GaNSense Motor Drive ICs Integrates Performance, Protection, & Bi-Directional Sensing for Motor Drives

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Electric motors and drives are estimated to consume about 45% of the total electricity generated worldwide. That's equivalent to more than 12,000 terawatt hours (TWh) per year, or about 1,000 times the total output of China's 5 GW Xinjiang solar farm (the world's largest), which was connected to the grid in June 2024 and occupies approximately the same area as New York City.

Saving Motor Energy

Eco-design regulations that target domestic appliances, which predominantly utilize motors to turn electrical energy into labor-saving mechanical movement, can each save many kilowatt-hours. But users of these naturally seek appliances that are more effective, provide more capabilities, and help them complete tasks more quickly.

Designers are therefore challenged to create systems that can handle more power within the same or smaller footprint, while raising efficiency, and deliver a competitive and affordable product to market.

GaN in Motor Drives

Migrating designs to GaN FETs, which are already available in the market, can realize an instant boost to efficiency and power density. This approach has already proved successful in markets for USB-C chargers and power adapters, where GaN-based products have quickly become prevalent.

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GaN transistors have the lowest switching losses of any commercial power semiconductors and can save more than 50% of the losses incurred with silicon MOSFETs and IGBTs. In a motor-control module, the lower losses reduce heat dissipation and thus help simplify thermal design, allowing heatsink size to be reduced or eliminated and enabling a small controller outline. This can make the unit easier to design into a cabinet such as the electronics compartment of a washing machine and may also simplify machine building to accelerate production.

In addition, GaN FETs can operate efficiently even at high switching frequencies, which silicon devices cannot. In power supply designs, raising the switching frequency leads directly to selecting smaller external components that allow a reduced footprint and greater power density. When a motor is involved, however, there are many more issues to consider.

On the one hand, a high switching frequency is inherently suited to use with control algorithms such as sinusoidal commutation and the DC link capacitor can be smaller. The capacitance must be sufficient to provide hold-up time and handle 50 Hz/60 Hz bus ripple. In practice, selection also depends on the ambient operating temperature and the capacitor's parametric stability, surge capability, required lifetime, and cost. GaN's outstanding switching performance results in fast turn-on and turn-off transitions, which permits precise switch timing with low latency and dead time, ensuring rapid dynamic response to load changes. EMI is also reduced, allowing the use of smaller filter components.

On the other hand, high switching speeds can incur problems. Because the motor represents a highly inductive load, the fast transitions can cause ringing and reflections that can result in poor running and reliability. Considering the typical appliance motor construction, 10-20 V/ns is generally viewed as the maximum practicable switching speed for optimum electrical and mechanical performance.

Performance Comparison

Comparing two 600 W washing-machine drives using silicon and GaN technologies helps understand how GaN-based converters can be optimized to save energy in domestic appliances.

The silicon-based drive, shown in figure 1, comprises a silicon IGBT intelligent power module (IPM) and bridge rectifier, both installed under the heatsink. Assuming a switching frequency of 8 kHz, which is typical for silicon IGBTs in a design like this, an appropriate value for the DC link capacitor is 220 µF. The circuit also requires a relatively large common-mode choke of about 3 mH to handle IGBT switching noise. The thermal resistance required of the heatsink can be calculated to be about 2.4 K/W. The chosen heatsink, which can be seen in figure 2, is 128 x 39 x 25 mm and weighs 89 g.

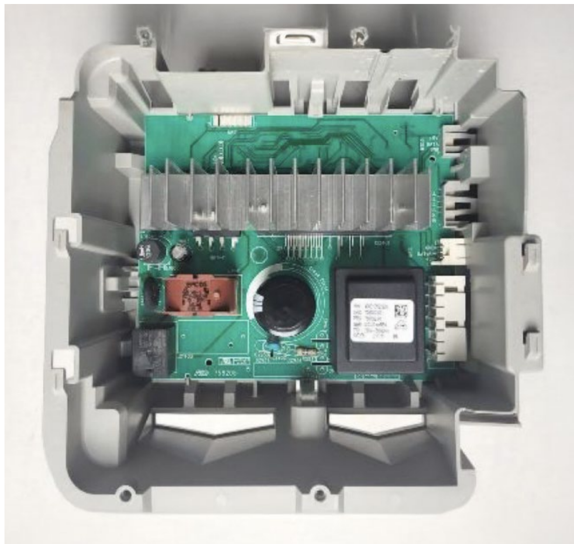

Figure 1: 600 W washing machine drive built with silicon IGBTs

Navitas' 600 W GaN-based inverter using GaNSense Motor Drive ICs (figure 2) can be built using three 10 x 8 mm QFN surface-mount half-bridge GaN ICs. With built-in gate drivers, these integrated devices ensure optimum switching and protect the sensitive GaN gate against threats such as voltage surges and ringing. System protection is also provided, contributing to lower overall component count, and the thermally enhanced QFN package with exposed source pads promotes cooling through the PCB for a heatsink-free design. With a switching frequency of 16 kHz, double that of the silicon-based design, the GaN IC's DC link capacitance is reduced to just 82 pF. The main GaN power ICs and most of the external components are surface-mount devices that are suited to high-speed, automated assembly.

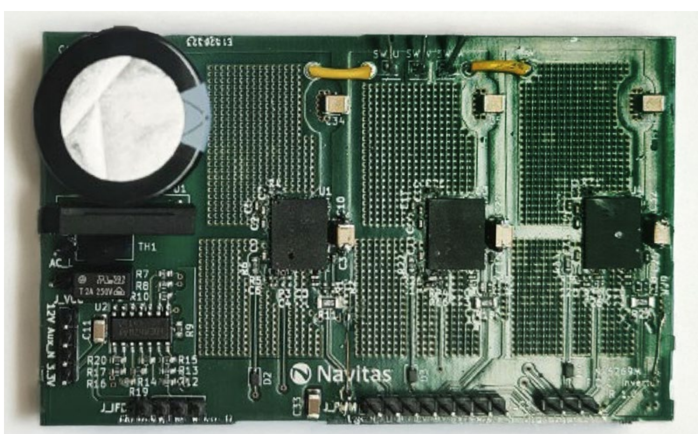

Figure 2: GaN power ICs allow a smaller DC link capacitor and heatsink-free design

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The following table compares critical characteristics of GaN- and silicon-based drives. For the same bus voltage, current, and motor power, GaN-based drives have significantly lower losses. Despite having higher thermal resistance due to the simpler, heatsink-free design, the device junction temperature is greatly reduced.

Power switch	GaN power IC				IGBT IPM			
Bus voltage	310 V				310 V			
Switching frequency	16 kHz				8 kHz			
Switching speed	10.0 V/ns				6.0 V/ns			
Load	20%	40%	60%	100%	20%	40%	60%	100%
Phase current (A rms)	0.52	1.03	1.55	2.60	0.52	1.03	1.55	2.60
Output power (W)	120	238	359	602	120	238	359	602
Switching loss (W)	0.5	0.81	1.19	2.15	20.88	20.88	20.88	20.88
Conduction loss (W)	0.11	0.43	0.98	2.76	1.87	3.82	5.94	10.59
Total losses (W)	**0.61**	**1.24**	**2.17**	**4.91**	**22.75**	**24.70**	**26.82**	**31.47**
Junction temp. (°C)	67.5	75.3	86.7	120.4	122.2	128.3	135.4	151.7

Figure 3: Performance comparison of GaN- and silicon-based drives

Optimizing GaN for Motor Control

In addition to optimizing for a slower switching speed than would be typical in a power supply or charger, high-speed short-circuit protection is a critical requirement in the GaN motor drive. In a generic motor drive, comprising a controller, an intelligent power module (IPM), with inverter and gate drivers, and sensing and filtering components, short-circuit protection typically relies on sensing the current as fed back through the noise filtering components to generate the warning signal (ITRIP) that turns off the gate driver (see figure 4). The signal latency through the noise filter, comparator and gate driver can be as long as 2μs.

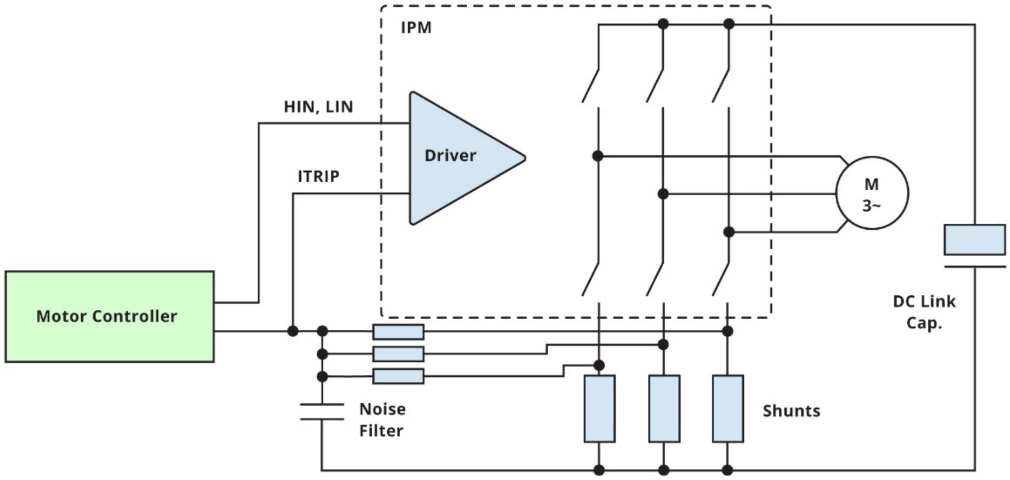

Figure 4: Generic features of the inverter-based motor drive

While an IGBT can withstand an overcurrent condition for several microseconds, GaN devices are more easily damaged and need faster-acting protection. Navitas' GaNSense™ technology in GaN half-bridge ICs implements lossless current sensing internally that generates a CS signal at a dedicated pin. This can be used to turn off the power switch within 100 ns, which is fast enough to protect the GaN devices against damage. Over-temperature protection, autonomous low-current standby mode, and an auto-standby enable input (STBYN) are also provided.

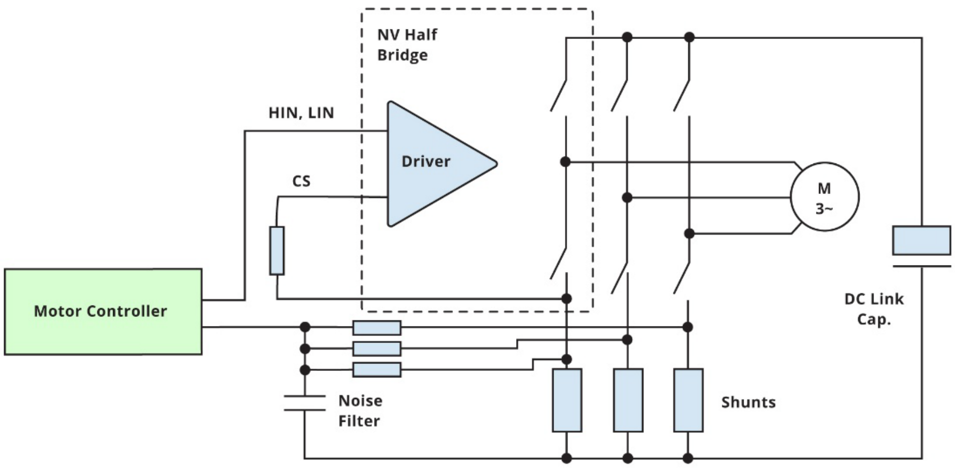

Figure 5: GaN half bridge optimized for motor control minimizes overcurrent protection latency

In motor drives, bidirectional current sensing in each phase is a critical requirement to ensure proper motor-control feedback and is typically accomplished using a shunt resistor inserted in the low side of each phase. These resistors are present in figure 4 and must be retained, as figure 5 shows, in combination with GaNSense fast-acting short-circuit protection.

GaNSense Motor Drive IC technology now provides bidirectional lossless current sensing integrated in the GaN IC. This permits the removal of the three external shunt resistors, making it possible for designers to eliminate both the power dissipation and bill-of-materials cost associated with these components. The outputs from this internal current-sensing (CS) block can all be OR'd together to support controllers that expect a single shunt or can be individually monitored for more complex control schemes.

Moreover, the internal CS function contains an amplifier that allows flexibility to use a precision external shunt resistor in applications that require high accuracy. The resistor can have a low value such that the maximum voltage across its terminals is less than 100 mV, whereas most external shunts are sized to provide 500 mV or even 1 V at the maximum expected load current. This lets designers save the majority of the loss associated with the external sensing shunt while also avoiding the BOM cost for a discrete amplifier to gain up the small shunt voltages.

Conclusion

Demands for increased power rating, higher performance, better efficiency and smaller form factors are everywhere, as legislation covering equipment such as home appliances is enacted to enforce motor drives to drive at higher efficiency and reliability.

Navitas' new GaNSense Motor Drive ICs, including bidirectional current sensing, are capable of meeting these demands in power-conversion applications

As power levels and performance requirements increase for motors, Navitas' new GaNSense Motor Drive ICs are poised to supersede silicon to enable appliance designers to simultaneously increase efficiency, power density, and reliability.