

What a voltage pulser is and how to specify one

A voltage pulser takes energy from a DC supply, stores it, and on a trigger releases it as a constant-voltage, high-peak-current pulse into a load. This primer covers what the loads are, what is inside the instrument, which six specifications decide whether a model fits, and what to send when asking for one.



Photo: PVX-4110



1 What a voltage pulser drives

Pulsers with maximum output voltages from tens of volts to 10,000 V are used for accelerated life testing of dielectric materials; for driving extraction grids and deflection plates in time-of-flight mass spectrometers and accelerators; for pulsed current-voltage characterization of semiconductor devices; and for driving Pockels cells, Q-switches, microchannel plates, acoustic transducers, image intensifiers and photomultiplier tubes. The load is usually connected through several feet of coaxial cable.

Most of these loads are capacitive: a Pockels cell, a deflection plate or a microchannel plate looks electrically like a small capacitor, typically tens to hundreds of picofarads with its cable. Some pulsers are designed for 50 Ω resistive loads instead, and a few applications, such as pulsed I-V testing, present a device that conducts during the pulse. Pulsers are generally not intended to drive plasma chambers or other loads that become a short or near short during operation, although the output stage is protected against an arc or a short at the load.

2 Capacitive loads: current on the edges, power from the rate

A capacitive load draws current only while its voltage is changing, so the current flows on the edges of the pulse and the flat top draws almost nothing. The peak current follows from

$$I = C \cdot dV/dt \quad (1)$$

A 100 pF load (the cell plus its cable) stepped by 1,000 V in 25 ns draws $100 \text{ pF} \times 1,000 \text{ V} / 25 \text{ ns} = 4 \text{ A}$ for the duration of the edge. That is why a pulser rated for a few milliamperes of average current is built to deliver amperes on each edge.

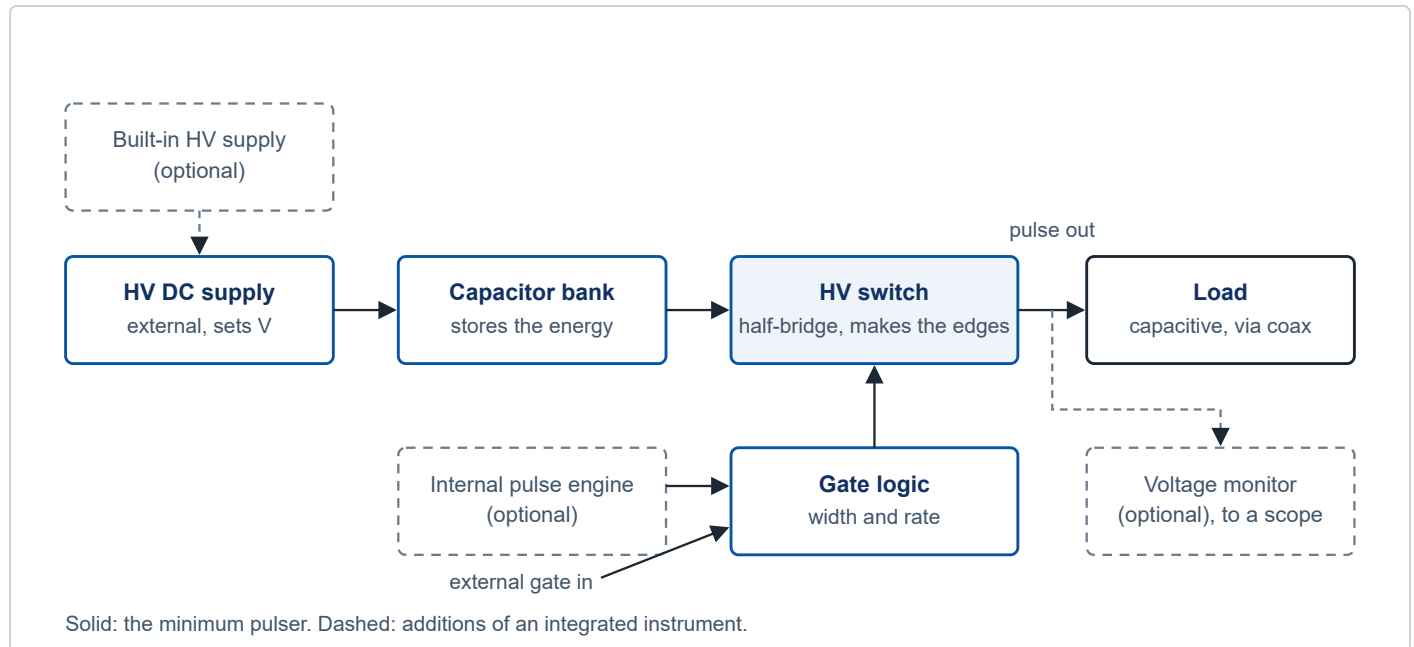
Each charge and discharge of the load dissipates energy in the pulser's output stage, so the average power rises with the repetition rate:

$$P = C \cdot V^2 \cdot F \quad (2)$$

The same 100 pF at 1,000 V and 10 kHz dissipates $100 \text{ pF} \times (1,000 \text{ V})^2 \times 10 \text{ kHz} = 1 \text{ W}$. At 10,000 V the square in (2) makes that 100 W, which is the maximum average power rating of the PVX-4110 and the reason its 10 kHz limit at full voltage applies to a 100 pF total load. (1) and (2) together decide which model a capacitive load needs; the note Capacitive-Load Pulsing works through both in more depth.

3 What is inside a pulser

At minimum a voltage pulser contains three things (Figure 1): a fast high-voltage electronic switch that creates the pulse edges; a local capacitor bank that stores energy between pulses and releases it during the pulse; and a logic-level trigger (gate) input that controls the pulse width and the repetition rate. The Directed Energy PVX and PVM models use a direct-coupled half-bridge, often called a totem-pole output stage: two high-voltage switches in series between a high rail and a low rail, with the gate deciding which rail is connected to the output. The pulse amplitude is the difference between the two rails, and the width and rate follow the gate.



SCHEMATIC Figure 1. The minimum pulser (solid blocks): a high-voltage supply charges a local capacitor bank, two series switches connect the output to the high or the low rail under control of the gate, and the load charges on each edge. The dashed blocks are the additions of a more integrated instrument: an internal pulse engine, a voltage monitor and a built-in high-voltage supply.

A more integrated pulser adds an internal pulse engine that generates its own trigger pulses, a voltage monitor that scales the output for an oscilloscope, and a built-in high-voltage DC supply to recharge the energy-storage capacitors. Modules such as the PVM-1001 and instruments such as the PVX-4110 take their high voltage from an external supply; the PVX-4000-2kV and the PVM-4210 carry their supplies inside. Depending on the model, the pulses are positive only, negative only, or bipolar.

4 The six specifications that matter

Six numbers decide whether a pulser fits an application, and they are the six to send when asking for one:

1. **Voltage.** The pulse amplitude, and its polarity: positive, negative or both, and whether the pulse is referenced to ground or offset from it.
2. **Pulse width.** The shortest and longest pulse needed. On the PVX and PVM models the width follows the gate from a minimum of tens or hundreds of nanoseconds out to DC.
3. **Repetition rate.** The highest rate, and the duty cycle. For a capacitive load the rate and the voltage set the average power through (2).
4. **Rise and fall time.** Specified 10 to 90 percent into a stated load. A half-bridge gives equal rise and fall; the series-resistor method in *How Do I Slow the Rise Time of My Voltage Pulser?* covers the case where a slower edge is wanted.

5. **Peak output current.** The current the output stage can source and sink on an edge, from (1) for the load and cable capacitance.

6. **Maximum average power.** The dissipation the pulser can sustain, which caps the product $C \cdot V^2 \cdot F$.

Table 1 gives the first four of these for the current Directed Energy line, from the datasheets.

Table 1. The Directed Energy voltage pulser line, from the published datasheets. Rise and fall times are 10 to 90 percent into each datasheet's reference load; repetition rates are the continuous maximum at full voltage unless noted.

Model	Output voltage	Rise and fall time	Pulse width	Repetition rate	Form
PVX-2506	0 to +50 V, 10 A, for pulsed I-V testing	See datasheet	Under 1 μ s to 100 μ s, 50% maximum duty cycle	See datasheet	Benchtop instrument
PVM-1001-P and -N	0 to +950 V or 0 to -950 V into 50 Ω	Under 10 ns rise (8 ns or less at 200 to 950 V positive)	55 ns to 10,000 ns	To 1 MHz, bursts to 5 MHz	Module, external HV supply
PVM-4210	0 to +950 V and 0 to -950 V, two channels, 1,900 V differential	25 ns or less	Under 50 ns to DC	Single shot to over 20 kHz, 5 MHz burst; 4 W per channel	Module, internal HV supplies
PVX-4151	0 to $\pm$ 1,500 V	Under 25 ns, typically under 20 ns	Under 60 ns to DC	Single shot to 240 kHz at 1,500 V; 150 W maximum average power	Instrument, external HV supply
PVX-4000-2kV	0 to $\pm$ 2,000 V, positive plus negative not over 2,000 V	50 ns or less from 500 V to 2,000 V	500 ns to DC on the external trigger	Internal trigger 40 Hz to 30 kHz; external single shot to 100 kHz	Instrument, internal HV supplies, RS-232 and USB
PVX-4141	0 to $\pm$ 3,500 V	25 ns or less	60 ns to DC	Single shot to 30 kHz at 3,500 V; 100 W	Instrument, external HV supply
PVX-4130	0 to $\pm$ 6,000 V	Under 60 ns	Under 150 ns to DC	Single shot to 10 kHz at 6,000 V; 100 W	Instrument, external HV supply
PVX-4110	0 to $\pm$ 10,000 V	Under 60 ns	Under 200 ns to DC	Single shot to 10 kHz; 100 W	Instrument, external HV supply

5 How to specify one

Send the load and what it is for (a Pockels cell, a deflection plate pair, a transducer, a device under test), its capacitance or impedance, the cable length to it, the voltage and polarity required and whether the pulse must be offset from ground, the pulse width range, the repetition rate and duty cycle, and the rise and fall time the application needs. From those an applications engineer can check the edge current with (1), the average power with (2), and name the closest standard model, or say plainly that the catalog does not cover it and what a custom build would involve.

Contact info@berkeley-nucleonics.com or 800-234-7858. The note Selecting an HV Pulse Generator on berkeley-nucleonics.com goes through the selection in more detail.

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Technical note

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