



# Operation and Installation Manual

---

## Q-DRIVE BENCHTOP

Driver for KD\*P Pockel Cells in Q-switched Lasers

LABORATORY MODEL

JULY 2021



---

## Contents

<b>I</b>	<b>Introduction</b>	<b>4</b>
	Description	4
	Specifications	4
<b>II</b>	<b>Installation</b>	<b>6</b>
	Trigger	6
	Power	6
	Voltage monitor test points	6
	DB-9 control connector	7
	High voltage control switch	7
	High voltage adjustment	7
	Status indicator	7
	Pockels cell leads	8
	Ground stud	8
<b>III</b>	<b>Operation</b>	<b>9</b>
	Setting the voltage	9
	Supplying a trigger signal	9
	Verifying operation	9
<b>IV</b>	<b>Theory of Operation</b>	<b>11</b>
	<b>Appendix</b>	<b>12</b>
	A - Ringing and damping	12
	B - Designing a circuit to drive the trigger	12
	C - Measuring the output waveform	13

**WARNINGS**

This equipment must only be used by qualified personnel.

This device produces 4.5 kV high voltage pulses. Normal precautions for working with high voltage must be followed.

When operating in a Q-switched laser this equipment is part of a system that generates high energy pulses of laser light that can cause serious injury.

The pulses produced by the driver are very fast – the wiring between the driver and the Pockels cell, and the Pockels cell itself, can be expected to produce a great deal of EMI. It is the user's responsibility to ensure that systems incorporating this driver do not cause undue interference.

There are no user serviceable parts in the driver. It should be returned to G&H for service if required.

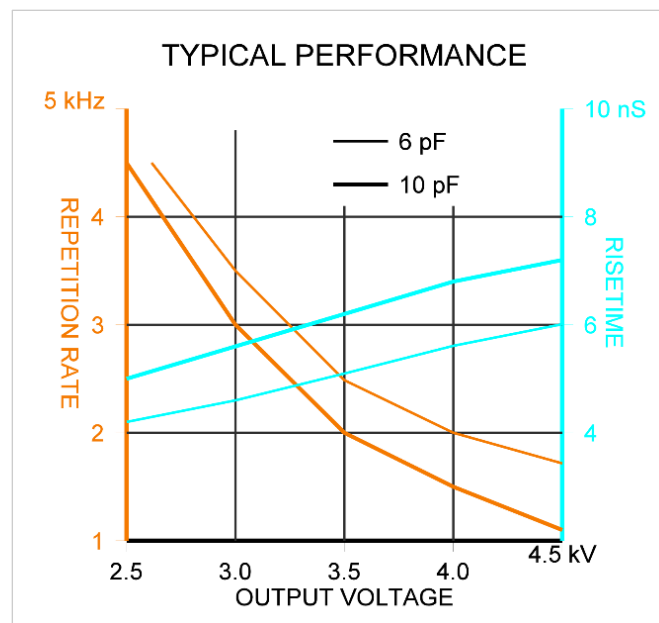
## I Introduction

### Description

The G&H Q-Drive Benchtop is a Pockels cell driver for Q-switched laser systems. It is meant for laboratory use. G&H supplies customized OEM drivers for incorporation into a product.

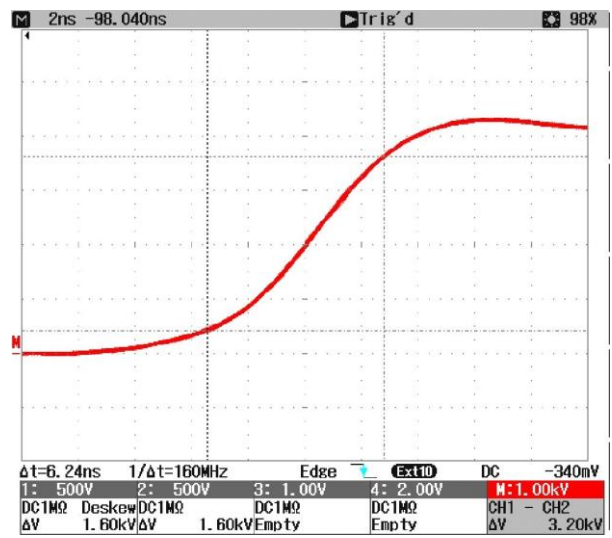
### Specifications

Output voltage	1.5 kV to 4.5 kV, adjustable
Output DC	Zero
Output rise time	5-7 ns depending on load capacitance and output voltage, see graph below.
Output waveshape	Differential +/- pulses, balanced with respect to ground, exponential decay with a 7 $\mu$ s time constant (factory special for other decay times)
Repetition rate	Up to 5 kHz, again dependent on load and voltage – see graph below
Power input	24 VDC, 250 mA maximum
Trigger input	5 V, 50 $\Omega$ BNC
Output wiring	Flying leads to cell, ground stud



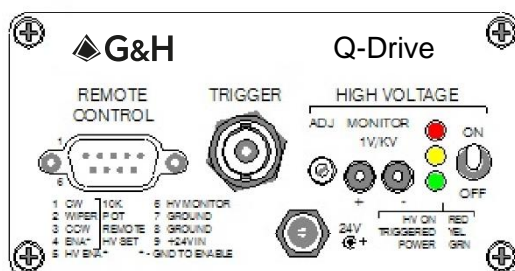


Output waveform



Output rise time

## II Installation



Front panel connections

### Trigger

The trigger is electrically isolated with a high speed GMR (giant magneto-resistive) device. Both the signal and the shield are isolated and no ground connection is made through the trigger input.

The triggering voltage is a nominal 5 V, with the driver triggering on the rising edge. The pulse width doesn't really matter, but it should be in the range of a microsecond to a square wave input.

The rise time should be as quick as practicable. A slow rise time will result in increased jitter – a truism with any driver.

The trigger input is a 50  $\Omega$  terminated circuit. It should be driven by a pulse generator that expects a 50  $\Omega$  load.

Although a 5V/50  $\Omega$  signal is sometimes referred to as TTL – it must be noted that TTL logic cannot drive a 50  $\Omega$  load. See Appendix A if you are designing your own trigger drive circuit.

The maximum frequency depends on the cell capacitance and the output voltage. If the maximum frequency is exceeded then the driver's internal power limiting circuits will come into play and the output voltage will be reduced. Naturally, the driver should not normally be operated at or over its power limit.

### Power

The front barrel connector has a positive 2.1 mm center pin and accepts 5.5 mm x 11mm/0.21" x 0.43" plug. You can also supply power through the DB-9 control connector.

The driver operates on 24 V DC at 130 mA maximum. A suitable power adapter is supplied with drivers sold in North America. If a laboratory supply is used the current limit should be set to ~250 mA.

### Voltage monitor test points

The high voltage setting can be monitored with a DVM. The output at the test points is approximately 1 V per kV of output voltage. You can also monitor the high voltage through the DB-9 control connector.

See section III for notes on setting and measuring the output voltage.

## DB-9 control connector

### Remote high-voltage setpoint

Connections to a remote 10K potentiometer, see section III

- 1: CW terminal
- 2: Wiper
- 3: CCW terminal

To enable the remote potentiometer:

- 4: Connect to pins 7 and/or 8 to use the remote potentiometer

### High voltage On/Off control

- 5: Enable – connect to pins 7 and/or 8 to turn on the high voltage, note the front panel switch must be set to OFF for remote control – either the front panel switch or the remote control can turn the HV on.

### High voltage monitor

- 6: Approximately 1V per kV of output, see section III

### Ground

- 7: Ground terminal
- 8: Ground terminal

The connector shell is also grounded, but this should not be depended on for an electrical connection.

### 24 V Power

- 9: +24 VDC at 250 mA, this duplicates the front panel AC adapter jack.  
Connect the minus end of the 24 VDC to pins 7 and/or 8.

## High voltage control switch

The switch controls the internal high voltage. It has no effect on the low voltage circuits. The driver consumes very little power with the high voltage off. Even with the high voltage on there will be no voltage on the output to the Pockels cell unless the driver is triggered.

## High voltage adjustment

The high voltage is set with the 15 turn potentiometer. This function is duplicated at the DB9 connector.

The limits of adjustment are 1.5 kV to 4.5 kV.

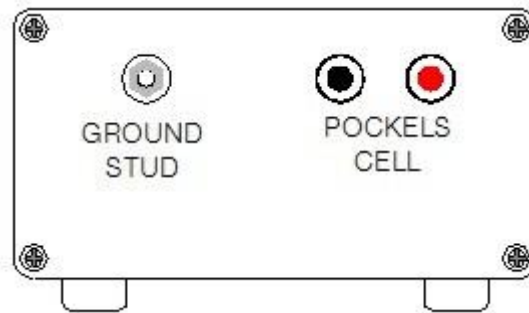
The voltage can be monitored at the front panel jacks and at the DB9 control connector.

## Status indicator

Green 24 VDC power has been applied

Yellow Trigger signal is present, the LED may flash at very low repetition rates

Red High voltage power is on



Rear panel connectors

### Pockels cell leads

Connection to the cell is made with the two flying leads. The connection should be as short as practicable and the leads kept at a (mostly) constant separation of 20 mm/0.75". The leads must be kept as far as possible from any metal or conducting object. 450  $\Omega$  "Ladder Line" is useful for long extensions. It is available on the web. Wiring must be kept away from metal objects.

Neither wire should connect to ground or to any other circuit.

50/75  $\Omega$  coaxial cable must not be used.

The flying leads are colored red and black – the red lead provides a positive pulse and the black lead a negative pulse. It makes no difference which lead is connected to which terminal of the Pockels cell.

### Ground stud

The system must be grounded at the ground stud. This grounds the case and internal circuitry to the local metal of the system, which in turn should be connected to earth ground. This ground connection would normally be made to the optical bench or to the laser case.

The supplied power adapter does not provide a ground. The ground on the 50  $\Omega$  trigger input is isolated from the rest of the circuit and cannot be used as a system ground.



## III Operation

### Setting the voltage

The voltage range is approximately 1.5 kV to 4.5 kV, and is normally set with the 15 turn potentiometer on the front panel.

The voltage monitor provides 1V/kV at both the front panel red/black test probe jacks and at the DB-9 remote control connector.

Some inexpensive hand-held DVMs may pick up the EMI from the Pockels cell or the flying leads and not function correctly when connected to the voltage monitor test jacks. In this case the voltage can be set by first disconnecting the trigger input signal so there is no high voltage pulsing.

The monitor voltage will be within ~5% percent of the output voltage. As the monitor reflects the driver's internal high voltage power supply, the relation of the monitor voltage to cell drive voltage will vary with normal internal component tolerances, the cell capacitance, the repetition rate, the wiring to the cell and the output voltage setting.

The final voltage setting is made by observing the operation of the optical system and adjusting the voltage for the optimum performance of the Pockels cell.

### Using the remote control DB9 connector to set the voltage

For remote control of the voltage connect pin 4 of the DB-9 connector to the driver's circuit ground, present on pins 7 and 8. Selecting remote control disables the front panel potentiometer.

A 10 k $\Omega$  remote control potentiometer is wired as described in section II, pg. 4. This potentiometer **must** be 10 k $\Omega$ ; the normal 10% tolerance for a potentiometer is acceptable.

### Using a remote control voltage to set the output voltage

For control by a remote voltage source, say an analog output on an instrumentation computer, the driver's output voltage can be controlled by applying a voltage to pin 2 of the DB-9 connector. The driver isn't really designed for this as there is no safety limit circuit on this voltage. But if the application demands it then applying ~0.6 V will result in ~1.5 kV and 1.9 V in 4.5 kV.

**Caution:** The voltage must not be allowed to vary outside of this 0.6 to 1.9V range. Voltages below 0.6 V will result in an unstable output voltage and voltages above 1.9 V will impose higher voltage stresses on the driver circuitry.

### Supplying a trigger signal

Connect the trigger source to the driver with a 50  $\Omega$  coaxial cable. The driver has an internal 50  $\Omega$  termination. See section II on page 5 and Appendix A on page 11 for more information on triggering requirements.

### Verifying operation

This procedure quickly verifies the driver outputs are working. It doesn't measure the driver's performance. See Appendix B for performance measurements.

Equipment needed:

- 100 MHz scope, 500+ MHz preferred
- 10x scope probe with tip covered
- 2 BNC-BNC cables
- BNC 'T' fitting
- Pulse generator

Insulate the tip of the scope probe to minimize the possibility the probe tip comes into contact with the high voltage pulses at the driver output.

Setup the scope:

- Channel 1: 20 V / division, trace centered
- Channel 2: 5 V / division
- Horizontal: 20 ns / division
- Trigger source: Channel 2, 2.5V
- Place the 'T' at the scope's Channel 2 input; connect the output of the pulse generator to one arm of the 'T'; connect the other arm to the driver's trigger input
- Display the rising edge of Channel 2 at the left of the scope CRT/LCD
- Connect the probe to Channel 1
- Apply power to the driver and turn on the HV

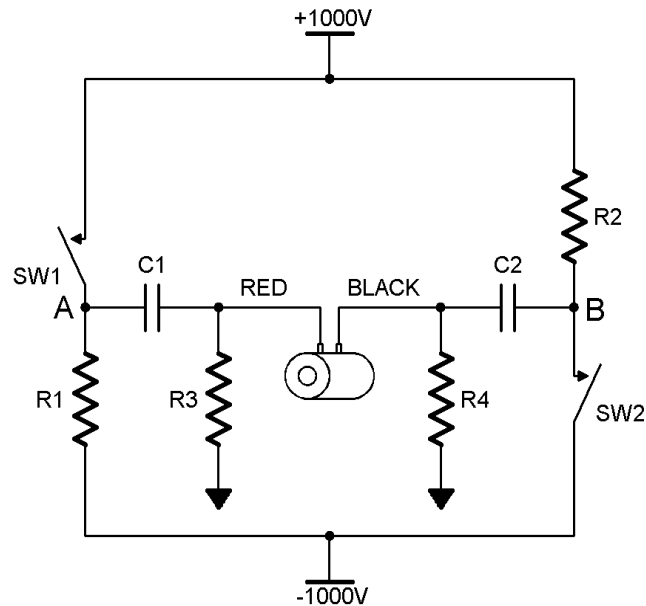
Bring the scope probe close to the black and red output leads.

**Caution:** Do not touch the probe to the bare wire at the end of the leads.

You will destroy the probe and possibly the scope.

You should see a ~60 V signal as the probe is brought close to each of the leads. The red lead should produce a rising edge and the black lead should produce a falling edge. The magnitude and rise time will vary with the scope bandwidth, the type of probe and how it is held. Not much importance should be attached to the actual waveform, but the signals from the two output leads should be complementary and very similar in shape and timing.

## IV Theory of Operation



A (very) simplified schematic of the driver's output circuit

At rest the two switches SW1 and SW2, made from high-voltage MOSFETs, are open. The red and black leads are held at ground potential by R3 and R4. Point A is brought to -1,000 V through R1, charging C1 to the same -1,000 V. Likewise point B, and the charge on C2, are +1,000 V.

The capacitances of C1 and C2 are much greater than the capacitance of the Pockels cell.

When the driver fires it closes switches SW1 and SW2 at the same time. This quickly takes point A from -1,000 V to +1,000 V – a positive 2,000 V swing. Capacitor C1 transmits this +2,000 V swing to the red output lead and one terminal of the Pockels cell. Likewise point B swings -2,000 V and this is transmitted to the black output lead.

The result of the two 2,000 V swings is a total voltage of 4,000 V across the Pockels cell.

After a few hundred nanoseconds SW1 and SW2 are opened. Point A returns to -1,000 V and point B to +1,000 V. The Pockels cell discharges to ground through R3 and R4. From this it is easy to see why the recovery time is influenced by the capacitance of the Pockels cell – and that this time can be varied by changing the values of R3 and R4. Other circuitry is, of course, involved and this increases the effective capacitance and slows down the recovery time.

An AC-coupled bridge circuit such as this brings several benefits. It reduces the output voltage to ground to one half of what it would be in a conventional design – lessening the stress on the insulation and reducing the chances of arc-over to ground. The internal voltages in the driver are one fourth what they would be in a standard driver, leading to increased system reliability.

## Appendix

### A - Ringing and damping

Excessive ringing may arise from the combination of the driver's fast rise time, the cell's capacitance and the wiring inductance.

The ringing can often be mitigated by careful routing of the wiring between the driver and cell.

If additional damping is needed then ceramic composition resistors can be placed in series with the cell terminals. 100  $\Omega$  ceramic composition resistors will usually provide adequate damping without impacting rise time. They are available from Digikey P/N A105581 (TE Connectivity 1623720-1) or Mouser P/N 660-HPC2C101K (KAO Speer HPC2C101K).

If critical damping is desired then the resistance can be determined by observing the ringing frequency with an oscilloscope, as detailed on Page 8 – "Verifying Operation". The value of the critical damping resistor is given by

$$R = 1 / (\pi * f * C)$$

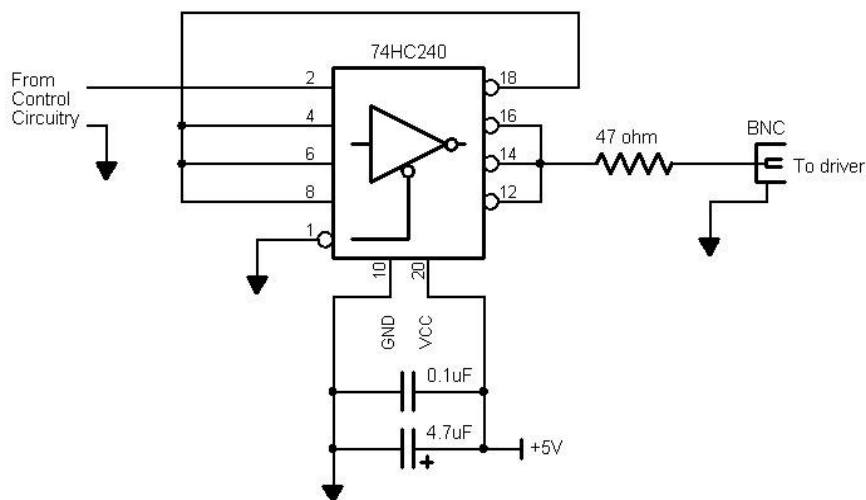
Where f is the ringing frequency in Hz and C is the cell capacitance in farads

(1 pF = 10<sup>-12</sup> farads). Half of this resistance should be put in series with each cell terminal. Note that critical damping will result in a slightly slower rise time.

### B - Designing a circuit to drive the trigger

As mentioned before, the input to the driver is a real 50  $\Omega$  terminated input with a 0-5 V signal range. It is meant for use with a pulse generator. A weak signal that rises slowly will produce jitter in the output.

It needs to be noted that a single 'TTL' gate does not have enough current drive capacity to drive a terminated 50  $\Omega$  cable. One possible circuit that uses the common 74HC240 gate is:



You can also use the 74F3037 or 74128 line drivers or use a circuit with discrete MOSFETs or bipolar transistors.

## C - Measuring the output waveform

**Caution:** these procedures should only be undertaken by personnel qualified to work with very high voltages at high frequencies.

Measuring the electrical output performance of the driver requires a 500 MHz or faster oscilloscope and a pair of low capacitance, high speed 100x high voltage probes. Do not under any circumstances attempt to use low voltage 10x probes as the probes and possibly the oscilloscope can be destroyed.

The measurement needs to be put in perspective: 5 kV in 5 ns is a slew rate of 1 trillion V/second and the peak output current into 10 pF is 10 amps. At 80 MHz, the fundamental of the output signal's rise, the impedance of a 10 pF capacitor is only 200  $\Omega$ . The peak pulse current into the tip of a scope probe can approach 4 amps.

The tip capacitance adds to the load capacitance, and this needs to be accounted for when making measurements.

The LeCroy PPE 4 kV probe has 9 pF of tip capacitance, though LeCroy claims less than 6 pF. The Agilent 10076B is slightly under the claimed 3 pF, but the bandwidth is 250 MHz which is barely adequate. The Tektronix offerings are normally rated at 500 MHz and 3 pF; we have no experience using them to measure driver output.

The two probes appear as two capacitors in series because of the differential output of the driver. As a result the effective added capacitance of the two probes is half the tip capacitance.

If you are using a large Pockels cell then you may want to add an additional 5pF capacitance to the output leads to better mimic the capacitance of a large Pockels cell.

6 KV ceramic capacitors are available from Digikey, Mouser and other electronic component distributors.

The oscilloscope should be set to display the difference of the two probe measurements, showing the red voltage minus the black voltage.

You should expect the measurement to produce ringing artifacts. The majority of the ringing viewed on the oscilloscope is due to the oscilloscope probes and the inductance of the probes' ground leads. The inductance can be minimized by wrapping the ground lead around the body of the probe so the ground clip is close to the probe tip. The other source of ringing is the inductance of the driver's red and black output leads – obviously these should be as short as possible.

For further information

[info@gandh.com](mailto:info@gandh.com)

[gandh.com](http://gandh.com)