GAN-BASED PRIMARY-SIDE POWER SWITCHES EXTEND THE POWER RANGE OF INNOSWITCH3 IC FAMILIES

In July 2019, Power Integrations announced new members of its InnoSwitch™3 families of offline CV/CC flyback switcher ICs. The new ICs feature up to 95% efficiency across the full load range and up to 100 W in enclosed adapter implementations without requiring a heatsink. This groundbreaking increase in performance was achieved using an internally developed high-voltage GaN switch technology (PowiGaN™).

WHITEPAPER

ac-dc converters

The Need for GaN

The highly successful InnoSwitch3, InnoSwitch3-Pro and LYTSwitch™-6 families of flyback power conversion ICs are extremely efficient and eliminate the need for heatsinks in compact power supply applications such as chargers, adapters, LED ballasts and other compact or sealed systems with negligible airflow. InnoSwitch devices utilize PI's unique FluxLink™ feedback system and provide high regulation accuracy, rapid transient response and a comprehensive suite of line, load and self-protection features. The InnoSwitch3 is ideal for USB PD and PPS rapid charging adapters, consumer product, appliance and industrial applications when high efficiency, high reliability and survivability, low component count and compact layout are critical to design success.

The advanced low-profile InSOP-24C package used for these devices is able to deliver between 30 W and 60 W without a heatsink depending on the input voltage range and power supply form factor using proprietary silicon MOSFET technology.

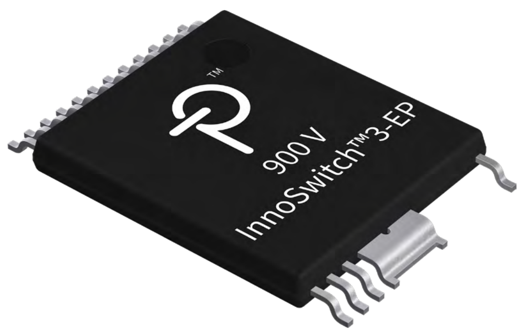

Figure 1 InSOP-24C proprietary surface mount power package used by Power Integrations InnoSwitch3, InnoSwitch3-Pro and LYTSwitch-6 power conversion product families

To deliver the power needed for higher power rapid charging, IOT connected appliances, LED lighting and industrial applications, and to further reduce converter size, a primary power switch with lower $R_{DS(ON)}$ per unit area and higher conversion efficiency is required. Wide band-gap semiconductors provide lower specific $R_{DS(ON)}$ (on resistance per unit area) and greatly reduced switching losses, making them an ideal match for the developing market requirements.

GaN Performance Comes from the Band-Gap of the Semiconductor Materials

Gallium Nitride (GaN) is a wide-bandgap semiconductor material that allows fabrication of switches that have very low switching losses both during turn-on and turn-off compared their silicon counter parts. In fact, unlike Silicon MOSFETs, GaN switches inherently have near-zero turn-off losses. Turn-on losses in GaN Switches are almost entirely due to inter nodal capacitances which are much smaller in GaN compared to Silicon MOSFETs. This is because both turn-on and turn-off in GaN are almost instantaneous and equivalent R_{DSON} GaN devices are much smaller in die size compared to Silicon.

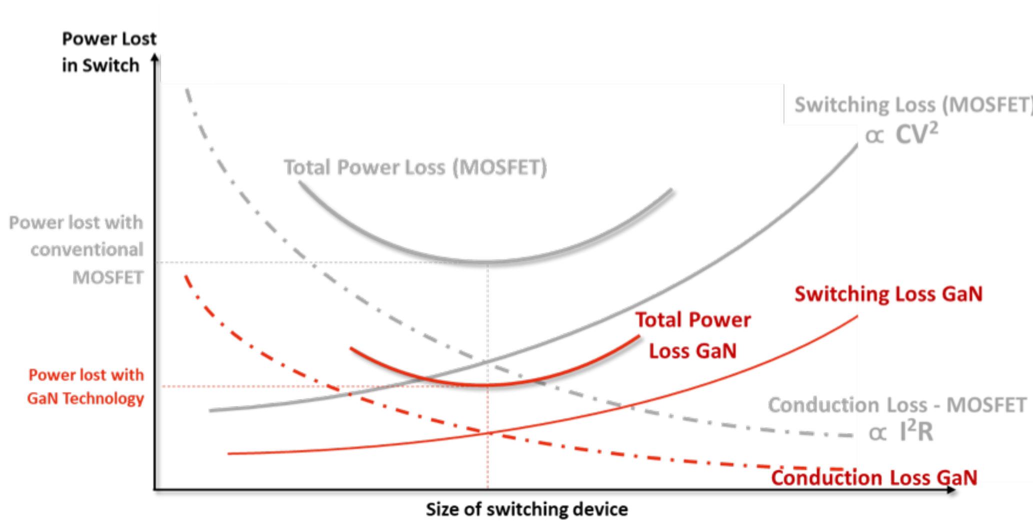

Figure 2 Comparison of the conduction losses (channel resistance) with switching losses in that a GaN device will have lower losses for a given die size than a silicon device

Performance Advantages of PowiGaN

Power Integrations has developed advanced GaN Switch technology (PowiGaN) and has optimized the devices for use in our integrated power solutions. PowiGaN devices allow the InSOP-24C package to deliver much higher power levels without a heatsink while also substantially increasing the overall power supply efficiency.

A major challenge for discrete GaN solutions is the difficulty in driving the transistors and protecting them. GaN is so much faster than silicon that even small amounts of inductance and capacitance introduced by the discrete GaN packages and PCB trace connections makes it very difficult to drive. Common challenges faced by designers are high a dv/dt and high frequency oscillation during switching which creates EMI, lowers efficiency and some cases can cause destruction of the device. The high switching speed also makes it very difficult to protect the transistor during fault conditions as the high speed of the GaN switches can cause the switch current to ramp to destructive levels - before the protection circuitry has a chance to safely turn off the device.

These issues are completely resolved by embedding the PowiGaN in Power Integration’s highly integrated switcher ICs. Integration significantly reduces parasitic inductances and capacitances making it easier to avoid oscillation. PowiGaN-based products incorporate drivers that are tailored to the specific PowiGaN device, optimizing switching speed to minimize EMI, maximize efficiency and to effectively eliminate oscillation. The protection circuitry is able to quickly detect unsafe currents to safely shutdown device under fault conditions, and Power Integrations' switching converter ICs include start-up circuitry which eliminates the need for external biasing circuits. PowiGaN devices also employ lossless current-sense technology, completely eliminating external sense resistors that frequently exceed the resistance of the GaN switch itself in discrete implementations. These benefits allow power supply developers to focus on meeting their customer's power delivery, form factor and thermal requirements, without worry about the needs of the enabling GaN technology.

The operation of PowiGaN-based InnoSwitch3 is indistinguishable from that of conventional (silicon-based) devices from the same family. Switching frequency, transformer design, EMI filtering, biasing and synchronous rectification circuitry is identical for PowiGaN and silicon devices. Changes are only necessary to accommodate the higher power of PowiGaN-based designs. The PI Expert™ automated power-supply-design-software suite supports both MOSFET and PowiGaN based devices, speeding up the design process by enabling the selecting of the best component and generating the full schematic, magnetics and BOM from basic parametric inputs.

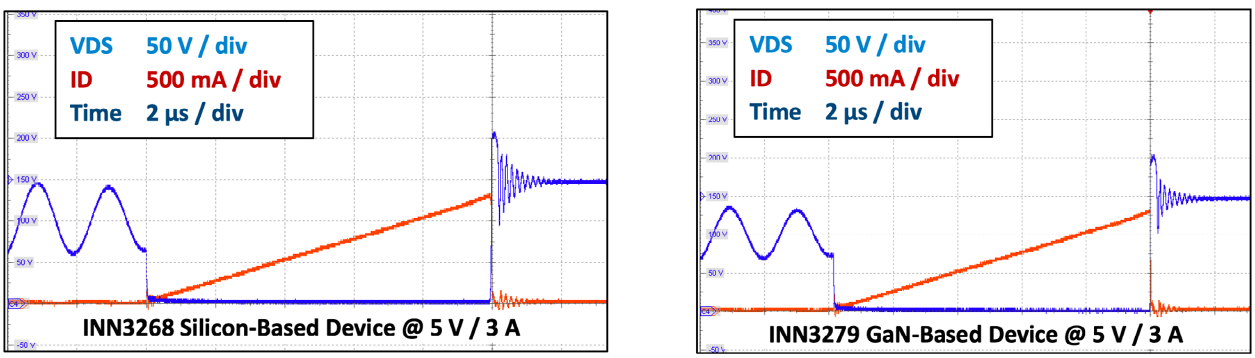

Figure 3(a) Low Line DCM Turn-On V_{IN}: 100 VDC

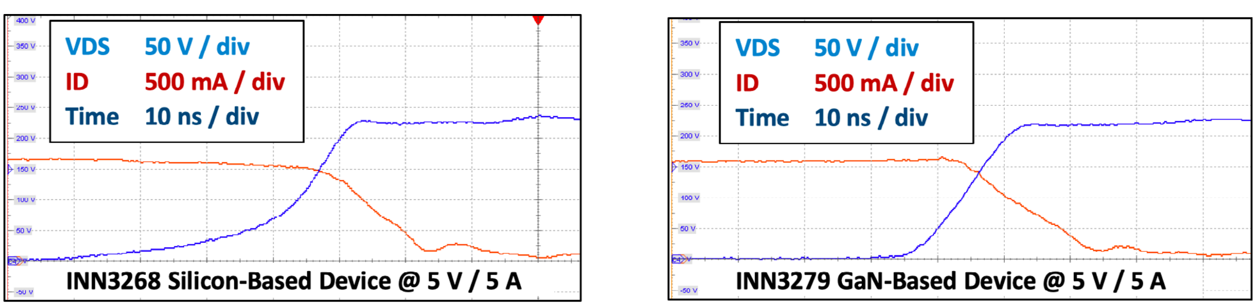

Figure 3(b) Low Line CCM Turn-Off V_{IN}: 100 VDC

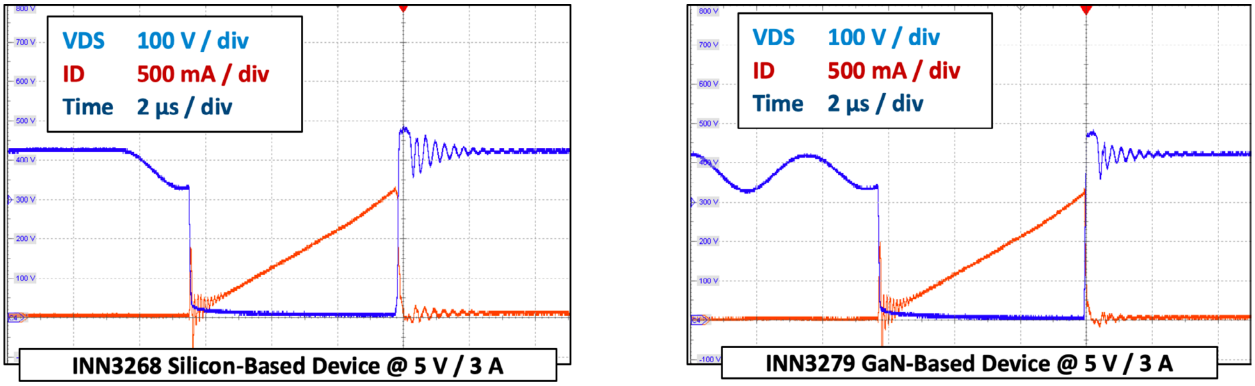

Figure 3(c) High Line DCM Turn-On V_{IN}: 370 VDC

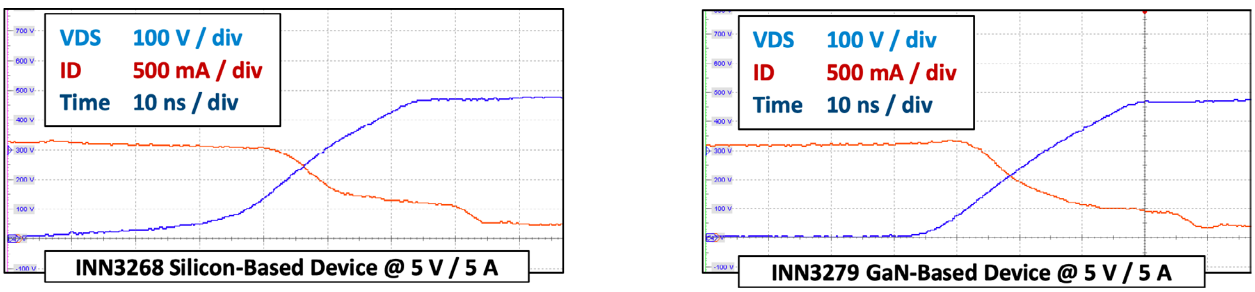

Figure 3(d) High Line CCM Turn-off V_{IN}: 370 VDC

Figure 3 Seamless transition between GaN and Silicon devices is demonstrated by the comparison of drain-source voltage waveforms during switching for PowiGaN and silicon InnoSwitch3 devices. Note that the waveforms are virtually identical—the same circuits can be used for silicon and PowiGaN based devices.

The faster turn-on characteristic of the PowiGaN switches can be seen in Figure 3(c); however the slope of the transition is the same and produces a similar EMI signature.

Lower $R_{DSON(MAX)}$ and switching loss increases efficiency compared to conventional silicon based technologies. Like other InnoSwitch3 devices, efficiency for PowiGaN-based designs is constant across line and load ranges. This makes them ideal for applications calling for high average efficiency and for adjustable output-voltage designs (USB PD and PPS).

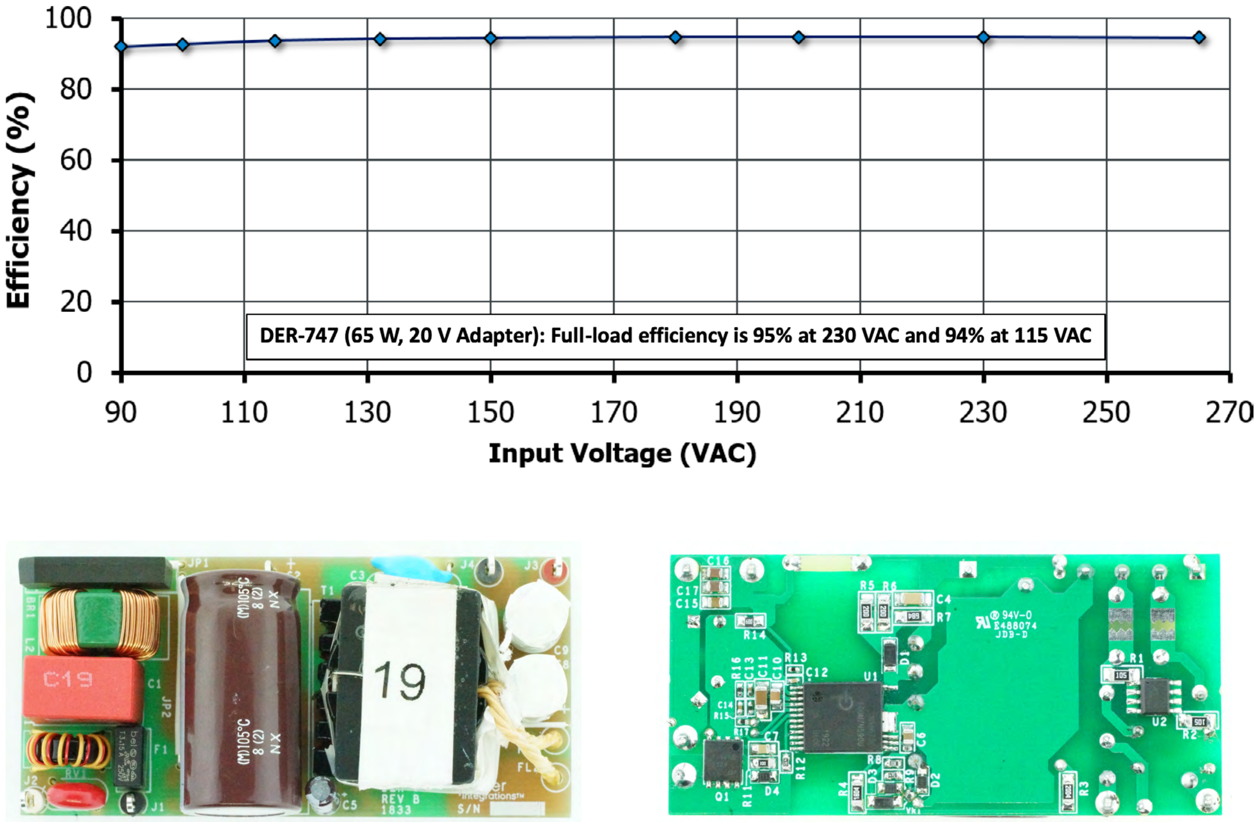

Figure 4 High full-load-efficiency across line voltage enables InnoSwitch3 designs to eliminate heatsinks ensuring smallest possible converter size – example is shown is DER-747 which is a 65 W adapter using InnoSwitch3-EP INN3679C.

In USB PD type applications, the need to accommodate multiple output voltage options limits transformer optimization and reduces efficiency. Despite this, InnoSwitch3 devices using PowiGaN switches still achieve high efficiency across load and are able to eliminate the heatsink for rapid-charge designs.

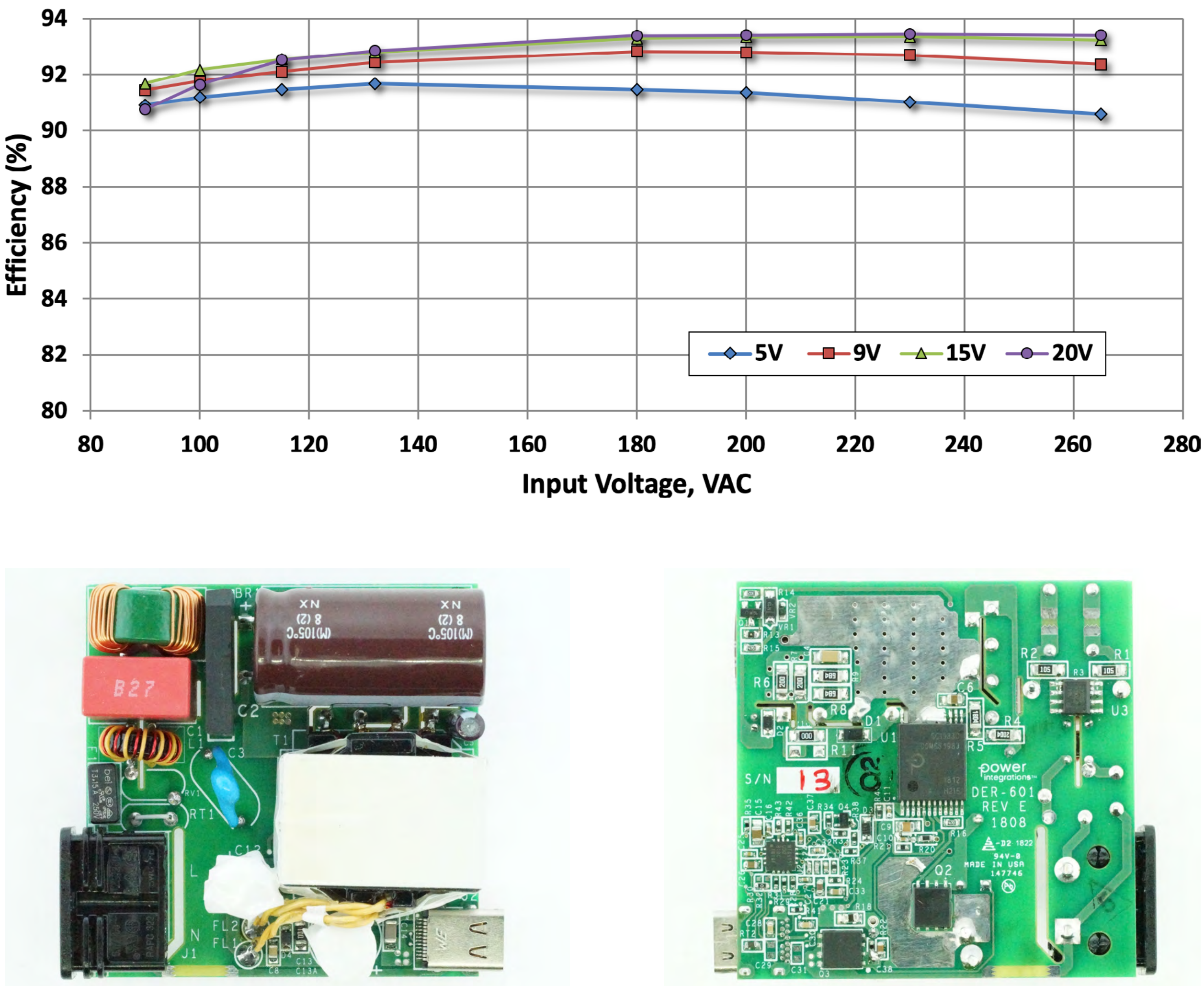

Figure 5 DER-601 – 60 W wide-range USB PD charger (5 V – 20 V output) showing high efficiency across load. InnoSwitch3-CP INN3279C-H215. 60 W adapter design—no heatsink required.

Figure 6 DER-805 – 100 W wide-range USB PD + PPS charger (5 V – 20 V output) with no-heatsink required. InnoSwitch3-Pro INN3370C-H302.

PI Product Families Featuring PowiGaN Switches

Power Integrations uses a smart-number system for describing parts within a device family. Parts from the families listed below with part numbers ending in 9 or 0 employ PowiGaN-based switches. Devices with part numbers ending in 78 also employ PowiGaN switches. Devices ending in 68 are 650 V $V_{DS(MAX)}$ rated silicon devices.

Product Famiily	Application	Typical Applications
InnoSwitch3-CP INN3278C-HXXX INN3279C-HXXX INN3270C-HXXX	Constant Power and CV/CC	Chargers/Adapters, IoT, USB PD Chargers
InnoSwitch3-EP INN3678-HXXX INN3679C-H60X INN3670C-H60X	Open Frame and Adapter CV/CC	Appliances, Industrial, Motors, Smart Meters, General Purpose Adapters
InnoSwitch3-Pro INN3678C-HXXX INN3379C-H302 INN3370C-H302	Digitally Programmable CV/CC	USB PD Chargers, Programmable Power Supplies
LYTSwitch-6 LYT6078C LYT6079C LYT6070C	CC/CV Lighting	Ballasts and LED drivers

Table 1 Product families with GaN parts. Size 8 devices available Q4 2019. Contact a PI representative for additional information and samples.

PowiGaN Devices – Robust and Reliable

PowiGaN devices are specifically designed to operate at the voltage levels seen in off-line flyback power conversion. They are manufactured in the same fabs as Power Integrations' conventional silicon products and have undergone extensive qualification testing to ensure reliable operation in power conversion circuits. In addition to the qualification tests listed below, Power Integrations' switcher ICs go through extensive long-term testing in real-world power supply designs which has resulted in a field failure rate of less than 0.2 PPM across all our products.

<table>
<tr><th></th><th>Test Description</th><th>Symbol</th><th>Test Method</th><th>InnoSwitch3</th><th>InnoSwitch3 (GaN)</th></tr>
<tr><td rowspan="6">Fab Process</td><td rowspan="2">Preconditioning and Moisture Sensitivity Level</td><td rowspan="2">PC</td><td>JESD22-A113</td><td rowspan="2">MSL3</td><td rowspan="2">MSL3</td></tr>
<tr><td>JEDEC J-STD-020</td></tr>
<tr><td>Temperature Humidity Bias</td><td>THB</td><td rowspan="11">Multiple units, multiple lots</td><td rowspan="11">Multiple units, multiple lots</td><td rowspan="11">Multiple units, multiple lots</td></tr>
<tr><td>Temperature Cycling</td><td>TC</td></tr>
<tr><td>High Temperature Storage Life</td><td>HTSL</td></tr>
<tr><td>Dynamic Operating Life</td><td>DOPL</td></tr>
<tr><td rowspan="2">Fab and Package</td><td>Highly Accelerated Life Test</td><td>HALT</td></tr>
<tr><td>High Temperature Reverse Bias</td><td>HTRB</td></tr>
<tr><td rowspan="5">Packaging Process</td><td>Preconditioning</td><td>PC</td></tr>
<tr><td>Moisture Sensitivity Level</td><td>PC</td></tr>
<tr><td>Temperature Humidity Bias</td><td>THB</td></tr>
<tr><td>Temperature Cycling</td><td>TC</td></tr>
<tr><td>High Temperature Storage Life</td><td>HTSL</td></tr>
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Table 2 Rigorous qualification testing of InnoSwitch3 GaN parts ensures reliable power supply operation

In addition to the standard qualification tests employed for all PI devices, PowiGaN based product qualification includes additional DOPL and HALT testing to confirm an extra degree of survivability for these devices in worst case (real-world) conditions. As part of the PowiGaN development process, unique and proprietary wafer level, die level and final-test level GaN-specific screening tests have been created to ensure device continuity and reliability.

Figure 7 DOPL stress-test board used for PowiGaN InnoSwitch3 device qualification testing

PI switcher devices operate at the highly variable range of mains voltage levels encountered in the off-line power conversion applications worldwide. Voltage stress on the primary switch in a flyback power supply is a combination of the rectified line voltage ($V_{BUS)}$ the output reflected voltage (VOR) – the output voltage reflected across the turns-ratio of the power transformer, and the voltage induced by the leakage inductance of the transformer primary winding (V_{LE}). In a typical flyback design the worst case voltage stress under normal operation occurs at maximum line voltage (264 VAC for European systems). Figure 8 shows the approximate magnitude of the different components compared to the voltage rating of a PowiGaN primary switch.

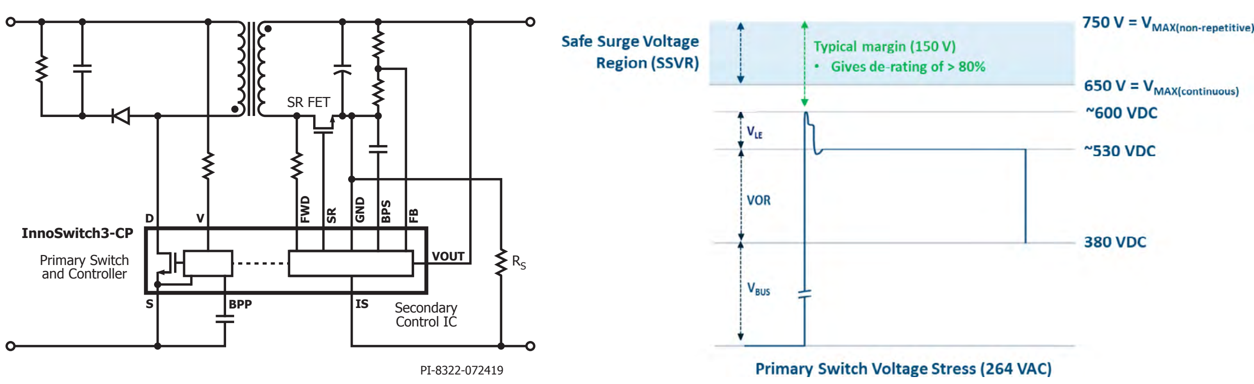

Figure 8 Voltage stress on the primary switch of an offline flyback power supply operating at 264 VAC. VOR is dependent on output voltage (V_S) and transformer design (for more information see appropriate data sheet and follow guidelines described in the PI Expert design software suite). All InnoSwitch3 families and LYTSwitch-6 devices monitor BUS voltage via the V pin and will interrupt switching to eliminate VOR and V_{LE} voltage-stress components during line surges.

Power supplies attached to mains may also experience line surges and swells, and to address this, two voltage ratings are provided for the PowiGaN switch, enabling the power supply engineer to optimize the power supply design for practical applications. The $V_{MAX(NON\ REPETITIVE)}$ rating (750 V) describes the maximum voltage-withstand under transient, swell and surge conditions. PowiGaN-based parts are 100% production tested at voltages in excess of the $V_{MAX(NON\ REPETITIVE)}$ limit to ensure operational reliability. This parameter is employed for derating purposes in the power supply design in the same way as the “abs-max” BVDss rating for a traditional MOSFET is used. The maximum continuous voltage ($V_{MAX(CONTINUOUS)}$) parameter describes the stress that may be applied continuously to the GaN switch. For PowiGaN devices this figure is 650 V. Operation above this limit will not damage the device, but repeated exposure to higher voltages may cause temporary $R_{DS(ON)}$ shift beyond the limits described in the datasheet. InnoSwitch products are provided with a fast line-over-voltage protection feature—they will cease switching to protect themselves should line voltage exceed a user-defined limit, ensuring that all of the 750 V of maximum voltage rating is available during transients.

The technology used in the PowiGaN-based InnoSwitch3, InnoSwitch3-Pro and LYTSwitch-6 is effective, reliable and easy to use. As a material for power semiconductors, GaN enables devices that behave much closer to an "ideal switch" than contemporary Silicon. The exceptional performance results of PowiGaN-based devices that the technology will be increasingly utilized in PI device-families moving forward

While this report is updated periodically, it is appropriate to check for latest updates on the PI website (www.power.com/GaN).

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