

An IGBT Integrated Power Module for Configurable Series/Parallel Operation at High Power and Frequency

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EAGLE HARBOR TECHNOLOGIES

Abstract:

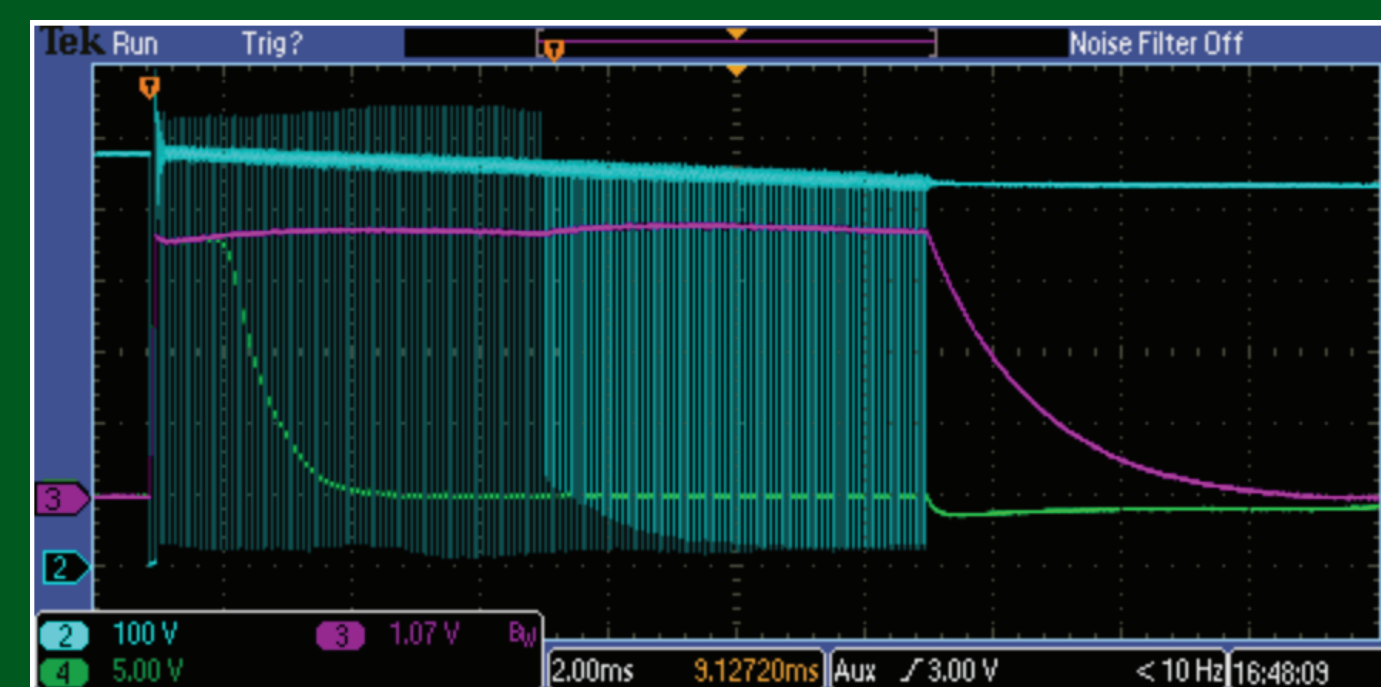
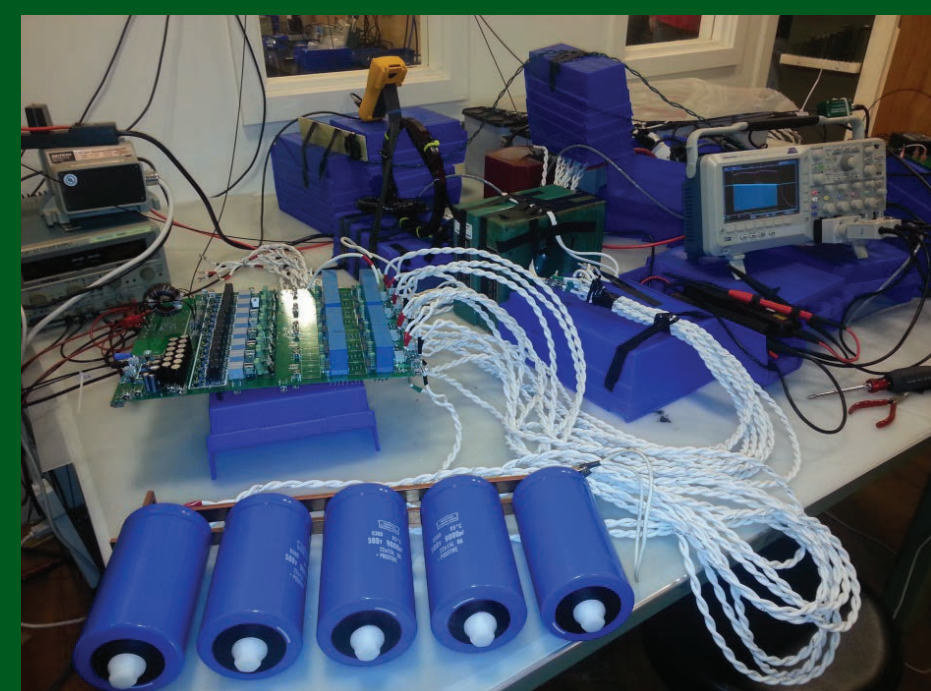
Eagle Harbor Technologies (EHT) has developed a modular, solid-state power supply based on IGBT technology, which can support a wide array of applications. The EHT Integrated Power Module (IPM) incorporates fast gate drive technology, high voltage isolation (~30 kV), fiber optic control, and optional crowbar diodes into a single unit. Modules are designed for pulsed/burst operation at frequencies up to 2 MHz. For a 10 ms 100 kHz pulse width modulated (PWM) burst, the modules have a nominal 1 kV at 2.5 kA output. Currents up to 10 kA can be switched for shorter periods. The modules can be stacked in series and/or parallel arrangements as needed to obtain higher voltages and currents. The EHT IPM utilizes off-the-shelf IGBTs that reduce cost while allowing a great deal of flexibility for output voltage, current, switching frequency and efficiency by simply choosing the correct IGBTs for the desired application.

Examples of power supplies using the EHT IPM include a fast rise time (< 100 ns) electron gun driver with a 10 kV at 1 kA output, a 1 MHz series resonant inverter with a 20 kV at 2 kA peak output, and a 100 kHz PWM magnet driver with a 500 V at 40 kA output. The ability of the IPM to provide fast PWM control with switching speeds up to 2 MHz allows for novel solutions for pulsed power applications, including significantly reduce inductor and transformer size and cost. Examples of the EHT IPM applications and testing data will be presented.

PWM Waveforms:

16 Boards in Parallel- Inductive Load:

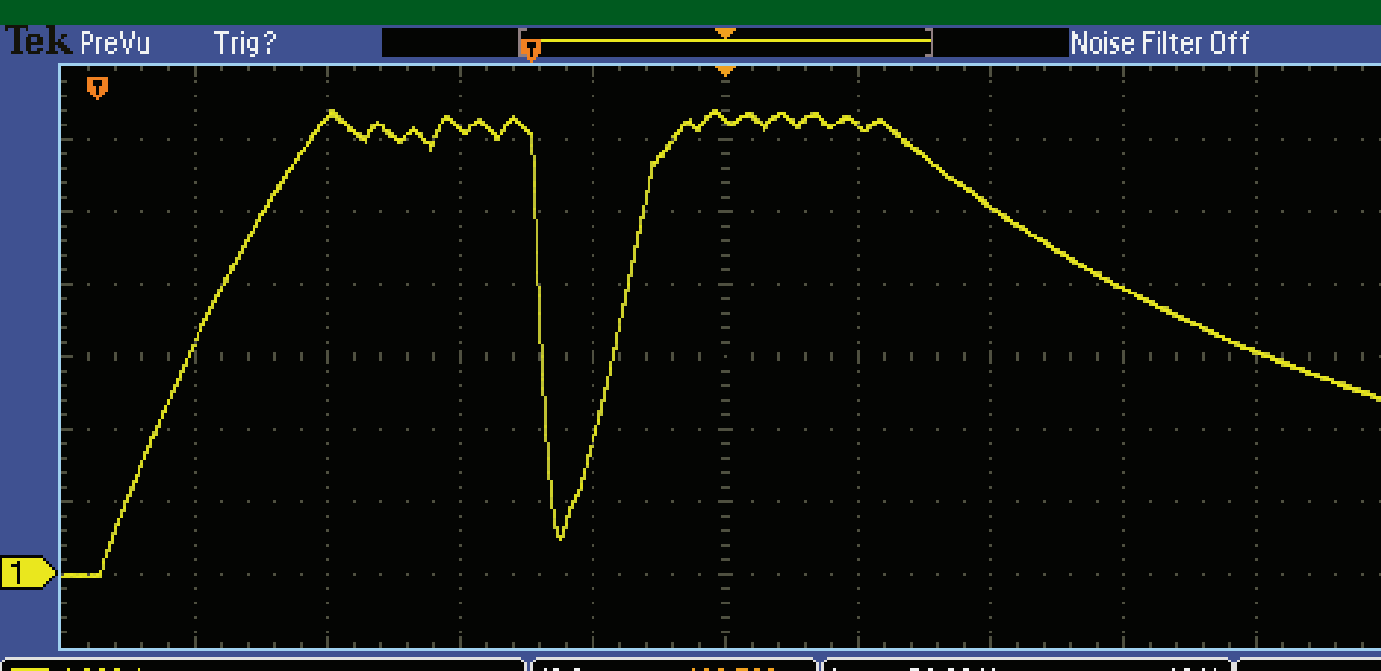
- 100 kHz PWM
- Total current: 40 kA (2.5 kA/IPM)
- Operation time: 10 ms.
- Single modules were tested in excess of 5 kA for 10 ms operation.
- Delivered to prime contractor



Purple: Current, measured by droop-free integrator
Green: Current transformer signal

Supply for Fast Magnetic Field Reduction and Reestablishment:

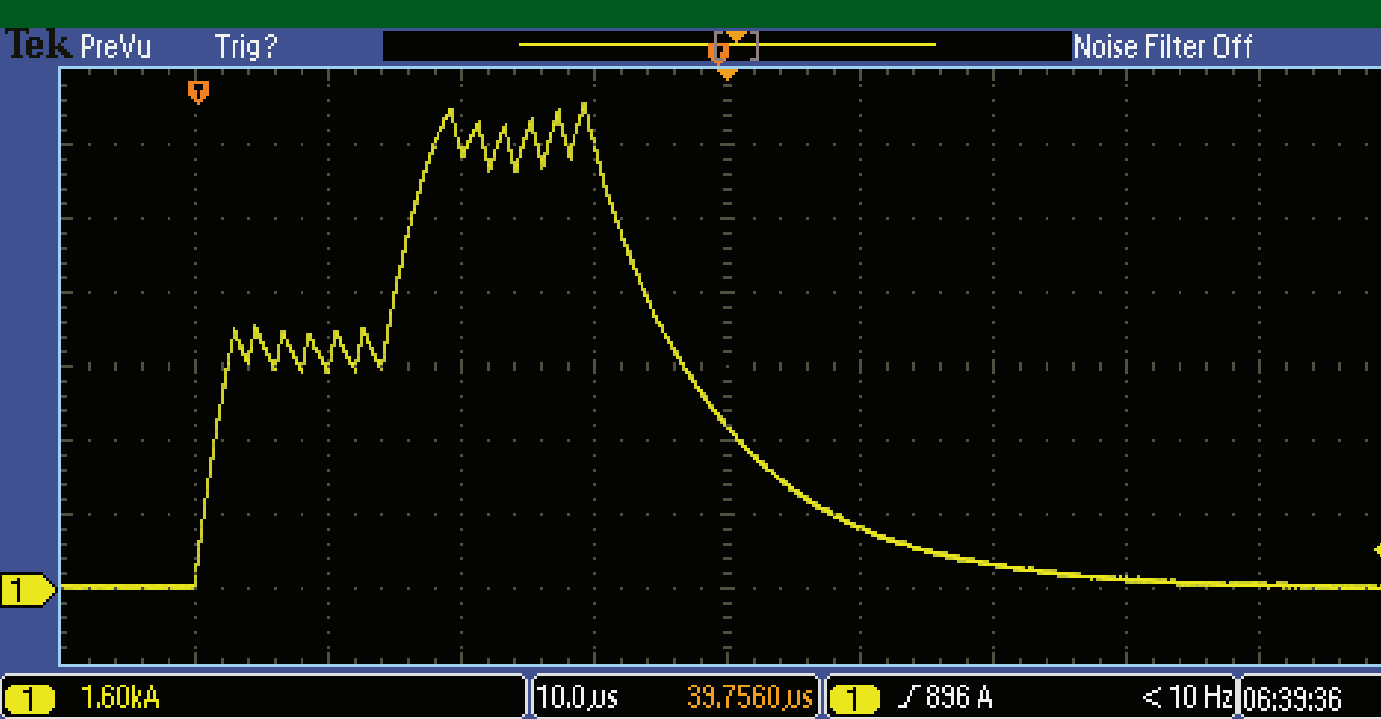
- 100 kHz PWM
- Peak current: 5 kA
- One module for PWM control and a second for the Notch switch.
- The Notch rise/fall times are independently controlled.



Output current waveform.

Double Step, High Current Supply:

- 500 kHz PWM
- Peak current: 10 kA
- Maximum current and pulse frequency can be increased with additional modules.

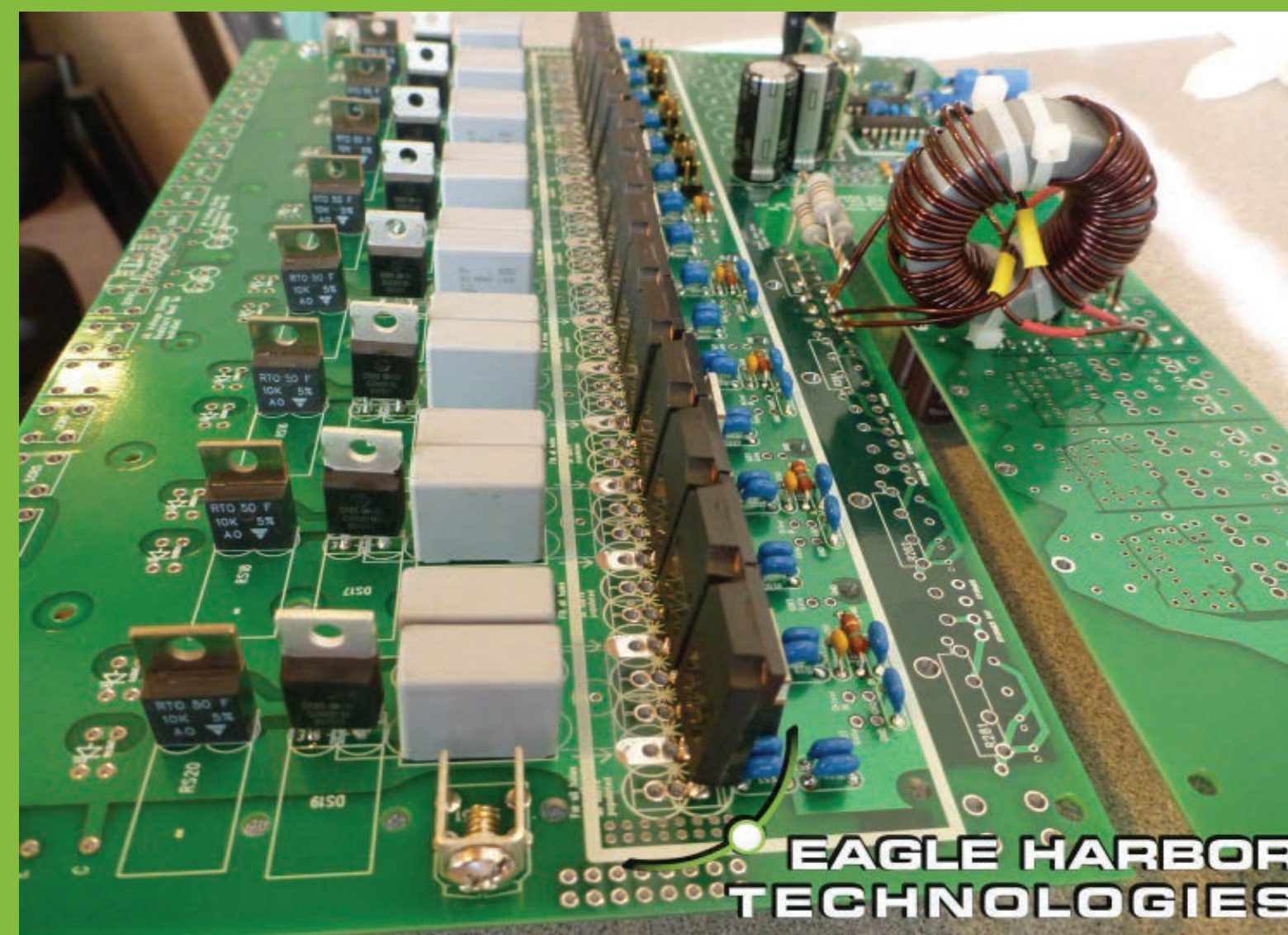


Output current waveform.

The Integrated Power Module (IPM-16P):

Integrated Power Module Specifications:

- Switching Frequency up to 1 MHz
- 1 kV, 10 kA with Opening Switch (< 1 ms)
- 1 kV, 3 kA, 100 kHz PWM (< 10 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)
- Robust Series and Parallel Operation 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"

Series Configuration:

- 12 module series configuration using the IPM-4P.
- 10 kV pulses.
- Rise time 40 ns.
- Longer pulse lengths are possible with additional energy storage.

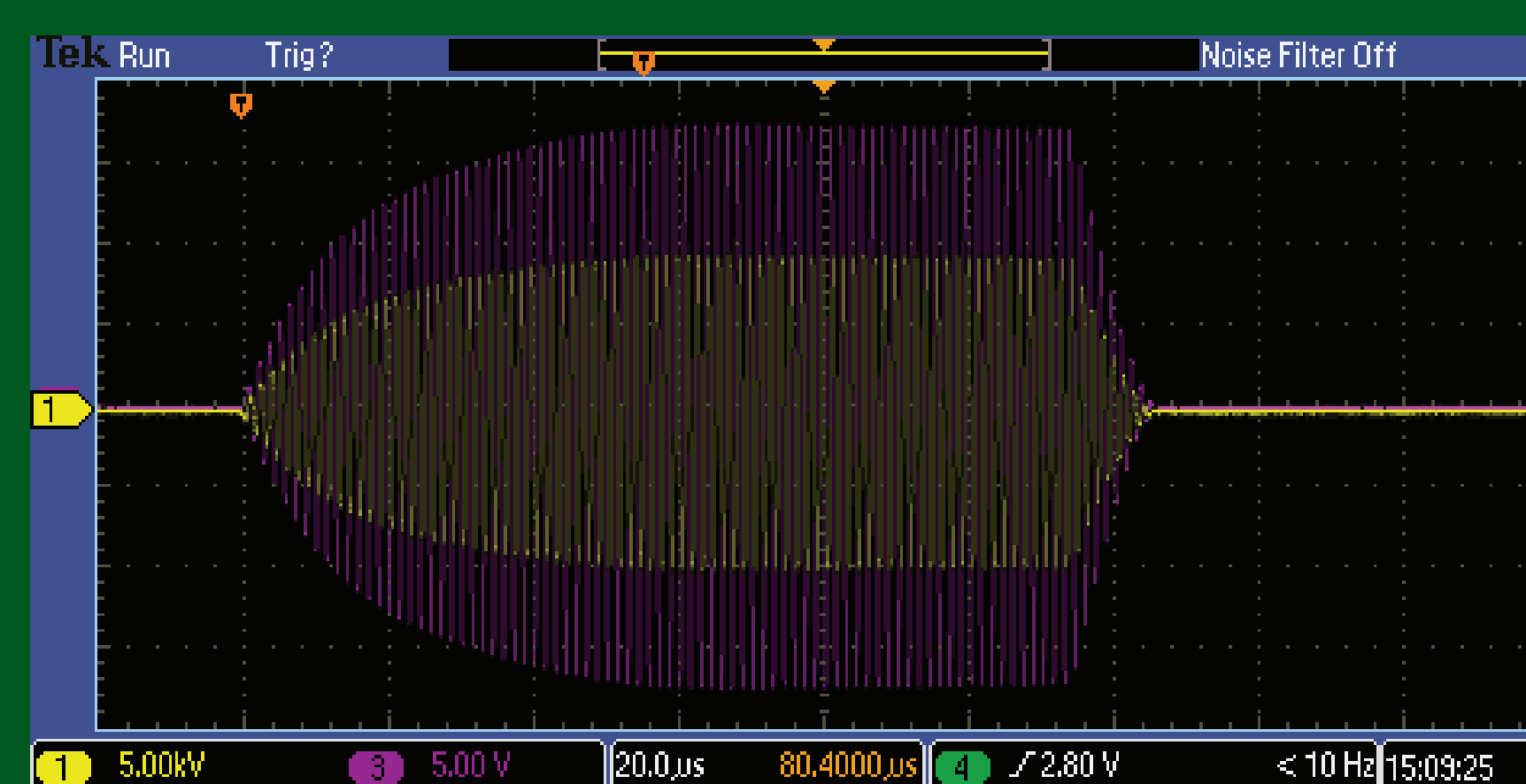


Left: Load voltage for 400 A, 400 ns pulse. Middle: Load voltage for 150 A, 600 ns pulse. Right: 12 module stack using IPM-4P.

Half Bridge Driven Series Resonant Converter:

Specifications

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

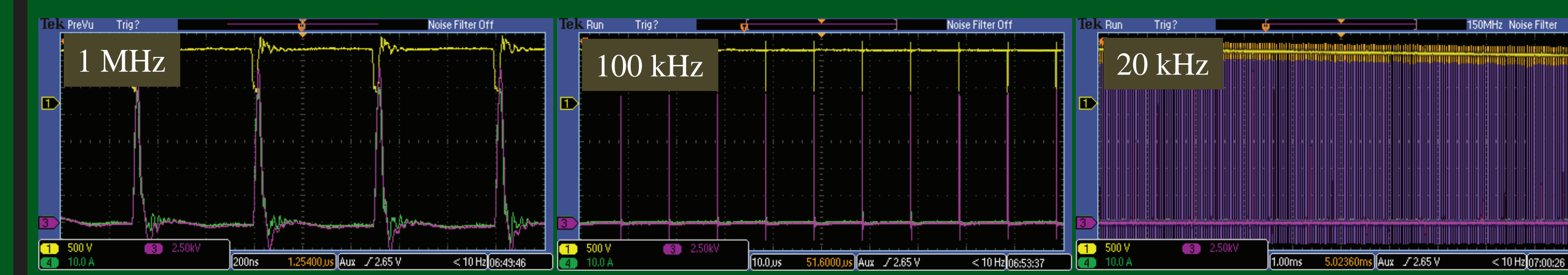
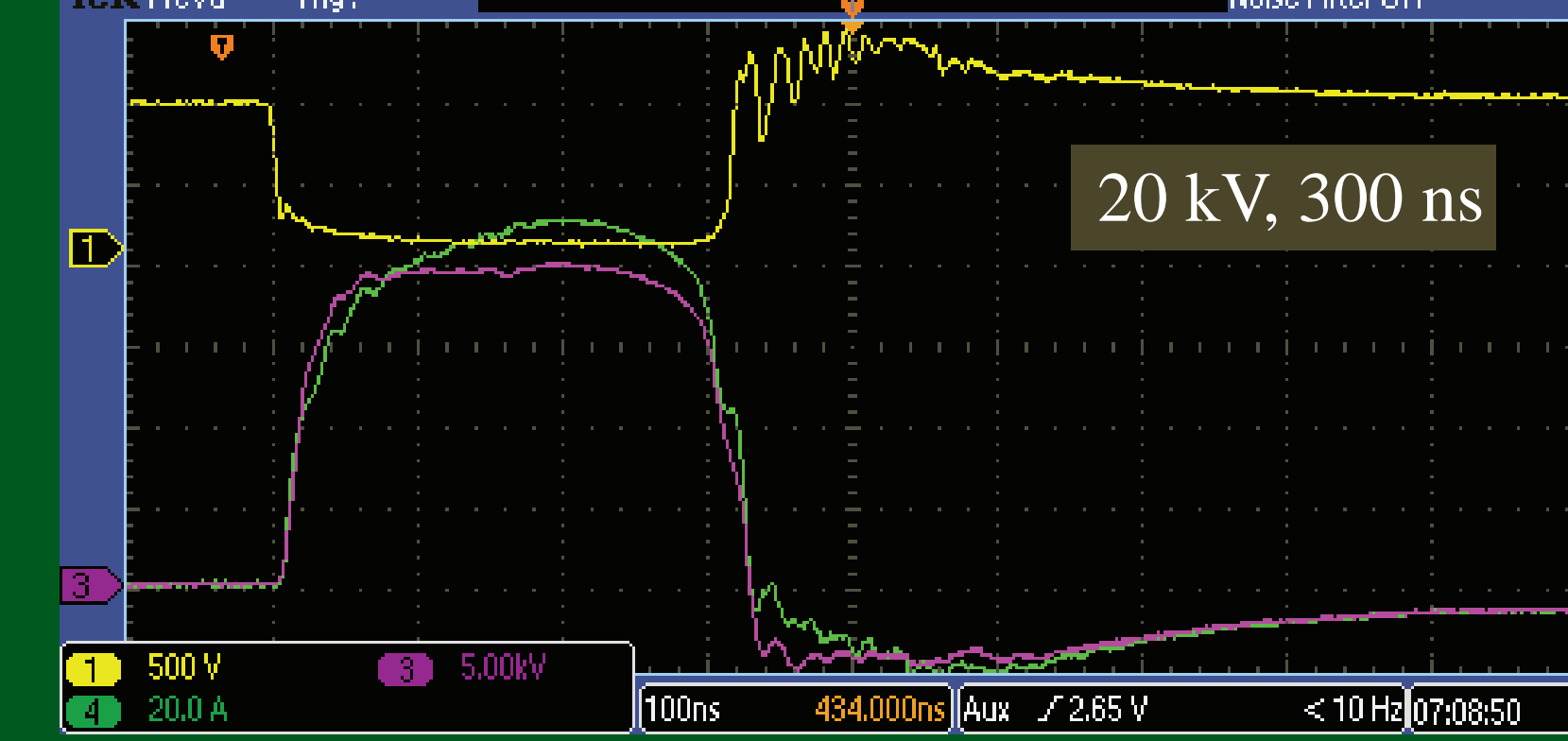
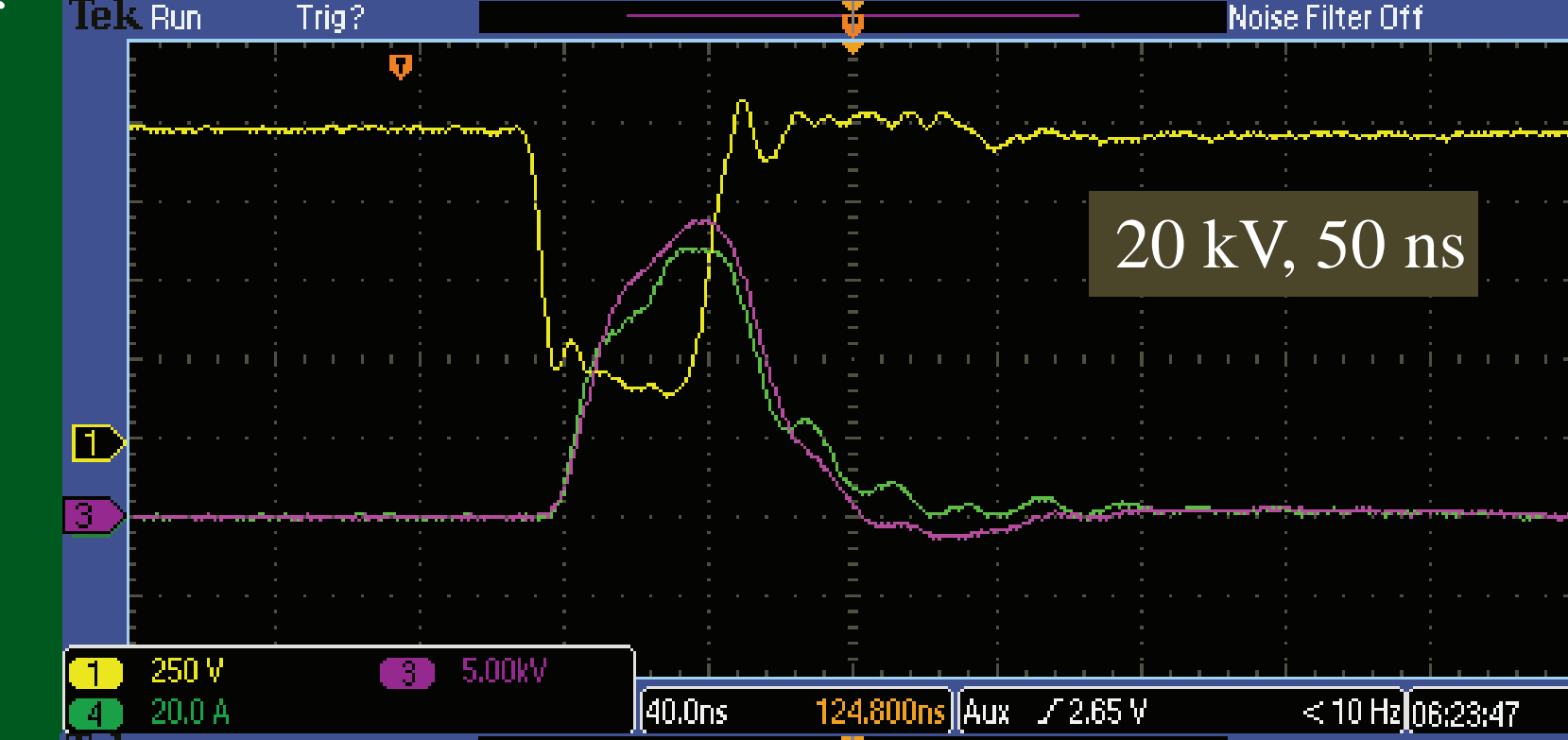
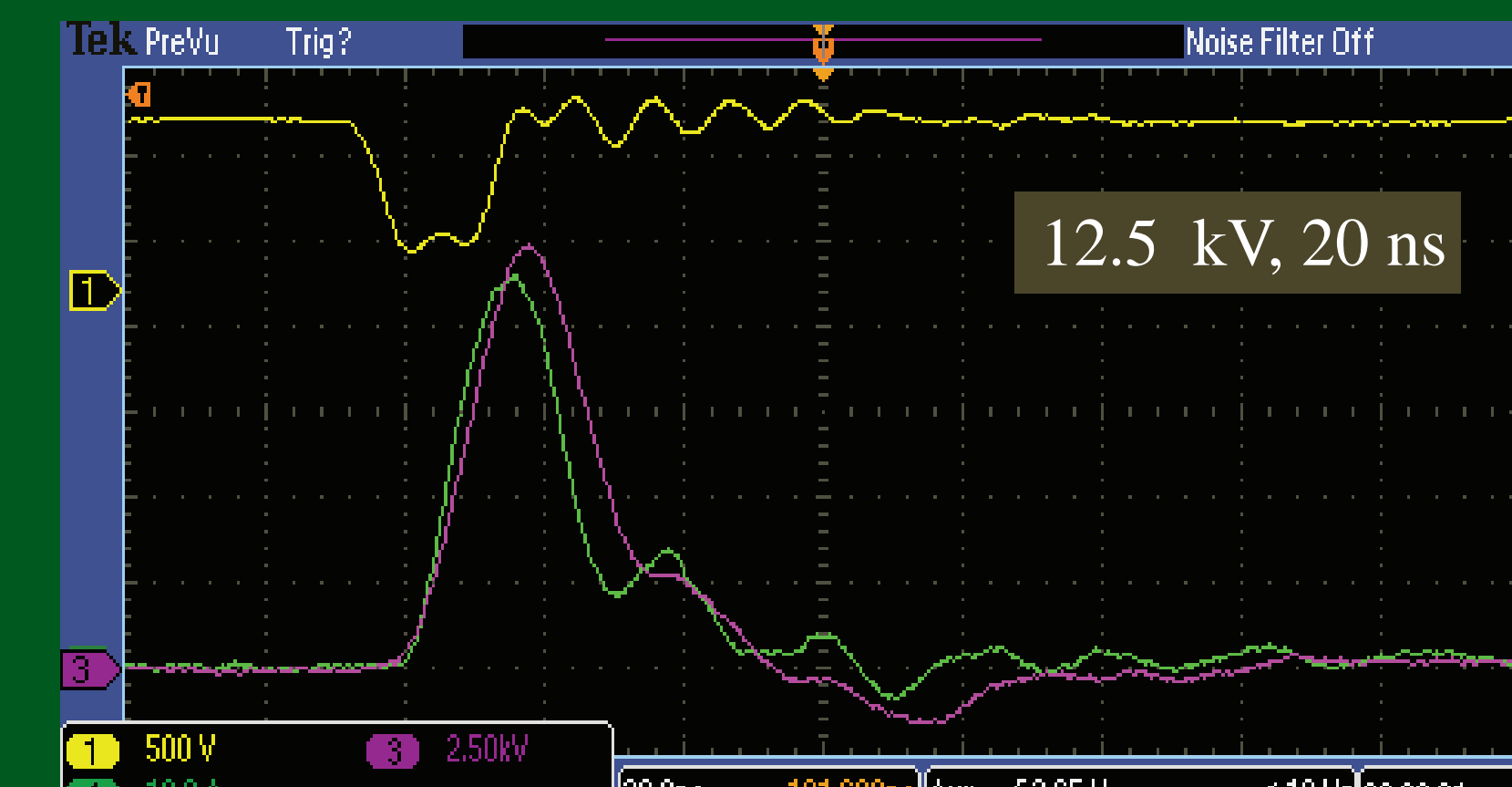


Left: One applications is driving an antenna for plasma creation. A hydrogen plasma is shown under the antenna. Above: Antenna voltage (Ch1) and antenna current (Ch2).



Nanosecond Pulsing at High Repetition Frequencies:

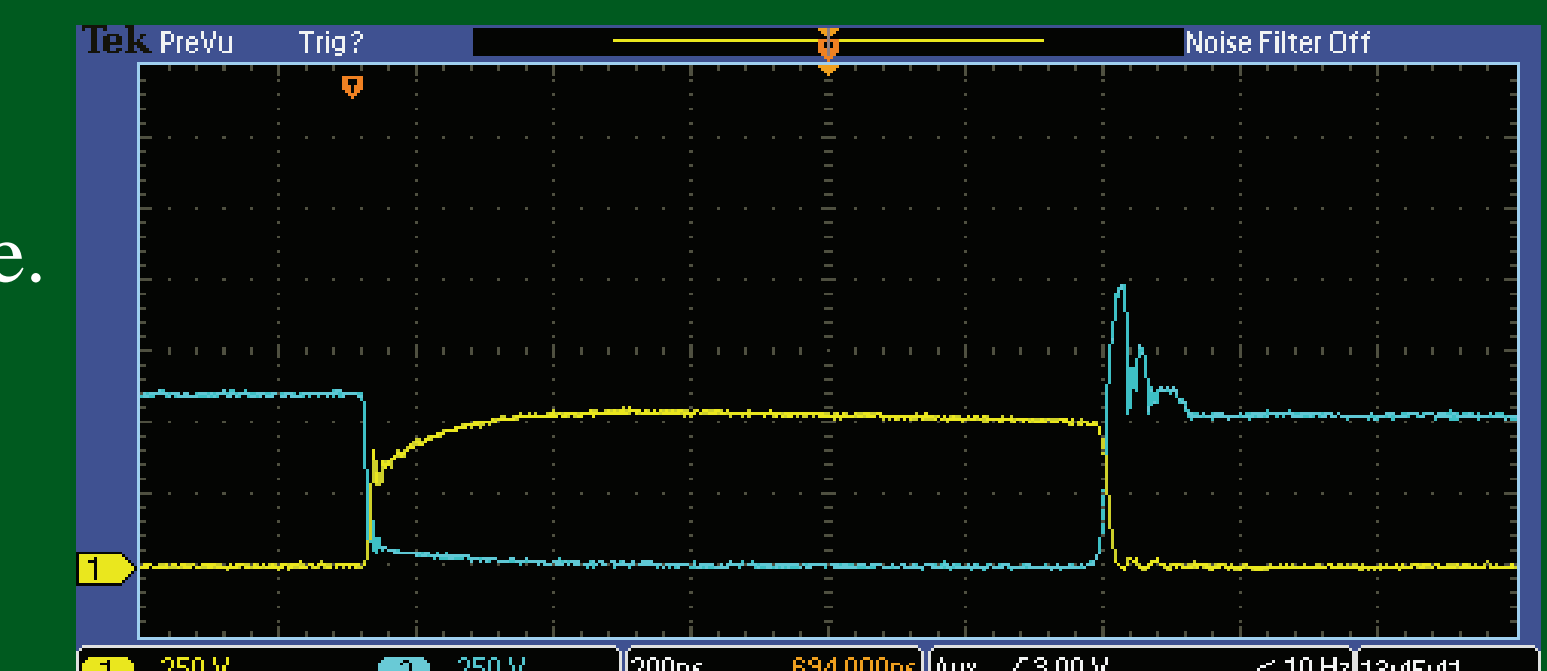
- High repetition frequencies in excess of several megahertz.
- Variable pulse characteristics, including pulse width and duty cycle, are controlled even within a burst of pulses.
- Single IPM utilized with custom 20:1 step-up transformer.
- No saturated magnetics used in the circuit.
- Voltage slew rates in excess of 400 kV/μs.
- Peak power levels of over 200 MW have been demonstrated.
- Pulsed widths from 20 to 400 ns have been demonstrated with current prototype. Longer pulse lengths possible with new pulsed transformer.
- Shorter pulses width below 20 ns are possible by including standard magnetic reactor and/or diode pulse sharpening techniques.
- Applications include laser drivers, materials processing, environmental, efficient combustion, pulsed plasmas, radars.



Single Board - High Current Waveforms:

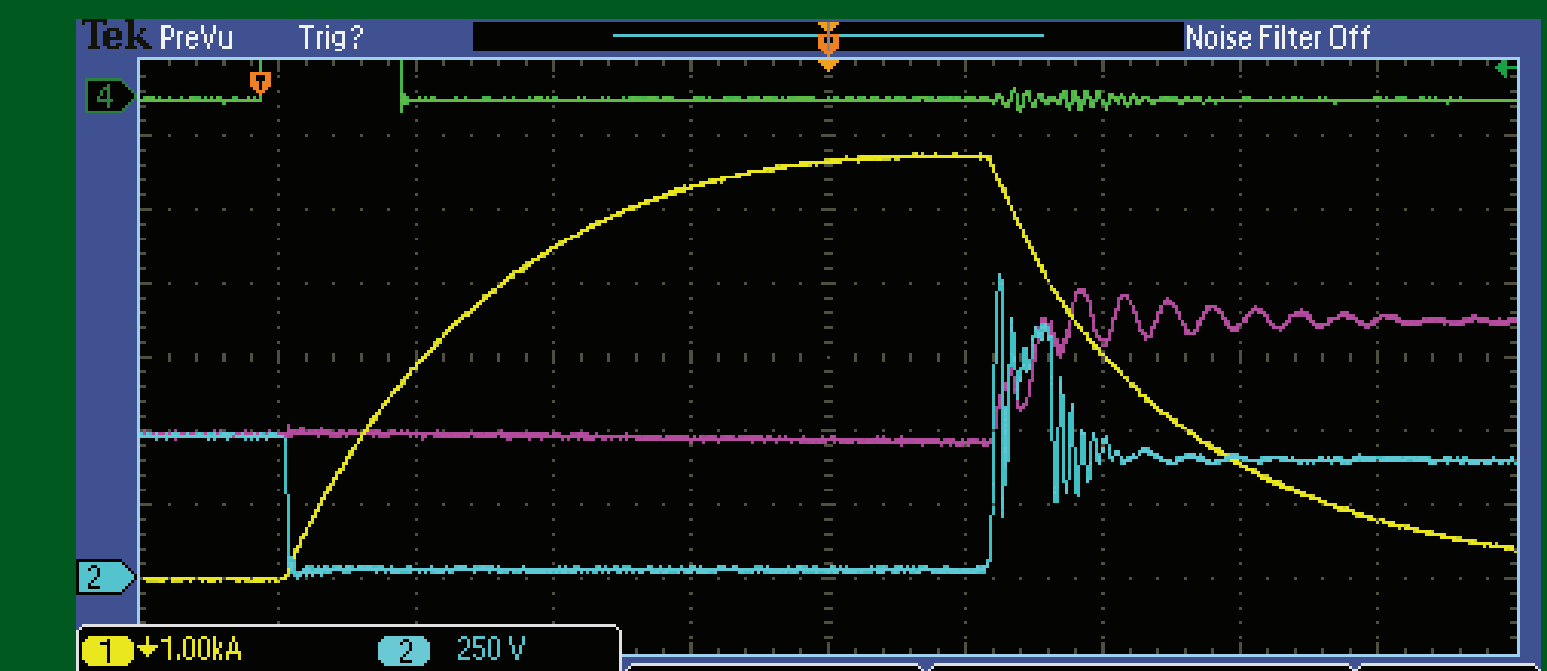
Single Board - Resistive Load:

- V and I load have the same profile.
- 600 V, 6 kA 1 μs pulse
- Current rise time < 50 ns.



Single Board - Inductive Load:

- Must account for L/R decay of current in coil – Use crowbar diodes
- 500 V, 6 kA, 2 μs pulse



Load current (Ch1) and V_{CE} (Ch2) for resistive load (top) and inductive load (bottom).

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