Power semiconductors the key component for motor inverters

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Introduction

Electric motors have shaped the world, and continue to do so at all levels. They range from small motors that automate simple household functions to heavy-duty motors that can, quite literally, move mountains. The number and variety of electric motors now being used is phenomenal, so perhaps it is not surprising to learn that motors and their control systems account for almost half of all the electricity consumed worldwide.

Breaking that down further, around 30% of the electricity generated globally is used for driving motors in industrial applications [1]. In absolute terms, the amount of energy consumed by the world's industrial sector is expected to double by 2040. With an increased awareness of the cost of energy and of limited resources, both in environmental and financial terms, the need for greater efficiency in the use of electricity to drive motors has become more prominent.

Low-voltage drives – demands and requirements

In the low-voltage segment of the market (standard and compact), applications can be classified as either light or heavy duty. The primary difference from the drives' point of view is that light-duty motors and controls must typically sustain an overdrive in inverter output current of 110% for short periods during acceleration such as in pump and fan applications (Figure 1). Heavy-duty motors and controls typically need to be designed to sustain an overdrive of as much as 150% of nominal inverter current. This higher overload current is attributed to the acceleration phase of conveyor belts among other things.

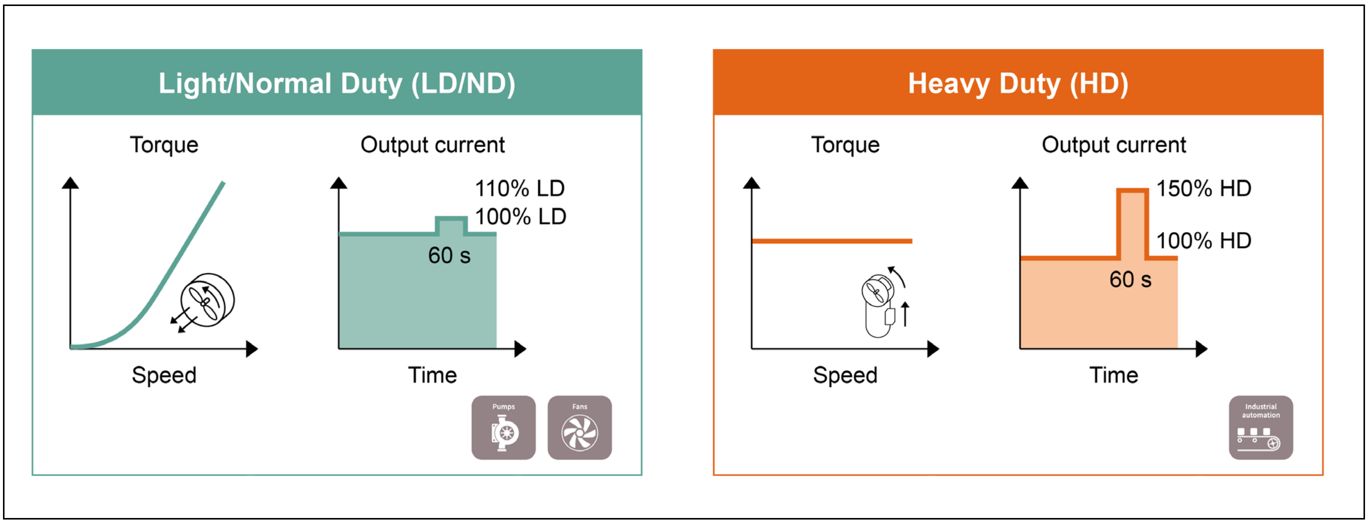

Figure 1 Overload capability defines a period of higher-than-rated current during acceleration operation of between 110% (light/normal duty) and 150% (heavy duty).

IGBT7 for drives

The unique and specific requirements of motor drive systems demand a new approach to IGBT design. With the right IGBT technology, it is possible to create modules that are better positioned to address these needs. This is the approach that Infineon has taken with its latest generation of IGBT technology, the IGBT7. At the chip level, the IGBT7 uses micro-pattern trenches (MPT), the structure of which contributes significantly to reducing forward voltage and increased conductivity in the drift zone. For applications with moderate switching frequency, such as motor drives, the IGBT7 delivers a significant reduction in losses over previous generations [2].
Another improvement offered by IGBT7 over the previous generation (IGBT4) is the freewheeling diode that has also been optimized for drive applications. Also, the forward-voltage drop of the emitter-controlled diode, EC7, is now 100 mV lower than the forward-voltage drop of the EC4 diode, with improved reverse-recovery softness.

SiC MOSFETs for servo drives

With more automation being used across industries, there is a correspondingly increased demand for servo motors. Their ability to combine precise motion control with high torque levels makes them the perfect fit for automation and robotics.

Using its manufacturing expertise and long experience, Infineon has developed a SiC trench technology that offers higher performance than the IGBT but with a comparable robustness, e.g. short-circuit time of 2 μs [3] or even 3 μs [4]. Infineon's CoolSiC™ MOSFETs also address some potential problems inherent in SiC devices, such as unwanted capacitive turn-on. Furthermore, the SiC MOSFETs are available in the industry-standard TO247-3 package, and now with even better switching performance, in the TO247-4 package. Beside these TO-packages, the SiC MOSFET is also available in Easy 1B and Easy 2B packages.

The 1200 V CoolSiC™ MOSFET offers up to 80% lower switching losses than the corresponding IGBT alternative, with the additional advantage of the losses being independent of temperature. However, as with IGBT7, the switching behavior (dv/dt) can also be controlled via the gate resistor, providing greater design flexibility.

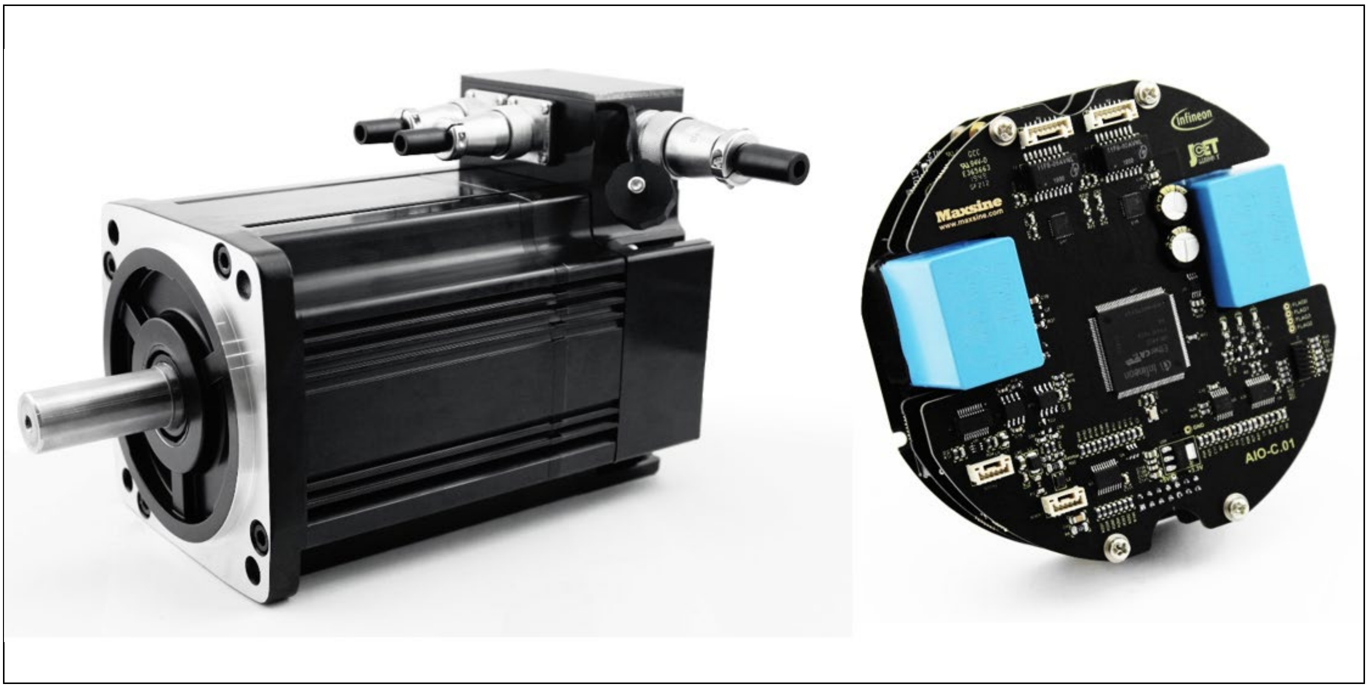

Figure 2 SiC MOSFETs simplify inverter integration in motors [5]

As a result, a drive solution using CoolSiC™ MOSFET technology can achieve as much as 50% reduction in losses (assuming similar dv/dt), based on lower recovery, turn-on, turn-off, and on-state losses. The CoolSiC™ MOSFET also has lower conduction losses than an IGBT especially under light-load conditions.

In addition to the overall higher efficiency and lower losses, the higher switching frequencies enabled by SiC technology has a direct benefit for both external and integrated servo drives in more dynamic control environments. This is possible due to the faster response of the motor current under changing motor load conditions.

Putting it all together

While integrating the rectifier, chopper and inverter into a single module delivers benefits in terms of power density and switching efficiency, motor drivers also require a closed-loop system to function correctly and efficiently.

More specifically, whatever switching technology is used, it is essential that it is accompanied by the right gate-driver solution. A gate driver is required to translate the low-voltage control signal used to turn the switching devices on and off into the high-voltage drive signals required by the switches themselves. Typically, the control signal will come from a host processor. As each switching technology has its own unique characteristics in terms of input capacitance and drive levels, matching it with the right gate driver is essential. As a developer and supplier of all power technologies currently in use, Infineon provides optimized gate drivers for its Si MOSFETs, Si IGBTs, SiC MOSFETs and GaN-HEMTs.

The final, but equally crucial, part of the control loop is the sensor that partially provides the feedback between the motor and the controller. It is common to use current sensors for this purpose. Infineon has developed a Hall-effect solution that eliminates the need for a ferromagnetic concentrator, making it simpler and less intrusive. This makes it ideal for fully integrated servo motors.

The XENSIV™ range of current sensors, such as the TLI4971, are differential Hall-current sensors that offer a high field range with a low offset value. In addition, they feature no magnetic hysteresis, and exhibit good stray field immunity. Their compact size, thanks to the coreless concept used, supports high levels of integration, while their ultra-low power loss and functional isolation make them extremely flexible and reliable.

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