

Smart IPM – Innovation by Integration

Christian Daniel

Infineon Technologies AG, Germany

christian.daniel@infineon.com

The Power Point Presentation will be available after the conference.

Abstract

Today's inverterized motor-control systems must fulfill a growing list of technical demands. At the same time, minimum system costs and a faster time to market should be achieved. iMOTION™ products meet this trend with a high integration of hardware and software, resulting in a simplified and fast development process and an optimized system-cost structure.

1. Constantly growing demand for new features impacts R&D budget and resources

An ever-growing demand for new features and complexity, such as added connectivity (wired or wireless), security & safety features, improved energy efficiency, and further noise reduction to name but a few, is a key challenge for every R&D organization.

Besides the technical tasks, increased pressure from competition, price erosion, and commodity markets require a constant effort to minimize system cost and time to market.

Even if requirements for motor-control subsystems are more stable, ongoing efforts to further improve cost structures or cope with new technology/regulation trends are still needed.

To cover this demand, more resources are required, resulting in higher R&D costs and lower return on investment. Either this is accepted, and the development process continues using more resources, or customers rethink their development process, and focus on their key system differentiators only.

One of the non-focused topics is more and more the inverter stage including motor and power factor control (PFC). This subsystem is either completely outsourced or the R&D effort/complexity of this subsystem is heavily reduced.

iMOTION™ Smart IPM products handle this R&D complexity reduction with a high degree of hardware integration and the integration of the main control algorithms for motor and PFC control.

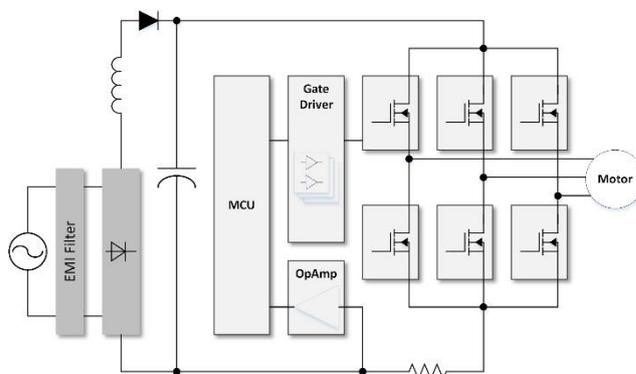


Fig. 1: Inverter block diagram showing main components

2. Hardware integration using iMOTION™ Smart IPMs

What is a Smart IPM? Smart IPMs integrate all major active components of an inverter design (one MCU, three gate drivers, the operational amplifier for current sense, and six power MOSFETs/IGBTs) into a single component.

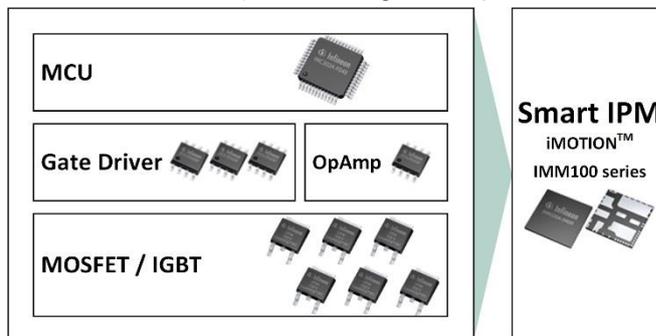


Fig. 2: Integration level of a Smart IPM

The advantages of this integration include:

Simplified selection process - As the different functions inside a Smart IPM are perfectly matched, the component selection process at the beginning of a design is simplified; hence, the common problem of checking whether selected ICs fit together is obsolete.

Savings at BOM level – The high integration minimizes external passive component count and reduces PCB area leading to ~30% overall savings on non-active components.

Smaller inverter design – Smaller PCBs allow for installations in space-limited applications, and further facilitate the integration of electronics inside motor housings.

A new generation of Smart IPM's like the IMM100 series has been explicitly designed to meet the requirements coming of the aforementioned market trends. The devices consist of three major building blocks:

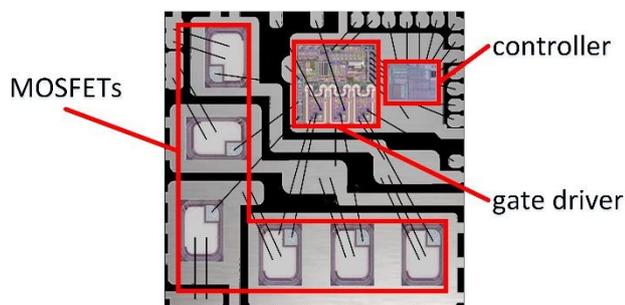


Fig. 3: IMM 100 Smart IPM bonding diagram

2.1 The controller

The controller benefits from recent developments in motor-control peripherals. The analog portion of the chip provides a state-of-the-art analog digital converter (ADC) with high accuracy and speed. This increases the precision of the control-loop calculation, and helps to reach the higher speed requirements for modern appliances.

Advanced ADC features such as dedicated reference inputs for differential measurements and switchable gain reduce the bill of material. Fast analog comparators are applied for overcurrent detection, and in combination with the ADC, provide the necessary means to meet the functional safety levels of the UL60730-1 Class B.

Special motor-control timers are able to generate various PWM patterns with both high speed and high accuracy.

For improved motor startup and low-speed operation, inputs to connect digital hall switches or low-cost, analog hall elements are available.

2.2 The gate driver

Designed for mains-powered inverters, the 3-phase gate driver supports voltages up to 600 V. The output impedance is balancing dv/dt for EMI and power switching losses. It is designed for 5-6 V/nsec at a rated current condition. The driver employs an anti-shoot-through protection, an integrated bootstrap function for high-side floating supplies, low standby power, and an undervoltage lockout protection function for VCC and high-side VBS supplies.

2.3 The power MOSFETs

The IMM100 Smart IPM is available with three different power stage options:

- 6 Ohm 500 V Trench MOSFETs
- 1.4 Ohm 650 V CoolMOS™
- 0.95 Ohm 650 V CoolMOS™

2.4 The package

The choice for adopting a PQFN 12mm x 12 mm package was based on the consideration that space savings is a key differentiator. The PQFN allows for a very compact design compared to other available power packages without sacrificing thermal performance.

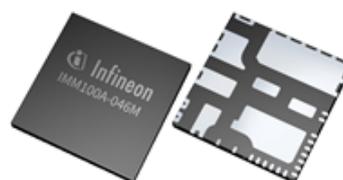


Fig. 4: IMM100 series – PQFN 12 mm x 12 mm package

This combination makes the IMM100 series ideal for fan, pump and small compressor applications in the range of 20 – 80 W.

3. Minimize R&D budget and time using algorithms integrated in iMOTION™ products

In the last few years, the proportion of software development in R&D has increased. In most cases, it even dominates development expenses.

Fig. 5 illustrates the different phases of a software development using a V-Flow model.

Minimize R&D budget and time using algorithms integrated in iMOTION™ products

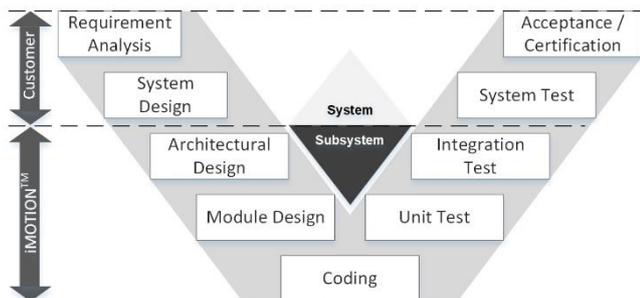


Fig. 5: V-Flow Software Development Phases

Using iMOTION™ Smart IPM's, the responsibility for the system (requirement analysis and system design phase) is covered by the customer, whereas iMOTION™ takes on responsibility for the subsystem functionality of motor and PFC.

This concept saves time and resources (12-24 men/month) without giving up system know-how or losing system-process sovereignty.

4. iMOTION™ MCE - Motion Control Engine

Corresponding to the new hardware design, the further development of the integrated motor control software, Motion Control Engine (MCE), also has to meet the changing market requirements. Seeing three-phase motors (PMSM/BLDC) being applied in more and more variable speed drives, from major to small home appliances, demands a high degree of flexibility to account for differing customer desires.

The MCE uses the field-proven, reliable and highly configurable algorithm that is already running millions of appliances in customers' homes around the world.

The MCE implementation uses a modular approach of building blocks that are linked to each other via a base framework. Which building blocks are used, and how these blocks are linked together, is configured by the customer using PC-based tools provided by iMOTION™. This flexibility allows for an easy adaption of the algorithm to dedicated motors and mechanical systems.

4.1. MOTOR & PFC algorithms

The heart of the MCE is the algorithm for sensorless field oriented control (FOC). Highest energy efficiency is achieved by using space vector Pulse Width Modulation (PWM) with sinusoidal signals. Current sensing is supported for single shunt as

well as leg shunt topologies. In addition to the standard feature set of a modern motor control implementation, the MCE offers advanced functions to support specific application requirements, e.g. a special catch spin algorithm to reliably catch and control a rotating fan, or initial angle sensing to guarantee a smooth and stable motor start.

Hall sensors can be used for applications require an exact motor position or applications need to operate at extreme low speed (<2% of the rated speed). A hybrid control mode, starting a motor using hall feedback and switch at a user-configurable speed to sensor-less operation, has been implemented.

As most of the mains-powered inverters require additional PFC functionality, the MCE includes the control engine for a standard high-frequency boost or a highly efficient totem pole PFC topology.

4.2. Scripting

The IMM100 series offers an additional degree of flexibility with the introduction of a scripting engine. This script engine runs as a background task of the MCE similar to a small virtual machine. Accordingly, additional flexibility is achieved without any additional hardware costs and without interfering with the motor and PFC control algorithm.

The script language uses an easy-to-understand 'C' style syntax, and supports things like the reading of sensor inputs, switching outputs or the communication with a remote host. In addition, with access to the MCE parameters, a modification of the motor behavior during run time is possible, e.g. to implement a special startup procedure.

4.3. Integrated functional safety and data security

The modular structure of the new MCE, combined with the clear distinction between motor control algorithm and customer functionality, allows the iMOTION™ products to be certified as functionally safe controllers according to the UL/IEC60730-1 Class B standard. The safety certificate considerably reduces customer efforts for certification of the full appliance.

The integrity of the code, parameters and script is assured via checksums, which are checked at every start.

The MCE itself is provided as an encrypted image that is decrypted on-chip. Customer scripts are

compiled into a compact byte code representation, and cannot be read-out from the chip.

Summary

- More functionality, faster time to market and lower system costs are key enablers to stay competitive in the home appliance market.
- Continuously increasing requirements demand review of R&D process flows
- Integration of hardware and software can help to reduce R&D complexity

For applications including motor control, iMOTION™ Smart IPM provides a possible answer to the most urgent issues by:

- Reducing system costs enabled via hardware integration
- Faster time to market with lower software development efforts using production-ready, pre-certified motor & PFC algorithms.