An IGBT-Based High Voltage, Variable Pulse Width Nanosecond Pulser for Plasma Creation Applications

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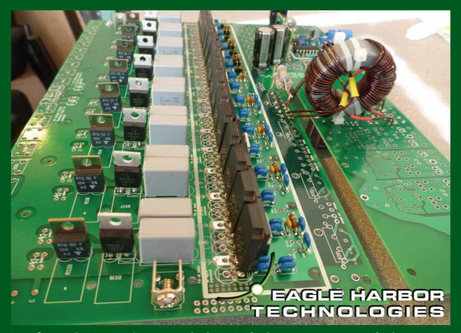
Abstract:

Eagle Harbor Technologies (EHT) has developed a modular solid state power supply based on IGBT technology which can support a wide array of applications. The EHT Integrated Power Module (IPM) incorporates fast gate drive technology, high voltage isolation (~ 30 kV), fiber optic control, and optional crowbar diodes into a single unit. The EHT IPM can be configured to produce variable pulsed width (20 to 1000 ns), high voltage (> 20 kV) high repetition frequency (2 MHz) nanosecond pulser. Nanosecond pulser applications include plasma creation for drag reduction, medical applications, water decontamination, fuel mixing and control of flue gas emissions.

The Integrated Power Module (IPM-16P):

Integrated Power Module Specifications:

- 1000 V, 600 A Continuous (Requires Heat Sinking)
- 1000 V, 100 A @ 1 MHz Switching (Continuous)
- 1000 V, 5000 A Pulsed (< 10 ms)
- 1000 V, 10 kA Pulsed (< 1 ms)
- Ultra Fast Rise/Fall time < 40 ns
- Fiber Optic Control/Isolation
- Requires Only 48 V DC Power Input
- Very High Voltage Isolation (25 kV)
- Robustly Demonstrated in Series and Parallel for a Wide Range of Applications



Left: IGBT-16P module. Right Upper: High current connectors. Right Lower: 2U Rack Mountable Module: 8" x 11" x 2.5"

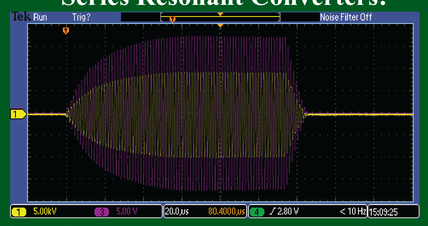
Other IGBT Integrated Power Module Applications:

PWM Magnet Controller:

100 kHz Pulsed Width Modulated (PWM)

- Total current: 40 kA (2.5 kA/IPM)
- Operation time: 10 ms.
- Single modules were tested in excess of 5 kA for 10 ms operation

Series Resonant Converters:

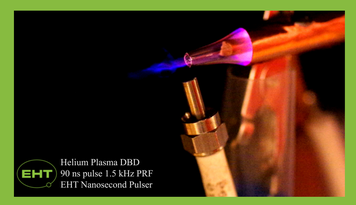


Specifications

- Q > 50
- 1 MHz Switching
- 3 kA (pk-pk) in antenna
- 28 kV (pk-pk) across antenna
- P_{peak} = 21 MW

EHT Nanosecond Pulser:

20 to 500 ns variable pulse width. (Longer Pulses ~ 1-10 µs are possible)
Single pulse to 20 kHz operation. (High PRF are also possible)
0-35 kV adjustable output voltage.
Continuous operation (~ 0.5 to 1 kW average power) limited by internal DC power supply.
6U package size (12" x 17" x 22"), Approx. 40 lb.
Designed for medical applications using dielectric barrier discharge



HV Nanosecond Pulsing with Variable Pulse Width:

- Single IPM utilized with custom 20:1 step-up transformer.
- No saturated magnetics used in the circuit.
- Voltage slew rates in excess of 400 kV/µs.
- Peak power levels of over 4 MW have been demonstrated.
- Pulse widths from 20 to 400 ns have been demonstrated with current prototype. Longer pulse lengths possible with new pulsed transformer.
- Shorter pulse width below 20 ns are possible by including standard magnetic reactor and/or diode pulse sharpening techniques.
- Applications include medical devices, aerodynamic drag reduction, laser drivers, materials processing, environmental, efficient combustion, pulsed plasmas, radars systems and high power microwave production.

12.5 kV, 20 ns (FWHM) pulse into 200 Ω load.

20 kV, 50 ns (FWHM) pulse into 1000 Ω load.

20 kV, 300 ns (FWHM) pulse into 1000 Ω load.

Nanosecond Pulses for Dielectric Barrier Discharge Plasmas

The EP Tech electrode under test with nanosecond pulser.

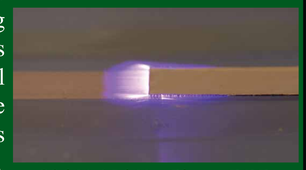
20 kV, 100 Hz Operation

20 kV, 10 kHz Operation

Dielectric Barrier Discharges (DBD) have many applications. EHT has been working with both NASA and EP Technologies on utilizing the nanosecond pulser to produce DBD and optimize the produced atmospheric plasmas. For the NASA applications DBD have been studied as a way to reduce the skin friction drag on aircraft. EP Technologies has developed a novel electrode system and are conducting research into its use for medical applications.

EHT Logo DBD, 20 kV, 5 kHz

~ 1m Long Cylindrical DBD



20 kV, 15 kHz, Planar DBD

High Pulse Repetition Frequency at Variable Pulse Widths:

- All solid state design without the use of magnetic reactor pulse forming networks all for greater pulse repetition frequencies.
- Repetition frequencies in excess of several MHz have been demonstrated.
- Pulse characteristics, including pulse width and duty cycle, are variable and controlled even within a burst of pulses.
- System can obtain high repetition frequencies in excess of several megahertz.
- The ability to vary pulse width brings new capabilities. Previously avaiable nanosecond pulsers have either fixed pulse width or limited repetition frequency.

20 kHz Pulse Repetition Frequency, 40 ns Pulse Width, 12.5 kV.

100 kHz Pulse Repetition Frequency, 40 ns Pulse Width, 12.5 kV.

20 kHz, 20 kV 60 ns PW into 200 Ohms from Nanosecond Pulser pictured above.

1 MHz Pulse Repetition Frequency, 40 ns Pulse Width, 12.5 kV.

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