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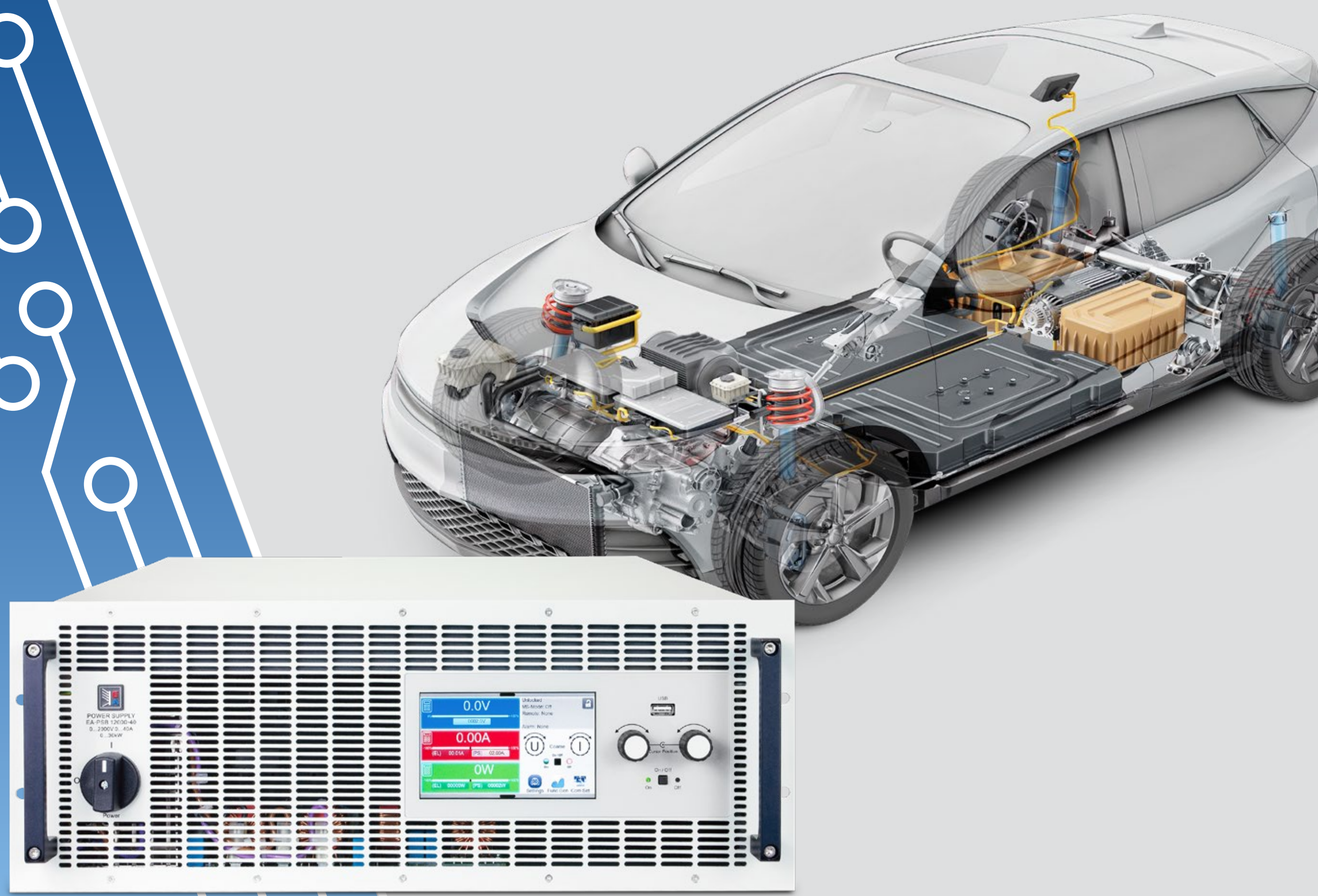

APPLICATION NOTE:
HOW THE EA-PSB 10000 PROGRAMMABLE POWER SUPPLY IMPROVES TESTING TO THE GERMAN LV123 AUTOMOTIVE STANDARD

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EA Elektro-Automatik's Programmable, bidirectional, autoranging DC power supplies, combined with EA's PC-based Power Control software offer OEMs of EVs and HEVs a fast, accurate and cost-effective way to test their high-voltage electronic systems for LV123 compliance.

INTRODUCTION

LV123 is a test standard developed for German automotive OEMs that tests electrical characteristics and safety of high-voltage (HV) components in hybrid electric vehicles and electric vehicles. These tests cover a range of electronic systems, including DC/DC converters, onboard chargers, inverters, batteries and more. To ensure automotive systems will continue to operate, the tests simulate the extreme real-world conditions that components may encounter, such as input voltage or output demand that is lower or higher than normal.

This application note will review the LV123 specifications and describe the unique combination of features that make the EA Elektro-Automatik (EA) PSB 10000 – a programmable, auto-ranging, bidirectional DC power source – the ideal solution for LV123 testing for HEV and EV applications.

TESTING TO THE LV123 STANDARD

The LV123 electric test standard falls under an organized listing of test requirements adopted by all German manufacturers of electric vehicles: BMW, Audi, Daimler, Volkswagen and Porsche. As OEMs of high-voltage electronic systems, they must qualify their products as meeting LV123 standard requirements. This systematic approach and transparent definition of test parameters enable the exchanging of qualification results among participants and the comparability of product qualifications between OEMs.

LV123 test conditions (as described in the next section, define input voltage variations under specific operational scenarios. The scenarios describe the operating status on the HV component (system under test ranging from "fully operational" to qualified operational status. The clear objective is to confirm that any LV123-qualified component or system will not fail under non-standard operating conditions.

LV123 TEST CONDITIONS AND TEST SEQUENCES

LV123 covers HV (60-1500VDC) systems in a methodical manner. Table 1 summarizes the test limits as spelled out in LV123. Table 2 defines each of the HV Status operating ranges (B1-B4).

HV-VOLTAGE RANGES	HV-OPERATING RANGE	UNIT	HV_1	HV_2a	HV_2b	HV_3
Overvoltage at load dump	**B3 / B4**	V pk	220	410	500	800
Upper HV circuit limit voltage	**B3 / B4**	V pk	220	410	500	800
Maximum operating voltage	**B2**	V d.c.	200	360	470	770
Upper limited operating capability	**B2**	V d.c.	**> 190 – 200**	**> 340 – 360**	**> 450 – 470**	**> 750 – 770**
Unlimited operating capability	**B1**	V d.c.	**90 – 190**	**170 – 340**	**250 – 450**	**520 – 750**
Lower limited operating capability	**B2**	V d.c.	**80 – < 90**	**160 – < 170**	**200 – < 250**	**450 – < 520**
Highly limited operating capability	**B2 a / B3 b**	V d.c.	60 – < 80	120 – < 160	150 – < 200	–
Undervoltage	**B3**	V d.c.	0 – **< 60**	0 – **< 120**	0 – **< 150**	0 – **< 450**

Table 1: LV123 Operational status vs. operating voltage ranges.

HV STATUS	DESCRIPTION OF HV – OPERATING STATUS
B0	The HV components are operational and there is no power demand.
B1	The HV components are fully operational and provide their intended performance.
B2	The HV components are still fully operational and provide a performance within the deviations permissible for operating status B2.
B3	The HV components are still operational, shall not assume any undefined states, and shall not interfere with other HV components.
B4	The HV components are still operational and shall not assume any undefined states.

Table 2: Definition of operating status of systems.

To effectively test for LV123 compliance, the device-under-test (DUT) should be subjected to a simulated operational load. For example, a battery charger (either configured with constant current or constant voltage output) should be operated into a simulated battery-charging profile. A DC-DC converter with a constant voltage output should be connected to a load bank or, better yet, a programmable DC electronic load.

Testing for compliance with LV123 involves a series of tests where the voltage applied to the DUT varies from one operating range condition to another. These tests are designed to put the electrical components in situations like the real-world conditions they may encounter during operation in EV and HEV motor vehicles.

Figures 1 through 4 are examples of test sequences defined by the LV123 test standard. In each case, the input voltage is moved from one condition (Bx) to another. And in each case, the duration of each condition and the transition time (slew rate) between conditions are defined.

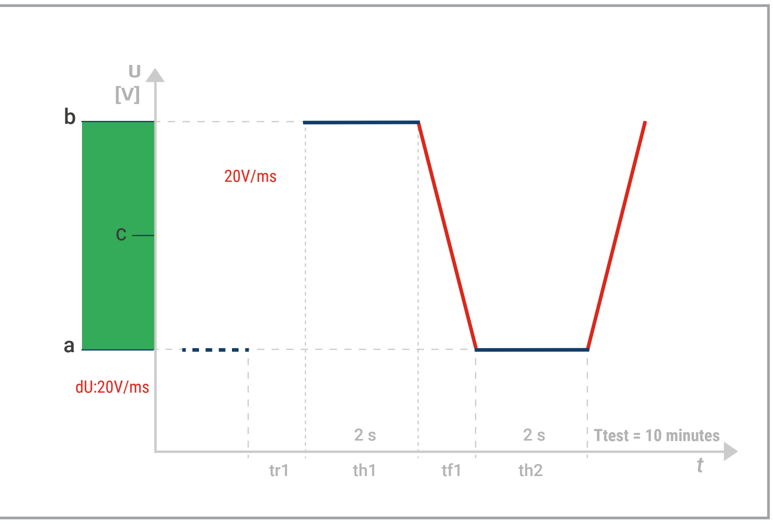


Figure 1. Range of Unlimited Operating Capability.

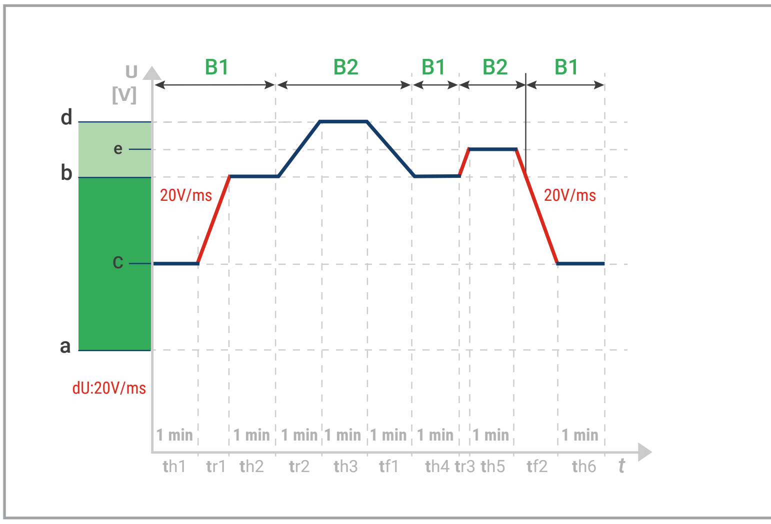


Figure 2. Upper Limited Operating Capability.

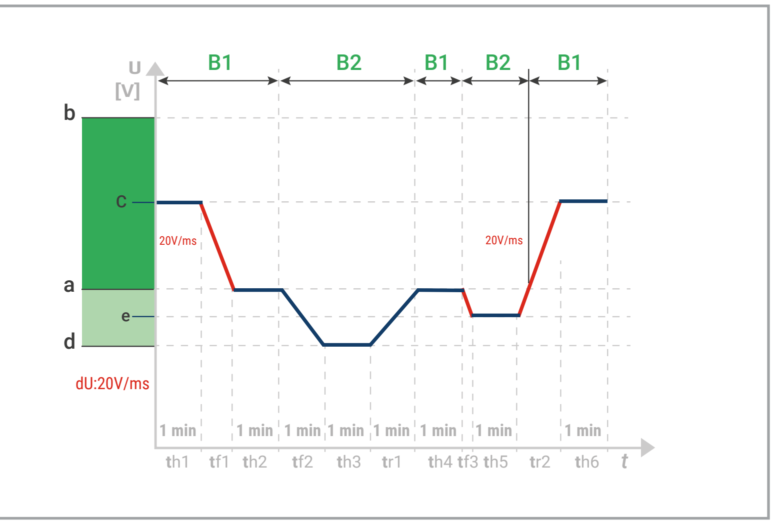


Figure 3. Lower Limited Operating Capability.

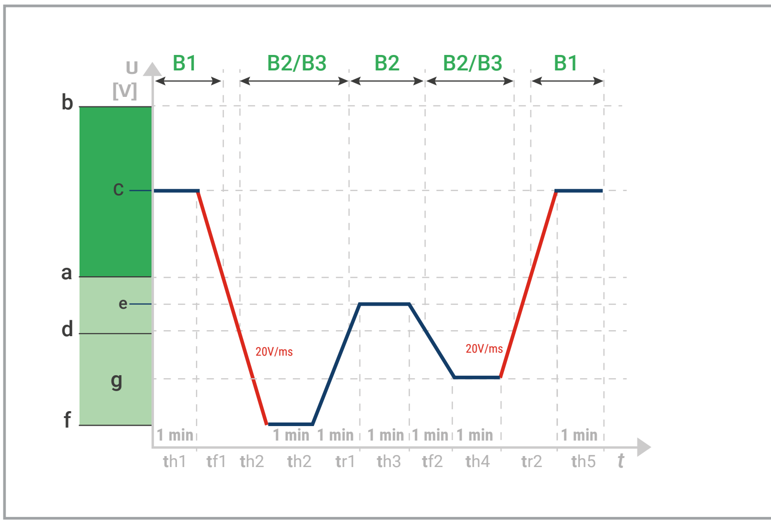


Figure 4. Controllable Voltage Range. Highly Limited Operating Capability.

A programmable DC power supply capable of generating these complex sequences is required to perform these tests. And, as indicated earlier, a programmable DC electronic load capable of simulating the demand on the output of the DUT is needed to complete the entire process.

PSB 10000 FEATURES AND FUNCTIONS

The remainder of this application note will describe the unique combination of features and functions of the EA-PSB 10000 bidirectional DC power supply that are ideally suited to LV123 qualification testing.

EA POWER CONTROL SOFTWARE - PREPROGRAMMED TEST PROFILES

Test profiles, like those described for LV123 in Figures 1-4, are commonly programmed using an “arbitrary waveform generator” feature found in the PSB 10000 and other programmable DC power supplies. This functionality allows for virtually unlimited control over the number and type of steps in a test sequence. But in the case of LV123 testing, the PSB 10000 power supply combined with EA “Power Control” applications software offers a far more convenient approach.

EA’s Power Control PC-based software includes an “Automotive” function with several pre-defined sequences for LV123 testing. Each of these sequences defines a test voltage sequence based on the parameters defined in the standard. Specific test sequences can be automatically generated and then uploaded to the PSB 10000.

Figure 5 shows the “Function Generator” function on a PC display. Selecting the “Automotive” tab and “LV123” mode presents the setup details for the selected LV123 test sequence. The user can simply select the test and voltage range under Step 1, then click ‘calculate’ and the software will automatically fill in the parameters for Step 2: Sequence setup. The number of cycles is prescribed in the “Control Setup” panel. This panel also allows for the display of a graphical representation of the test profile. Finally, the test sequence can then be uploaded to the PSB 10000 via Ethernet or USB.

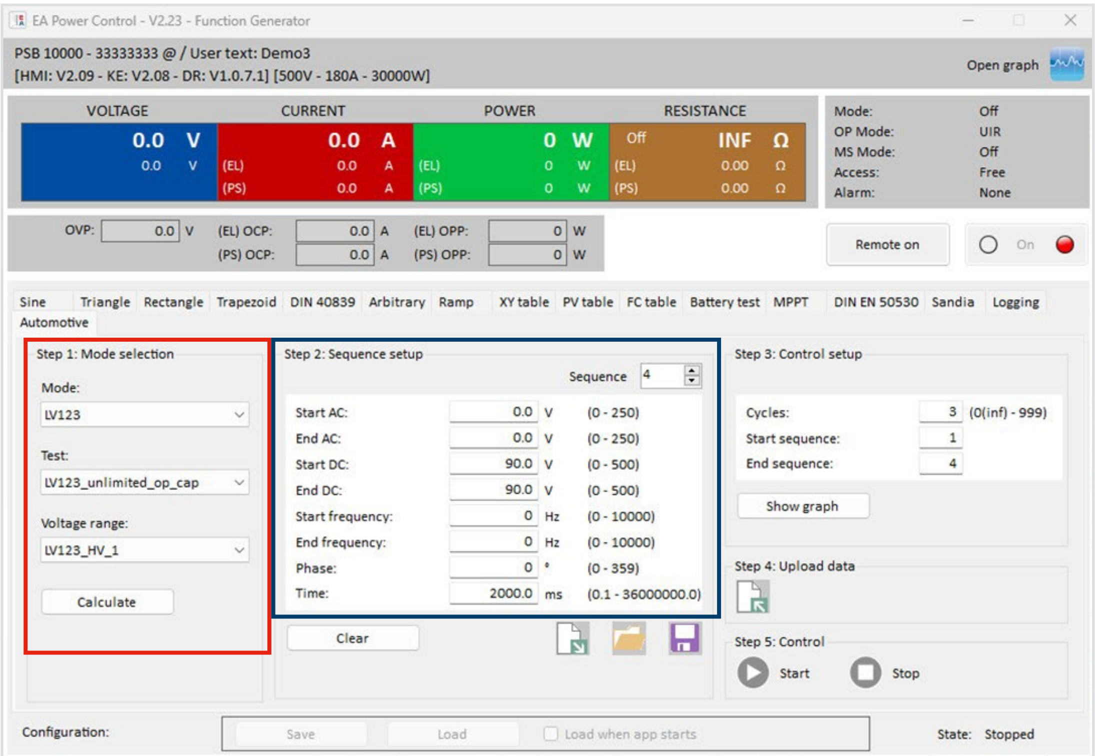


Figure 5. PC display presenting setup details for selected LV123 test profile.

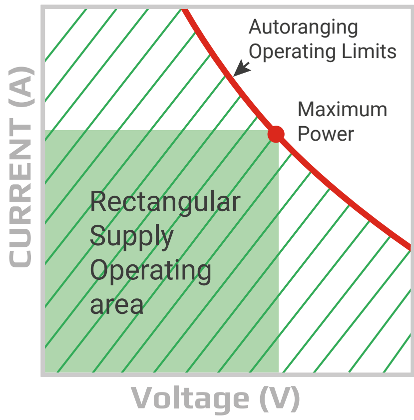
TRUE AUTORANGING POWER OUTPUT

As noted in Figures 1-4, there can be a wide range of voltages applied during a particular LV123 test sequence. The PSB 10000 series can provide up to 2000 VDC from a single device to meet the wide range of voltage requirements and features an autoranging output.

Autoranging refers to the ability of a programmable DC power supply to provide its rated maximum power over a wide range of **output voltage and current** conditions. This autoranging capability is distinct from the more common "rectangular" power supply. As shown in Figure 6, the rectangular power supply can operate at any voltage/current combination within the limits of the rectangular box. The supply's power rating is defined by the single point of maximum voltage and maximum current. In contrast, the autoranging supply can deliver maximum rated power within a wide envelope of voltage and current combinations, described by the cross-hatched area.

If the DC programmable power supply does not have autoranging capability, a supply with a higher rating would need to be used, which adds both to the cost and to the wide variations in efficiency when the unit is operated at lower power.

Figure 6.
A standard (rectangular supply) operating range compared to the wider operating limits of an autoranging supply with the same power rating.



REGENERATIVE OUTPUT

The PSB 10000 power supply can also act as a regenerative electronic load. An electronic load with regenerative output provides the prescribed load profile and an internal micro-inverter that is used to return the power to the AC source.

The secret to the implementation of a regenerative load is a back-end conversion system. As shown in Figure 7, DC energy flows into a DC-DC converter, which is tied into a DC-AC inverter (current source), and then synchronizes with the distribution grid to recycle the energy. This technology is similar to grid-tied photovoltaic inverters.

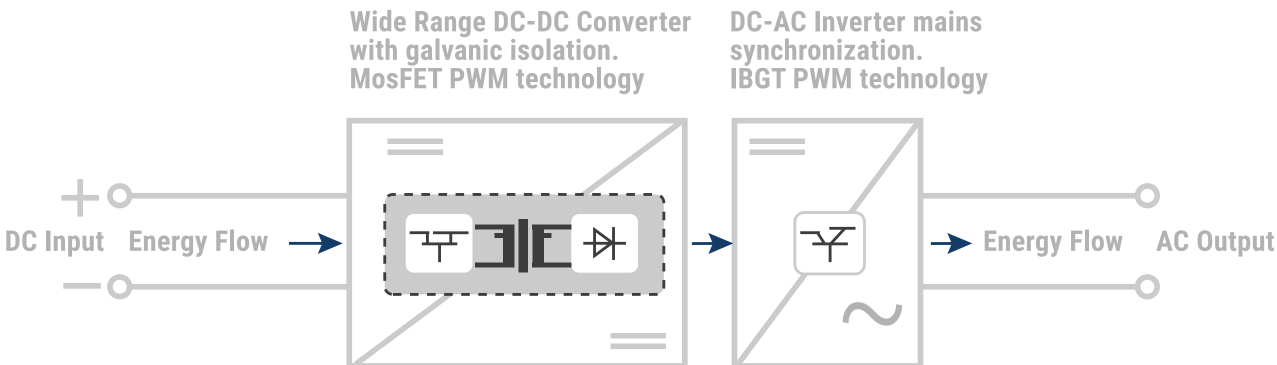


Figure 7. Electronic load DC output is applied to a grid-tied inverter stage.

PROGRAMMABLE LOAD PROFILES

The bidirectional PSB 10000 is equally capable of serving as a programmable DC power source or programmable electronic load. Utilizing the device's built-in Arbitrary Waveform Generator (Figure 8), load simulations can be set up to mimic the actual operating conditions for the selected device under test.

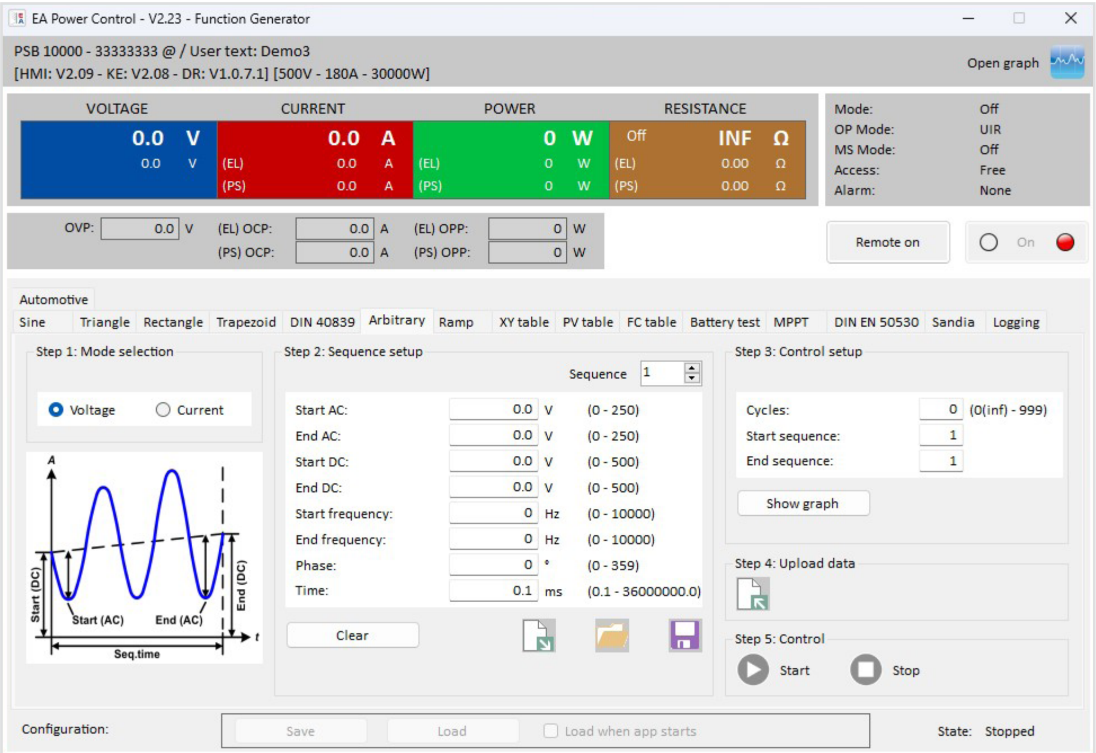


Figure 8. Arbitrary wave form generator used to profile load driven by the DUT output.

EXAMPLE: FULLY INTEGRATED LV123 DC-DC CONVERTER TEST SYSTEM SETUP

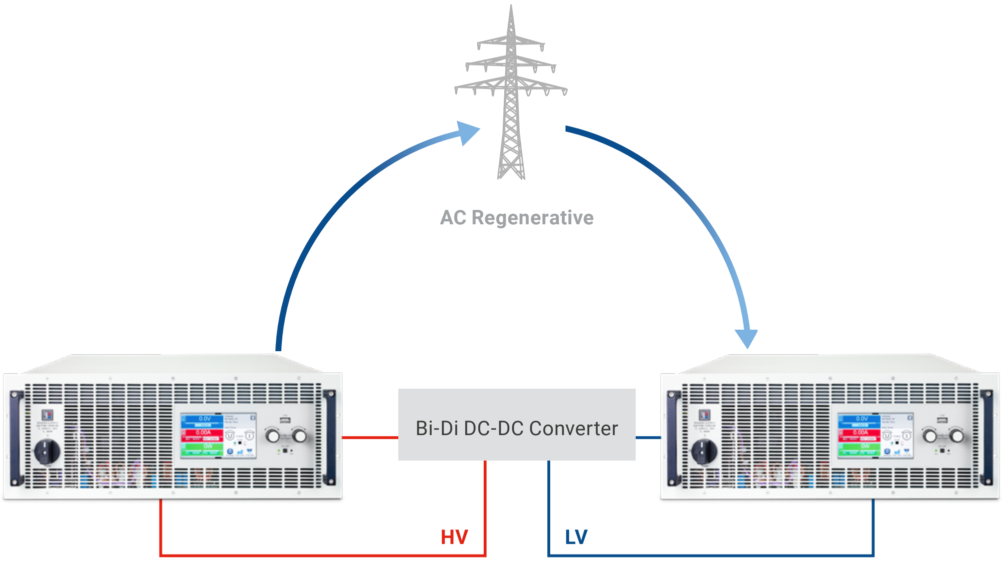


Figure 9. DC-DC converter test uses regenerative load to return 96% of energy back to its source.

Figure 9 describes the complete test set-up for DC-DC converters that includes in clockwise rotation:

- A PSB 10000 Programmable DC Power Supply.
  - The input to the unit is the available AC power source.
  - The output is a programmed LV123 DC output sequence.
- The Device Under Test (DC-DC Converter).
- A PSB 10000 Programmable DC Load equipped with Regenerative Output.
  - The input to the unit is the output of the DUT.
  - The unit provides a simulated load profile for the specific DUT.
  - The output is synchronized AC power returning to the AC power source.

CONCLUSION

The European automotive test standard, LV123, is a well-defined process allowing electronics OEMs to qualify their devices and systems for purchase by all of the major EU auto manufacturers.

This application note has described a test system comprising EA Elektro-Automatik's PSB 10000 bidirectional programmable DC power supply, a second PSB 10000 functioning as a regenerative electronic load and EA's PC-based Power Control Software.

The EA approach to LV123 testing enables OEMs to conduct the prescribed tests efficiently and cost-effectively on their equipment. The unique combination of features and functions of the PSB 10000 system makes it an ideal choice in this application. Benefits include:

- The PSB bidirectional DC power supplies from EA Elektro-Automatik combine the power supply, electronic load, and function generator into one device.
- Pre-programmed Power Control Software LV123 test sequences eliminate the requirement to manually program the aribtrary waveform comprised of the intricate series of steps.
- True autoranging allows the PSB 10000 programmable DC power supply to handle a wide variation of voltage/current combinations, potentially eliminating the need for a higher power rating to meet all test conditions.
- Programmable electronic load profiles provide accurate representations of the load driven by the DUT.
- Regenerative output from the PSB 10000 DC electronic load returns up to 96% of the test power back to the grid.

SERVICE FOR YOU WORLDWIDE.

At the headquarter in Germany in the industrial centre of North Rhine Westphalia more than 300 qualified associates, in a facility of 19000 m², research, develop and manufacture high-tech equipment for laboratory power supply, high power mains adaptors and electronic loads with or without power feedback. The sales network includes branches in China and USA, sales office in Spain and an extensive partner network.

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