Ripple, Stability and Regulation in Precision HV

What line and load regulation, response time, ripple, long-term stability, and temperature coefficient mean, and how each number shows up in the result you measure.



TECHNICAL NOTE · HVX-SERIES

1 Five Numbers That Decide Quality

Two supplies set to the same voltage can give you very different results. The setpoint tells you where the output is aimed. It does not tell you how well the output holds when the mains sags, when the load changes, or after the supply has been running for hours. Five specifications govern that behavior: line regulation, load regulation, response time, ripple, and stability, with temperature coefficient close behind. Read them together, because a number that looks impressive alone can be undone by a weak partner.

The HVX-Series is fully digitally regulated, with a microcontroller and FPGA closing the loop rather than an analog error amplifier alone. That architecture is what makes the numbers below tight and repeatable. The rest of this note explains each one in plain terms and what it means for your measurement.

2 Line Regulation

Line regulation answers a simple question: if the AC mains moves, does the DC output move with it? In a real lab the mains is never perfectly steady. A large load switching on elsewhere in the building can sag the supply voltage by several percent. A good HV supply rejects that.

The HVX-Series holds line regulation tighter than **+/-0.01% of nominal voltage** across a **+/-10% swing in the mains**. On a 10 kV unit, a full 10% mains excursion moves the output by no more than about 1 V. For a calibration reference or a detector bias, that rejection is the difference between a measurement that drifts with the building and one that does not.

The input stage earns part of that rejection and the digital loop the rest. The HVX-Series draws from a single-phase mains (230 V plus or minus 10% on the 3 kW models, 187 V to 253 V on the 2 kW models) with active power factor correction. Where line regulation falls short, you see it as a slow wander on the output that tracks the building load: lights and motors switching on and off elsewhere on the same feed. A tight line-regulation figure means you can run a sensitive experiment during normal facility activity rather than waiting for a quiet shift.

3 Load Regulation

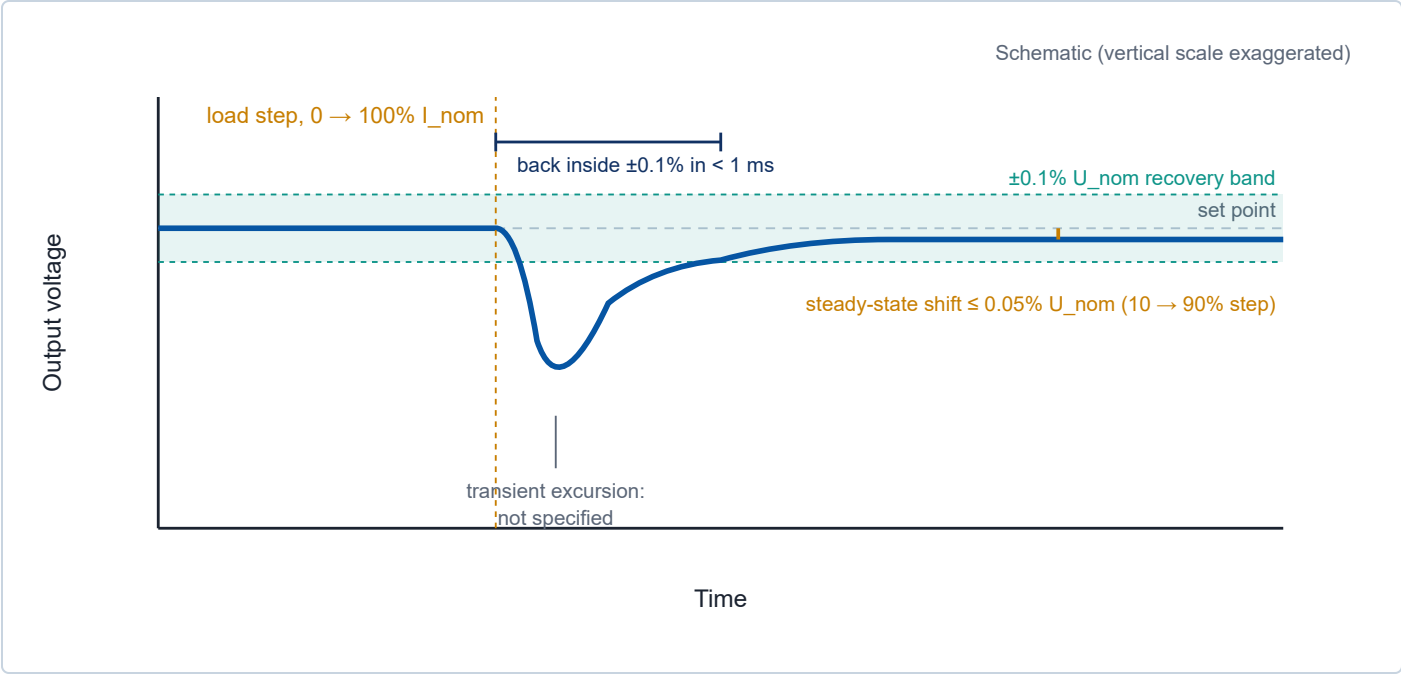
Load regulation answers the partner question: if the load current changes, does the output voltage hold? Many loads are not constant. A capacitor draws heavy current while charging and almost none once charged. A gas tube draws a step of current when it strikes. Each of those events tugs on the output, and a supply with poor load regulation lets the voltage dip or overshoot.

The HVX-Series holds load regulation within **0.05% of nominal voltage** for a load step from **10% to 90%** of rated current. On a 5 kV unit, that is 2.5 V of deviation across a large change in draw. The current channel is held within 0.05% of nominal current for a 0 to 100% load step, so a constant-current setup is as well behaved.

Load regulation and response time are best read as a pair. Load regulation sets how far the output departs from the setpoint when the draw changes; response time sets how long it stays there before the loop pulls it back. A supply can have excellent steady-state regulation and still misbehave during transients if it recovers slowly, and the opposite is also true. The HVX-Series keeps both tight, which is why it suits loads that switch hard rather than only loads that sit still.

4 Response Time

Regulation tells you how far the output deviates. Response time tells you how long the deviation lasts. When the load steps, the output briefly departs from the setpoint, then the regulator pulls it back. After a 0 to 100% change in load current the HVX-Series recovers to within **0.1% of nominal** in **under 1 millisecond**. For a double-pulse test, where the bus capacitor supplies each pulse and the supply recharges it between pulses, or any load that draws in bursts, a fast recovery brings the bus back to its set point before the next event.



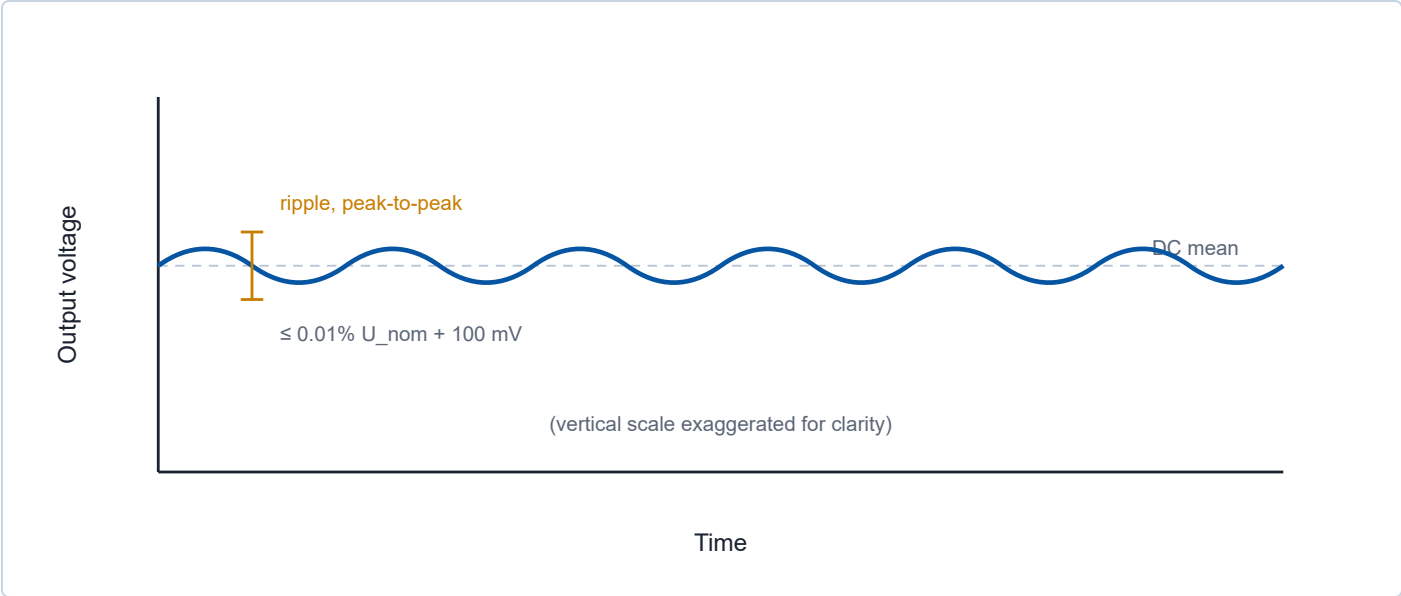
SCHEMATIC **Figure 1.** Output voltage after a 0 to 100% load step. The transient excursion is not specified; the supply recovers to within 0.1% of nominal in under 1 ms, and the steady-state shift for a 10 to 90% load step is within 0.05% of nominal. Vertical scale exaggerated.

5 Ripple

Ripple is the small AC residual riding on the DC output. No real supply produces perfectly flat DC. Some periodic content always survives the conversion and filtering. For many loads it does not matter. For a photomultiplier, an electron optic, a precision deflection plate, or a low-level detector bias, ripple shows up directly as noise in the result, because the load translates voltage variation into a measurable signal.

The HVX-Series keeps voltage ripple at or below **0.01% of nominal voltage plus 100 mV**, peak to peak. Both terms are fixed for a given model, because the percentage is of nominal voltage, not of the setting: a 10 kV unit allows 1.1 V peak to peak at any set point and a 1.5 kV unit 0.25 V. At a low setting that ripple is a larger fraction of the output, which is one

reason to choose the lowest voltage class that covers the job. On the current channel, ripple is at or below **0.01% of nominal current plus a fixed term on models below 20 kV**, and at or below **0.02% of nominal current plus 0.5 mA at 20 kV and above**.



SCHEMATIC **Figure 2.** Ripple riding on the DC output. The periodic residual rides on the DC mean; its peak-to-peak magnitude stays within 0.01% of nominal voltage plus 100 mV. The vertical scale is exaggerated to show the shape.

6 Stability Over Time

Stability covers the slow drift that the regulation specs do not. A supply can reject the mains, hold against a load step, and still creep over a long run as components warm and age. The HVX-Series holds stability within **0.01% of nominal per 8 hours** on both the voltage and current channels. For a measurement that integrates over a shift, or a calibration where the supply is the reference, that slow drift is often the limiting error, not the fast regulation. Pair it with the **16-bit setting resolution** across 0.01% to 100% of range, and an operating point can be placed precisely and held. Reproducibility, the agreement between one setting of a point and the next, is **0.1% of nominal**, so a point is re-established to within 10 V on a 10 kV unit.

7 Temperature Coefficient

Temperature coefficient tells you how much the output moves per degree of ambient change. A lab that swings several degrees over a day will push any supply around, and the temperature coefficient sets how far. The HVX-Series holds at or below **0.01% of nominal per kelvin** on both channels. If the environment is not tightly controlled, this number, combined with the 8-hour stability figure, predicts how far the output moves between calibrations: at 0.01% of nominal per kelvin, a 5 K swing moves a 10 kV output by up to 5 V.

8 Reading the Spec Sheet Together

The table below collects the precision specifications in one place. Read across, not down. A measurement that needs a clean, steady reference cares about ripple and stability; a measurement with a bursty load cares about load regulation and response time. The right supply is the one whose weakest relevant number still clears your error budget.

Table 1.

Specification	Voltage channel	Current channel
Setting range / resolution	0.01 to 100% U_nom, 16-bit	0.01 to 100% I_nom, 16-bit
Reproducibility	≤ 0.1% U_nom	≤ 0.1% I_nom
Line regulation (+/-10% mains)	< +/-0.01% U_nom	< +/-0.01% I_nom
Load regulation	≤ 0.05% U_nom (10 to 90% load step)	≤ 0.05% I_nom (0 to 100% load step)
Response time (0 to 100% load current change, to 0.1%)	< 1 ms	< 1 ms
Ripple (peak to peak)	≤ 0.01% U_nom + 100 mV	≤ 0.01% I_nom plus a fixed term (< 20 kV); ≤ 0.02% I_nom + 0.5 mA (≥ 20 kV)
Stability	≤ 0.01% U_nom / 8 h	≤ 0.01% I_nom / 8 h
Temperature coefficient	≤ 0.01% U_nom / K	≤ 0.01% I_nom / K

How to budget

Add the relevant terms as worst case. For a 10 kV output held for a shift in a room that swings 5 K: 8-hour stability 1 V, temperature coefficient 0.01% per kelvin times 5 K is 5 V, ripple 1.1 V peak to peak, total 7.1 V, or 0.07% of nominal. Check that total against the precision you need.

9 Talk to an Engineer

Specifications only matter against a real error budget. To work through which of these numbers limit your measurement, and which HVX-Series model clears them, contact Berkeley Nucleonics at **800-234-7858** or info@berkeleynucleonics.com.

For a quick question, chat with an engineer at berkeleynucleonics.com.

Berkeley Nucleonics Corp.
Test, Measurement and Nuclear Instrumentation since 1963
For details: info@berkeleynucleonics.com or 800-234-7858

Technical Note
HVX-Series