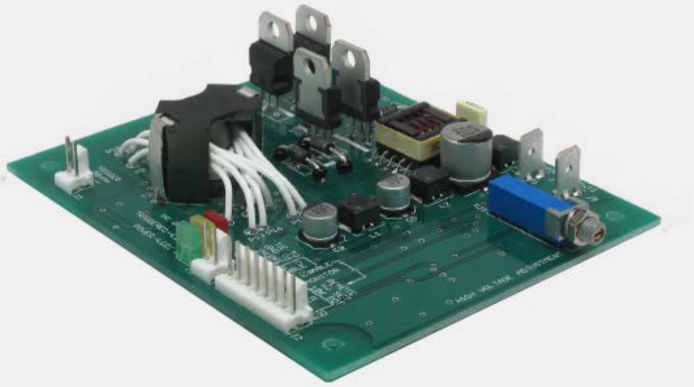
Design-In Manual

Q-DRIVE™ POCKELS CELL DRIVER

For Q-Switched Laser Systems

OEM MODEL

OCTOBER 2017



Gooch & Housego (Ohio)

Contents

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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 insure that systems incorporating this driver do not cause undue interference.

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

I Introduction

Description

The Gooch & Housego OEM Q-Drive™ is a Pockels cell driver for Q-switched laser systems. It is meant for incorporation into a product and not for general laboratory use. Gooch & Housego supplies laboratory Pockels cell drivers for stand-alone use.

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 the graph on page 5.
Output waveshape	Differential +/- pulses, balanced with respect to ground, exponential decay with a 7 µs time constant (factory special for other decay times)
Repetition rate	Up to 5 kHz, again dependent on load and voltage – see graph on page 5.
Power requirement	24 VDC, 130 mA maximum, less at lower repetition rates and voltages
HV On/Off time	The high voltage power supply turns on in 40 mSec and off in 400 mSec after either application of 24 V power or enabling via J2 pin 7, as described on page 7.
Trigger input	5 V, 50 Ω

Performance Envelope

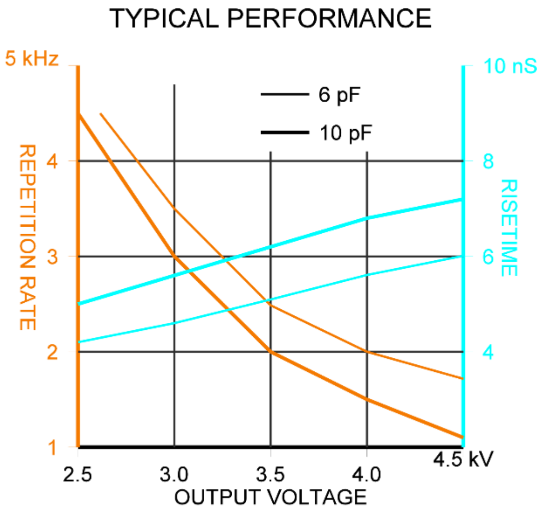
The driver has two limits, as shown in the graph on the right:

A power limit (orange line)

The power required to charge the cell increases with voltage, cell capacitance and repetition rate. If the repetition rate is increased past the driver's capabilities then the output voltage will taper back.

A current limit (blue line)

The driver provides a constant current to charge the cell. As a result, the rise time increases with cell capacitance and voltage.

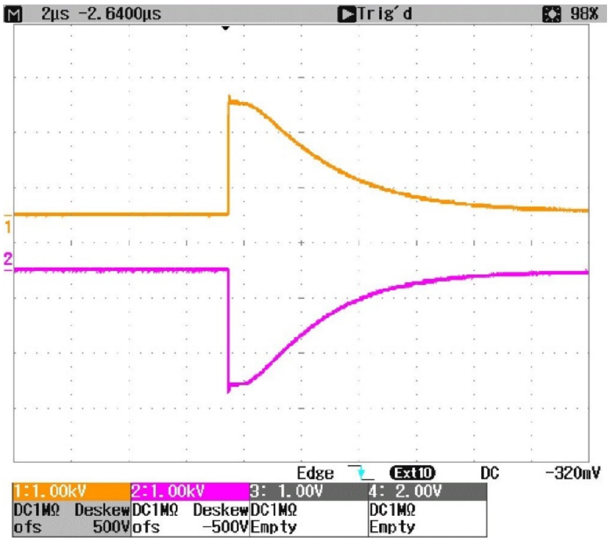


Driver Output

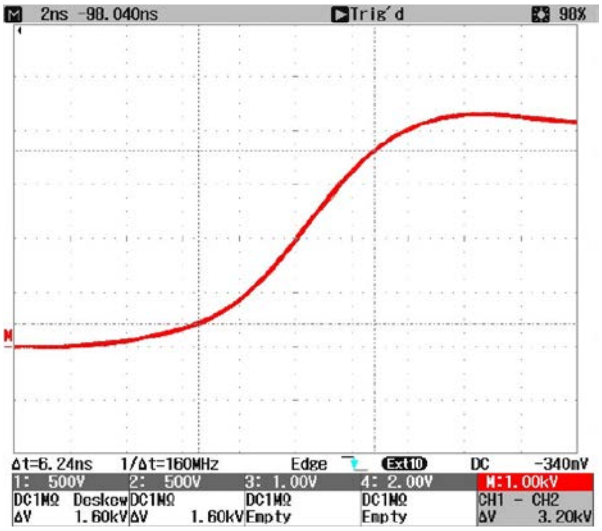
The driver produces complimentary balanced output pulses. The cell sees the difference between the two outputs.

The driver pulses the cell terminals from ground to +/- 1/2 the output voltage in ~6 ns. The voltage then returns to ground slowly with a time constant of 7 ìs.

At rest the driver outputs sit at zero voltage. Because of the balanced output it is important that leads to the driver are routed symmetrically with respect to the driver, the cell and any sheet metal. Routing a lead close to metal will introduce extra load capacitance and slow down the driver's output.



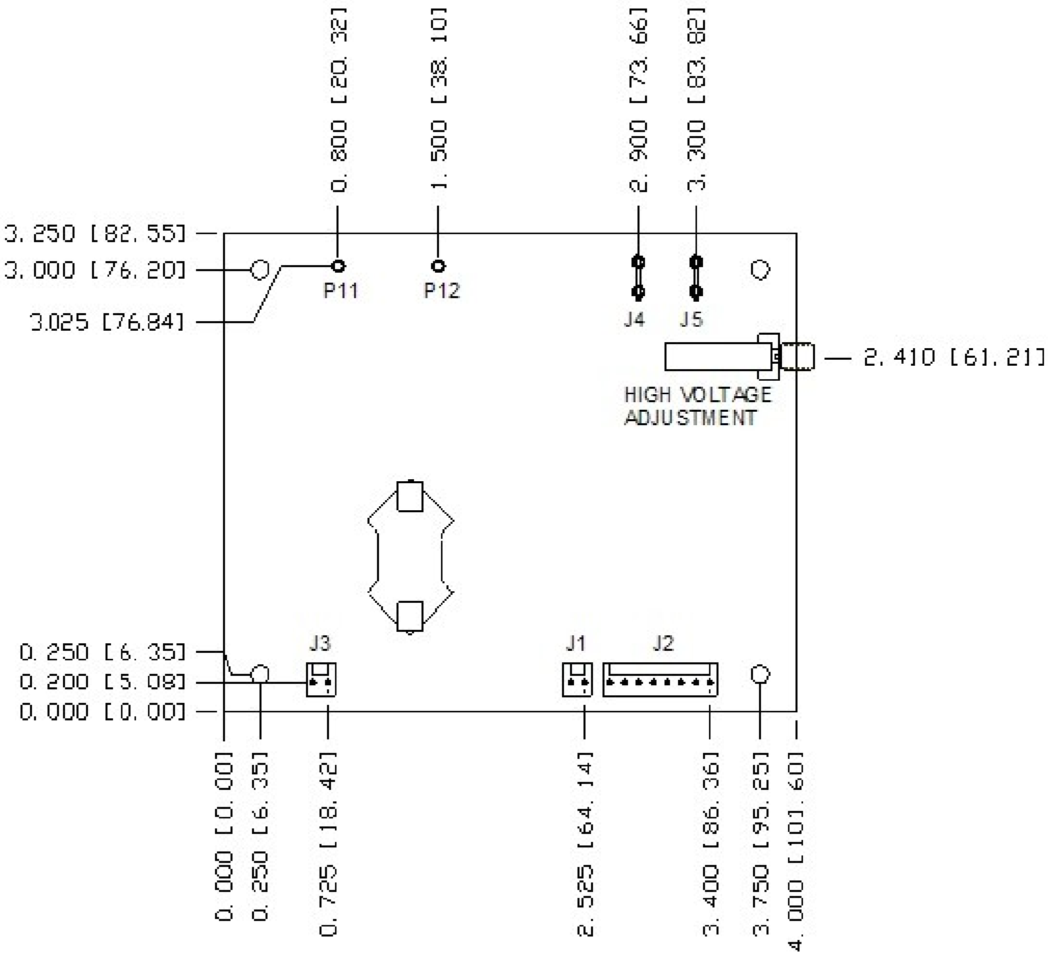
Output waveform



Output rise time

II Installation

Dimensions and Connector Locations



Connections

J1-J3Power, trigger and control

Pin 1 is at the right of all the MTA connectors as shown in the illustration above.

J1, J2 and J3 mate with TE Connectivity (AMP) MTA100 receptacles:

		TE Part No.
2 pin	22 ga	3-640440-2
	24 ga	3-640441-2
8 pin	22 ga	3-640440-8
	24 ga	3-640441-8

It is possible to mate the headers to other connectors that accept 0.025" posts on 0.100 centers. G&H can also supply the drivers with unshrouded "Berg-Stick" headers.

J1 24 V power – 2 position MTA100

Pin 1	Ground
Pin 2	+24 V

J2 Remote control and monitoring – 8 position MTA100

Pin 1	Ground	
Pin 2	CW terminal	Connect to a 10k potentiometer to remotely
Pin 3	Wiper	set the high voltage – be sure to ground pin 6.
Pin 4	CCW terminal	This potentiometer MUST be 10 k. If the cable length is over a few inches then a shielded cable should be used with the shield connected to pin 1 or 8.
Pin 5	High voltage monitor – 1 V/kV of output, referenced to Pin 1 or 8	
Pin 6	Enable the remote voltage adjustment potentiometer. Ground the signal to Pin 1 or Pin 8 to enable. Leave the pin unconnected to use the on-board potentiometer.	
Pin 7	Enable the high voltage. Ground the signal to Pin 1 or Pin 8 to disable the driver's internal high voltage power supply. Leaving the pin unconnected will turn on the driver's internal high voltage power supply when 24 V power is applied. If control over the high voltage supply is desired then this pin would be connected to either an open-collector circuit, switch or relay. Note that the DC high voltage does not appear at the output pins even though the high voltage power supply is on.	
Pin 8	Ground	

J3 Trigger – 2 position MTA100

Pin 1	Trigger (-)
Pin 2	Trigger (+)

J4-J5 Ground – AMP 0.25” Faston tab

Connect to the metal mounting surface and shielding.

P11-P12 Pockels cell – soldered wires

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 0.75”/20 mm.
- The leads must be kept as far as possible from any metal or conducting object.
- Neither wire should connect to ground or to any other circuit.
- 450 Ω “Ladder Line” is useful for longer extensions. It is available from radio supply houses and on the web. The rise time slows down as the wire length from the driver to the cell gets longer.
- 50/75 Ω coaxial cable must not be used.

III Operation

Triggering the Driver

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 Ω terminated circuit. Drivers are available with 100 Ω inputs for use with twisted pair – contact G&H Ohio.

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

The maximum trigger frequency depends on the cell capacitance and the output voltage, as shown in the graph of the driver's performance envelope on page 5. 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.

Powering the Driver

The driver operates on 24 VDC and has a maximum current draw of 130 mA. The range of operation is 22 V to 26 V.

High Voltage Adjustment

The high voltage is set with the 15 turn potentiometer. The limits of adjustment are 1.5 kV to 4.5 kV.

A remote potentiometer can be used as described on page 7.

The voltage setting can be monitored at pin 5 of J2 with a voltmeter. The pulses from the driver may interfere with the operation of some hand-held DVMs – if this is the case then remove the trigger signal when setting/monitoring the voltage.

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.

Remote Control 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 3 of J2. The driver is not 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.

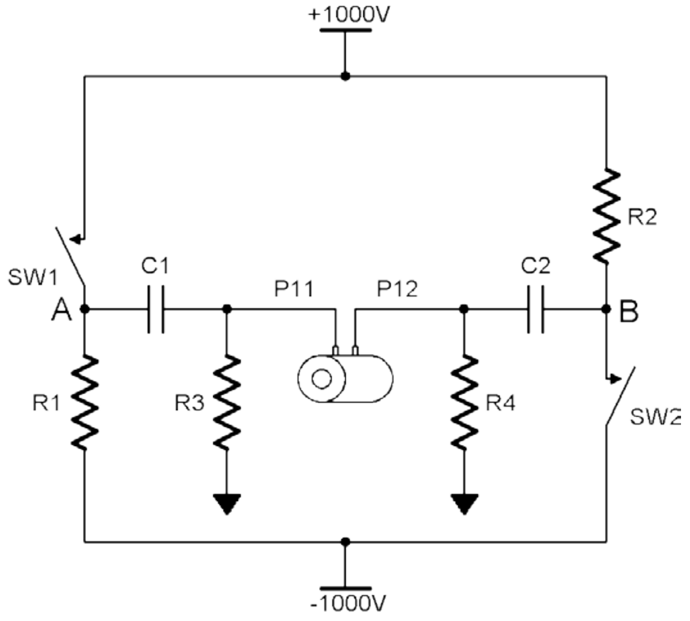
Warning: The voltage must not be allowed to vary outside of this 0.6 to 1.9 V range. Voltages below 0.6 V will result in an unstable output voltage and voltages above 1.9 V will impose higher voltage stresses on the driver circuitry.

Status Indicators

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

Appendix

A - 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 Pockels cell outputs, P11 and P12, 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 On/Off. 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, resulting in a positive 2,000 V swing at Point A. Capacitor C1 transmits this +2,000 V swing to P11 and one terminal of the Pockels cell. Likewise point B swings -2,000 V and this is transmitted to P12 and the other terminal of the cell.

The result of the two 2,000 volt 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. Additionally, the internal voltages in the driver are one fourth what they would be in a standard driver, leading to increased system reliability.

B - 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 Ω 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 11 - “Verifying Operation”. The value of the critical damping resistor is given by

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

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

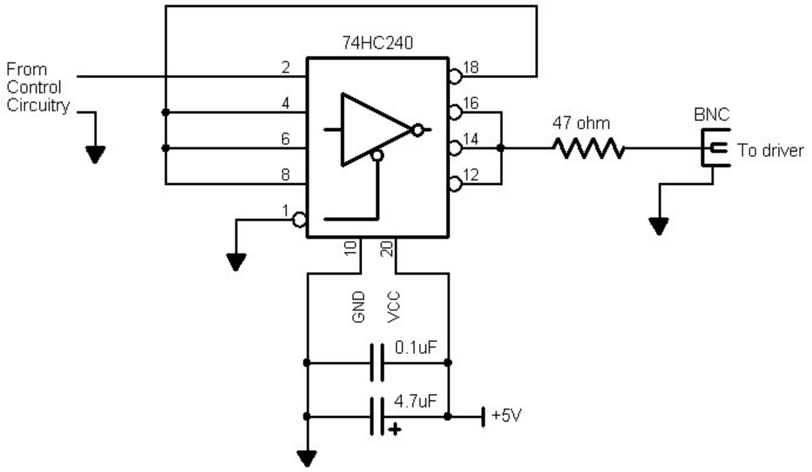
(1 pF = 10^{-12} farads). Half of this resistance should be put in series with each cell terminal.
Note that critical damping will result in a slightly slower rise time.

C - Designing a Trigger Drive Circuit

As mentioned before, the input to the driver is a real 50 Ω 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 Ω 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.

D - 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
- 2 10x scope probes.

Insulate the tip of one of the probes with several wraps of electrical tape to minimize the possibility of the probe tip coming into contact with the high voltage pulses at the driver output.

Setup the scope:

- Channel 1: 20 V / division, trace centered
- Channel 2: 2 V / division
- Horizontal: 20 ns / division
- Scope trigger: channel 2; 2.5 V; rising edge
- Connect Channel 2 to the driver's trigger input
- Display the rising edge of channel 2 at the left edge of the scope CRT/LCD
- Connect the probe to channel 1
- Apply power and trigger to the driver and turn on the HV

Bring the scope probe close to the leads going to the Pockels cell.

Caution: Do not touch the probe to the cell's terminals or to any 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 Channel 1 probe is brought close to each of the leads. The lead from P11 should produce a rising edge and the lead from P12 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.

E - 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 5ns 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 Ω. 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 9pF 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 5 pF 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 P11 (positive going) voltage minus the P12 (negative going) 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 leads from the driver to the Pockels cell – obviously these should be as short as possible.

For further information

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