

# Fast 8 kV metal-oxide semiconductor field-effect transistor switch

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A fast high voltage switch based on ten transformer-isolated power metal-oxide semiconductor field-effect transistors in series is described. This circuit can switch 8 kV to ground with a fall time of  $\approx 230$  ns, and has proven to be useful for beam potential re-referencing in pulsed ion beam experiments.

Ion beam experiments are often complicated by the necessity of maintaining either the source or detector region at a high potential for effective beam transport. In pulsed ion beam experiments, however, this problem can be avoided by re-referencing the ion beam with a "potential switch" as shown by Johnson and co-workers.<sup>1</sup> We have built a fast-beam photodissociation apparatus in our laboratory that operates at beam energies up to 8 keV,<sup>2</sup> and have assembled an inexpensive yet reliable fast-switching metal-oxide semiconductor field-effect transistor (MOSFET) circuit for re-referencing the beam potential to ground. This circuit can drop an isolated 25 cm long, 8 cm diam stainless steel tube from 8 kV to ground in  $\approx 230$  ns at repetition rates in excess of 100 Hz, with a duty cycle of up to  $1.5 \times 10^{-4}$ .

Power MOSFETs capable of rapidly switching up to 1 kV are now available, but to apply MOSFET circuitry to switching higher voltages, schemes must be developed to use several in series. We have used ten transformer-isolated MOSFETs in series to rapidly switch 8 kV. A key to this approach is the use of a metal-oxide varistor (MOV) to clamp the voltage across a given MOSFET to less than the rated voltage. MOV devices display a nonlinear resistance as a function of voltage and serve as rugged, fast-acting surge suppressors.<sup>3</sup> Use of the MOV devices allows the requirement for accurate synchronization of the triggering of the MOSFETs to be relaxed, greatly simplifying the construction of the device.

A schematic diagram of the circuit is shown in Fig. 1. Ten identical varistor-bypassed MTP1N100 MOSFET stages are connected in series, with one end of the chain connected to the isolated tube and the other end at ground. The MOSFETs are triggered in two groups of five each through transmission line transformers by two Siliconix D469CJ quad MOSFET drivers. To increase the driving current available, the four outputs of each D469CJ are strapped together. The transmission line transformers were made by wrapping 17 turns of RG 316/U coaxial cable around Fair-Rite #59-77-001601 ferrite toroids, using the outer conductor of the coaxial cable as the primary and the inner conductor as the secondary of the transformer.<sup>4</sup> As the schematic shows, the D469CJ's are triggered through an HCPL-2601 optoisolator to prevent damage to external pulse generators, etc., in the event of failure. The MOVs used are 920 VDC rated Panasonic ZNR-C20DK102's.

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Figure 2 shows a trace of the high-voltage (HV) pulse recorded with a Tektronix P6015 probe and a Tektronix 2467B 400 MHz oscilloscope. To reduce the instantaneous current and decrease the fall time of the isolated tube, care was taken to minimize the capacitance of the tube, with a measured capacitance of 85 pF achieved. Thus, for 230 ns switching time,  $I = C(\Delta V/\Delta t) = 3$  A. This instantaneous current is well below the 6 A rated limit of the MOSFETs. A current limiting resistor  $R_m$  is placed between the high voltage power supply and the tube to allow the tube to be brought as close to ground as possible. With  $R_m = 130$  k $\Omega$ ,  $I = 60$  mA, so, given the 10  $\Omega$  on resistance of each MOSFET, the tube is brought to within  $\approx 6$  V of ground.  $R_m$  could be increased significantly, bringing the tube much closer to ground, if desired.

Our application only requires the falling edge to be fast, so the rising edge of the pulse has a time-constant of

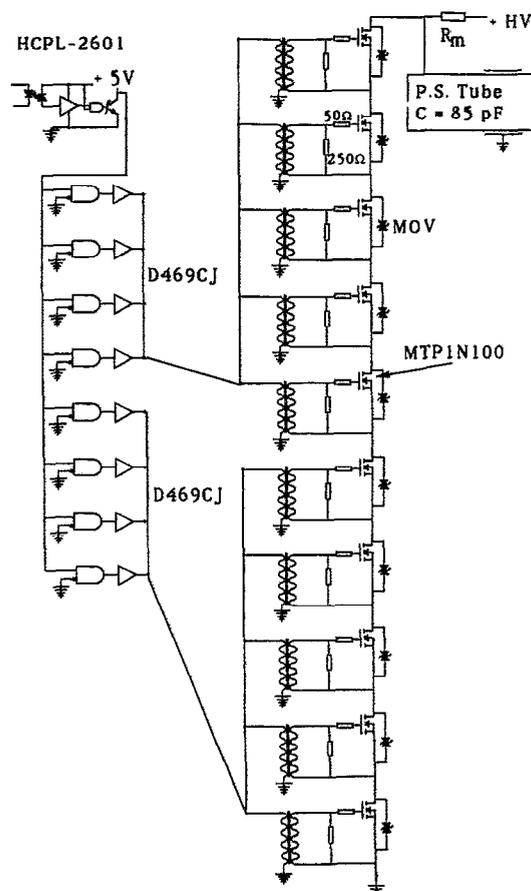


FIG. 1. Schematic of the 8 kV MOSFET switch.

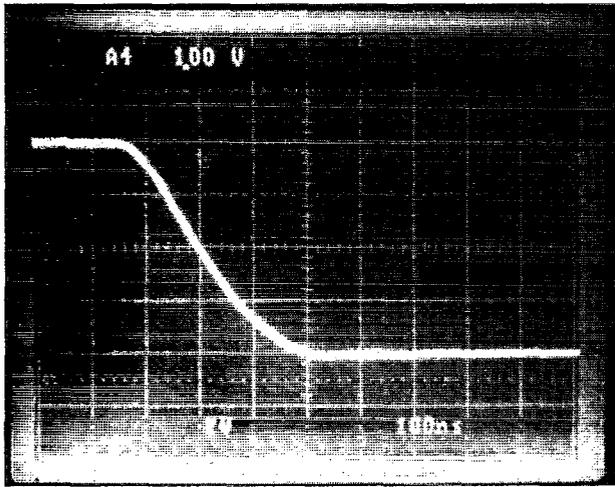


FIG. 2. Oscilloscope trace of the 8 kV falling edge as measured with a 1000:1 probe (1 vertical division = 2000 V).

11.1  $\mu\text{s}$  as determined by the capacitance of the tube and the size of  $R_m$ . In applications where both edges of the pulse must be fast, a push-pull version of this circuit should be easy to implement. This circuit works reliably and has proven to be an excellent, cost-effective way of re-referencing our beam energy.

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<sup>1</sup>L. A. Posey, M. J. DeLuca, and M. A. Johnson, *Chem. Phys. Lett.* **131**, 170 (1986).

<sup>2</sup>R. E. Continetti, D. R. Cyr, R. B. Metz, and D. M. Neumark, *Chem. Phys. Lett.* **182**, 406 (1991).

<sup>3</sup>P. Horowitz and W. Hill, *The Art of Electronics*, 2nd ed. (Cambridge University, New York, 1989), p. 53.

<sup>4</sup>P. Horowitz and W. Hill, *The Art of Electronics*, 2nd ed. (Cambridge University, New York, 1989), p. 882.