High Voltage Solid-State Switch for Magnetron Driving

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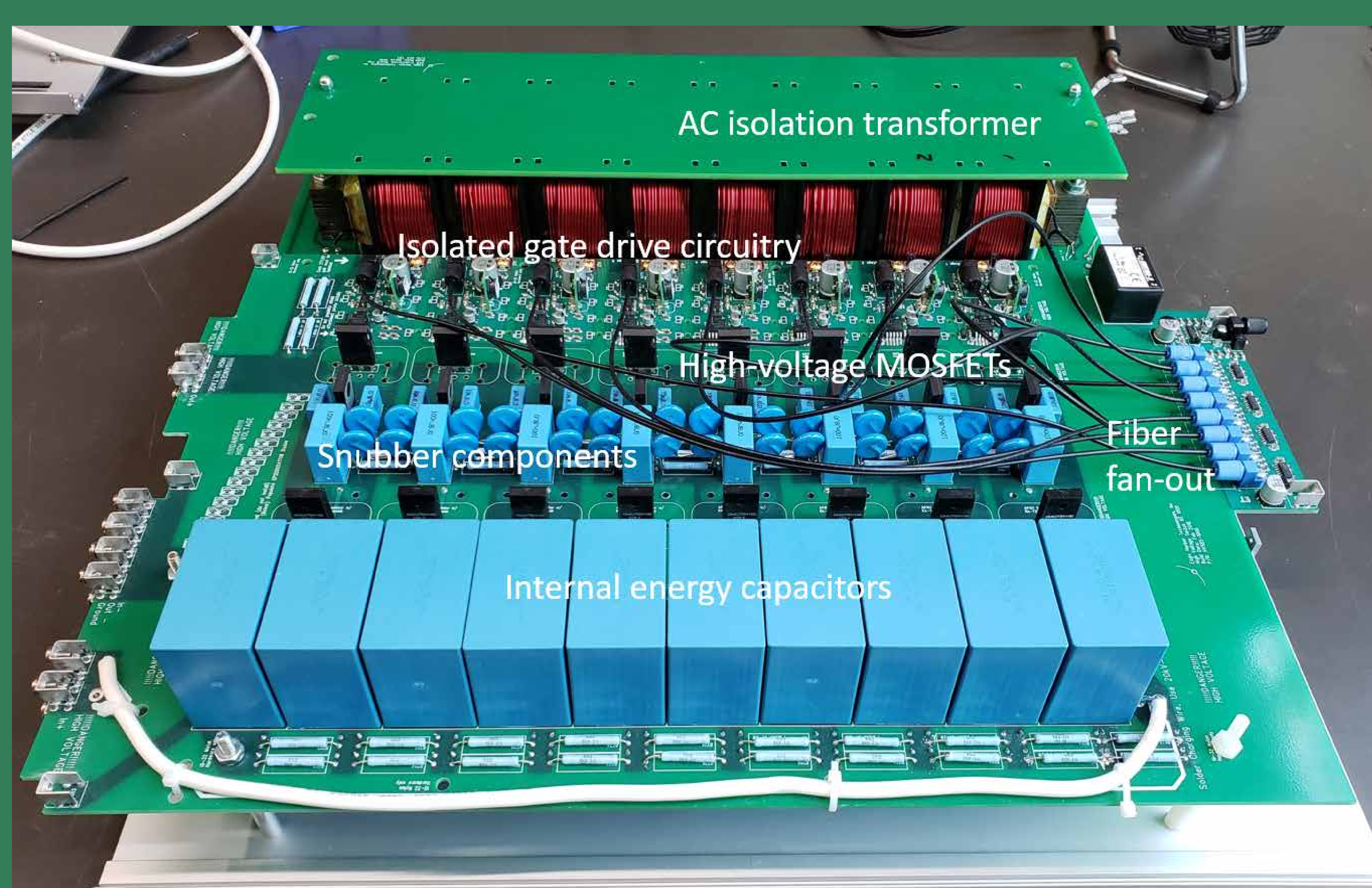
EAGLE HARBOR TECHNOLOGIES

Introduction

Eagle Harbor Technologies, Inc. (EHT) is developing a 35-kV solid-state switch that can be utilized for driving magnetrons. This 35-kV solid-state switch will be packaged into a driver for a pulsed magnetron at the Lithium Tokamak Experiment (LTX) at Princeton Plasma Physics Laboratory. This system will be delivered to LTX for testing the Year 2 of the Phase II program, where it will remain at the completion of the Phase II program. EHT will present high voltage switch results, including voltage sharing, fault mitigation, and resistive load driving. On the road to 35 kV, EHT has developed a 10-kV switch that has been packaged and commercialized. Results from the lower voltage switch will also be presented.

2nd Generation HV Switch

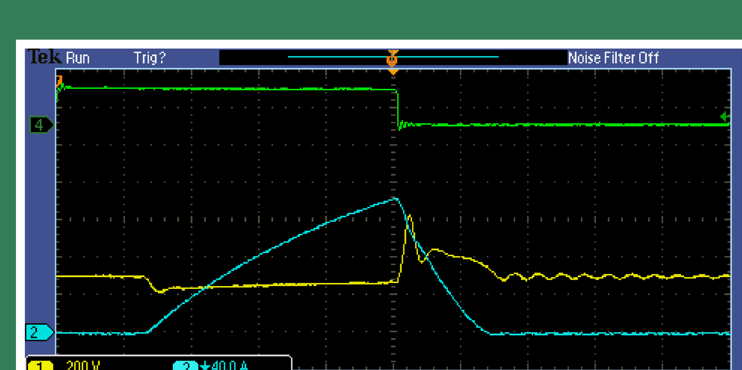
The EHT high voltage solid-state switch uses independently powered gate drive to maintain precision switching when solid-state switches are stacked in series. The second generation PCB uses 1700 V MOSFETs instead of the 1200 V devices used in the Phase I program, which reduces the number of stages to eight. The second generation HV switch module and transformer have been designed to easily integrate into a single 3U rack mountable box whereas the original, from Phase I, could not.



Second generation HV Switch PCB.

Single Switch Short Circuit

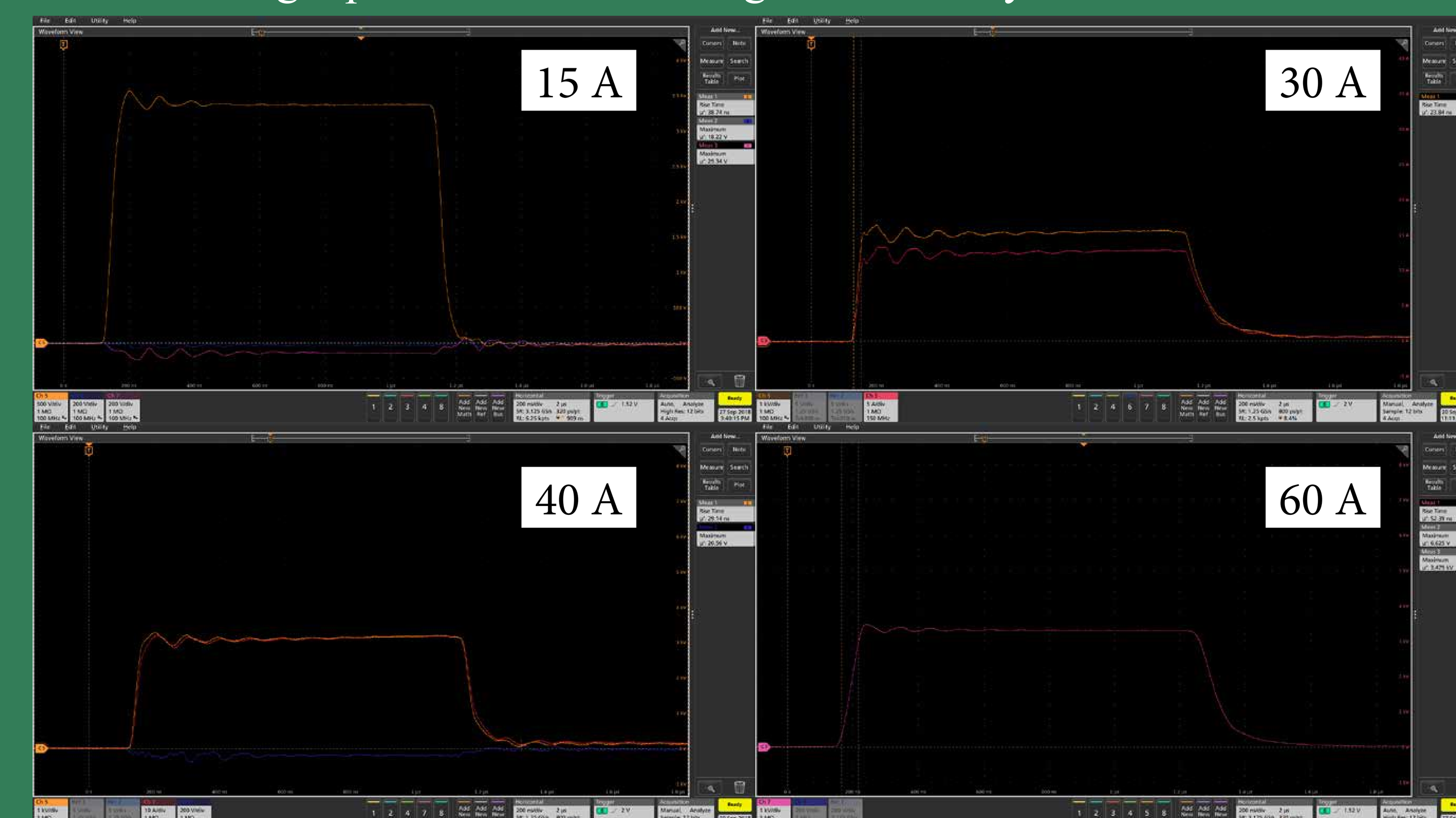
Some SiC MOSFETS have an inherent current self-limiting property when the gate voltage is carefully controlled. The selected MOSFETs self-limit sufficiently well that they can be exposed to a direct short circuit condition for all pulse widths of interest without failure.



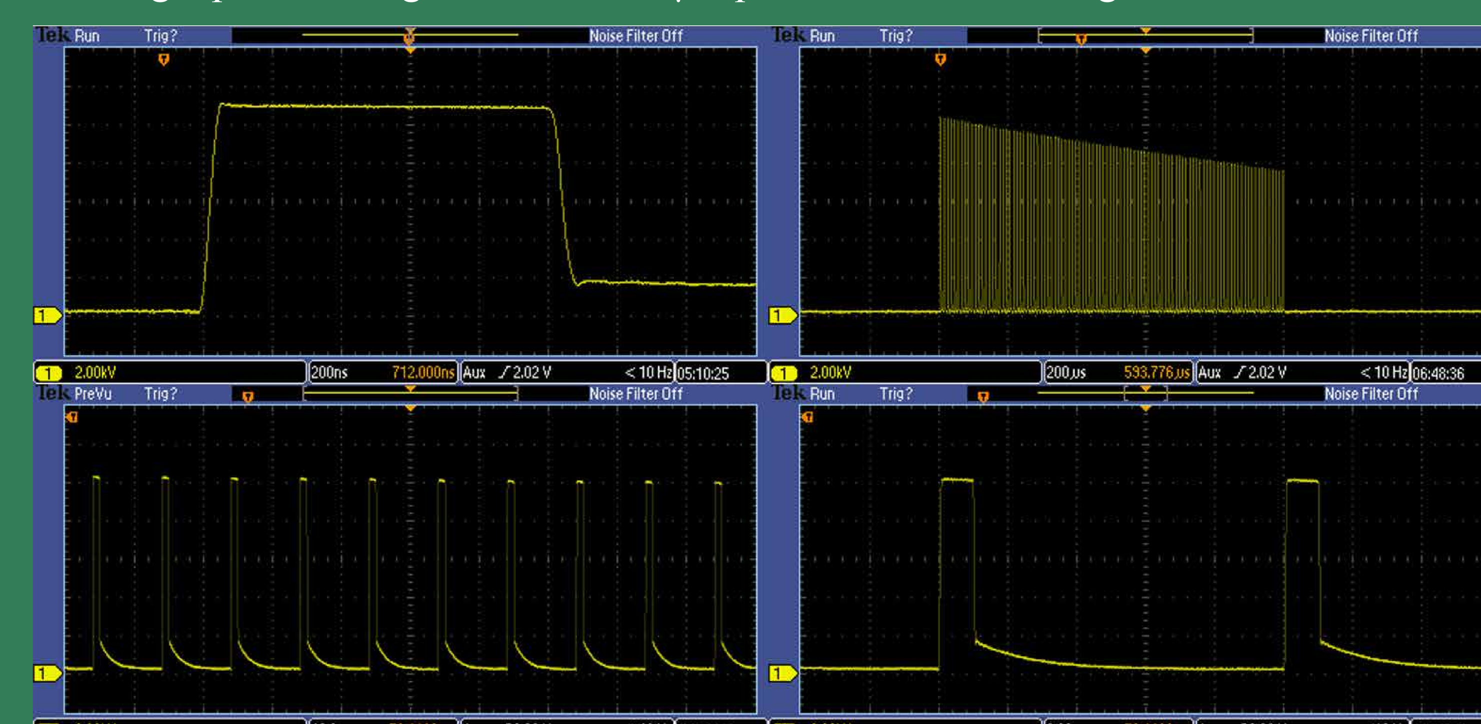
V_{DS} (yellow) and output current (blue) of a current limiting SiC MOSFET.

Second Generation HV Switch Testing

After constructing the second generation HV switch, EHT conducted extensive single pulse and burst testing into a variety of resistive loads.



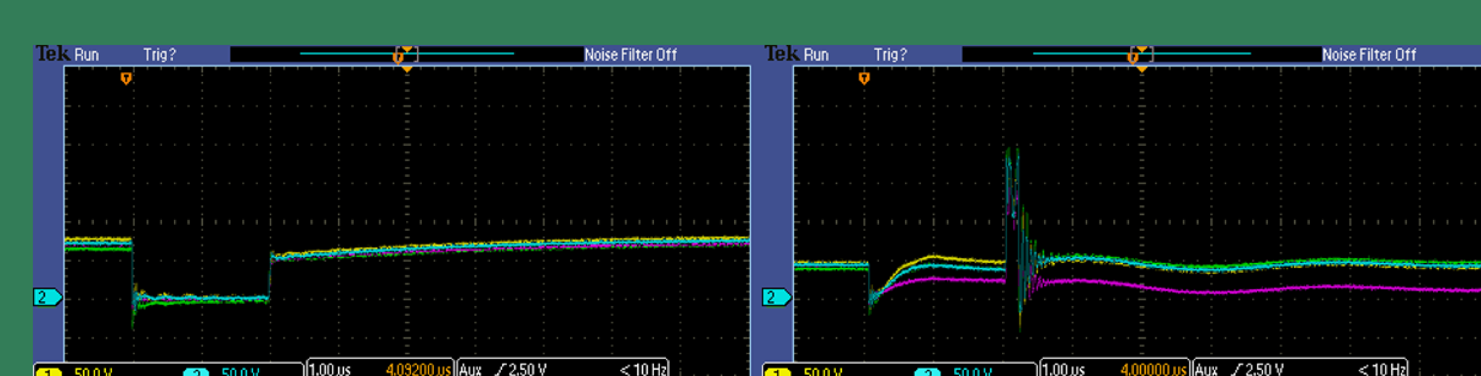
Single pulse testing: 10 kV with 1 μs pulse width into a range of resistive loads.



10 kV burst testing at 100 kHz and 50% duty cycle into a 280 Ω load.

Fault Mitigation

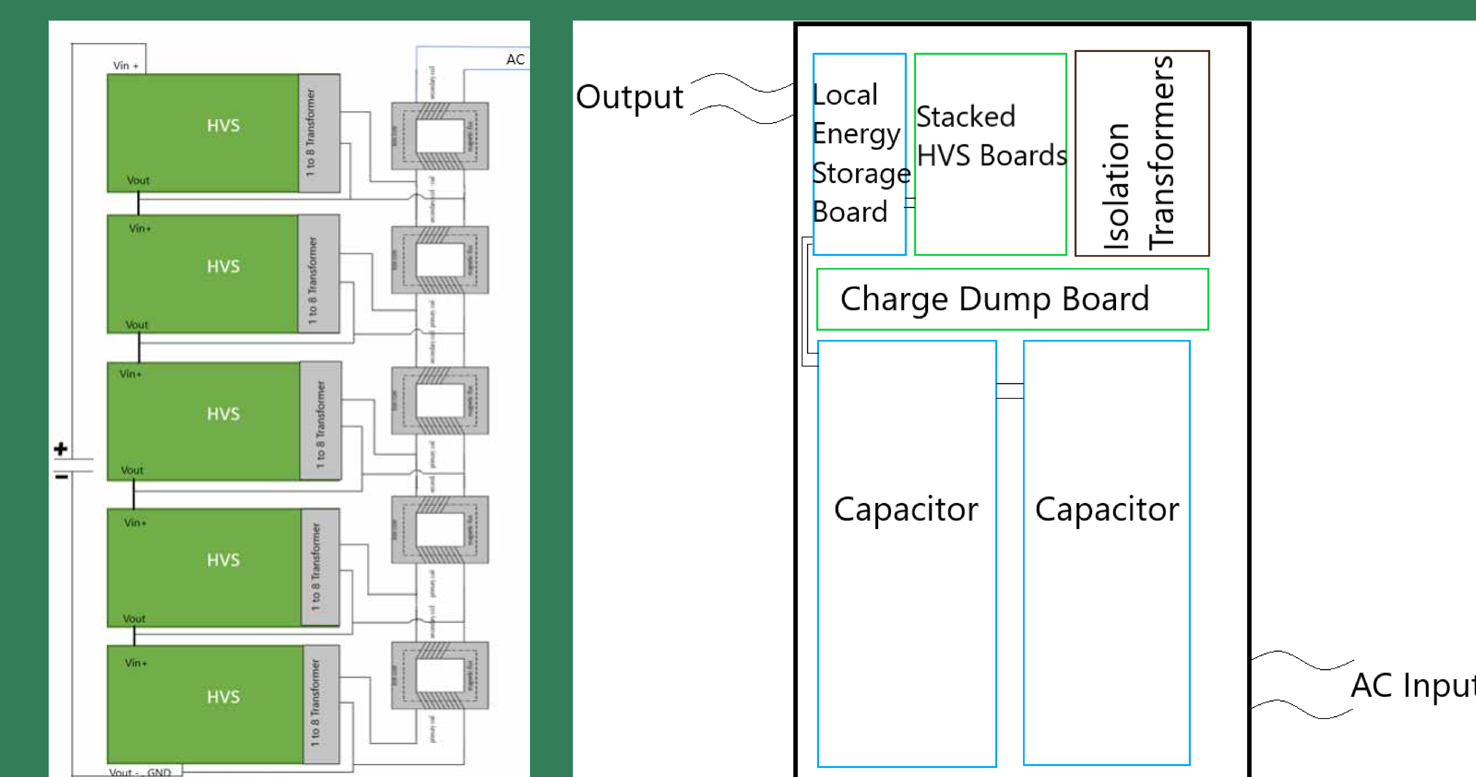
Passive short circuit protection is insufficient because small differences in the MOSFETs cause some stages to preferentially take up much more of the voltage during short circuits than other stages. When combined with MOVs, the MOSFETs do allow a few microseconds of short tolerance. An active system with a fast response time can shut down the HV switch in the event of a fault. The conduction voltage falls to near zero on each switch during normal switching, but stays above zero during a short. This large difference in voltage can easily be detected by a comparator through a voltage divider.



VDS during normal operation (left) versus short circuit operation (right).

Initial Design of Pulsed Magnetron Driver

To reach the 35 kV output required for the pulsed magnetron driver, five 10 kV switches will need to be operated in series. EHT will use isolation transformers to provide isolated power to each HV switch in the series stack. EHT has begun to design the enclosure that will contain the energy storage, HV switches, isolated power, and safety systems. Floating components will be contained in a grounded rack.



Circuit diagram (left) and physical layout (right) of multiple pulsed magnetron driver.

Conclusion

EHT has designed, built, and tested a second generation HV Switch using SiC MOSFETs. The testing has demonstrated single pulse operation and burst operation at 100 kHz with similar current draw to the pulsed magnetron. EHT has also investigated fault mitigation techniques that will protect the HV switch in the event of a short circuit. The SiC MOSFETs have some current limiting capabilities, which when combined with MOVs allow sufficient time for fast logic to shut down the switch.

In Year 2 of the Phase II program, EHT will stack multiple HV switches in series to produce a 35 kV pulsed magnetron driver. Initial system design of the has been conducted to show sufficient voltage isolation. The Lithium Tokamak Experiment at Princeton Plasma Physics Laboratory will test this driver with a high power (0.1-2 MW) magnetron for plasma startup and localized electron heating. The magnetron will be operated for 5-10 ms after the initial conditioning with shorter pulses has occurred.

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

Acknowledgment

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