High-Voltage Solid-State Trigger for HEDP Applications

K. E. Miller; J.R. Prager*; I. Slobodov; T. M. Ziemba; C. Bowman
*prager@eagleharbortech.com

EAGLE HARBOR TECHNOLOGIES

Introduction

Eagle Harbor Technologies (EHT), Inc. is developing a solid-state thyratron replacement that can be used to trigger higher voltage spark-gap switches at Sandia and other laboratories. The current trigger generators used at Sandia are marginally reliable and have a long manufacturing and delivery time, and there is concern about the long-term availability of these thyratrons. When measured over short timescales, thyratrons typically have a jitter of a few nanoseconds; but over longer timescales, they can have a much larger drift. Additionally, thyratrons need stable, high-current, low-voltage power sources, have long warm-up times, and require conditioning shots to achieve a stable operating point. In the Phase I program, EHT will develop a first-generation prototype solid-state thyratron replacement, which will be able to produce 20 kV into 50 Ω with a sub-10 ns rise time and 100 ns e-folding fall time. EHT will present the Phase I program plan and initial results.

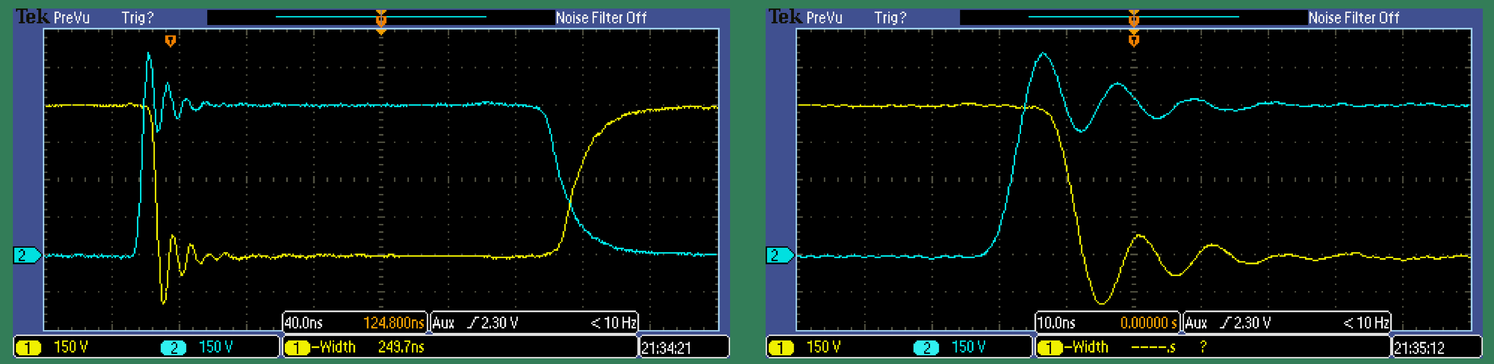
Solid-State Thyratron Replacement Requirements

For experiments like the Z-machine at Sandia, reliable triggering of high voltage (200 kV) spark-gap switches is critically important to the functionality of the system. A solid-state thyratron replacement suitable for HEDP applications at Sandia should meet the following specifications:

- Output voltage: 20 kV
- Capable of driving 50 Ω transmission lines
- One-sigma jitter: < 2 ns
- Rise time: < 10 ns
- Fall e-folding time: 120 ns
- High reliability
- Low volume
- Low cost (< $30k)
- Long lifetime

Fast Switching Waveforms

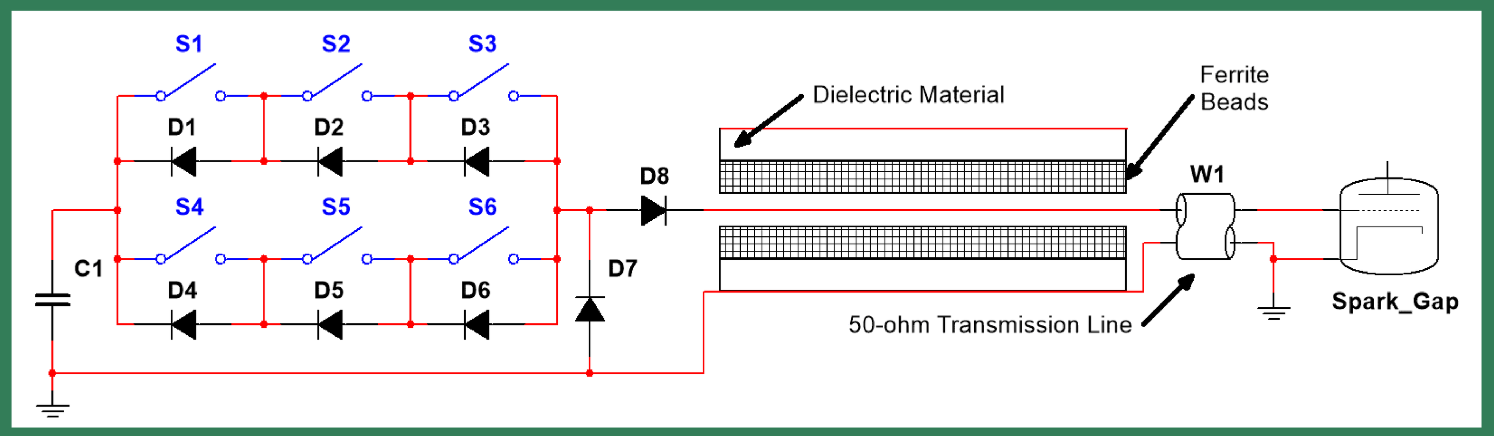
EHT specializes in the development of solid-state switching solutions. In the past, we have developed proprietary gate drive technology that allows for rapid switching of discrete IGBTs and MOSFETs (< 10 ns rise time) with high reliability. The switching waveforms of an IGBT are shown below. In this case, 1200 V devices were operated at 600 V into a 50 Ω load (12 A). The rise time in this test was 4 ns and the pulse width was 250 ns.



Measurement of switch voltage (yellow) and current (blue) of an IGBT at EHT at two different timescales. The IGBT was operated at 600 V and 12 A. The rise time was 4 ns.

Topology Selection

Originally, EHT proposed a high-voltage series-stack switch that could drive a 50-Ω transmission line. EHT has previously constructed a 10 kV high voltage switch module (10 - 15 ns rise time) out of 1.2 kV IGBTs in series. The plan was to build a series parallel arrangement with reasonably fast rise time. The rise time could further be reduced with a nonlinear transmission line (NLTL). At the start of the Phase I, we reconsidered circuit topologies.



Circuit diagram of proposed series/parallel arrangement of switches with NLTL

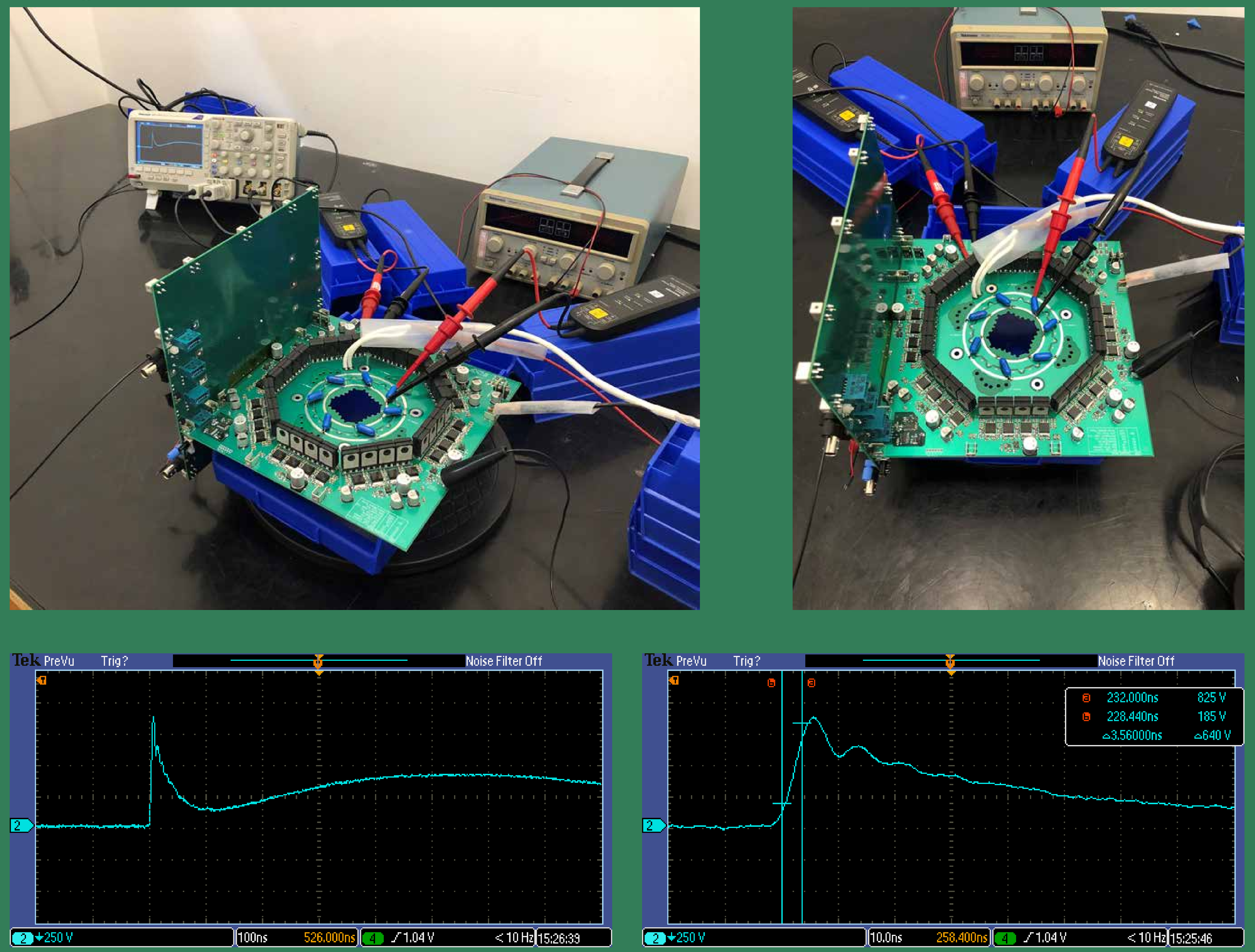
High Voltage Switch

- Expensive charging supply
- Corona issues at DC
- Closing switch only
- Needs snubbers for safety
- Isolation transformer needed
- More fibers (increases cost)

Inductive Adder

- No HV DC
- No corona
- May need to open
- More fault tolerant
- Less complex
- Modular/scalable
- Better NLTL integration
- Coated transformer cores

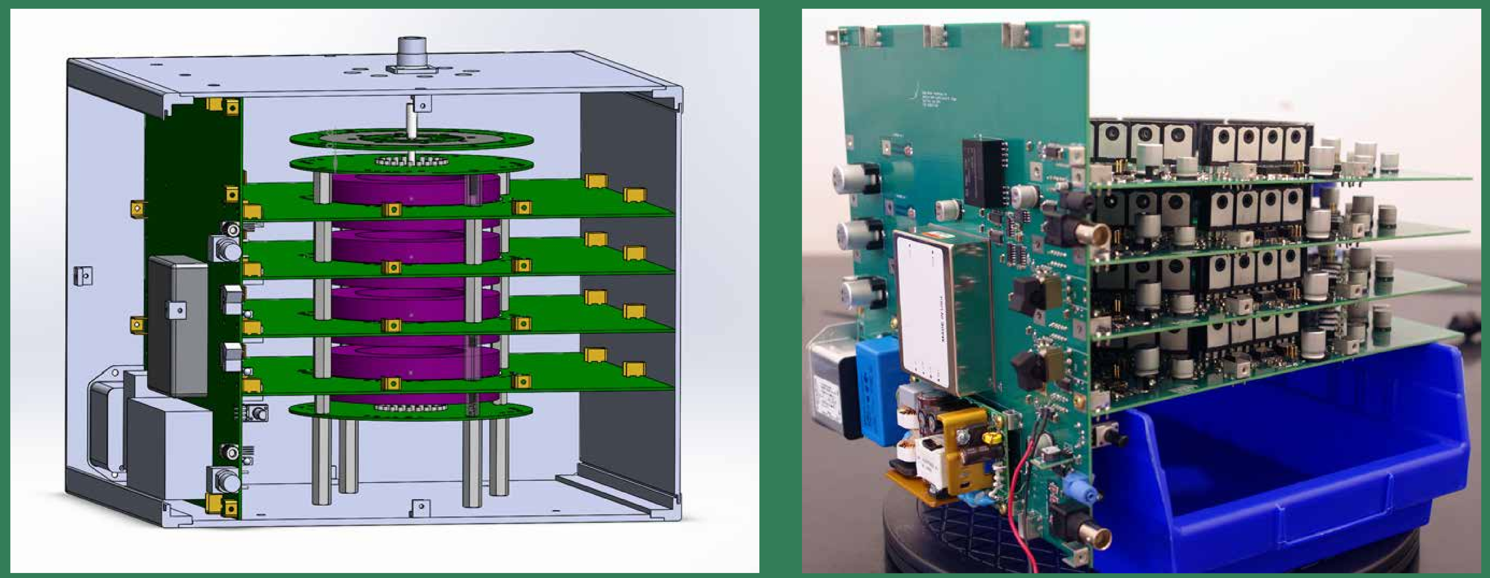
Single Board Testing



Top: Single-board test setup. Bottom: Output waveform on two timescales (V_{charge} = 830 V and R = 3.1 Ω). Cursors show a sub-4 ns rise time (10-90%).

Multiple Boards in Parallel

With single-board testing complete, the next step is to install the transformer cores and wind the transformer secondary. With the addition of the secondary, we expect that the rise time will increase, but should remain below the desired 10 ns. If this is not true, we will integrate an NLTL with the output to reduce the rise time to below 10 ns. This system will be bench tested again before it is integrated into the box. Once the inductive adder is in its enclosure, the system will be tested again.



Left: CAD model of inductive adder in enclosure. Right: Four-board inductive adder stack with control board mounted on left side.

Conclusion

EHT's Phase I SBIR development of a solid-state high-voltage thyratron replacement is well underway. The system has been re-envisioned from the original circuit topology to simplify the design and reduce system cost. The inductive adder is designed for single pulse to mitigate corona issues while reducing size and cost.

The first-generation switching and control boards have been built. EHT conducted single-board testing with a simulated load of the correct impedance so that the four board stack will be able to drive 50 Ω, which produced waveforms with rise times below 4 ns. The next step is winding the transformer and testing the full inductive adder in a 50 Ω load.

In a potential Phase II program, EHT will refine the design to further reduce size and lower cost. EHT plans to deliver several units to Sandia for testing. At the end of a Phase II program, EHT would have solid-state thyratron replacement that could be commercialized.

For more information: http://www.eagleharbortech.com/

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