GaN-Based Switcher ICs Empower Next-Generation Power Products

There have been a number of disruptive advances in the power electronics community over the last 20 years. These changes - from switching power supplies to digital power management to AI-driven systems - have moved the industry forward. Up until recently, these advances have mainly been topology and system design. However, in recent years, arguably the most significant disruptive change has been the advent of wide-bandgap semiconductors such as Gallium Nitride (GaN). **Chris Lee, Power Integrations, San Jose, USA**

GaN offers very real benefits over Silicon, including enabling much higher switching frequencies and/or significantly increasing energy efficiency. By all metrics, a GaN device is simply a better switch than Silicon. However, GaN devices have mostly only been available in the form of discrete components, which require considerable effort and finesse to design into systems than would a more integrated solution.

Incorporating GaN

In 2019, Power Integrations launched its GaN-based InnoSwitch™3 family of offline CV/CC flyback switcher ICs, delivering up to 95 % efficiency across the full load range, and up to 100 W in enclosed adapter implementations, all without requiring a heatsink. This industry-leading increase in performance is enabled by using an internally-developed high-voltage GaN switch technology (Figure 1).

Developed specifically for offline power conversion applications, the devices realize the performance benefits promised by wide band-gap technology. Losses in GaN switches are almost entirely due to inter-nodal capacitances, which are much smaller in GaN compared to silicon MOSFETs due to the reduced size of the switch for a given $R_{DS(ON)}$. Power Integrations calls its advanced GaN Switch technology 'PowiGaN™'. The new switches give the InSOP-24C-packaged devices the ability to deliver much higher power levels without a heatsink, a benefit which comes from substantially increasing the overall power supply efficiency.

A major challenge when using GaN is the difficulty in driving the transistors and protecting them. GaN is so much faster than silicon that even small amounts of parasitic trace inductance and capacitance causes challenges to safe operation. Common issues include high dv/dt frequency oscillation during switching, which creates EMI, lowers efficiency, and some cases can cause destruction voltage stress on the device. Power Integrations resolved the issue by embedding the PowiGaN GaN switch in its highly-integrated switcher ICs, which significantly reduces parasitic inductances and capacitances.

PowiGaN technology

A key advantage to PowiGaN-based products is that they incorporate drivers tailored to the specific GaN-based device, optimizing switching speed to minimize EMI, maximizing efficiency, and effectively eliminating oscillation (as described above). Integrated protection circuitry is able to quickly and accurately detect excess currents and safely shut down the device during fault conditions, and Power Integrations' switching converter ICs include start-up circuitry that eliminates the need for external biasing circuits.

PowiGaN devices also employ lossless current-sense technology, eliminating the need for the external sense resistors seen in discrete implementations. In order to bias the control loop sufficiently to ensure a response fast enough to protect the switch, the value of these resistors can exceed that the GaN switch itself. The operation of PowiGaN-based InnoSwitch3 is indistinguishable from that of legacy Silicon-based devices from the same family, with switching frequency, transformer design, EMI filtering, biasing, and synchronous rectification circuitry remaining the same for both PowiGaN- and Silicon-based parts.

InnoSwitch and LYTSwitch

Incorporating GaN technology into the InnoSwitch3 and InnoSwitch3-Pro families of flyback power conversion ICs and LYTSwitch™-6 LED driver ICs allows the elimination of heatsinks in chargers, adapters, LED ballasts and other compact or sealed power systems that must rely on convection cooling. Another advantage to InnoSwitch devices is that these ICs also use high speed FluxLink™ communications technology that ensures high regulation accuracy, rapid transient response, and advanced line, load and protection features without the need for optocouplers.

Able to deliver between 30 W and 100 W without a heatsink, the low-profile highly-integrated surface-mount InSOP-24C package is ideal for use in applications that employ PCB cooling. FluxLink feedback technology enables very fast control – virtually eliminating overshoot and undershoot during transient load transitions.

A drop-in solution

Because the operation of the PowiGaN-based InnoSwitch3 is indistinguishable from that of legacy devices from the same family, the new products provide a drop-in replacement for existing InnoSwitch-based circuits, and changes are only necessary to accommodate the higher power of the PowiGaN-based design. PI Expert automated power supply design software supports both MOSFET and PowiGaN-based devices, speeding up the design process by optimizing component selection and generating the full schematic, magnetics, and bill of materials (BoM).

Figure 2 shows the seamless transition between GaN and silicon devices which is demonstrated by the side-by-side comparison

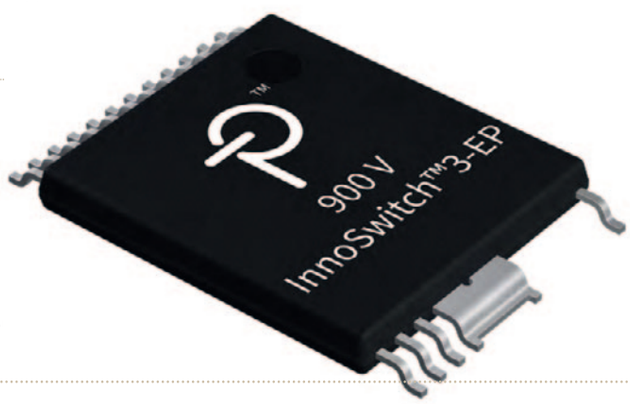

Figure 1: **InnoSwitch3 offline CV/CC flyback switcher ICs deliver up to 95% efficiency across the full load range**

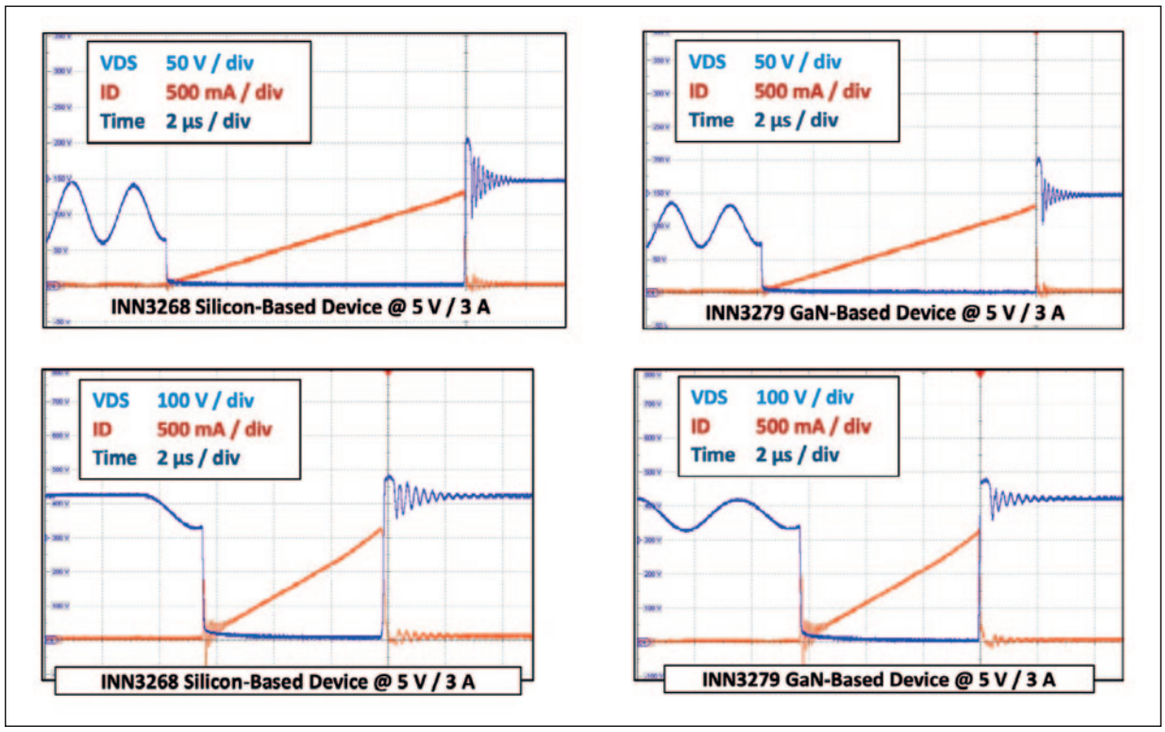

Figure 2: A comparison of drain-source voltage waveforms during switching for Silicon InnoSwitch3 devices (left) and PowiGaN (right) at 50 V (upper) and 100 V / div (lower) image

of drain-source voltage waveforms during switching for PowiGaN and Silicon InnoSwitch3 devices. The waveforms are virtually identical, showing the same circuits can be used for Silicon and PowiGaN-based devices. The slope of the transition is the same and produces a similar EMI signature.

Because the efficiency of PowiGaN-based designs is constant across line and load, they are particularly suitable for applications requiring high average efficiency, as well as for adjustable output-voltage designs such as USB PD and for PPS. In USB PD type applications, designs using InnoSwitch3 devices with PowiGaN switches achieve the high efficiency across load vital for eliminating heatsinks in applications with widely varying output conditions.

Reliable and rugged

Specifically designed to operate at the voltage levels seen in off-line flyback power conversion, PowiGaN devices have undergone extensive qualification testing, which includes challenging environmental and highly accelerated life testing, as well as extensive long-term testing in real-world power supply designs, resulting in a field-failure rate of less than 0.2 parts per million (PPM). Product qualification includes additional DOPL and HALT testing to confirm survive ability in worst-case (real-world) conditions (Figure 3).

The company's switcher devices operate across variable mains voltage levels encountered worldwide. In a typical flyback design the worst case voltage stress under normal operation occurs at maximum line voltage (264 V AC for European systems). All InnoSwitch3 family members and LYTSwitch-6 devices monitor the bus voltage via the V pin and will interrupt switching to eliminate VOR and VLE induced voltage-stress on components during line surges.

The existence of two voltage ratings for the PowiGaN switch enable optimization for practical applications, with a VMAX(non-repetitive) rating (750 V) describing the maximum voltage-withstand under transient, swell, and extended surge conditions. This parameter is employed for derating purposes in the power supply design, in the same way as the absolute max BVDss rating for a traditional MOSFET is used.

The maximum continuous voltage 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 extended exposure to higher voltages may cause temporary RDS(ON) shift beyond the limits described in the datasheet. As described, the fast line-over-voltage protection feature will cause the device to cease switching in the event that the line voltage exceeds a user-defined limit, increasing safety margins in fault conditions.

Summary

Power Integration's approach yields overall circuit performance, size and system cost benefits. This has provided customers with an easy adoption curve: the new GaN devices build on established Silicon products delivering significantly improved performance that can be cost-effectively implemented into existing designs.

Figure 3: DOPL stress-test board used for PowiGaN InnoSwitch3 device qualification testing¶