

HVLR Series High-Voltage Resistors

Application Note: High-Side Voltage-Divider Sensing in High-Voltage Power Supplies

High-side resistor selection for feedback, monitoring, and protection sensing chains in high-voltage power supplies

Item	Description
Document type	Application note
Applicable product	HVLR series precision non-inductive high-voltage resistors
Core application	High-side resistors used in high-voltage output feedback, output monitoring, and overvoltage/undervoltage protection sensing

Summary

High-voltage power supplies must convert kV-level output voltage into a low-voltage signal compatible with controller, ADC, operational amplifier, or comparator. Although output feedback, output monitoring, and protection sensing serve different downstream purposes, their front ends all depend on a high-side resistor and a low-side network to establish a stable ratio. The primary role is resistance stability under continuous high voltage, rather than energy absorption capability, but maintaining resistance stability while continuously withstanding high voltage.

Key Takeaways

- 1) For the high-side resistor, first confirm the maximum applied voltage, resistance value, power derating, and resistance-stability parameters.
- 2) Divider-sensing accuracy is mainly affected by initial tolerance, TCR, VCR, load life, and self-heating.
- 3) In kV-level applications, VCR can become a significant error term; passing low-voltage calibration does not guarantee accuracy after high voltage is applied.
- 4) The HVLR series covers 1 kΩ to 1 GΩ and 2.5 kV to 48 kV, with specified tolerance, TCR, VCR, and load-life performance, making it suitable for high-side sensing positions in high-voltage power supplies.

1. Application Scope and Operating Principle

In high-voltage power supplies, output feedback, output-voltage monitoring, and overvoltage/undervoltage protection all require a low-voltage signal proportional to the high-voltage output. Although these functions serve different downstream circuits, their front ends

all rely on a high-side resistor in series with a low-side network to form a voltage divider. This note therefore treats them collectively as high-voltage output divider-sensing applications.

Application Scope

This note discusses high-side sense resistors that continuously withstand high voltage. Applications dominated by pulse energy or continuous energy dissipation, such as precharge, fast discharge, RC/RCD snubbers, and braking loads, are outside the main scope of this note.

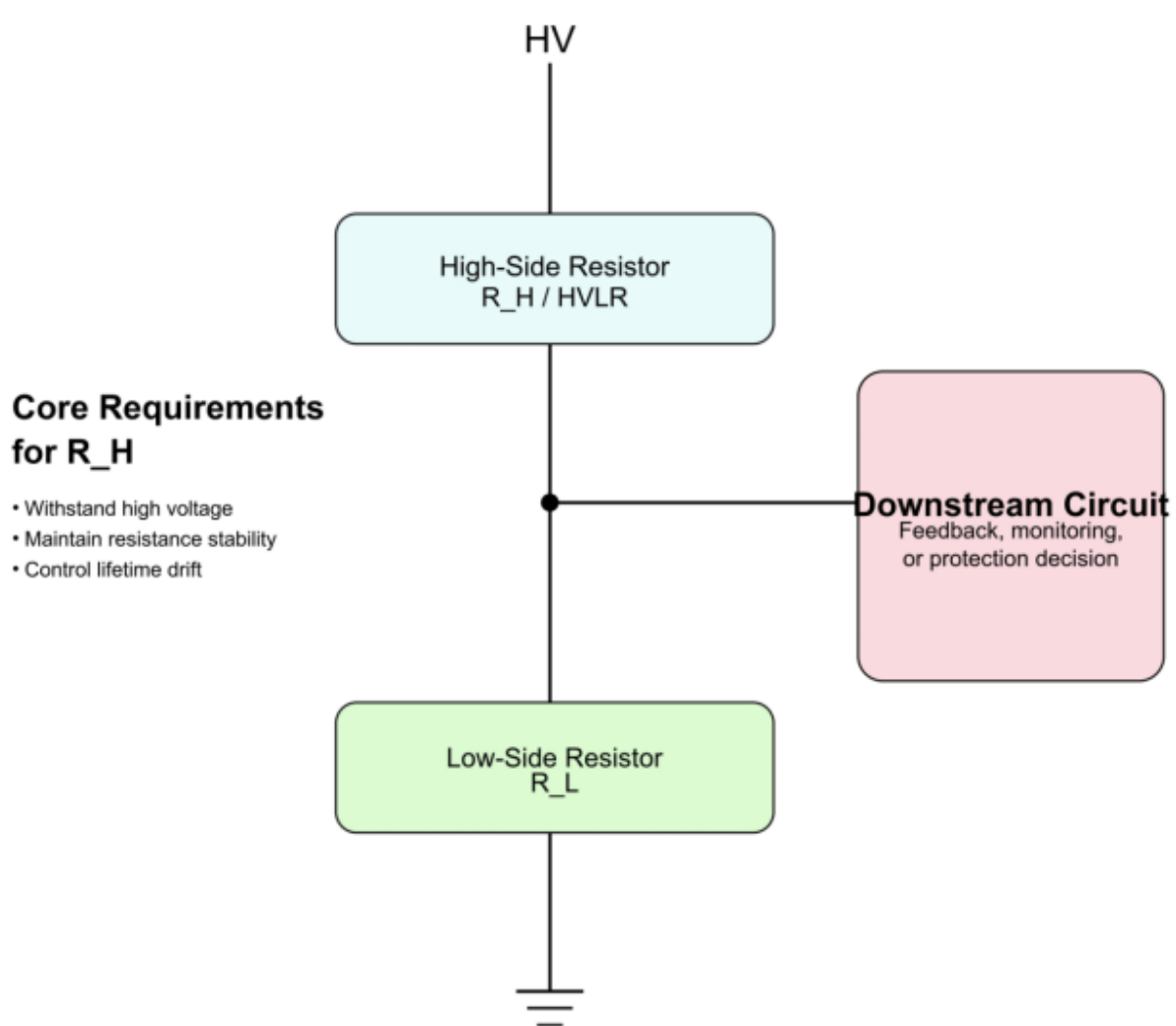


Figure 1. High-side voltage-divider sensing in a high-voltage power supply

Operating relationship is:

Divider Sensing

$$V_{\text{SAMPLE}} = V_{\text{HV}} \times R_L / (R_H + R_L)$$

When $R_H \gg R_L$, V_{SAMPLE} is approximately $V_{\text{HV}} \times R_L / R_H$

Here, R_H is the high-side resistor and is continuously exposed to nearly the full high-voltage output. As the equation shows, when V_HV and R_L are fixed, any change in R_H directly changes V_SAMPLE. The high-side resistor therefore must not only meet the required working voltage, but also maintain controlled resistance change over temperature, applied voltage, and service life.

2. Main Error Sources in Divider-Sensing Accuracy



Figure 2. Main factors affecting high-side resistor stability

Error Source	Impact Mechanism	Evaluation Standard	Selection Note
Initial tolerance	At power-up, deviation of R_H from its nominal value directly creates initial ratio error.	Include resistance tolerance in the initial error budget.	For precision sensing, choose a tighter tolerance grade first.
Temperature coefficient, TCR	Ambient temperature and self-heating change the temperature of R_H, causing resistance drift.	$\Delta R/R = TCR \times \Delta T$	Consider both TCR and actual temperature rise, not ambient temperature alone.
Voltage coefficient, VCR	After high voltage is applied, R_H changes with the applied voltage, affecting high-voltage linearity.	$\Delta R/R = VCR \times V_{\text{applied}}$	In kV-level applications, include VCR in the error budget.
Load life	Long-term energization, high temperature, and electrical stress can cause R_H drift.	Reserve margin based on the datasheet load-life specification.	For long-term stability, do not rely on initial tolerance alone.

System Note

The low-side resistor, ADC input impedance, leakage of protection devices, and calibration strategy also affect final sensing accuracy. These are system-level divider errors. The comparative calculation below evaluates only the error contribution of the high-side resistor itself.

3. Comparative Calculation for a Typical Application

The following calculation uses a common output-sensing approach in high-voltage power supplies: converting a 10 kV output into a 1 V sense signal. Assume that a customer's original design meets the reading requirement during low-voltage calibration at room temperature, but no longer meets the system accuracy requirement when 10 kV is applied. For this review, the high-side resistance is kept unchanged. Only the key parameter differences of the high-side resistor R_H are compared; low-side errors and system calibration are evaluated separately.

Application Conditions

V_HV = 10 kV

V_SAMPLE = 1 V

R_H = 100 MΩ

R_L approx. 10 kΩ

$P_H = V_{HV}^2 / R_H = (10000 \text{ V})^2 / 100 \text{ M}\Omega = 1 \text{ W}$

Therefore, the high-side resistor must support at least 10 kV continuous working voltage and, after accounting for ambient temperature and derating, must handle 1 W continuous power dissipation. The comparison below contrasts the conventional design with an HVLR-based design. The key issue in the original design is VCR: the initial reading at low voltage or room temperature can be corrected by calibration, but once high voltage is applied, the voltage coefficient directly introduces additional resistance change.

Parameter	Conventional Design	HVLR series design
High-side resistance	100 MΩ	100 MΩ
Initial tolerance	±1%	±0.1%
TCR	±100 ppm/°C	±100 ppm/°C
VCR	5 ppm/V	Typical 0.02 ppm/V; maximum 2 ppm/V
Load life	$\Delta R \leq \pm 2.0\%$	$\Delta R \leq \pm 1.0\%$

Assuming the operating temperature differs from the calibration temperature by 50°C, the resistance change introduced by TCR is approximately:

TCR Variation

Conventional design: $100 \text{ ppm/}^\circ\text{C} \times 50^\circ\text{C} = 5000 \text{ ppm} = 0.5\%$

HVLR: $100 \text{ ppm/}^\circ\text{C} \times 50^\circ\text{C} = 5000 \text{ ppm} = 0.5\%$

At a 10 kV working voltage, the resistance change introduced by VCR is approximately:

VCR Variation

Conventional design: $5 \text{ ppm/V} \times 10000 \text{ V} = 50000 \text{ ppm} = 5.0\%$

HVLR :

Typical: $0.02 \text{ ppm/V} \times 10000 \text{ V} = 100 \text{ ppm} = 0.02\%$

Maximum: $2 \text{ ppm/V} \times 10000 \text{ V} = 20000 \text{ ppm} = 2.0\%$

Error Term	Conventional Design	HVLR typical value	HVLR maximum value
Initial tolerance	1.0%	0.1%	0.1%
TCR, 50°C	0.5%	0.5%	0.5%
VCR, 10 kV	5.0%	0.02%	2.0%
Load life	2.0%	1.0%	1.0%
Total error	8.5%	1.61%	3.6%

Conclusion

Using linear summation to estimate error magnitude, the customer's original design is approximately 8.50%; the HVLR design is approximately 1.61% when calculated with typical VCR and approximately 3.60% when calculated with maximum VCR. This result shows that in a 10 kV high-side application, even when TCR is the same, VCR differences can lead to substantially different sensing error after high voltage is applied. In high-voltage applications, VCR may even be the dominant factor causing resistance shift.ⁱ

4. HVLR Series Product Fit

Design Requirement	Driving Mechanism	HVLR Series Response
Long-term high-side voltage withstand	R _H is directly connected to the high-voltage output.	Maximum working voltage: 2.5 kV to 48 kV
High resistance requirement	High divider ratios typically require MΩ to GΩ resistance values.	Resistance range: 1 kΩ to 1 GΩ
Initial ratio accuracy	Initial R _H deviation affects the power-up sensing ratio.	Tolerance: ±0.1% to ±10%
Temperature drift	Ambient temperature and self-heating change the resistance.	TCR: ±100 ppm/°C
High-voltage linearity	Applied high voltage causes resistance change.	VCR: typical 0.01 ppm/V; maximum 2 ppm/V
Continuous power dissipation	$P = V^2/R$ produces self-heating.	Power range: 0.7 W to 15 W

Long-term operation	Electrical and thermal stress cause lifetime drift.	Load life: 125°C, rated power, 1000 h, Delta R <= ±1.0%
Factory consistency	High-voltage applications require device-level screening.	100% high-voltage energized testing

5. High-Side Resistor Selection Procedure

Select the high-side resistor in the following order to avoid screening only by resistance value or nominal voltage rating.

- Define the maximum voltage.** Include the maximum continuous output voltage, regulation upper limit, possible overshoot during startup or shutdown, and the maximum voltage under fault conditions.
- Select the high-side resistance value.** Determine R_H from the target sensing ratio, allowable sense current, system power budget, and the noise immunity of the high-impedance node. Higher resistance reduces power dissipation, but makes the node more sensitive to leakage and noise.
- Evaluate power and thermal conditions.** After calculating $P = V^2/R$, confirm the power margin based on ambient temperature, mounting method, thermal conditions, derating curve data and target service life.
- Verify key electrical parameters.** Resistance tolerance, TCR, VCR, load life, and related parameters: initial tolerance affects the power-up sensing ratio, TCR affects drift over temperature, VCR affects high-voltage linearity, and load life affects long-term stability.
- Check mechanical and insulation constraints.** Confirm package dimensions and mounting conditions. High-voltage applications also require checks for package length, terminal spacing, assembly height, cleanliness, and project-level insulation requirements.

Selection Tip

If a single device cannot simultaneously meet the maximum voltage, power, and mechanical spacing requirements, reassess the high-side resistance value, power rating, or use multiple devices to share the voltage. When multiple devices are used, each device must still be independently evaluated for voltage, power, TCR, VCR, and load life.

6. Conclusion

Output feedback, output monitoring, and protection sensing in high-voltage power supplies all depend on stable proportional conversion from the high-voltage output to a low-voltage signal. In this application, the high-side resistor is the key component continuously exposed to high voltage, and its resistance stability directly affects output regulation, monitor readings, and protection thresholds.

With a wide working-voltage range, broad resistance coverage, precision tolerance options, specified TCR, VCR, load-life performance, and 100% high-voltage energized testing, the HVLR

series provides a calculable and verifiable basis for selecting the high-side sensing resistor in high-voltage power supplies.

Get Support

For help selecting an HVLR part based on your output voltage, target sense voltage, ambient temperature, power margin, and accuracy target, contact us for samples, datasheets, and selection support.

ⁱ Linear summation is a conservative order-of-magnitude estimate and does not replace the full system error budget or calibration.