AN4390
Application note

ST's MOSFET technologies for uninterruptible power supplies

Introduction

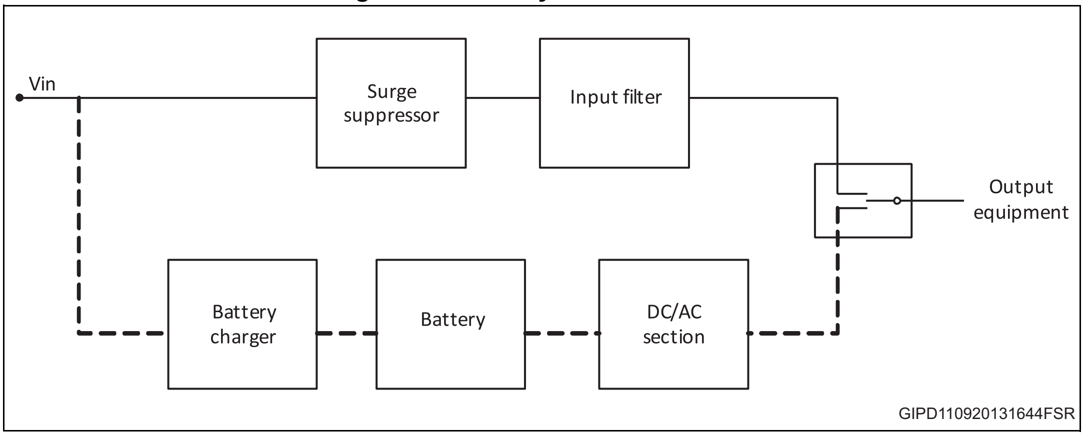
The UPS (uninterruptible power supply) is gaining ever increasing importance in office and industrial environments, because it preserves the information and business operations from power supply failure or blackout. Thanks to its technological improvement, it is now suitable both for big customers and for individual users. The right designer's choice about MOSFETs in DC-AC (H-bridge converter) section enhances the overall system performance: THD, power and thermal management and short-circuit ruggedness. In this article, ST's MOSFET technologies are described, highlighting their benefits as well.

Contents

1 Description

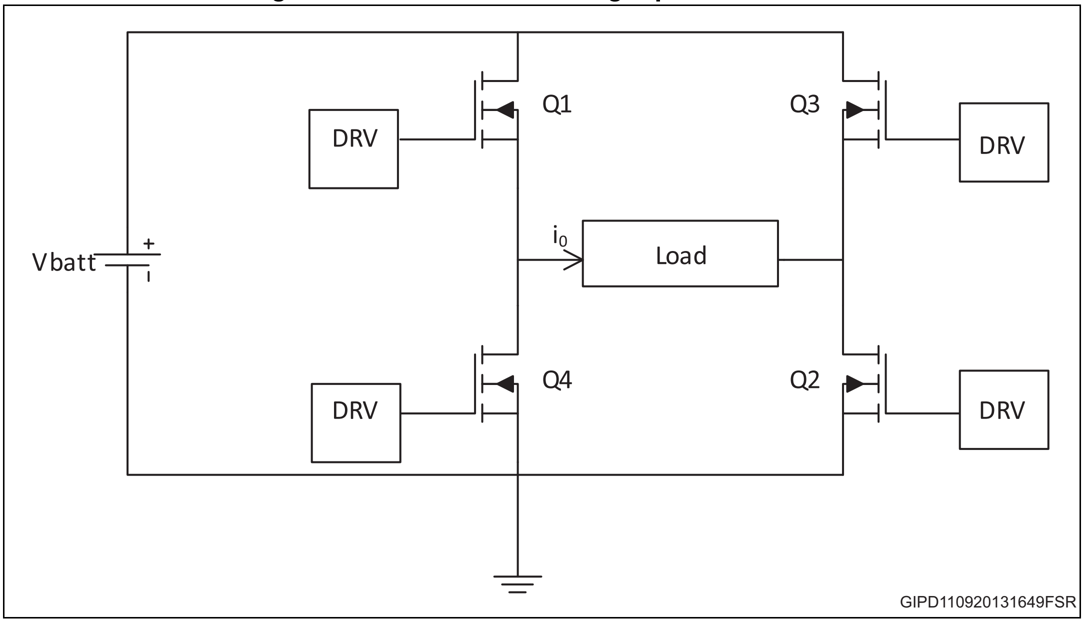
Uninterruptible power supplies (UPS) are widely used to avoid a sudden loss of data or information caused by a power supply disconnection (blackout). Power and voltage spikes, supply frequency changes, noise and radio frequency interference affect negatively the load. In *Figure 1*, the basic schematic of a "standby UPS" is shown; it is the most common type of UPS present in the market [*1*]. Surge suppressor and input filter protect the output equipment respectively from current spike and noise coming from input line. During an input supply failure, the transfer switch enables the battery-powered path.

Figure 1. Standby UPS schematic



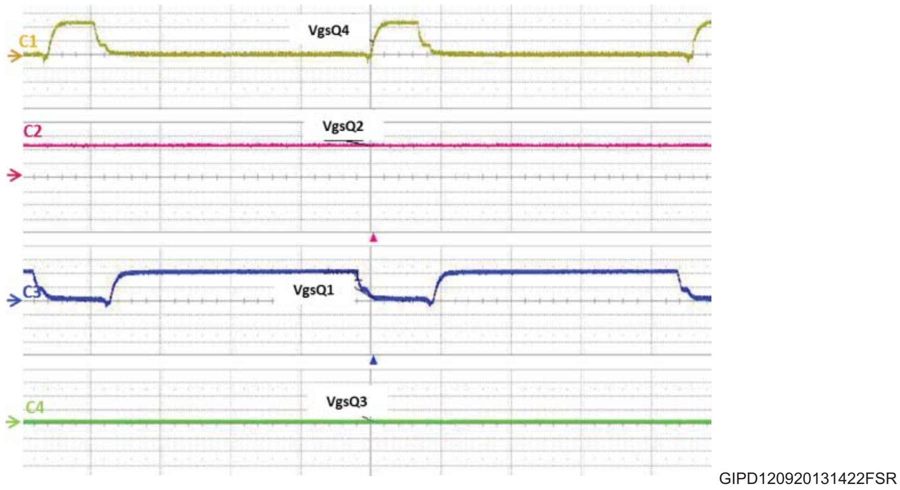
The UPS DC-AC section is formed by a H-bridge supplied by the battery voltage, which is converted into a usable AC voltage for the output equipment (*Figure 2*).

Figure 2. DC-AC section: single-phase inverter



Q1-Q2 and Q3-Q4 are driven to allow current to flow through the load to both directions. When Q1 and Q2 are in ON state, the voltage across the load is positive and the current flows from Q1 source to Q2 drain. Vice versa, when Q3 and Q4 are turned on, the voltage becomes negative. Typical switching frequencies are in the range of 50-100 kHz. In *Figure 3*, relevant gate signals for a H-bridge topology are showed.

Figure 3. MOSFET gate signals in H-bridge DC-AC converter



As per previous picture, when Q1 is turned off, the load current freewheels through Q4. In this way, FETs of the same leg cannot be in ON state simultaneously avoiding any shoot-through risk. Same considerations are valid during Q2 and Q3 switching. Together with MOSFET power losses and efficiency analysis, evaluation tests on UPS systems include two important tests:

- Short-circuit test: the output of DC-AC section is shorted for few seconds to test both semiconductor cross-conduction robustness and system protection intervention.
- Back-feed test: back-feed protection prevents the electric shock from any electric current feeding when a main supply fails.

2 MOSFET key parameters in UPS

Power MOSFETs are key components for the UPS, because of their impact on DC-AC section and on the whole system performance. Device's features are below reported:

a) **$R_{DS(on)}$**: the major MOSFET loss in H-bridge configuration is the conduction loss, because of the device's on-time duration; so $R_{DS(on)}$ optimization is mandatory for the system efficiency enhancement.

b) **R_{th}** (thermal resistance): low R_{th} values allow a good heat dissipation, reducing the temperature.

c) **V_{SD}** (body-drain diode forward voltage drop): during the freewheeling phase, the current flows through body-drain diode, so the lower V_{SD} is, the lower diode losses are.

MOSFET dynamic parameters (such as: gate charge and/or intrinsic capacitances) don't play a crucial role in the device's performance, due to low switching frequency values for this kind of application. In UPS, typical MOSFET breakdown voltages are in the range of [55 V - 100 V], while most common package is TO-220.

3 Technologies for UPS systems

In ST portfolio, favorite silicon technologies for the UPS environment are:

- STripFET™ IV DeepGATE technology ("F4 series")
- STripFET VI DeepGATE technology ("F6 series")

Both of them are trench technologies, which allow a good $R_{DS(on)}$ performance. Here below the cross-sections of STripFET IV DeepGATE technology (*Figure 4*) and STripFET VI DeepGATE technology (*Figure 5*).

Figure 4. STripFET IV deepGATE technology cross-section

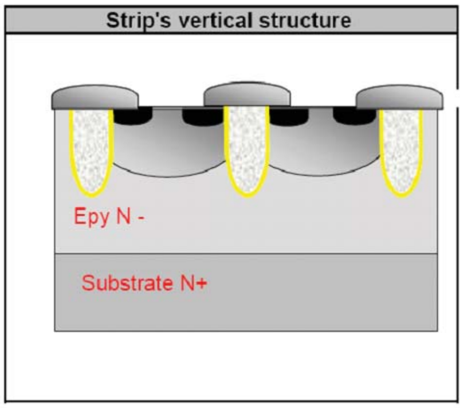
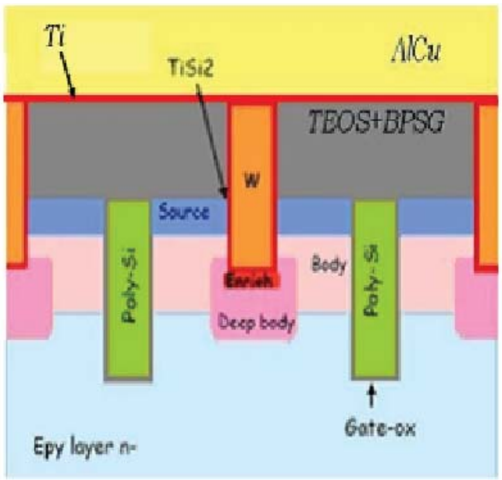
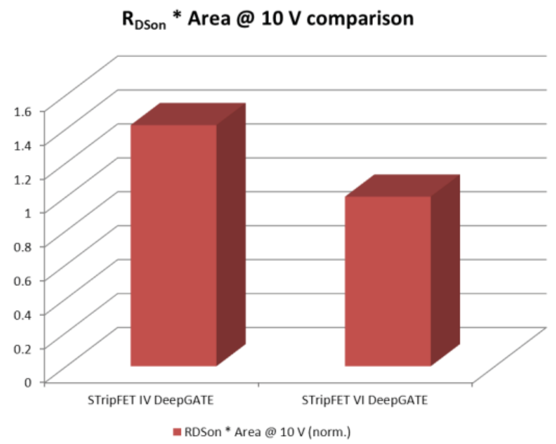


Figure 5. STripFET VI deepGATE technology cross-section



By comparing two above mentioned technologies, STripFET VI DeepGATE shows a better performance in specific $R_{DS(on)}$ (or $R_{DS(on)}$ *area); in *Figure 6*, the relevant specific $R_{DS(on)}$ is compared by taking into account the breakdown voltage and die size.

Figure 6. $R_{DS(on)}$ comparison



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On the other side, considering devices with the same BV_{DSS} and die size, STripFET IV DeepGATE technology has lower intrinsic capacitances and total gate charge (~ -20% for Q_G @ V_{GS} = 10 V). Obviously, for low switching frequency (<100 kHz), higher intrinsic capacitances don't affect the device’s performance (especially, temperature and efficiency).

3.1 STripFET IV DeepGATE technology

The STP90N55F4 is a 55 V Power MOSFET, housed in TO-220 and realized with STripFET IV DeepGATE technology. Steady-state and turn-off waveforms, mounted as high-side and low-side switches in a 1500 VA UPS, are reported in *Figure 7* and *Figure 8*.

Table 1. STP90N55F4 main electrical parameters

Type	$R_{DS(on)}$ max. @ 10 V	V_{TH} @ 250 µA	BV_{DSS} @ 250 µA
STP90N55F4	6 mΩ	3.2 V	> 55 V

Figure 7. STP90N55F4 steady-state waveforms

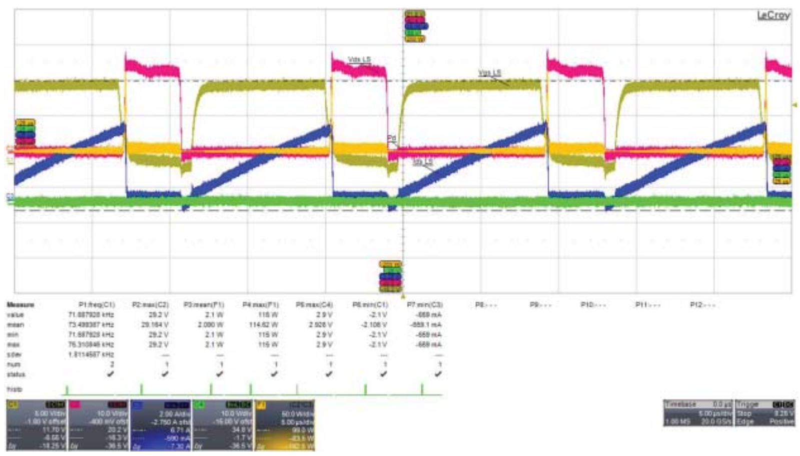

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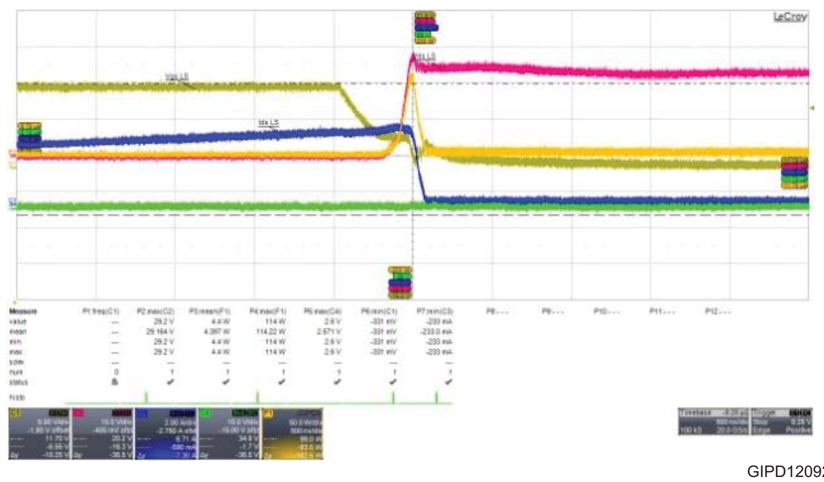
Figure 8. STP90N55F4 turn-off waveforms



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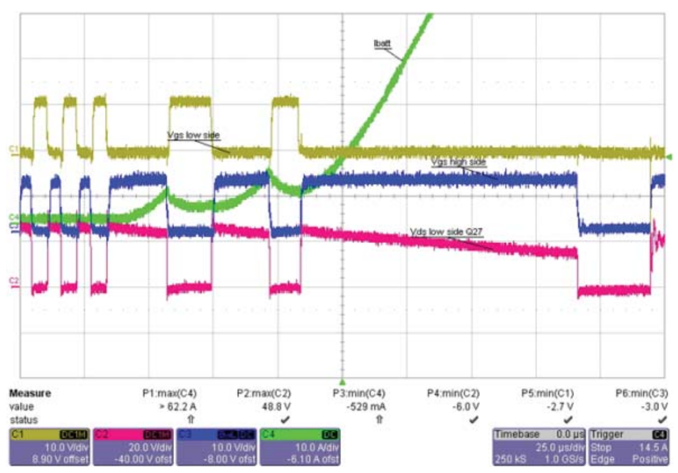
The average power dissipation at turn-off is around 114 W, while the maximum drain-source voltage spike is lower than 30 V. The STP90N55F4 has a good robustness during short-circuit tests, when the UPS output is shorted for a fixed time. During a short-circuit test, high-side and low-side gate-source voltages must not overlap to avoid the shoot-through phenomenon. *Figure 9* shows the screenshot, where yellow and blue traces are low-side and high-side V_{GS}.

Figure 9. STP90N55F4 short-circuit waveforms



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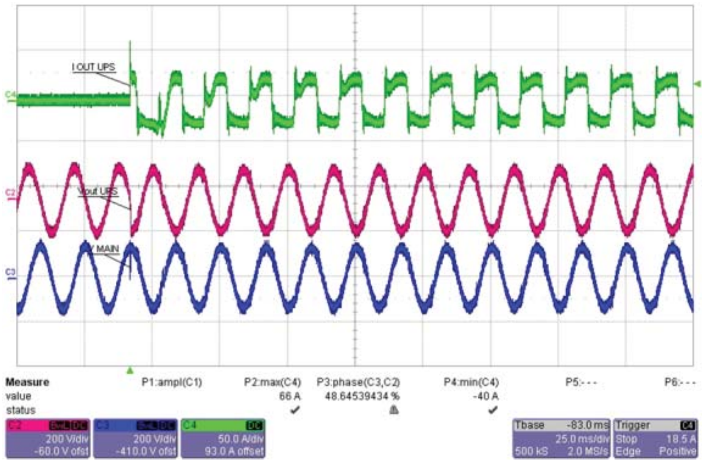
Another important feature for MOSFETs used in UPS is its ruggedness during back-feed test (see *Section 2: MOSFET key parameters in UPS*). *Figure 10* shows the UPS output current, output voltage and AC main waveforms, when AC main voltage and UPS output voltage are shifted 90°. The shortcut between AC main and output voltage (typically for a hundred of ms) allows the user to check if the device passes the test without any failure.

Figure 10. STP90N55F4 back-feed test waveforms



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3.2 STripFET VI DeepGATE technology

The STP110N55F6 (STripFET VI DeepGATE) is tested in a 1500 VA UPS; below its main electrical parameters. The high-side waveforms, during turn-on and off, are captured at P_{OUT} = 430 W (*Figure 11* and *Figure 12*).

Table 2. STP110N55F6 main electrical parameters

Type	$R_{DS(on)}$ max. @ 10 V	V_{TH} @ 250 µA	BV_{DSS} @ 250 µA
STP110N55F6	4.3 mΩ	2.7 V	> 55 V

Figure 11. STP110N55F6 turn-on waveforms

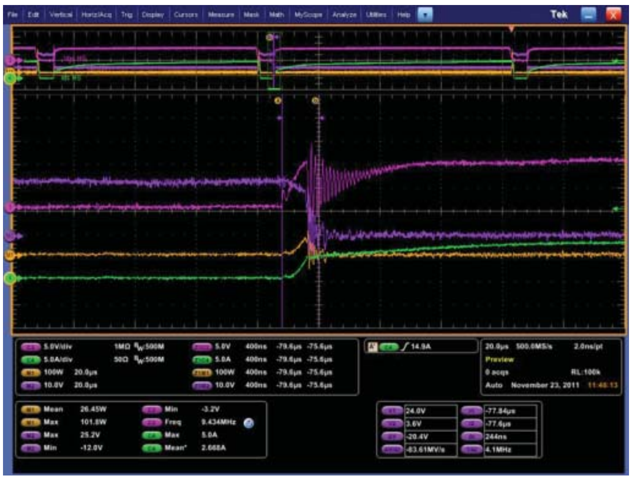

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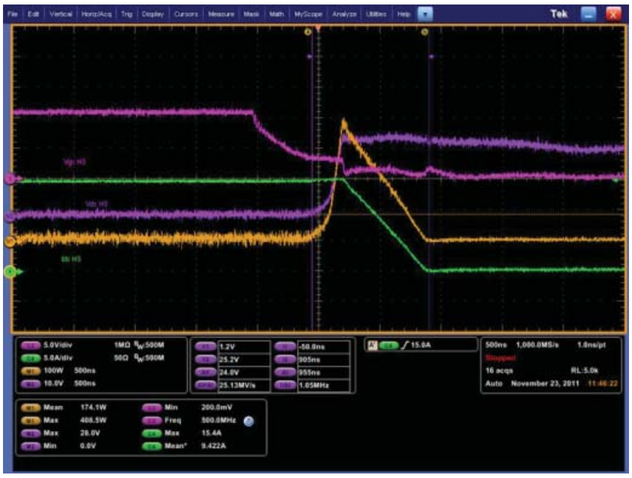
Figure 12. STP110N55F6 turn-off waveforms



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During the device’s turn-off, there is a bigger power dissipation (174 W vs. 27 W at turn-on, considering mean values); moreover, there are not important voltage spikes at turn-off. The STP110N55F6 also shows a good short-circuit ruggedness performance; in fact, when the short-circuit is repeated many times, the system shuts down so to avoid any damage, and neither HS/LS gate-source voltage overlap and nor cross-conduction risk are present (*Figure 13*, HS and LS G-S voltages are purple and yellow traces).

Figure 13. STP110N55F6 short-circuit test waveforms

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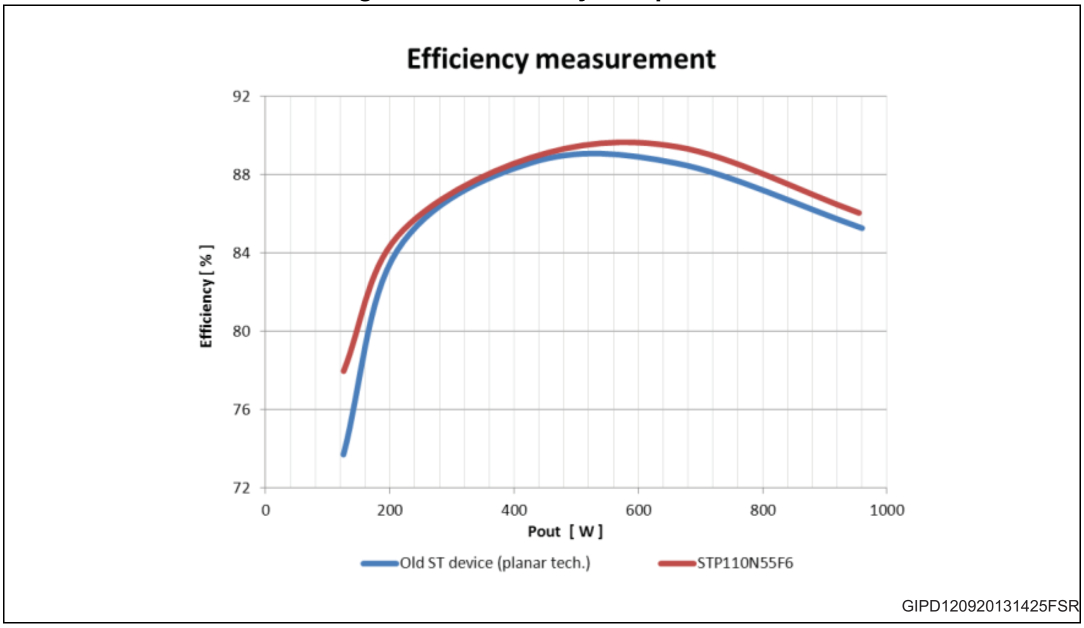
The good STP110N55F6 power management performance is highlighted considering the efficiency curves, here below reported (*Figure 14*). The STP110N55F6 has higher efficiency at full load conditions than the old ST’s planar device, thank to its lower $R_{DS(on)}$ (4.3 mΩ vs. 5.7 mΩ).

Figure 14. Efficiency comparison



The STP110N55F6 is suitable for UPS applications, thanks to its good switching behavior, efficiency performance and robustness in short-circuit tests.

4 Conclusions

The improvement of the UPS performance (THD, power management, short-circuit and back feed test ruggedness, etc…) depends on the right design of DC-AC section. In this document, ST’s trench MOSFET technologies (STripFET IV DeepGATE and STripFET VI DeepGATE) are analyzed in 1500 VA UPS, showing a good switching behavior and power management performance (any dangerous voltage spikes and/or cross-conduction risks) and also passing short-circuit and back-feed tests without any failure. Both technologies are hence suitable for high-side and low-side devices in DC-AC section of the modern UPS.

5 References

1. "An overview of uninterruptible power supplies", Racine M.S., Parham J., Rashid M., University of West Florida

6 Revision history

Table 3. Document revision history

Date	Revision	Changes
26-Nov-2013	1	Initial release.