High Voltage (HV) Testing For Today’s EVs

Review of Technology and Requirements

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• Brief History of Test Standards and Development
• Market Awareness
• HV Testing with HV Supply

• Testing Beyond the HV Supply
  • How Ripple is coupled
  • Benefits and negatives

• Extended use for LV testing
Complexity Made Simple
Standards

- LV123 Original HV EV standard
  - Created in 2009
  - Updated 2014
  - Updated Recently

- 2 basic test setups
  1. Voltage variation
     - “Not Fast” performed by programmable PS
  2. Voltage Ripple
     - Fast above the capabilities of the PS
     - Ripple was first introduced at Hz-20 kHz
     - Current standards increased to 200 kHz
     - … 200 kHz and some going up to 300 kHz
Current Standards

• ISO 21498
• ISO 7637-4
• VW 80300
• MBN 1123
• Nissan 28400N
• PSA B21 7112
• Stellantis CS.00245
• FORD FMC 1280
• .............
How to Size the System
Voltage / Current
Market Trends

• DUT’s Voltage and Current are Known?
• Where is the future going
• Today, systems 400V ➕ 600V ➕ 800V
• Proposed for 1200V ➕ 1300V ➕
  
  • Higher Voltage = more available power
  • Higher Voltage = less current
  • High Voltage = more safety concerns

• How much current will a DUT need??
HV PS Features

• 500 V / 1000 V / 1500 V / 2000 V
• Building Blocks: 18 kW / 27 kW / 36 kW / 54 kW
• Modularly scalable up to 44 power supply modules,
  • serial / parallel / combined
  • Even modules of different power scalable
• Regenerative
• Voltage dynamics:
  • Voltage rise time 10% - 90%: <200 µs
  • Voltage fall time 90% - 10%: <200 µs
Power Supply Speed

- VW 80300 INCLUDING LOAD DUMP EXECUTION

![Voltage Curve to HV voltage limit](image)

Figure 2: Voltage Curve to HV voltage limit

- 568V
- 471V
- 566µs

1ms PS are too slow
HV PS Features

• Voltage dynamics:
  • Voltage rise time 10% - 90%: <250 µs
  • Voltage fall time 90% - 10%: <250 µs
Power Supply Control

• Need Good Software and Hardware Control

• Some tests can run hours/days

• Standard ARB (Arbitrary Waveform Generator)
  • G-Samples run out of points in long tests
  • Requires the use of a system with an endless buffering system
    • No limitations

• Easy Software Interface, pre-programmed and user Generated tests
Tests Beyond the PS

• When test speed/frequency is faster
• Ripple tests
  • 20kHz, 150kHz, 200kHz, 300kHz, ...

• An amplifier is required
  • Bypass CAP needed

• Needs to be coupled to HV PS
  1. Transformer
  2. Capacitor
  3. 4 Quadrant Amplifier In-series
CAPACITOR BANK

• Active/passive discharge
• internal, external Interlock
• 10 mF
• Protections
  • Temperature
  • Over Current
  • Over Voltage
Transformer Coupling

• Historically, how testing was done
  • < 20 kHz
• Worked for earlier requirements
The behavior of an inductive impedance $Z_L$

- With increasing frequency, the impedance of an inductive transformer is increasing exponentially.
- Higher resistance of the coupling transformer causes significant voltage drop inside the transformer.
- If voltage drops in the transformer, this voltage is missing at the DUT; it cannot be compensated as this voltage drop is dramatic.
Transformer Coupling

Graphic: Losses in transformers depending on current

Blue: With no or less current flow, a transformer solution can work quite properly.

Purple/Green: At higher frequencies and DUTs with high/current requirements, the losses are dramatic.
Transformer Coupling

Workaround:

- Frequency ranges are divided up for using different transformers for the specific frequency ranges, e.g.

  a) 15 Hz ... 200 Hz: Ripple with power supply
  b) 200 Hz ... 1 kHz: CT 1
  c) 1 kHz ... 50 kHz: CT 2
  d) 50 kHz ... 150 kHz: CT 3
Transformer Coupling

Disadvantages:
• AC signals only
  • Can not pass DC or low frequencies, saturation
• Low freq. >200 Hz must be done with HV PS
• Extended frequency range requires more Transformers
• Larger, higher current systems require more amp/transformers
• Not able to sweep from DC to 200kHz in one test
Capacitor Coupling

• Not used extensively
• Similar disadvantages as transformer:
  • AC signals only
  • Low freq. >200 Hz must be done with HV PS
  • Larger, higher current systems require more amp/CAP
  • Not able to sweep from DC to 200kHz in one test
  • Safety concerns
Amplifier in Series

- Amplifier is placed in series with HV PS
Amplifier in Series

- Ripple tests without interruption from 15 Hz ... 200 kHz +
  - Continuous sweep
- Load Dump out of VW 80300, EHV-10 feasible Triangle, rectangle, trapeze, pulses, spikes can be performed easily
- Highest signal quality
- Prepared for upcoming changes in standards and new standards
- 4-Quadrant Amplifier system can be used for 12 V / 24 V / 48 V standard testing as well
Real Measurements
Amplifier in Series

Fast Load Dump
3000 V/ms (3 V/μs)

\[ V_{\text{peak}} = V_{\text{N,HV}} + 20 \text{ V} \]

\[ \text{---~} V_{\text{peak}} = 20 \text{ V} / 7 \mu\text{s} \]

100TS: 20 V / 1 μs

- is 7 times faster with best signal quality

• is 7 times faster with best signal quality
Amplifier in Series

RECTANGLE SIGNALS (Nissan, MES, etc.)

BOLAB’s solution is flexible for generating all kinds of waveforms (not only sine interferences), also rectangle, respectively trapeze waveforms are feasible!
Amplifier in Series

High Speed + HV transitions

- DC/DC Converters
- Rising times up to 10μS and amplitudes 220V
The Complete Package

• ISO 21498
  • 10Hz to 150kHz (200kHz)
  • Resistors Ri,HV: 10mΩ, 50mΩ, 100m Ω, or 200m Ω
  • In both + and return lines (other standards only +)
The Complete Package

- ISO 21498
  - 10Hz to 150kHz (200kHz)
  - Resistors $R_{i,HV}: 10\,\Omega, 50\,\Omega, 100\,\Omega,$ or $200\,\Omega$
  - Calibration over Freq (not just DC) while powered!
The Complete Package
Amplifier System

- Modular
- Extendable
- Scalable
- Flexible
- Easy Service
LV Testing with Same Amp

- ISO 7637-2,...
- 4-Quad Amp (same)
- Load Dump
- Fast Switch
- EFT/Micro-pulse
- Advanced Software Control
- Real-Time Measurement
Thank you

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