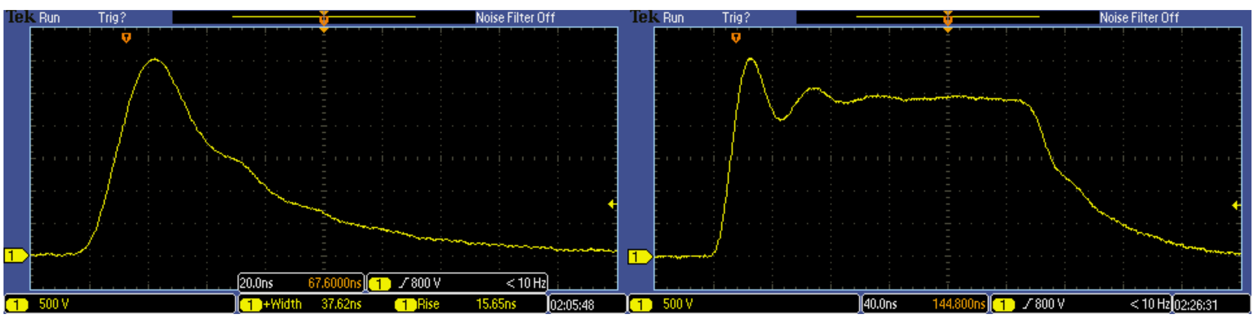


Figure 12. Minimum (left) and maximum pulse widths at 10 kV.

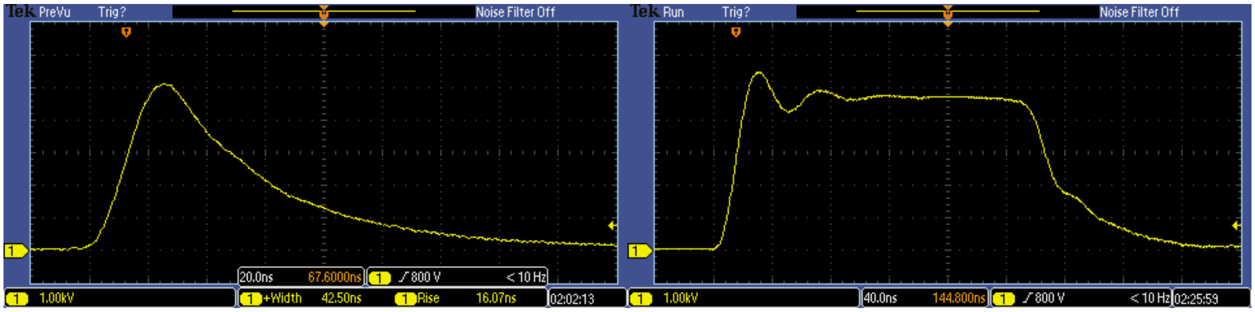


Figure 13. Minimum (left) and maximum pulse widths at 20 kV.

9.2 Capacitive Voltage Divider Waveforms

The user can measure the full voltage output using a capacitive voltage divider. The waveform below shows that measuring the output voltage with a capacitive voltage divider with a small total capacitance (1 pF) produces similar results as using the internal R_p (not user accessible).

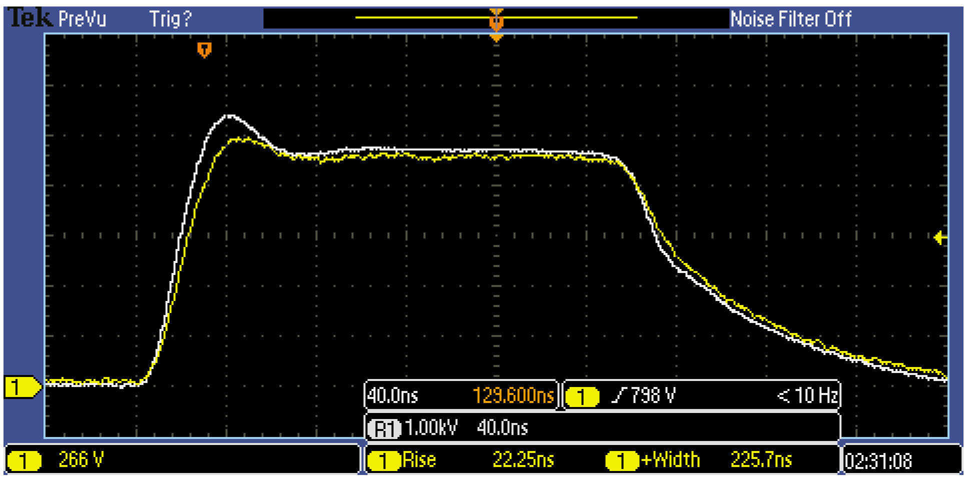


Figure 14. Comparison of internal voltage divider (white) with 1 pF capacitive voltage divider (yellow).

9.3 Dielectric Barrier Discharge Waveform

The NSP can be used to drive a dielectric barrier discharge (DBD). The voltage and current driving a DBD can be measured using the 1 pF voltage divider and fast current monitor. The DBD had a capacitance of 8 pF. The current profile (green) shows the current flowing into the DBD as the capacitance is charged. The voltage stays constant and the current near zero until the DBD is discharged at which point the current is negative.

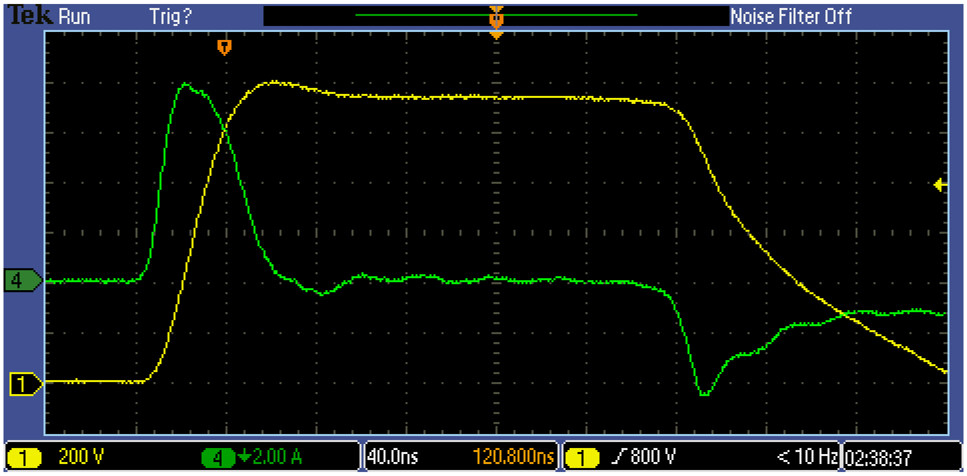


Figure 15. Load voltage (yellow) and current (green) for an 8 pF DBD and a 1 pF voltage divider.

A similar waveform at a shorter pulse width for a larger, 35 pF DBD is shown below:

Figure 16. Load voltage (yellow) and current (blue) for a 35 pF DBD with a 5 kΩ voltage divider.

9.4 Arc Waveforms

The NSP can be used to drive and turn off arcs. Using the 1 pF voltage divider and current monitor, the load voltage and current can be measured. This waveform shows the voltage reaching a peak before the discharge occurs and current begins to flow. Once current starts flowing, the voltage across the electrodes collapses and the current is constant for the duration of the pulse.

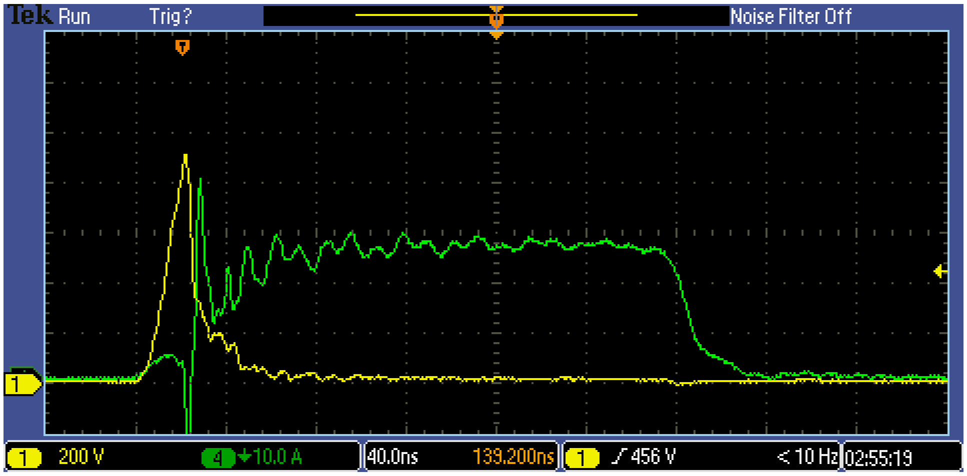


Figure 17. Load voltage (yellow) and current (green) for an arc and a 1 pF voltage divider.

9.5 NSP-120-30-N-500 Output Waveforms

Waveforms specific to this unit. Unless otherwise specified, all shots were taken at full voltage and with 6" output cables unless otherwise specified. This unit has recently undergone a redesign and these waveforms are no longer accurate.

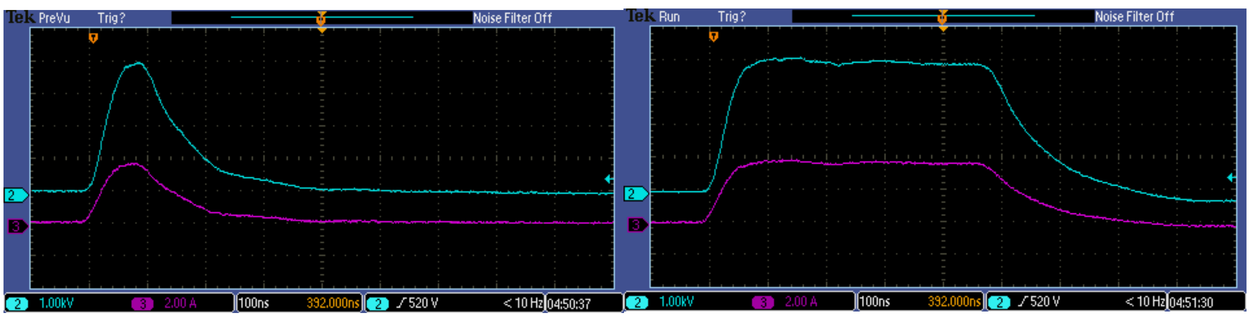


Figure 18. Voltage (blue) and current (purple) for minimum (left) and maximum pulse widths across a 2.5 kΩ 1:9 resistive voltage divider.

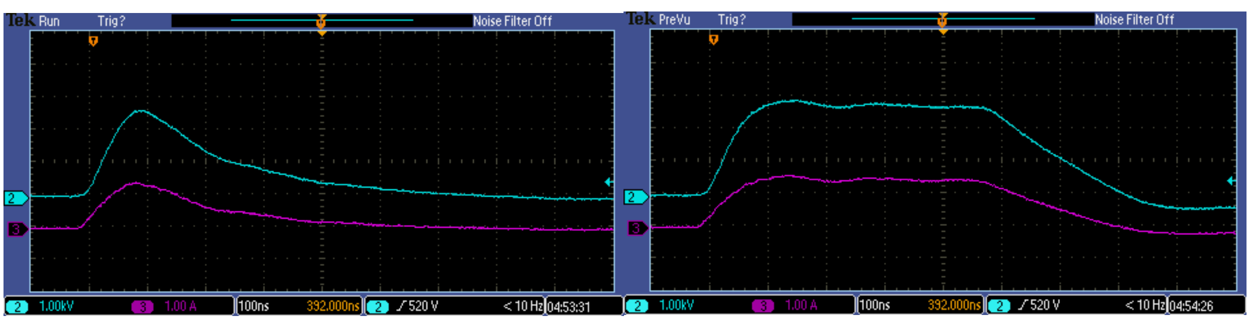


Figure 19. Voltage (blue) and current (purple) for minimum (left) and maximum pulse widths across a 10 kΩ 1:9 resistive voltage divider.

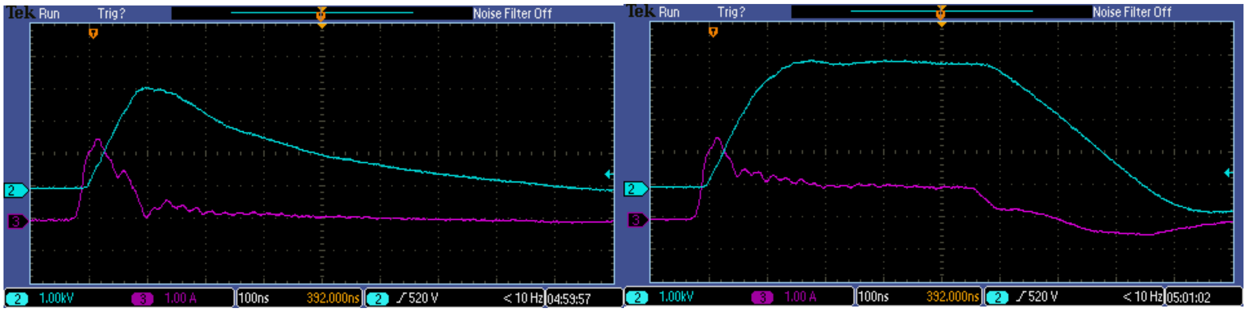


Figure 20. Voltage (blue) and current (purple) for minimum (left) and maximum pulse widths across a 10 pF 1:9 capacitive voltage divider.

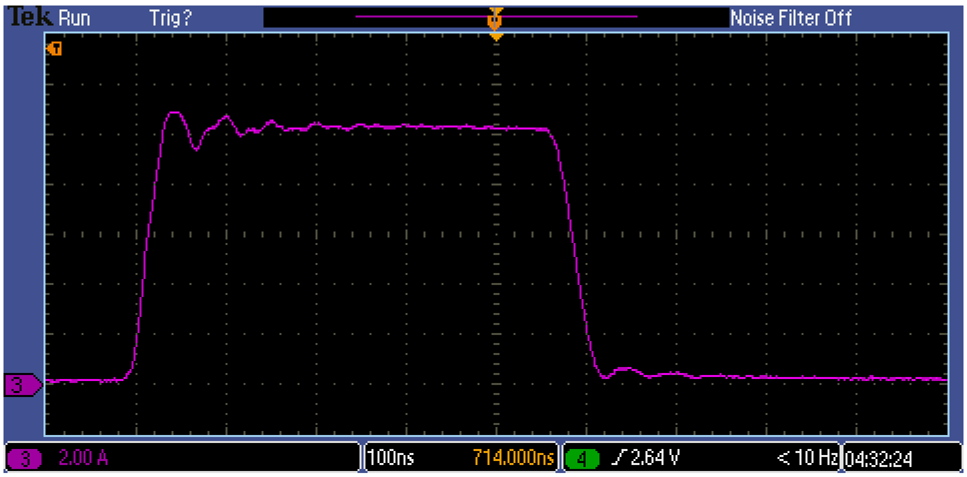


Figure 21. Maximum pulse width on a shorted output, demonstrating the maximum dI/dt and current for the unit (1.1 A/ns up to a 34 A peak with a flat-top of approximately 30 A). Please note that the vertical scale reported by the oscilloscope is incorrect.

9.6 NSP-120-20-P-500 Output Waveforms

Waveforms specific to this unit. Unless otherwise specified, all shots were taken at full voltage and with 6" output cables unless otherwise specified. This unit has recently undergone a redesign and these waveforms are no longer accurate.

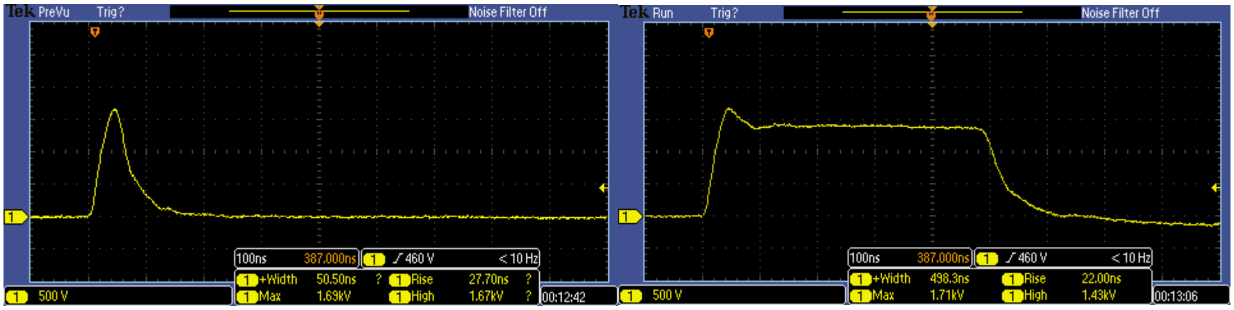


Figure 22. Minimum (left) and maximum pulse width voltage across a 1 kΩ 1:9 resistive voltage divider.

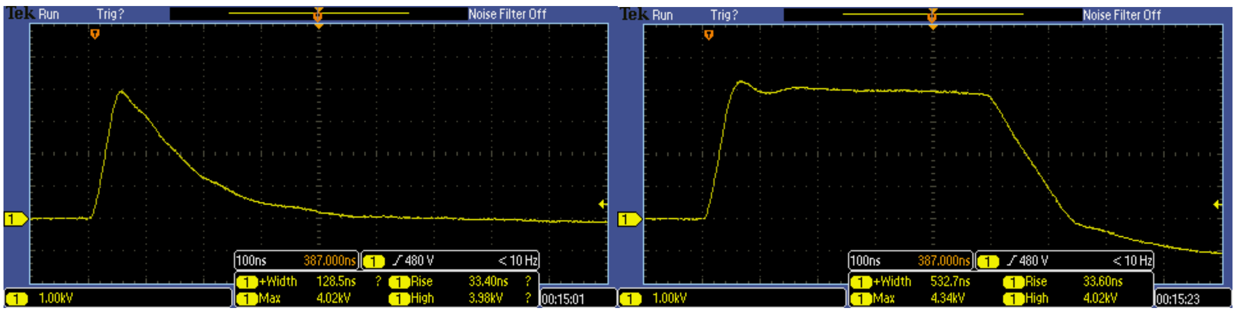


Figure 23. Minimum (left) and maximum pulse width voltage across a 10 kΩ 1:5 resistive voltage divider.

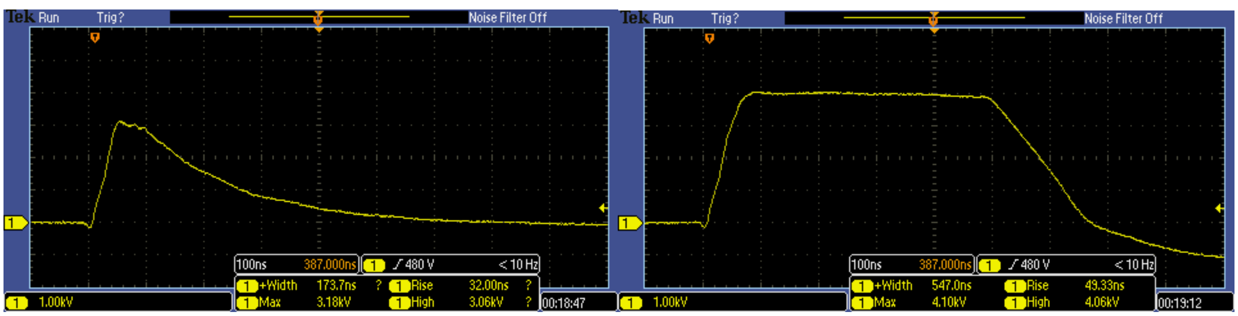


Figure 24. Minimum (left) and maximum pulse width voltage across a 10 pF 1:5 capacitive voltage divider.

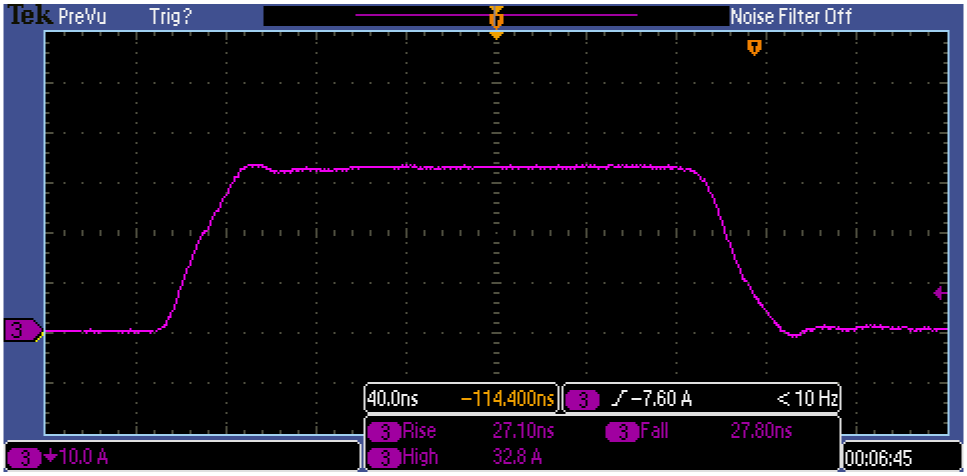


Figure 25. Maximum pulse width on a shorted output, demonstrating the maximum dI/dt and current for the unit (1.2 A/ns up to a flat-top of approximately 33 A).

10 User Notes