

# High Voltage Nanosecond Pulser Operating at 30 kW and 400 kHz

M. Quinley \*, T. M. Ziemba; K. E. Miller; J. R. Prager; I. Slobodov  
\* morgan@eagleharbortech.com

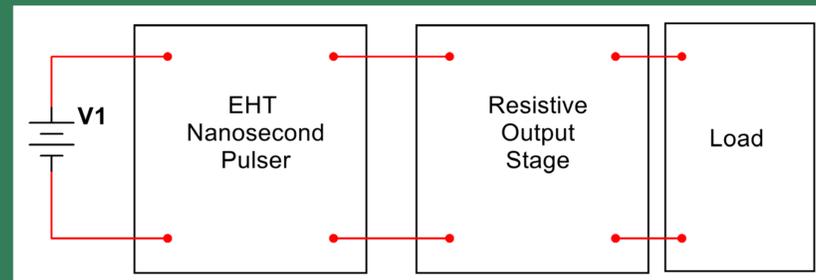
## EAGLE HARBOR TECHNOLOGIES

### Introduction

The generation of high voltage nanosecond pulses at high average power is important for a variety of industrial applications including water treatment, semiconductor processing, materials processing, and sterilization. Eagle Harbor Technologies, Inc. (EHT) has previously developed high voltage nanosecond pulsers that operate at 5 kW of average power and pulse at 100 kHz. This work has been extended to an average power of 30 kW. This new nanosecond pulser can drive capacitive loads to 10 kV: up to 850 pF at 400 kHz and up to 3.5 nF at 100 kHz. Typical rise times are 55 ns and pulse widths are up to 200 ns. The system can produce pulses continuously or in bursts with higher peak power. The output voltage can be modulated between 500 V and 10 kV on the load's RC timescale. This system can be air or water cooled.

### Typical NSP Operation Into Various Loads

The output voltage of the system can be modulated using pulse width, limited only by the characteristic RC time of the load.



EHT Nanosecond Pulser with DC charging supply, resistive output stage, and load.

### 30 kV Arbitrary Pulse Generator (APG)

EHT pulse generators can drive capacitive loads with longer pulses than the Nanosecond Pulsers. These units have been used to produce low-temperature plasma by driving dielectric barrier discharges for biomedical applications. They also can be used to produce pulsed electric fields for agricultural and food processing applications.



The APG family has the following specs:

- Charge Voltage: 0 – 600 V
- Output Voltage: 0 – 30 kV
- PRF: 1 kHz at 20  $\mu$ s pulse width
- Pulse Width: 1  $\mu$ s – 10 ms
- Shot Frequency: Continuous
- Control: External Gated Mode
- Short Tolerant: Up to 3 seconds
- Average Power: 5 kW
- Peak Power: up to 1 MW

### EHT Nanosecond Pulser System

EHT has a product line of versatile high-power, high-voltage nanosecond pulsers with independently adjustable output voltage and pulse repetition frequency for driving capacitive loads. Multiple pulsers can be used in parallel for increased power and pulse repetition frequency. The addition of a resistive output stage provides fast fall times while minimizing wasted power.



5 kW NSP with ROS

EHT has produced 15 kW systems measuring 4.5 feet tall (29 U rack) and 30 kW systems measuring 6.3 feet tall (43 U rack). EHT is currently developing water-cooled systems, which allow for up to 70% reduction in system size for a given power.

EHT is currently developing a 25 kV, 5 kW pulser for water treatment and combustion applications. This version will have fixed pulse width, but allow higher voltage operation at high frequency

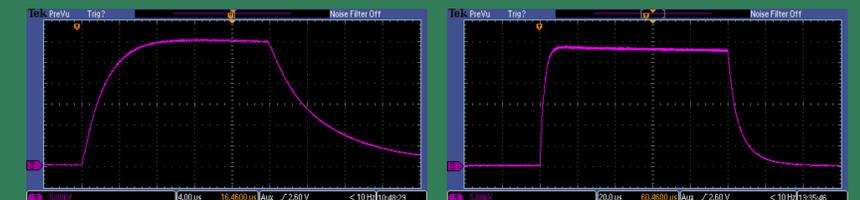
Typical parameters are:

- Maximum output voltage: 10 - 20 kV
- Maximum pulse repetition frequency: 100 - 400 kHz
- Maximum power: 5 - 30 kW
- Maximum pulse width: ~ 500 ns (voltage and load dependent)
- Rise time: 20 - 100 ns (load dependent)

### Capacitive Load

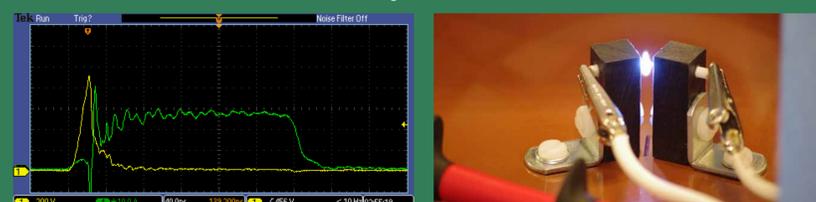


Left: The voltage (green) and current (blue) waveforms into 1 nF load from a 10 kV pulse with 100 ns rise time. Right: The waveform shows 9 kV pulses with 40 ns rise time repeating at 400 kHz into a 600 pF load.

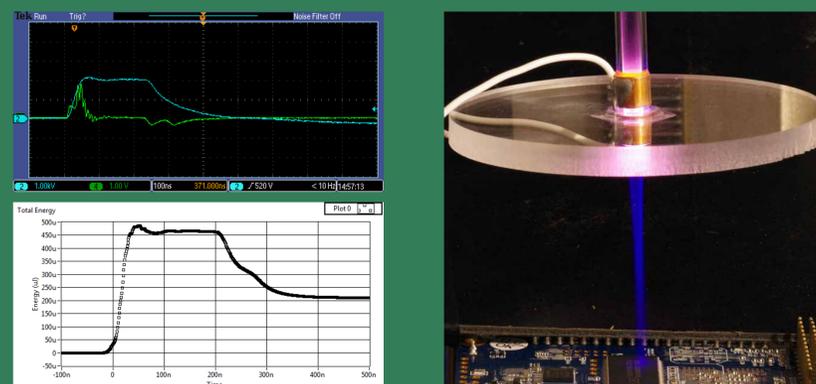


APG 30 kV output voltage across 20 pF load at the end of a three-foot cable with 20  $\mu$ s (left) and 100  $\mu$ s (right).

### Plasma Loads: Arc and DBD jet



Left: Arc waveform. Voltage (yellow) and current (green). Right: arc photo.



Top: Current (green) and voltage (blue) waveforms. Bottom: Energy per pulse.

### Conclusion

EHT has developed versatile high voltage nanosecond pulsers that have been used for development of medical devices, water treatment, sterilization processes, in-situ fertilizer production, and many other applications. EHT nanosecond pulsers can be parallelized to achieve average power of up to 30 kW and pulse frequency of up to 400 kHz for industrial plasma applications. The output voltage can be modulated using pulse width from 500 V to 10 kV.

These modular pulsers allow the user to investigate a wide range of pulse parameters and tailor the pulse waveform to the specific application. Their high peak power (hundreds of MW) and short pulse widths (up to 150 ns) allow for high process duty ratio in industrial plasma applications.

For more info: <http://www.eagleharbortech.com/>