Adjustable, High Voltage Pulse Generator with Isolated Output for Plasma Processing

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Introduction
Eagle Harbor Technologies (EHT), Inc. has developed a high voltage pulse generator with isolated output foretch, sputtering, and ion implantation applications within the materials science and semiconductor processing communities. The output parameters are independently user adjustable: output voltage (0 – 2.5 kV), pulse repetition frequency (0 – 100 kHz), and duty cycle (0 – 100%). The pulse generator is capable of very high current switching (> 3 kA) into resistive loads at switching frequencies of 1 MHz under pulsed conditions. The pulse generator has been tested at lower current levels and switching frequencies and demonstrated average output levels in excess of 5 kW at continuous operation. The wide range of switching conditions and power levels allows the same system to be utilized for multiple applications as demonstrate below.

Motivation
There is a need both the experimental scientific and industrial communities for an arbitrary power supply system which can be configured to drive a wide range of loads for various applications. Power supply efficiency is a critical parameter for both high peak power (> 1 MW) and high average power systems (> 10 kW). There is also a need to increase system switching frequency to provide shorter output pulse widths or to drive higher frequency resonant loads at high power. To meet these needs EHT surveyed commercially available SiC MOSFETS and IGBTs and selected devices for in house testing based on maximizing switching and conduction efficiency at the highest possible current per device. The goals of this testing were to investigate if the EHT gate drive technology would improve SiC MOSFET switching, measure the overall switch efficiency, and determine the maximum current per device. After device selection both moderate and high power switch modules were made to investigate system capabilities.

Pulser Output into Resistive Load
EHT has conducted full-bridge testing into a variety of low-inductance resistive loads to demonstrate high power switching at high peak power levels. The new pulser system is capable of very high current switching (> 3 kA) into resistive loads at switching frequencies of 1 MHz under pulsed conditions. The pulser has been tested at lower current levels and switching frequencies and demonstrated average output levels in excess of 5 kW at continuous operation. The wide range of switching conditions and power levels allows the same system to be utilized for multiple applications as demonstrate below.

Full-Bridge Testing with Series Resonant Tank Circuit
EHT tested the ability of the full-bridge to drive a series resonant tank circuit at two resonant frequencies. During the high frequency test, the full-bridge achieved a peak-to-peak current of 5.4 kA. The 1 MHz switching test achieved 1 kA through the resonant load. The limitation of both tests was the voltage rating of the series resonant capacitor. The both tests demonstrated capability for precision magnetic control with fast PWM.

Conclusions
EHT has developed a high voltage, isolated pulser product series (APG Series) capable producing arbitrary square wave pulses for driving resistive, inductive, tank circuit, and plasma loads with the following characteristics:

- Floating (galvanic isolated) output that can be biased with respect to other systems
- Pulse repetition frequency DC - 100 kHz
- Duty cycle can be varied in real-time from 0 to 100%
- Clean square wave with 20 to 200 ns rise/fall time (load dependent)
- Front panel control with remote interface options
- Output voltage (adjustable) up to 10 kV (load and application dependent)
- Average Power levels: 0.1, 0.5, 1.0, 5.0 kW
- Peak Power levels: > 1 MW

These pulser can be used in research areas including plasma science linear particle accelerator supplies, high voltage ion implantation supplies, and RF cyclotron power supplies. This system enables new capabilities for etch, ion implantation, and sputtering applications for the materials science and semiconductor processing communities.

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