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Improving Switching Performance of Power MOSFETs Used in High Rep-Rate, Short Pulse, High-Power Pulsers

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As their switching and power handling characteristics improve, solid-state devices are finding new applications in pulsed power. This is particularly true of applications that require fast trains of short duration pulses. High voltage (600-1200V) MOSFETs are especially well suited for use in these systems, as they can switch at significant peak power levels and are easily gated on and off very quickly. MOSFET operation at the shortest pulse durations is not constrained by the intrinsic capabilities of the MOSFET, but rather by the capabilities of the gate drive circuit and the system physical layout. This project sought to improve MOSFET operation in a pulsed power context by addressing these issues.

Project Goals

The primary goal of this project is to improve the switching performance of power MOSFETs for use in high rep-rate, short pulse, high-power applications by improving the design of the gate drive circuits and the circuit layouts used in these systems. This requires evaluation of new commercial gate drive circuits and upgrading the designs of LLNL-developed circuits. In addition, these circuits must be tested with the fastest available high-voltage power MOSFETs.

Relevance to LLNL Mission

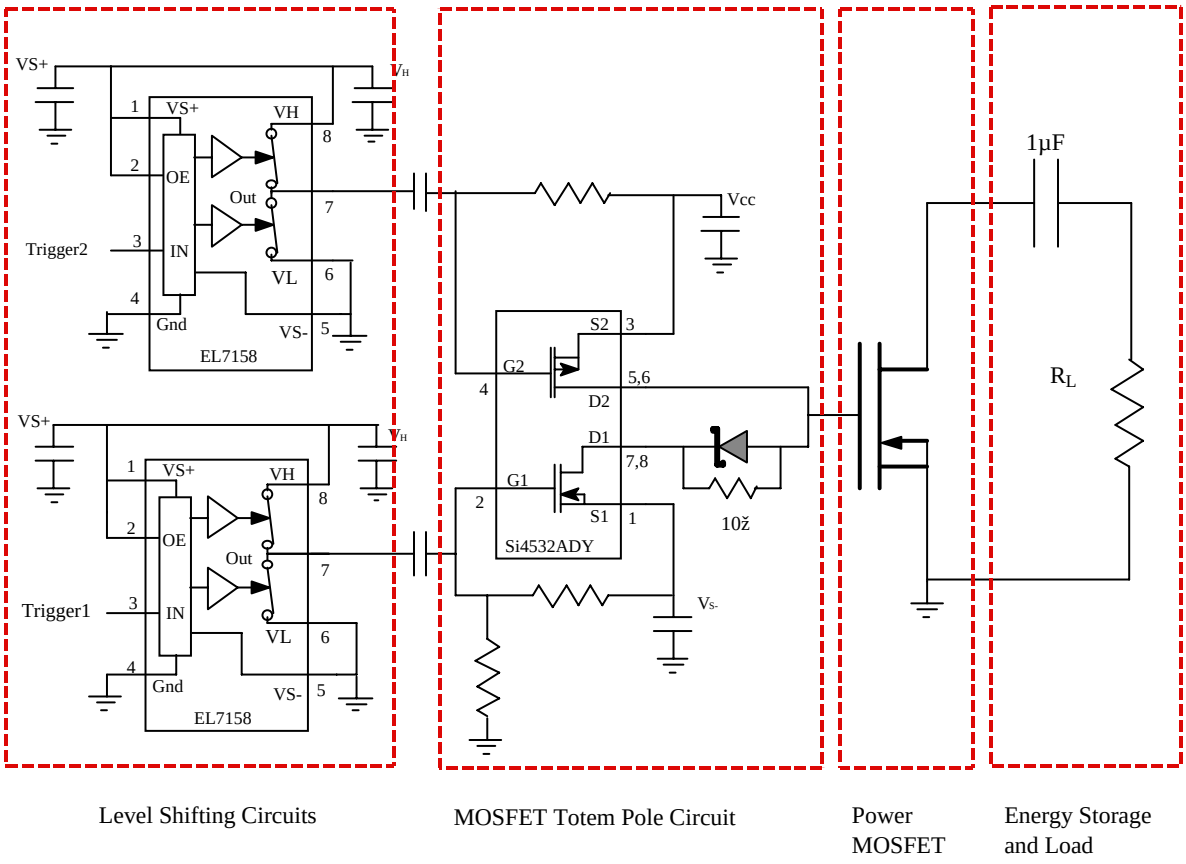
Solid-state pulsed power circuits are replacing older technology devices that have availability and reliability issues, such as vacuum tubes and thyratrons. This is especially true in a number of LLNL programs, such as the accelerator and laser development efforts, where MOSFET switched inductive adder circuits allow detailed control of voltage waveforms which would be impossible with the previous technology. Fast solid-state pulsed power is therefore an enabling technology that finds applications in both new and existing programs at LLNL, which frequently push the limits of switching speeds and short duration pulses.

FY06 Accomplishments and Results

We have identified several commercial gate drive devices that exhibit excellent stability and are capable of generating pulses with fast rise and fall times and at high burst frequencies. These devices are very useful for many pulsed power applications. However, these commercial circuits are inherently incapable of generating pulses of very short pulse duration. Their internal construction is specifically designed to limit the minimum pulse-width to a value that maintains stable operation and prevents the production of oscillating gate drive pulses.

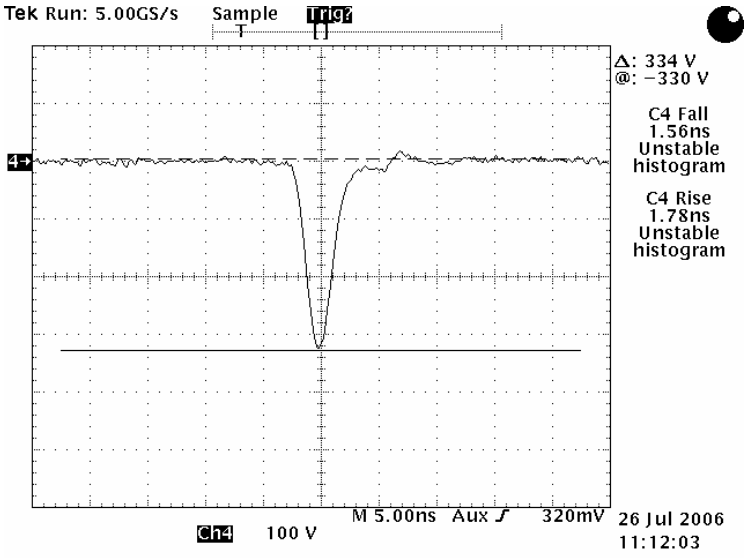
In an effort to generate shorter duration pulses, we have turned to a LLNL developed circuit composed of discrete components as shown in Fig. 1. This circuit uses

commercially available level shifting components and discrete MOSFETs arranged in a totem-pole configuration. To achieve the best control, multiple independent trigger pulses are used to overcome the limitations of turn-on and turn-off delays, shoot-through, and the MOSFET Miller capacitance.



MOSFET Gate Drive Test Circuit

The best of the commercial gate drive circuits are capable of generating pulses having a minimum pulse duration (measured at the base of the pulse) of 12-16 ns. With the LLNL developed gate drive circuit layout, we have been able to reduce the minimum pulse-width to 5 ns with rise and fall times (10-90%) of less than 2 ns. Results are shown in Fig. 2. The switching speeds of this circuit, as measured by rise and fall times, are approximately twice as fast as those achieved with the commercial circuits. Additionally, we have operated this circuit at burst frequencies of 3 Mhz for 50 pulse bursts with no degradation in the measured waveforms. This level of gate drive circuit performance can only be realized when operated with MOSFETs that are optimized for high frequency or pulse applications. In this respect, the gate drive circuit and the power MOSFET should be considered to be an integrated system.



Related References

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