ISSN: 1863-5598

ZKZ 64717
04-21

Bodo´s Power Systems®

Electronics in Motion and Conversion

April 2021

Integration meets Flexibility – SmartDriver IMD110 for Variable Speed Drives

SmartDriver Provides Highest Flexibility for Power Stages in Variable Speed Drives

The continuing trend towards more efficient energy consumption in motor drives has led to a wide offering of devices for the power stage of variable speed drives. An integrated solution like the new SmartDriver provides a highly flexible method to control and drive almost any MOSFET and IGBT.

By Ingo Skuras, Infineon Technologies

Over the last decades, the global share of electrical energy used in motor drives has not only been constant, but has actually increased. A few years ago, studies showed the portion of global electrical energy consumption to be in the range of 43% to 46%. However, the latest numbers are now indicating a value beyond 50%. [1] This trend is not only driven by prominent examples such as the electrification of private cars and commercial vehicles. In fact, the highest number of electrical motors is found in applications like small and major home appliances, and in even less obvious applications such as cooling fans and pumps in the rapidly growing data centers.

Reducing the amount of energy consumed in these drives is on the one hand becoming indispensable due to increasingly stringent regulations. On the other hand, companies are responding to higher customer awareness by focusing on ‘green’ designs, i.e., highly energy-efficient devices and appliances.

The semiconductor industry has responded to this market demand by offering a large range of power devices for each power class. Parallel to the further improvement of silicon MOSFETs and IGBTs, wide-bandgap devices like SiC MOSFETs or GaN HEMTs are becoming more popular in applications, where their performance can translate into significant advantages. Other than the power stage, the setup of the full drive inverter requires additional system components including the gate driver, the controller and the respective control algorithm. The new iMOTION™ SmartDriver family IMD110 (figure 1) integrates these three building blocks, providing a very compact yet highly flexible drive solution for a wide range of power stages.

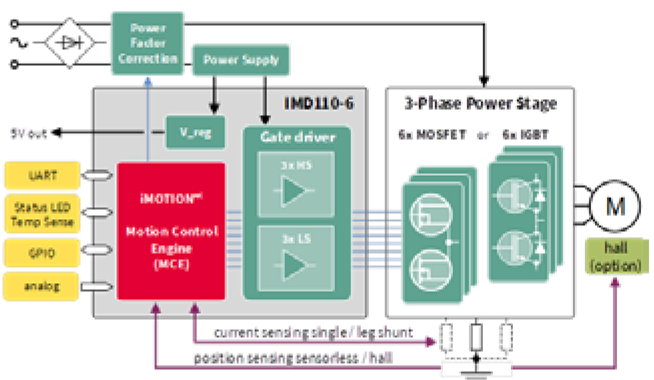

Figure 1: SmartDriver motor inverter block diagram

Application requirements define the power device choice
Over the last few years, wide-bandgap devices have received much attention, with a large number of publications providing insight into their technical advantages. These benefits, including very low switching or conduction losses and significantly higher switching speeds, demonstrate their value in applications such as electrical drive trains in cars, where they are key in achieving higher driving ranges.

But in high-volume markets, where the cost-performance ratio is key, silicon devices maintain their role as the dominating technology. New generations of high-voltage MOSFETs like the latest CoolMOS™ PFD7 family or the 650 V TRENCHSTOP™ IGBT6 and the 600 V Reverse Conducting Drive 2 (RC-D2) demonstrate that silicon technology is clearly not at the end of its life cycle, and improves significantly with each new generation (figure 2). [2], [3]

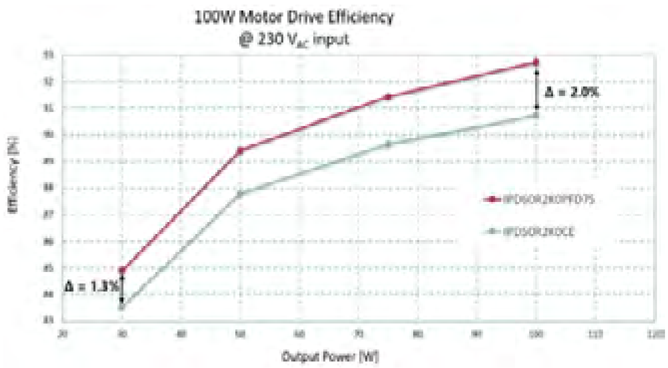

Figure 2: Latest CoolMOS™ PFD7 MOSFET allows up to 2% efficiency increase

For the customer implementing a drive inverter, or moving from a simple on-off motor to an inverter-driven system, choosing the right power device can be quite overwhelming. There is no such thing as ‘the best device’ but rather, the recommended power transistor type depends on the specific application. Let us look at two typical motor applications in the appliance market – an air-purifier fan and a cooling compressor for a refrigerator or air-conditioning unit.

Fans use high-speed motors, and thus require high-speed drive schemes. In addition, the actual phase currents are quite low, making this a target application for MOSFETs. On the other side, a compressor needs to provide significant torque at a fairly slow rotational


360°

speed, so the PWM switching rate for driving it would be low. Older cooling liquids used in compressors have a negative impact on the ozone layer. Driven by regulation, new refrigerants have been introduced that are more environmentally friendly. Since these refrigerants show a higher dielectric constant, the actual switching speed of the power stage needs to be limited. These requirements clearly favor the use of an IGBT such as the above-mentioned 650 V TRENCHSTOP™ IGBT6/ 600 V RCD2 family. Figure 3 shows an example of how the switching speed can be adjusted by varying the gate resistors.

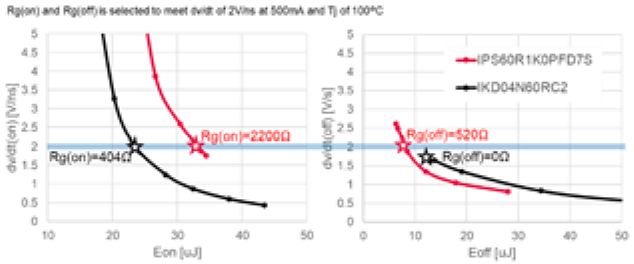

Figure 3: Optimizing EMI by varying gate resistance

Admittedly, the choice is not always as clear as in the two examples, and there might be several other factors influencing the choice of power stage implementation like cost, availability, EMI behavior, etc.

Different power devices require specific drive schemes to achieve their optimal performance. The SmartDriver allows different gate-drive schemes to be implemented and fine-tuned to reach the optimum balance between system performance and cost.

SOI gate driver with wide safe operating area (SOA)

The gate driver integrated into the IMD110 family uses Infineon's silicon-on-insulator (SOI) technology. This level-shift technology provides unique advantages, including integrated bootstrap diodes (BSD) and industry best-in-class robustness to protect against negative transient voltage spikes. Each transistor is isolated by buried silicon dioxide, which eliminates the parasitic bipolar transistors that may cause latch-up.

In a real inverter circuit, the VS voltage swing does not stop at the level of the negative DC bus but swings below the level of the negative DC bus. This undershoot voltage is called "negative VS transient." The test setup used in the system verification lab at Infineon is shown in figure 4 together with the characteristic –VS waveform.

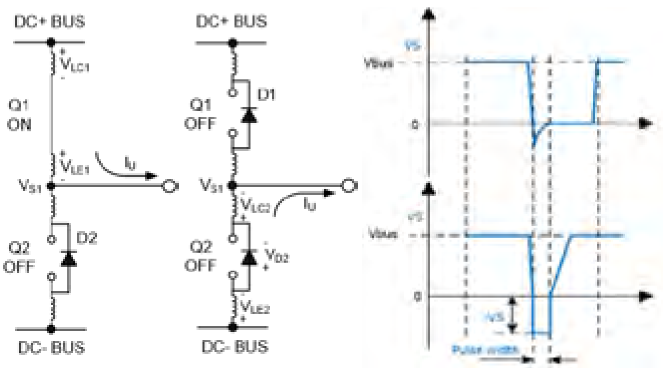

Figure 4: Negative voltage – VS transient verification

A large safe operating area is the result of the superior negative VS transient immunity of Infineon's SOI as shown in figure 5 for pulses up to -100 V for 300 ns. The common mode transient immunity (CMTI) is typically 50 V/ns.

With the integration of the bootstrap diodes for powering the high-side driver circuitry the bill-of-material cost and board complexity are reduced. The very low diode resistance of RBS ≤ 40 Ω in combination with lowest level-shift power losses minimize the device-switching power dissipation and allow driving larger IGBTs without the risk of overheating. [5]

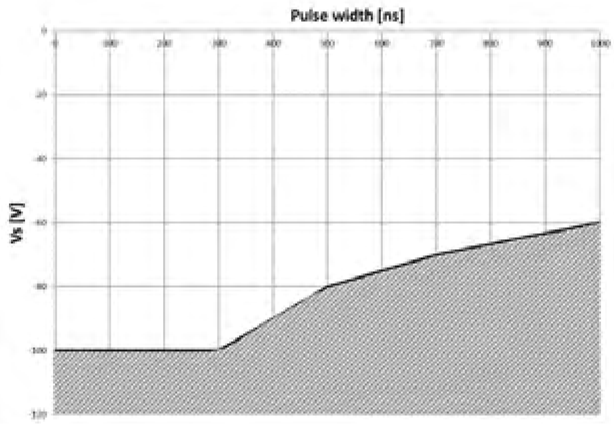

Figure 5: SOI-based gate driver negative transient safe operating area (NTSOA)

Monitoring the thermal behavior (figure 6) and reacting in case of an over-temperature occurrence is a significant advantage of the IMD110 family, where the Motion Control Engine (MCE) and gate driver are already integrated. Depending on the concrete application use case, this reaction does not necessarily need to be a full shutdown, but can also be the reduction of the switching losses, by running a special drive scheme until the temperature is back into the specified range.

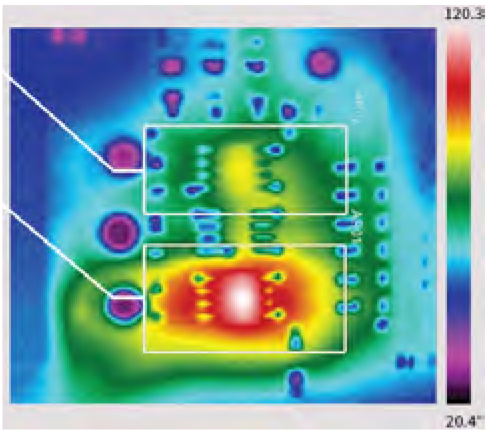

Figure 6: SOI gate driver operates at almost half the temperature of older generations

Designing a drive inverter requires the selection and PCB design of controller, gate driver and power stage as well as the respective software development. The SmartDriver family reduces this to the choice of the suitable power stage and the configuration of the Motion Control Engine for the respective motor. The very wide voltage range supported by the SmartDriver helps to cover the highest number of possible applications. The IMD110 series has a specified range of 12 to 600 V for the DC bus and can control the majority of both battery-driven as well as mains-connected variable speed drives. With the integrated voltage regulator, the SmartDriver only requires a single supply voltage, thus achieving a minimal hardware bill-of-material for lowest-cost solutions. For applications that target highest energy efficiency, the internal regulator can be disabled, and replaced with an external switched-mode supply.

Motion Control Engine (MCE) – field-proven motor control
The integrated motor controller uses the latest Motion Control Engine (MCE) that operates all current iMOTION products. Nearly 15 years after its first release, the MCE provides a field-proven, reliable and robust algorithm that is already running millions of appliances around the globe. Following the integration of former International Rectifier into Infineon Technologies AG, the iMOTION portfolio, including the MCE, has been completely updated, and multiple new products have been launched on the market.

In addition to being highly configurable, the latest implementation of the MCE uses a modular system of building blocks, linked to each other via a basic framework. The individual modules are thus easier to maintain, and new, functional building blocks that customers may request can be added to the system without interfering with the existing ones.

In the race towards ever-increasing efficiency of power devices, the MCE implements a state-of-the-art motor control with an efficient field-oriented control scheme (FOC). The power stage is driven via configurable PWM outputs based on space vector modulation. Aiming at maximum flexibility, the MCE uses single-shunt current reconstruction and sensor-free operation for the most cost-effective inverters. For more demanding applications, support for analog as well as digital Hall sensors is included, as well as leg-shunt or even phase-output current measurement. The MCE can be configured for almost any PMSM motor and power stage via parameter sets stored on the device. Configurations via parameter sets also cover the optional power factor correction (PFC). The SmartDriver can store multiple parameter sets for different drive profiles, and switch between them either autonomously or in response to an external command. In this way, a single pre-programmed device can store configurations for several different inverters, and automatically select the correct configuration, e.g. based on the sensing of states of IO pins.

The implementation of the MCE uses a balanced combination of hardware and software modules, which is specifically adapted to the application as motor controller. This clear application focus reduces the final bill of material for things like analog comparators, amplifiers or special digital filters, which have already been integrated. As a positive side effect, the use of high-performance hardware blocks leaves ample headroom in the central control block, the CPU.
The new iMOTION products utilize the available resources for the introduction of a scripting engine. Writing scripts gives customers a significant amount of flexibility beyond the actual configuration of the SmartDriver for the respective motor and/or PFC setup.

The script language uses an easy-to-understand 'C' style syntax, enabling things like the reading of sensor inputs, switching outputs, or communicating with a remote host. In addition, with access to the MCE parameters, modifying the motor behavior during run time is possible, e.g. to implement a special startup procedure. The script engine can run two parallel tasks, one having a minimum cycle time of 1 ms, and the other running every 10 ms. Scripts are executed in the script engine which runs as a background task of the MCE (figure 7), similar to a small virtual machine. Hence, the added flexibility comes without additional costs for hardware, and without interfering with the motor and PFC control algorithm.

The Motion Control Engine is under continuous improvement. Since the release of the first products from the new iMOTION portfolio, its designers have adopted modern development principles like agile software development. The use of sprint releases has made it much easier to respond to specific customer requests, and still run a cycle of several releases per year. All iMOTION software releases can be downloaded from the Infineon website, enabling customers to use the latest MCE version, or to continue using a certain revision.

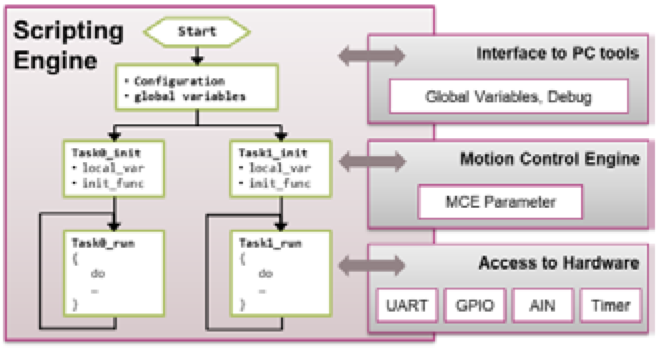

Figure 7: Script engine implementation

In modern appliances or embedded drives, the MCE is no longer limited to only 'running the motor.' Hence, the further development of the MCE targets the improvement of control algorithms as well as the support of soon-to-be released power devices. Having an in-depth and instantaneous knowledge about the status of the drive allows our customers to address their pain points at the system level, such as on-demand maintenance and support of pay-per-use models.

Protection and functional safety integrated
In terms of thermal protection, as briefly mentioned, the SmartDriver family IMD110 comes with a full set of drive protective measures to safeguard power stage and motor. The implementation is a mixture of hardware and software measures based on application requirements, effectiveness and ease of use. As an example, cross-conduction prevention or minimum dead time have to be fast, robust and act on a cycle-by-cycle basis. Accordingly, these tasks are performed in the hardware. This is also the case for a protection that is purely hardware-related and cannot rely on a running software like under-voltage lockout.
On the other side, the MCE contains protective measures that are application-specific or that need to be configurable, such as execution monitoring, rotor lock, link-break protection or temperature monitoring, as described earlier.

In today's global economy, an increasingly large number of companies are not only serving their local market but are exporting to other regions. Quite often, this corresponds with the request to meet regulations for functional safety. The most common standard for home appliances is the UL/IEC60730-1 Class B.[7] One of the main differences between iMOTION products and standard microcontrollers is that iMOTION motor control devices are per se functional building blocks. This allows the 'motor control building block' to be defined in such a way that it can be certified as a functionally safe component.

This is a clear advantage over standard microcontrollers (MCU), where the supplier offers a C library implementing the individual safety functions, but the drive manufacturer has to integrate the functions into the drive application, and then apply for certification. The available iMOTION safety certificate considerably reduces the effort of certifying the entire appliance. A customer using the iMOTION SmartDriver can rely on the hardware and software having been checked to meet the respective safety standards. Use of the safety functions is configurable, i.e. if no safety is required. The respective functions can simply be disabled, leaving more headroom for motor and PFC calculations or the integrated scripting engine.

Design support

Infineon provides a complete design platform for motor-control applications called the Modular Application Design Kit (MADK, figure 8). Using the MADK standardized platform interface, with the combination of different control and power boards, results in a system that perfectly matches the requirements of the application.

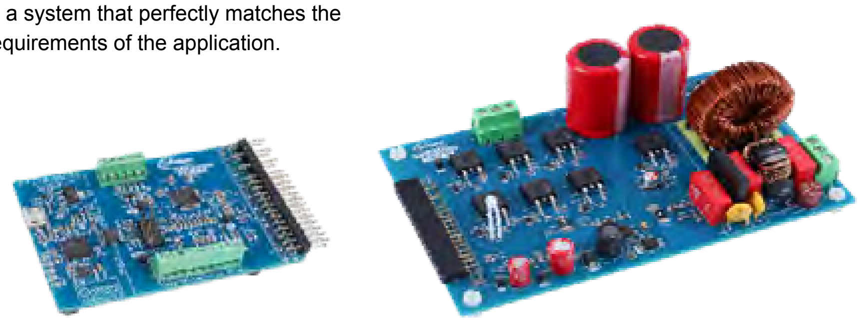

Figure 8: SmartDriver Modular Application Design Kit (MADK)

The rating of the power boards covers the full range from small motors in low-voltage applications up to a few kilowatts in applications like compressors or small industrial drives. Depending on the power rating, voltage class and typical application setup, the board uses either discrete devices or modules from the extensive Infineon portfolio.

For the SmartDriver family, two control boards are available, with and without power factor correction (PFC). Several power boards, which highlight the different discrete power stages, are already available or currently in the design phase. The power boards target high-voltage drives applying a CooMOS CFD7 MOSFET with a rating of 600 V / 600 mΩ (IPN60R600PFD7S), and using an OptiMOS 5 MOSFET rated 60 V / 3.3 mΩ (IPD033N06N) for low-voltage applications. High-power applications are addressed with an IGBT-based board that contains an active boost PFC. The IGBT is from the latest TRENCHSTOP 600 V RCD2 generation.[6]

The configuration tools for the embedded Motion Control Engine (MCE) are available for download from the Infineon website. An easy-to-use MCEWizard helps in generating the initial configuration, and the MCEDesigner connects to the running system, providing insights into the running motor drive. Oscilloscopes are used to measure and monitor both physical and calculation parameters. By modifying the respective parameters in the SmartDriver, the drive is tuned to the targeted application performance.

Infineon is currently working on the next generation of these tools. The combination of formerly separate tools into one workbench allows for a much improved user experience, and provides a seamless configuration, parameter and data handling. An integrated editor and debugger provides scripting support. The new ecosystem gives way to additional use cases with improved tuning capabilities and more customization options for experienced users.

Summary

Motors remain the largest consumers of electrical energy on a global scale. Increasing the efficiency with variable speed control has a significant impact on reducing the ecological footprint.

The SmartDriver IMD110 comes as a highly integrated solution that can drive a large variety of power devices. The family offers a wide operating voltage range and a flexible configuration. Access to the gate drive circuitry enables fine-tuning of the power-stage switching. And the combination of these features allows for the implementation of a drive inverter requiring a minimum of effort and a small bill of material.

The iMOTION product portfolio provides an easy way to implement speed-controlled motor drives. Infineon Technologies is further expanding its offerings of hardware solutions - from the controller to the inverter-in-a-package. In parallel, the ready-to-use motor control software, Motion Control Engine (MCE), ensures continuous improvements and additional features for existing as well as upcoming hardware products.

References

[1] Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems, IEA, 2011

[2] www.infineon.com/CoolMOS

[3] www.infineon.com/RCD2 Introduction to discrete 650 V TRENCHSTOP™ IGBT6 and 600 V reverse conducting IGBT

[4] RCD2 families, Infineon Technologies AG, 2020

[5] Advantages of Infineon's high-voltage gate driver ICs (HVICs) based on its silicon-on-insulator (SOI) technology, Infineon Technologies AG, 2019

[6] www.infineon.com/MADK

[7] UL listing, www.ul.com

www.infineon.com