

**This technical bulletin describes a method of using the Voltage Multipliers Inc. OC100HG high voltage opto-coupler in a high voltage push-pull configuration.**

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<http://www.jlab.org>

**Note: This document describes an application using high voltage. Construction of this or similar circuits should only be performed by qualified individuals who understand the hazards associated with high voltage and take the proper precautions.**

The OC100HG push-pull configuration is useful for driving strictly capacitive loads or very high resistive impedance loads. Low capacitance loads can be driven at relatively high speeds, while large capacitance loads can be slowly charged to a desired voltage.

Typical applications include high voltage biasing or switching of:

- Pockels Cells
- Electrostatic plates for steering electron beams
- Photo-multiplier tubes.
- High voltage piezo-electric devices

The application described in this document required fast high voltage bipolar drive of a Pockels cell. Remarkably, in this particular application, the push-pull OC100HG configuration was able to replace a \$10,000 commercial high voltage switch, resulting in superior performance at a fraction of the cost.

The complete description of the high voltage switch studies leading to this development can be found at:

[http://www.jlab.org/accel/inj\\_group/laser2001/pockels.htm](http://www.jlab.org/accel/inj_group/laser2001/pockels.htm)

Introduction:

A Pockels Cell is an electro-optic device commonly used in laser systems to manipulate the polarization properties of light. The process is similar to that of the liquid crystal display, but uses the voltage induced birefringence stress properties of certain crystals to manipulate light at much greater speed with very high optical power handling and very high polarization purity. By manipulating polarization, laser light can be rapidly redirected or attenuated by downstream optics with no moving parts.

Speed is a relative term. Fast can mean picoseconds to one person while another would consider microseconds to be fast. While there are very high speed (nano-second) applications for Pockels cells, this particular application required clean switching between two distinct polarization states where the cell might remain in a given state for long time periods (milliseconds to seconds). Our application demands a transition time between states of less than 100 micro-seconds, yet if we switch this cell faster than 20 microseconds, a

piezo-electric ringing will be induced that is detrimental to our experiment. Our application switches between + and -  $\lambda/4$  birefringence states to create right hand and left hand circular polarization. At our particular wavelength, the required cell voltage is + and - 2560V.

Our application also requires perfect symmetry between the left and right hand circular polarization states. To accomplish this we built a push-pull switch configuration using two commercial high voltage switches as shown in figure 1 below.

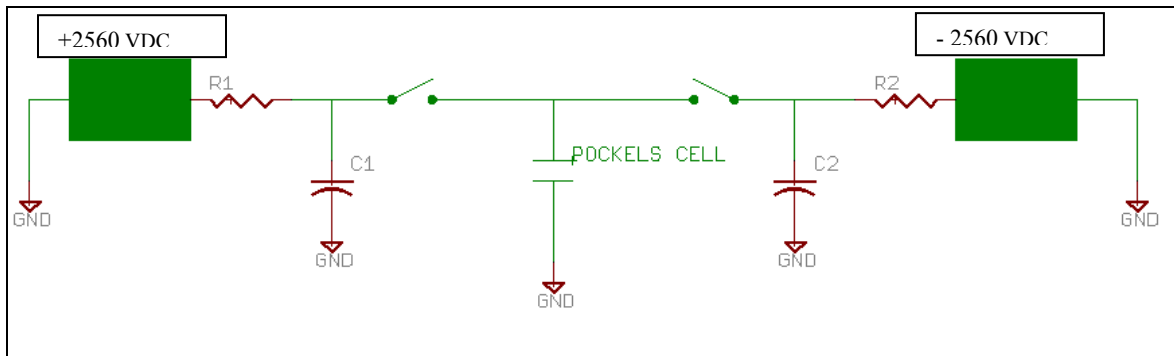


Figure 1

The two switches were driven in opposition. Obviously it would be a grave danger to close both switches at the same time, so transfer timing logic is required to ensure one switch is opened before the other is permitted to close. It is easy to see that when the left switch is closed, the purely capacitive Pockels Cell charges to +2.56 KV with respect to ground. Conversely, when the right hand switch closes, the cell charges to -2.56KV.

This is all well and good, but there were several issues that plagued us. Most notably, the switches were large, expensive, and could not be placed at a close distance to the Pockels cell. This resulted in a need for several feet of high voltage coaxial cable between the switch assembly and the cell. This added cable introduced a significant amount of capacitance to the assembly, resulting in higher power handling requirements on both switches and power supplies. (\$\$\$) It also created additional problems beyond the scope of this discussion.

While looking for an alternative we discovered the Voltage Multipliers Inc. OC100HG.

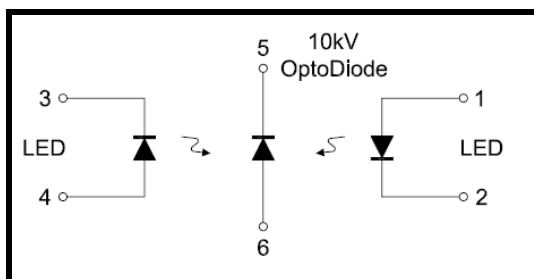


Figure 2

The OC100HG high voltage diode is presently rated to have a reverse “leakage” of 230 micro-amps while biased at high voltage and exposed to the infrared light from the two LED’s being driven at 50mA. The leakage drops to 250 nano-amps when the LED’s are off.

**What can you do with 230 uA? Let’s take a look.**

We placed two of the model OC100HG opto-couplers in series and created a drive circuit. The LED’S for each opto-coupler are driven in opposition, so the center junction is pulled to the positive rail (2.56kV) or the negative rail (-2.56kV) depending on the TTL input state. The circuit is really just a simple voltage divider that is equally balanced when all LED’s are off. By turning on one set of LED’s, we can shift the balance of power in the circuit from the neutral state up to one rail. The other set of LED’s will take the balance to the other rail. One thing should be immediately obvious. Since the diodes in full conduction only pass 230 uA, there is really not a problem with a momentary period of both diodes in conduction.

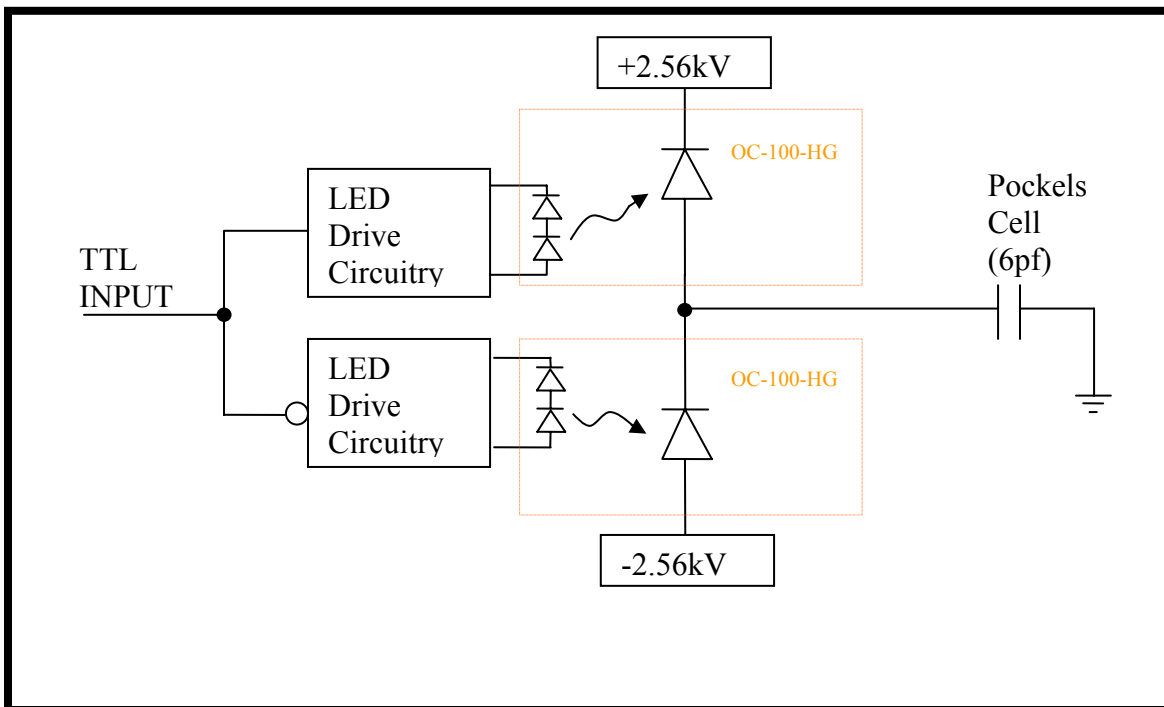


Figure 3

Our pockels cell is a strictly capacitive device of 6pf. Because these opto-couplers are so small, they can be mounted directly to the top of the cell. This eliminates the cable capacitance and stray inductances that have plagued us in the past. Without a large capacitance charge transfer, the load seen by the power supply rails is insignificant. The system can now be driven by very low wattage power supplies.

Running the numbers:

Begin with the cell charged to 2.56KV, so a transition to -2.56KV will be a voltage change of 5120V.

$$\text{Capacitor charge time} = [V_{\text{high}} - V_{\text{low}}] * C / I = 5120V * 6\text{pf} / 230\text{uA} = 133 \text{ us}$$

This means that in this application of driving a Pockels cell from one high voltage state to the other, the transition time will be 133us. One thing should be immediately apparent. Two more opto-couplers can be placed in parallel with the first set. The resulting transition time would be reduced to 67us because you would get twice the charge transfer speed.

Figure 4 below is a picture of our modified OC100HG push-pull switch. We used external high power LED's to drive the diodes harder, eliminating the need to parallel several units. The complete test results are provided on the jlab web site link provided above. Voltage Multipliers Inc will probably be offering this configuration as a standard product in the near future.

**Note: If pushing the OC100HG beyond its normal parameters, one needs to be mindful of the power dissipation in the high voltage diodes. This particular application does not stress the device, but higher voltages at high currents can create significant  $I^2R$  losses and will overheat the device if permitted to flow for extended periods.**

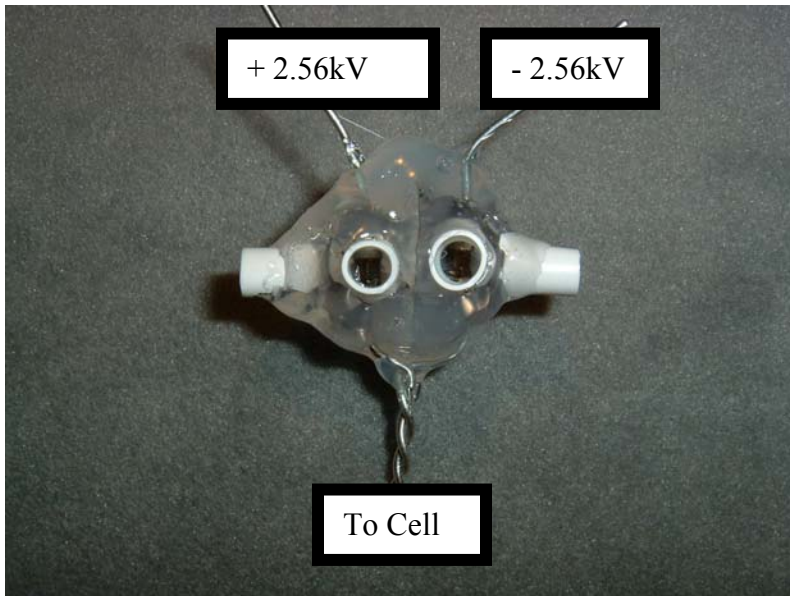


Figure 4. Both HV diodes joined in series. Mounting tubes for 6 LED's. Opaque barrier between individual units.

### Switch performance:

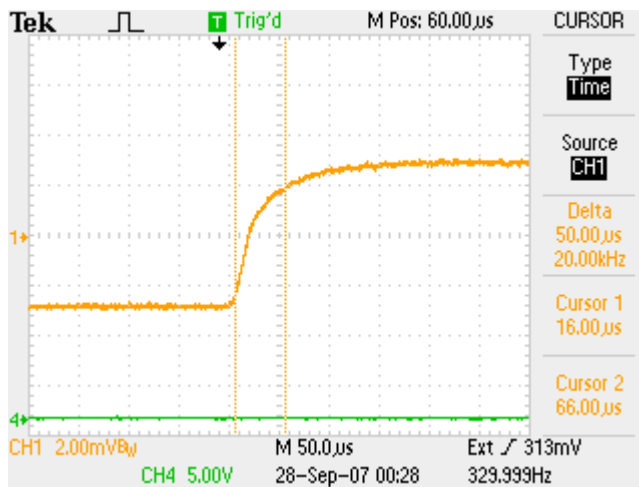


Figure 5. Pockels cell transition of 5160V as analyzed by light passing through. Taking optical measurements is the only way to truly verify the circuit response. A high voltage probe placed on the cell would disturb the circuit by introducing additional capacitance and a resistive component that would significantly slow down the transition.

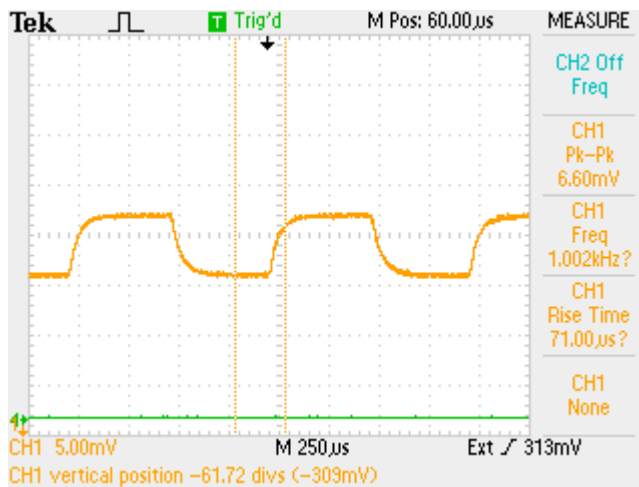
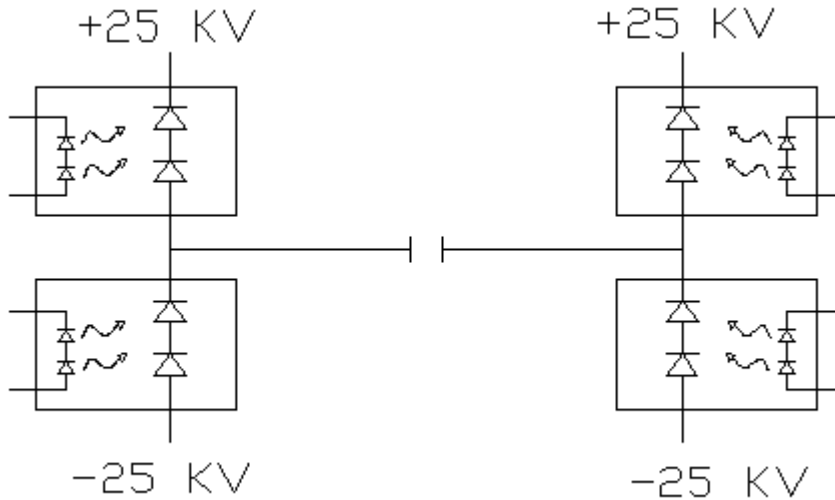


Figure 6. Pockels cell flipping at 1kHz to +/-  $\lambda/4$  birefringence states. (780nm). Perfect symmetry, no ringing, no overshoot. – Perfect!

## Some food for thought:

Up to 50,000 V bipolar differential drive using four of Voltage Multiplier's model OC250. A possible application is electrostatic deflection of an electron beam in a linear accelerator.

One can assume that multiple devices can be stacked in series to achieve even higher potentials.



If your thinking about your own vacuum chamber application, you will need to know your capacitance to calculate switching speed:

Capacitance in a vacuum =  $8.85 \cdot 10^{-12}$  F/m \* Area in  $m^2$  / distance between the plates in meters

*Or just carry your RLC meter to your device and measure it.*

**Caution: High voltage on a vacuum system is a potential X-ray source. Follow all necessary precautions.**

Note: While this application note has concentrated on ON-OFF control of the LED's to create bipolar switching, the same voltage divider configuration can be driven in an analog mode to shift the center point to any desired voltage between the upper and lower rails. With the addition of a feedback signal, a closed loop low current (very) high voltage operational amplifier can be realized.