GaNSense™ Half-Bridge Integration Accelerates the Power-Electronics Revolution

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High-speed gallium nitride (GaN) half-bridge integration delivers smaller, faster-charging, next-generation power systems to obsolete the silicon chip.

Five years into the second revolution in power semiconductors[i], gallium-nitride-(GaN)-based mobile fast-chargers dominate flagship smartphone and laptop models, taking market share from legacy power silicon chips. This next-generation 'wide band-gap' technology is cascading into mainstream mobile applications and simultaneously breaking-out from that beachhead market, into higher-power consumer, solar, data centers and EVs[ii]. A new power-platform - the integrated, feature-rich, high-efficiency GaNSense™ 'half-bridge' - is a fundamental building-block in high-power, high-speed applications, where GaN not only delivers smaller, fast-charging and lower system-cost applications, but also can save an estimated 2.6 Gtons of CO_2/year by 2050[iii].

Fundamental building blocks: full-bridge and half-bridge architectures

One of the simplest methods to measure current is to add a shunt series resistor into the current path of interest, and then measure the voltage across it as a representation of that current, knowing the relationship of Voltage = Current * Resistance, (V = I*R), and assuming a stable, or linear, resistance.

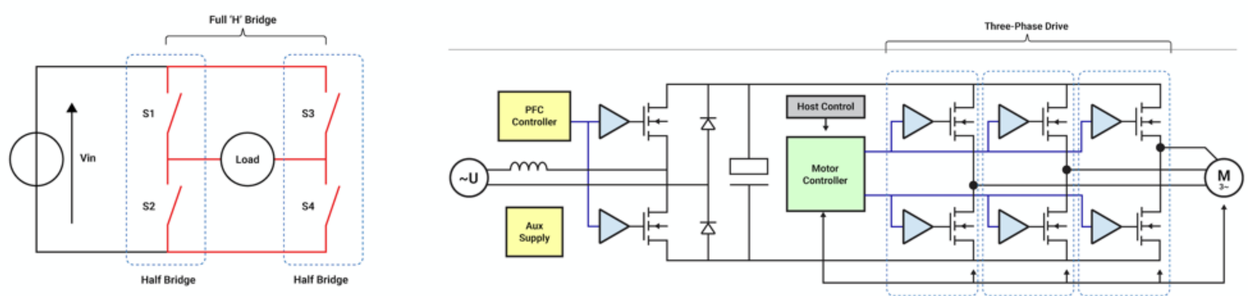


Fig.1 Half-Bridge configuration is a fundamental building block in power electronic circuits

Speed #1: Soft-switching optimizes power-conversion performance

High-speed – or rather, high-switching-frequency – operation shrinks the size, weight and cost of 'passive' elements (transformers, capacitors, EMI filters, etc.) within a power system. However, simply running a standard topology at high speed means extreme losses and reliability risks due to silicon's highly-capacitive material properties. 'Soft-switching' is a control technique in which excess voltage and/or current across a power device are eliminated before the device is switched on or off, avoiding capacitive- or switching-speed-related losses. The summary below details the efficiency benefits of soft- vs. hard-switching, and also highlights the material advantage of GaN power ICs vs. legacy Si discrete FETs[iv].

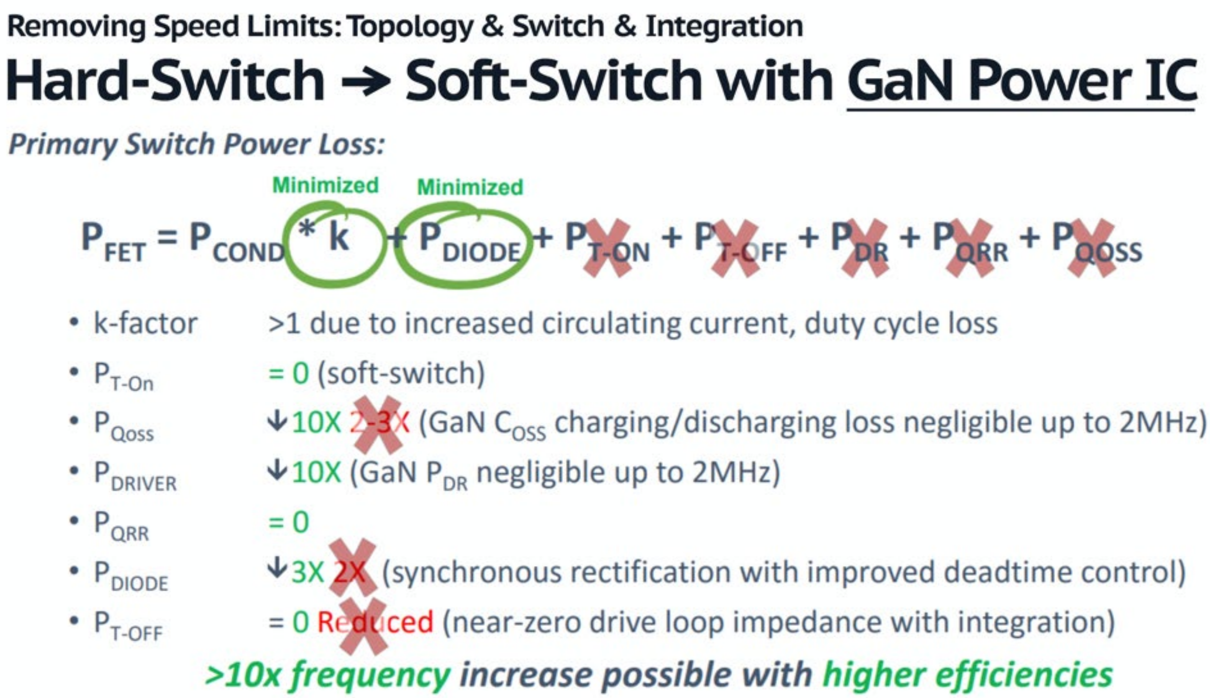


Fig.2 Using GaN Power ICs in soft-switching topologies eliminates turn-on losses, device recovery and driver losses.

In the mobile fast-charger market, the transition from Si to soft-switching GaN has been remarkable. In 2019, the best-in-class 65 W, Si-based OEM charger (Lenovo) achieved a power density of 0.85 W/cc, and retailed for US$46. In the same year, a 65W 'soft-switching, half-bridge' GaN-based charger (Xiaomi) achieved 1.27 W/cc and retailed for only US$26[v,vi]. Now, GaN-based designs dominate flagship mobile phone fast-charging, and a new category – 'ultra-fast' charging – has emerged where a 5,000 mAhr phone battery can be charged from 0-100% in less than 10 minutes with a GaN-based 150 W charger[vii].

Moving up to higher powers, multi-kW AC-DC power supplies for data centers host several soft-switching, half-bridge elements. A typical design is split into two sections: the first for mains AC-DC rectification and 'power-factor correction' (PFC), with the second 'DC-DC' stage combining isolation and voltage step-down functions. Modern designs use a 'totem-pole' (TP) structure which combines AC-DC and PFC functions by using two half-bridge circuits, one operating at a low speed to handle the AC mains frequency (50-60 Hz) and the other at 100's of kHz or MHz+ to control the PFC. The DC-DC stage is another half-bridge, typically in an LLC topology, or sometimes full-bridge for higher power, and again running at high switching-speeds. An example 3.2 kW "MHz" design is shown, with variable-frequency boundary-mode T-P PFC running between 500 kHz and 1.5 MHz, and downstream DC-DC running at 1 MHz, delivering impressive power density, 2x higher than typical industry-standard W/cc[viii]. This is an 'all-GaN' powertrain design, with 650 V GaNFast power ICs for the PFC and DC-DC primary, and 200 V GaN FETs for the DC-DC secondary.

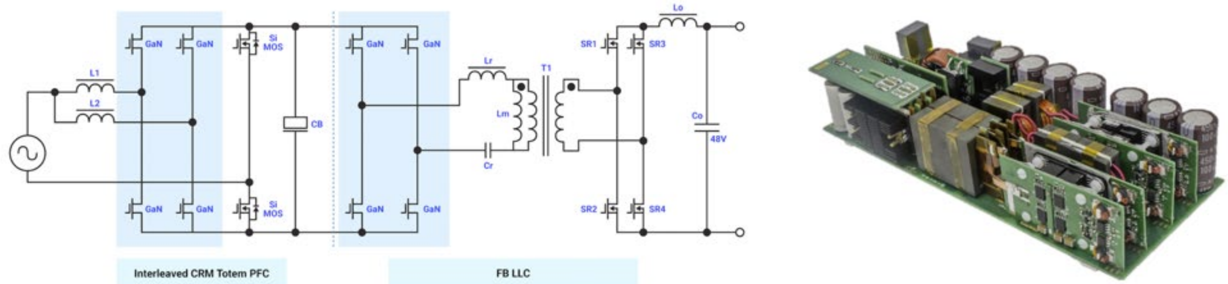


Fig.3: 3.2 kW Server Power Supply using GaNFast Power ICs for Totem-Pole PFC and LLC in MHz switching to achieve 98% efficiency and 4.4 W/cc

Speed #2: Motor-drive applications spin the hard-switch exception.

Modern 'variable-speed drives' (VSDs) for electric motors, as used in domestic appliances, HVAC, industrial machinery, EVs, robotics, etc. use three half-bridges to create a 'three-phase' topology, as shown earlier. While there are advanced academic studies into soft-switching with wide band-gap materials (GaN, SiC) in bi-directional arrangements, most motor-drives in mass production today are low-frequency (~6 kHz) and 'hard-switched'. Even in this hard-switch application, GaN's low switching-capacitance material properties and zero 'reverse-recovery' charge mean that switching speeds can be increased while reducing losses[x,xi].

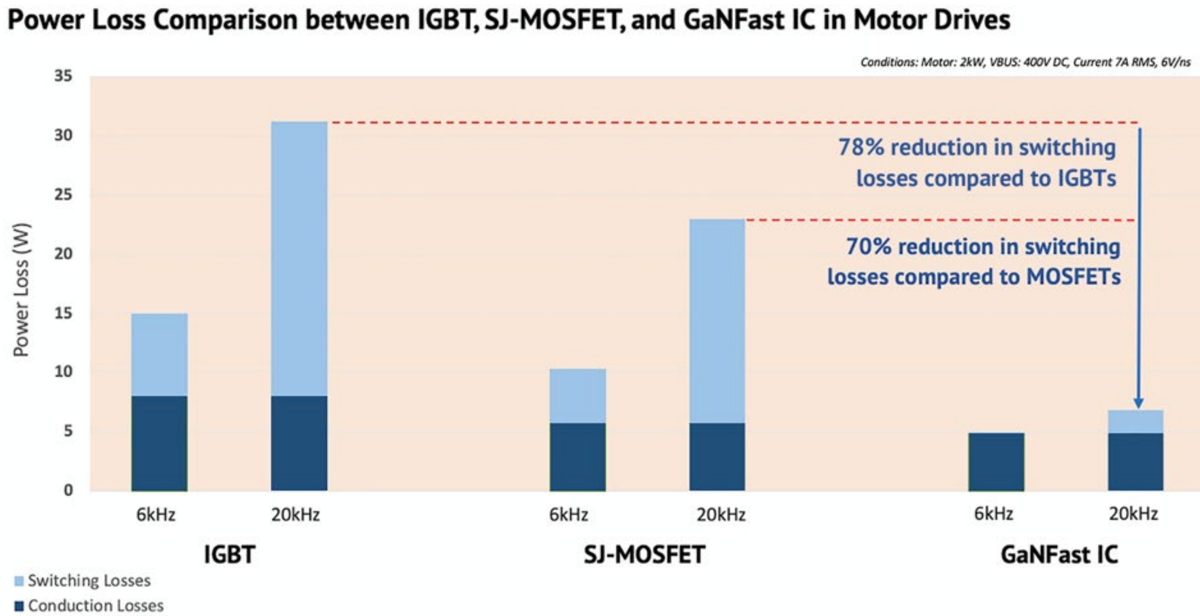
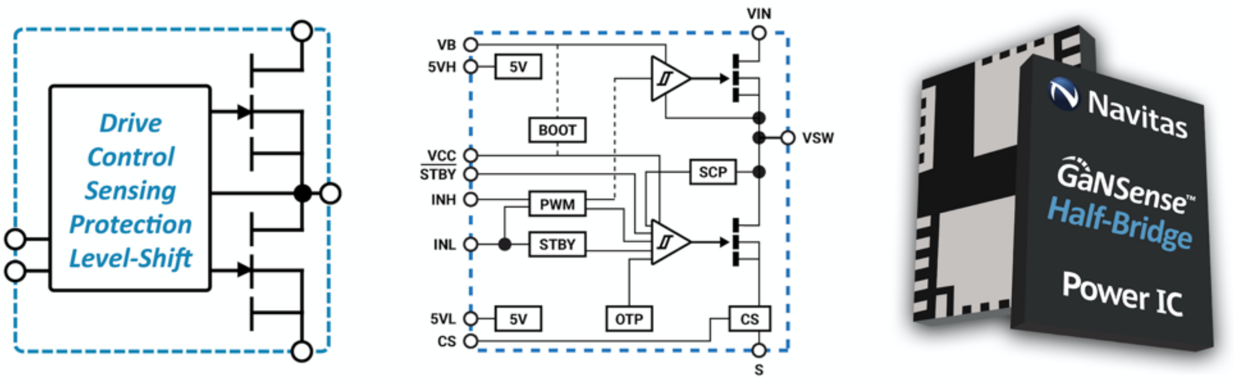


Fig 4. GaN achieves a 78% reduction in total power loss, while simultaneously running 3x faster than a legacy Si IGBT design.

Integration: Introducing the GaNSense™ Half-Bridge

Historically, power designers had to create half-bridge circuits from discrete transistors and a myriad of external controllers, sensors and peripheral components. Now, new, easy-to-use, high-performance GaNSense Half-Bridge power ICs are available in small 6 x 8 mm surface-mount PQFN packages for a broad range of applications from 200 W TV / monitors to 1 kW motor-drives. Highly integrated, these next-generation power ICs combine two GaN power FETs with GaN drive, plus control, sensing, protection and isolation.



High level Diagram

Simplified Schematic

Navitas NV6247 GaNSense Half-Bridge in 6x8 mm PQFN

Fig. 5 GaNSense half-bridge integrates drive, control, sensing and protection, with level shifting isolation, into a single 6x8 mm PQFN package

Unlike complex, costly and potentially unstable discrete implementations, the GaNSense half bridge includes advanced features to simplify design such as standard digital-logic inputs, high-side bootstrapping and level-shifting, and loss-less current-sensing for the highest efficiency and maximum chance of first time-right, fastest-time-to-market designs. As a true IC, protection features such as over-current, over-temperature sensing and autonomous control, shoot-through protection, 2 kV ESD and 200 V/ns slew-rate capabilities come as standard. Compared to discrete GaN solutions, the GaNSense half bridges deliver a 60% reduction in both component count and PCB area, eliminate unreliable operation, deliver 6x faster 'detect-to-protect' operation and higher efficiency. The NV6247 (2x 160 mΩ) and NV6245 (2x 275 mΩ) half bridges are the first available with a higher-power portfolio to follow.

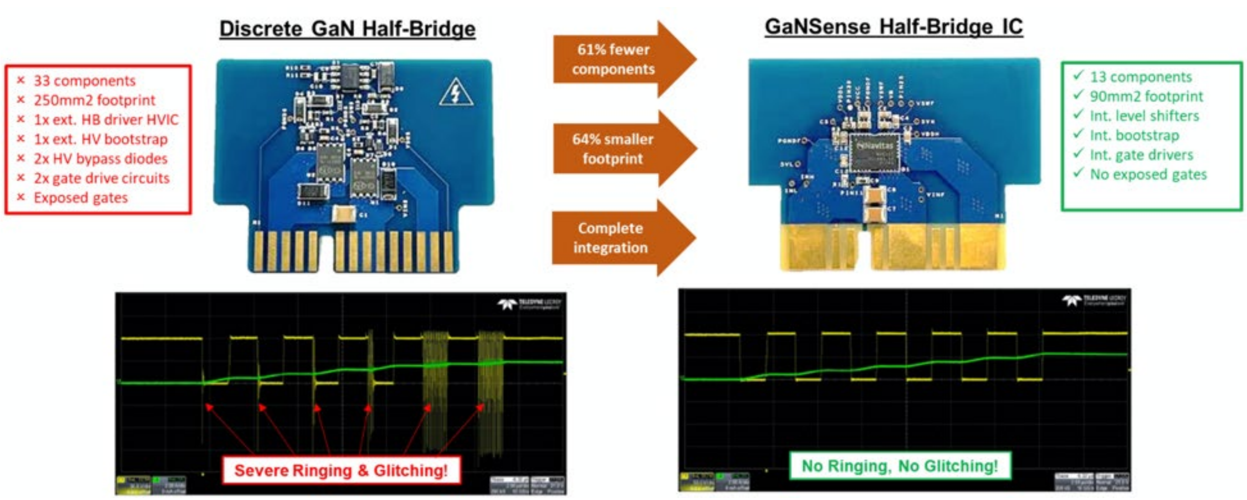
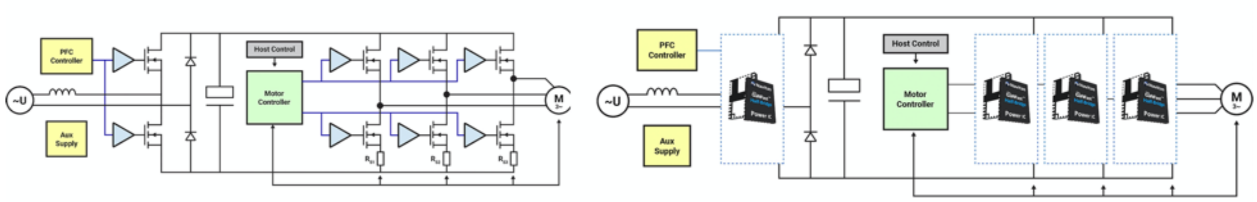


Fig 6. GaNSense half-bridge IC solution offers smallest PCB area, fewest components, with no ringing and no glitching during switching transitions

Below, is an example 140 W fast charger for a 16" laptop, using the GaNSense half-bridge IC to achieve PCBA size 60 x 60 x 25 mm (90 cc) and estimated case size 65 x 65 x 30 mm (130 cc) and power density of 1.1 W/cc[xii]. Both the TP-PFC and asymmetric half-bridge (AHB) DC-DC use NV6247 and achieves an uncased efficiency of 93.5% @ 90 V_{AC}, 140 W / 20 V - a full 1% efficiency increase or up to 15% energy savings - vs. discrete GaN solutions.

Fig.7 140W fast charger using GanSense half-bridge IC in asynchronous half-bridge (AHB) topology to achieve 93.5% efficiency at 1.1 W/cc.

Standard motor drives have a lossy current-sensing resistor in each of the lower-legs of the three-phase topology. This sense resistor is a burden to the designer in terms of energy loss, PCB space, component count, cost and reliability due to higher temperatures. With GaNSense, these three points of loss are immediately eradicated, leading to lower temperatures, more energy savings and smaller, more reliable systems. For higher-power systems, arrays of single GaNFast power ICs with high-speed digital-isolators create kW+ half-bridge building-blocks that enable EV OBCs, traction drive, large-scale air-conditioning, heat-pumps, etc.



a) Discrete 3-phase motor drive with phase-current resistors

b) GaNSense half-bridge integrated solution with integrated loss-less current sensing

Fig.8 Integrating a complete half-bridge stage with loss-less phase-current sensing and autonomous short-circuit protection allows simplest and most compact solution.

Market expansion, and acceleration:

GaN is already proven in mobile fast chargers with over 50,000,000 GaNFast power ICs shipped, zero reported GaN field-failures, and an industry-first 20-year limited warranty[xiii,xiv]. Now, GaNSense half bridges accelerate design-ins for consumer applications, motor drives, solar, data center and EV power and an estimated $14 B per year GaN market opportunity.

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