Application Note 2

How do I Choose a HVPS for my Voltage Pulser?

Most BNC voltage pulser models require an external high voltage power supply. Choosing the appropriate supply helps ensure success with the application!

The first requirement is obvious: The supply must be rated for the desired pulse voltage. But another important consideration is the amount of current that the supply is asked to deliver. In this app note we explain three important current specifications associated with voltage pulsers, and indicate the most important one when selecting a HVPS. (Please note this information applies to applications involving capacitive loads, not inductive or resistive.)

Peak Current

Let's first consider the current that flows from the output of the pulser to the load. The PVX series of high voltage pulsers are designed to drive small capacitive loads of, say, hundreds of picofarads. We might assume that the currents involved are small. But the current is in the form of narrow spikes, one at the leading edge of the pulse and another at the trailing edge. At all other times, no current flows because the load capacitance is either charged or discharged. If the pulse rise and fall times are very short – dozens of nanoseconds – the current in these spikes can be surprisingly large.

How large?

The current required to charge a capacitor (and the current returned when the capacitor discharges) is found via:

$$I = C \bullet dv/dt$$

where I is the current in amperes, C is the capacitance in farads, and dv/dt is the change in voltage over time. Note that C should include all of the capacitance being driven by the pulser, including that of the connecting coaxial cable. For example, if the load capacitance is 50 pF and it's connected via 6 feet of RG-59 with a capacitance of 21.5 pF per foot, the total capacitance is 179 pF. If the pulse voltage is 1500 V and the rise time is 25 ns, the current is:

$$I = (1.79 \text{ x } 10^{-10}) \; [(1.5 \text{ x } 10^{3}) / (2.5 \text{ x } 10^{-8})] = 10.7 \text{ A.}$$

Put another way, the voltage across the capacitor will go from zero to 1500 V in 25 ns if you can supply 10.7 A. It's a good idea to check the pulser's *peak current* rating to be sure. This specification indicates the maximum current the internal MOSFET switches can safely handle during the very short time period that energy is transferred from internal storage capacitors to the load. For example, the PVX-4110 manual states the peak current rating is 25 A.

But peak current does not come directly from the external HV power supply. That supply is situated too far away and is not designed to deliver 16 kW instantly (1500 V x 10.7 A = 16050 W). In addition, there are current limit resistors in line with the pulser's V+ and V- inputs that add delay. Instead, the pulse energy comes from a bank of high-voltage, low-ESR storage capacitors located inside the pulser and near the switching devices. So, while peak output current is an important consideration, it's not the HVPS specification we're looking for.

Continuous Current

The pulser manual also specifies *continuous* current output, which is 100 mA in the PVX-4110 example. It's the maximum current the pulser can output continuously without damage, and it's plainly much lower than the peak current. The specification is intended for use in calculations where a resistor is the load rather than a capacitor. For example, if the pulse voltage is 1000 V and the pulser's continuous current rating is 100 mA, the resistor must have a value of 10 kΩ or greater (1000 V/10000 Ω = 0.1 A).

Average Current

The pulser's capacitor bank transfers energy to the capacitive load in the form of current spikes, and that energy must be replenished. That's the job of the external HVPS – to recharge the cap bank between current spikes. The current needed to do the recharging is the *average current* specification we're looking for.

How do we determine average current? We first calculate *average power* in watts, and then calculate the average current from that. The average power calculation tells us two things:

(1) The power we expect the pulser to dissipate, and thus whether we are inside the safe operating area. We don't want to exceed the pulser's cooling capability. Using the PVX-4110 datasheet as an example again, we know that we cannot exceed a maximum power dissipation of 100 W.
(2) The power needed from the HV PS.

The average power is found by:

$$P = C \bullet V^2 \bullet F$$

where C is the total capacitance of the load, the cable, and the pulser’s output circuit in farads; V is the pulse voltage; and F is the repetition rate in pulses per second. The combination of capacitance, voltage, and pulse frequency must result in a dissipation lower than maximum.

Let’s work on an example. Say the load capacitance is 600 pF, the cable capacitance is 180 pF (6 feet at 30 pF/foot), and the pulser’s internal capacitance is 200 pF for a total of 980 pF. At 1500 V and a 10 kHz pulse rate, the power dissipation is:

$$P = (9.8 \times 10^{-10})\ (2.25 \times 10^{6})\ (1.0 \times 10^{4}) = 22\ \text{W}$$

If the pulser is a PVX-4110, we are safely below the maximum. We can now proceed to calculate the average current needed from the HVPS.

Power Supply Current

To find the average current, divide the average power by the voltage:

$$I = P / V$$

In this example:

$$I = 22\ \text{W} / 1500\ \text{V} = 15\ \text{mA}$$

Due to internal losses, the actual current may be up to 10% greater than this figure.

Fun Fact #1

If we wish to skip this power dissipation calculation:

$$P = C \bullet V^2 \bullet F$$

we can divide both sides of the equation by V, yielding this equation instead for average current:

$$I = C \bullet V \bullet F$$

It’s similar to our initial equation, $I = C \bullet dv/dt$, with 1/time replaced by frequency.

When the current draw of a device is dominated by the charging and discharging of capacitors (such as in pulsers and CMOS devices), it's sometimes referred to as *CVF current*.

Fun Fact #2

You may have noticed we haven't mentioned anything about pulse *duty cycle*. It doesn't come into consideration in these formulas because very little power is dissipated when the load capacitance is either fully charged or fully discharged. We *do* care about the pulse rate (frequency) because that translates directly to the number of edges per second.

Plan Ahead

You may purchase a HVPS for a particular application and then discover later that you need to drive a higher load capacitance or a longer coaxial cable, or you need a higher pulse repetition rate. If the supply is underrated, you may encounter current limit problems and need a bigger supply (with a significantly higher price tag). On the other hand, obtaining a sufficiently large supply at the outset can avoid this kind of problem.