EAGLE HARBOR TECHNOLOGIES

A Solid-State Thyratron Replacement as a High-Voltage Trigger for HEDP Applications

James Prager*, Kenneth E. Miller, Chris Bowman, and Kyle McElaney
*prager@eagleharbortech.com

Introduction
The Z Machine at Sandia National Laboratory uses thyratron-based trigger generators to trigger higher voltage switches. The long-term availability of these trigger generators is a concern as well as their marginal reliability and manufacturing lead times. Thyratrons need stable, high-current, low-voltage power sources, have long warm-up times, and require conditioning shots to achieve a stable operating point. 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.

To address the needs of Sandia and other pulsed-power laboratories, Eagle Harbor Technologies (EHT) Inc. developed a prototype solid-state thyratron replacement to trigger higher voltage spark-gap switches typically used in these HEDP applications. The first-generation EHT solid-state thyratron replacement can produce 20 kV pulses into 50 Ω with a sub-10 ns rise time and 100 ns e-folding fall time. The unit is designed to be compact and low cost. EHT will present the design tradeoff study, selected topology, and key waveforms results.

Solid-State Thyratron Replacement Requirements
A solid-state thyratron replacement suitable for HEDP applications at Sandia should meet the following specifications:

- Output voltage: 20 kV
- One-sigma jitter: < 2 ns
- Rise time: < 10 ns
- Fall e-folding time: 120 ns
- Low volume
- Low cost (< $30k)
- Long lifetime

High Voltage Switch
- Expenses charging supply
- Corona issues at DC
- Needs snubbers for safety
- Isolation transformer needed
- More fibers (increases cost)

Inductive Adder
- No HV DC
- No corona
- More fault tolerant
- Less complex
- Modular/scalable
- Better NLTL integration

Nonlinear Transmission Line
To reduce the rise time 20 ns to below 10 ns, an NLTL was used. NLTLs have a nonlinear permittivity, ε(Ψ), and/or nonlinear permeability µ(Ψ). This NLTL is consists of an inner conductor surrounded by ferrite beads, encapsulated by a dielectric surrounded by an outer conducting braid.

Conclusion
Facilities such as Sandia National Labs’ Z Machine would benefit greatly from the increased reliability and decreased jitter and cost offered by modern solid-state switching technology. EHT successfully designed, built, and tested a compact (< 1500 in³) proof-of-concept solid-state HV trigger system that met the waveform specifications outlined for use as a thyratron replacement for spark-gap switch triggering. This HV trigger system utilizes proven inductive adder and NLTL technology developed at EHT to achieve a 20 kV pulse into a 50 Ω load with a sub-10 ns rise time. Future improvements would optimize the pulse-sharpening stage for compactness and reduce the complexity of the high voltage pulse transformer design.

HV Test Setup
High voltage test setup for the HV Trigger based on inductive adder and NLTL.

High Voltage Testing
The transformer output (yellow) and NLTL output across the 50 Ω load (magenta) with 20 mcdiv (left) and 4 mcdiv (right). The cursors in the left image indicate 20 kV. NLTL solenoid bias magnetic field was 29 kA/m, DC charge voltage of 950 V.

HV Test Setup for the NV Trigger driving a 0.15” spark gap at the end of the delay line (left) and spark gap voltage (right). VCE (yellow), voltage across 50 Ω resistor in series with the spark gap (blue), output voltage of the transformer (magenta), the voltage across the spark gap and 50 Ω series resistor (green), and spark gap voltage.

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