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APPLICATION NOTE

High Voltage Ripple Testing For Electric Vehicles and Aircraft

INTRODUCTION

The increasing electrification of transportation, especially electric vehicles (EVs) and electric aircraft, demands rigorous testing of high-voltage (HV) systems. Voltage ripple, a form of electrical noise or fluctuation superimposed on a DC voltage, is a critical parameter that can impact system reliability, electromagnetic compatibility (EMC), and operational safety. Regulatory and internal standards across the automotive and aerospace industries mandate comprehensive ripple testing to validate design robustness under real-world conditions.

AE Techron's family of HVR test system products offer full or near-full compliance with a wide array of high-voltage ripple test standards, providing an indispensable solution for OEMs, Tier 1 suppliers, and test labs.

UNDERSTANDING HIGH VOLTAGE RIPPLE

High voltage ripple refers to rapid, repetitive fluctuations superimposed on the nominal DC bus voltage in electric power systems. These ripples can originate from:

- Power electronics switching noise (e.g., from inverters, DC-DC converters)
- Regenerative braking systems
- External electromagnetic interference (EMI)
- Load transients from high-power components (e.g., electric motors, compressors)

Ripple testing ensures that critical HV subsystems – such as traction inverters, battery management systems, and power distribution units – perform safely and reliably despite these disturbances.

STANDARDS-BASED REQUIREMENTS

High-voltage ripple testing is explicitly mandated or implied in multiple global standards. The **HVR Series** is engineered to meet these requirements across automotive and aerospace applications.

AEROSPACE AND DUAL-USE IMPLICATIONS

While not all civil aviation standards explicitly define ripple tests today, emerging standards from hybrid-electric aircraft projects increasingly mirror automotive test approaches. The HVR 1000's flexibility makes it an ideal platform for R&D, qualification, and future compliance in this rapidly evolving sector.

HIGH VOLTAGE RIPPLE TESTING: KEY CHALLENGES BY INDUSTRY

This table summarizes the key challenges encountered during high voltage ripple testing in the automotive and aerospace industries. Understanding the differences and similaries is essential for developing test solutions that meet the rigorous standards and operational needs of both sectors.

Challenge Area	Automotive & Aerospace
System Voltage Levels	28VDC – 2000V+ in EV architectures
Ripple Limits	Very tight (<1% of nominal voltage)
Component Sensitivity	Onboard chargers, inverters, and converters are ripple-sensitive
Transient Behavior	Fast ripple transients needed for inverter and HV battery emulation
EMI/EMC Considerations	Must avoid test system-induced EMI affecting results
Test System Requirements	Flexible, high-accuracy systems with advanced waveform and timing capabilities
Environmental Constraints	Must simulate operating conditions (temperature, load, regen braking)
Safety & Isolation	HV safety protocols, protective grounding, isolation during tests
Documentation & Repeatability	Extensive logging and repeatability for qualification and certification

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THE HVR 1000 ADVANTAGE IN RIPPLE TESTING

AE Techron's HVR 1000 high-voltage test system is purpose-built for advanced HV transient and ripple testing. It supports waveform generation, real-time control, and seamless DUT integration.

The HVR 1000 is designed for the majority of HV ripple testing that does not require heavy power. For example, many automotive and aerospace components require 20A or less.

Performance Capabilities:

RIPPLE:

- Frequency range: 10 Hz to 200 kHz
- Voltage/Current: Up to 50 Vp, 200 Ap
- Adjustable ripple current limit

SYSTEM:

- Output voltage: Up to 1000VDC
- Power/Current: Up to 60 kW, 160A DC (2000V option available soon)
- Adjustable DC current limit
- Bi-directional DC capability

Key Capabilities:

- **Waveform Fidelity:** Can reproduce ripple waveforms with high frequency content (up to several kHz), necessary for standards like Stellantis C_ET_03_HV_V and VW EHV-08.
- **Programmable Modulation:** Sinusoidal, trapezoidal, square, or custom waveforms with precise frequency and amplitude control.
- **DUT Safety:** Fast fault shutdown and accurate voltage clamping protect connected equipment.
- **Multi-Standard Profiles:** Pre-loaded test templates aligned with industry standards minimize setup time and reduce operator error.

HVR 1000

THE HVR 1200 ADVANTAGE IN RIPPLE TESTING

AE Techron's HVR 1200 is a high-current ripple generator system that can produce a wide range of ripple interference on electric vehicle high-voltage power systems. It is specifically focused on meeting this customer test requirement at the highest power levels, into the most difficult loads such as traction inverters, and Power-HIL test stands.

Modular, expandable design and field configurability make the HVR 1200 a great solution for testing all major automakers and standards now and in the future.

Performance Capabilities:

- Maximum Ripple Current: 100Ap – 600Ap
- Maximum Ripple Voltage: 0 – 150Vp / 300Vp-p
- Frequency Range: 150 Hz – 300 kHz
- Supported DC Voltages: 0 to 1200 V, or 2000V in bridged configuration

Key Capabilities:

- **Data Gathered:** Tracks and reports Voltage, Current, and Impedance
- **Rugged:** Protected against all kinds of DUT failure (including failure to a short when DUT under full load)
- **Compatibility:** Most HV Standard DC power supplies
- **Noise Reduction:** Built-in noise-rejecting monitoring circuits allow for accurate testing in conditions even where DUT noises are higher than ripple test signals.

Configurations:

- **HVR 1200-100:** 100 Ap
- **HVR 1200-200:** 200 Ap
- **HVR 1200-300:** 300 Ap
- **HVR 1200-400:** 400 Ap
- **HVR 1200-500:** 500 Ap
- **HVR 1200-600:** 600 Ap

HVR 1200

Standards Coverage:

Standard	Test Clauses	Test Types
ISO 21498-2 (2021 + 2024)	Full Coverage	High Voltage Electric Powertrain Testing
MBN LV123 (2014)	10.4.1 to 10.4.8	Operating Range, Voltage Dynamics, Overvoltage, Undervoltage
BMW GS95023 (2009)	9.2.1 to 9.2.9	Operating Range, Voltage Dynamics, Over/Undervoltage
VW 80300 (2016)	HVPT-1 to HVPT-4, EHV-01 to EHV-07	Voltage Cycles, Pre-charging, Discharge, Dynamics
VW 80300 (2021)	EHV-01a, EHV-01b to EHV-08	Full Suite including HV Ripple
MAN CVS43	4.1.1 to 4.2.2	Voltage Range, Ripple, Load Dump
Stellantis CS.00245	C_ET_01_HV_V to C_ET_05_HV_V	Voltage Resistance, Ripple, Transients

Low Voltage Testing:

In addition to HV ripple testing, the HVR 1000 includes a powerful low voltage test system for automotive, aerospace, and industry standards tests. Included is our 3110A Standards Waveform Generator with its expansive test standards library. Over 3,600 tests are included. When coupled with the HVR 1000, the 3110A can create virtually all waveforms, DC offsets, dropouts and surges needed for EMC tests.

REAL-WORLD USE CASE EXAMPLES

Automotive EV Powertrain Testing:

A major EV supplier uses the HVR 1200 to apply ripple voltages ranging from 1–10 kHz onto the HV battery bus to validate inverter stability and battery management under worst-case noise conditions. The system's fine waveform tuning allows them to simulate both design-intent and fault-induced ripple environments.

Aerospace Hybrid Propulsion System:

An aircraft propulsion R&D lab deploys the HVR 1000 to emulate HV ripples caused by high-speed switching in onboard power electronics. With ripple harmonics superimposed on 700VDC up to 20 kHz, the lab assesses impacts on sensitive avionics and insulation systems in development.

CONCLUSION

As electric mobility expands into both ground and air domains, high voltage ripple testing becomes critical to ensuring system reliability, electromagnetic compatibility, and user safety. AE Techron's HVR 1000 provides a versatile, standards-compliant, and field-proven platform to meet the exacting demands of modern EV and aircraft power systems.
The HVR 1000's coverage of VW, Stellantis, MAN, and other global standards positions it as the premier choice for validating high-voltage ripple tolerance and response. Whether for compliance, development, or research, the HVR 1000 enables engineers to meet today's test requirements – and anticipate tomorrow's.

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