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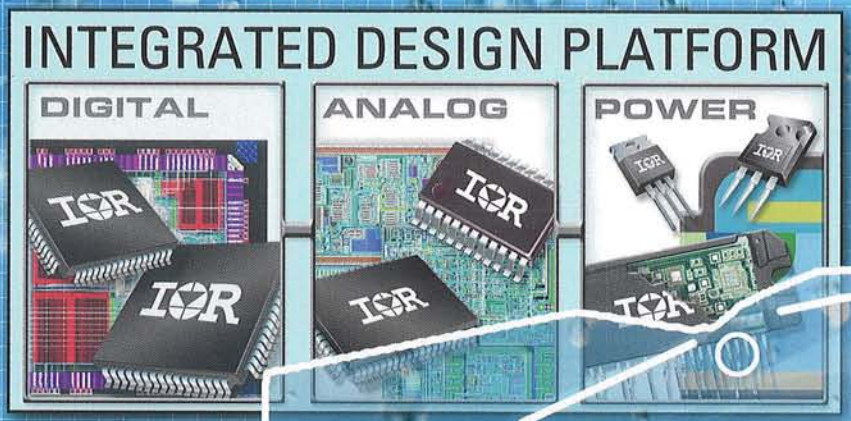

Smart, Efficient Pumping.
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Smart, Efficient Pumping

By Aengus Murray, Director of iMotion Product Management, International Rectifier

The rising cost of energy, the need to comply with environmental legislation, and the opportunity to reduce operating costs are fuelling a growing interest in energy-efficient, variable-speed "intelligent" pumps for applications such as water and waste-water management. This article explains how the latest semiconductor-based motion-control platforms are helping to simplify the delivery of intelligent, variable-speed pumping systems.

One of the key factors in the development of efficient, intelligent pumping applications is the system chosen to control the permanent-magnet synchronous motor (PMSM), on which such pumps are typically based. As well as delivering rapid response and accurate speed control for a wide range of flow requirements, the motor-drive scheme must also ensure smooth start-up and low acoustic noise throughout the pump's operating range.

PMSM control

Accurate control of a PMSM requires knowledge of both the rotor angle and the speed. The traditional method of detecting these parameters is to use external components such as Hall-Effect sensors. However, on top of requiring additional circuitry and contributing towards increased cost, such sensors can also reduce the reliability of a design when compared to a sensorless alternative - a fact that is exacerbated by the environment in which they are expected to operate. As a result, many designers are now looking towards sensorless mechanisms for the PMSM-control schemes deployed in intelligent pumping applications. While the most straightforward approach to deriving rotor angle and speed without sensors is to measure motor-winding current, the cost this technique incurs usually makes it commercially prohibitive. Fortunately, position and speed can also be calculated using indirect current measurement via the DC link. However, to achieve this designers have had either to devote significant time and effort to creating the requisite analogue circuitry and developing the necessary software algorithms, or outsource the work to third parties. Now, however, a new semiconductor platform dedicated to intelligent pumping applications offers an alternative, paving the way to the rapid and cost-effective deployment of such applications based on sensorless motor control.

Sensorless motor control

International Rectifier's iMotion integrated motor-control platform is designed to control PMSM-based variable-speed-pump applications with power requirements up to 300W. By providing a mixed-signal motor controller, a companion intelligent power module for the power stage, control-algorithm IP blocks, development software and design tools, this platform is an "off-the-shelf" approach that will significantly reduce the development time, complexity and cost of variable-speed-pump control. Furthermore, basing their applications on this platform allows designers to achieve higher performance and reliability than is possible with alternative discrete approaches: it is possible to better control system-load changes, improve control-pump operations, and provide control over a wide range of load conditions. At its heart is the IRMCF371 controller, which integrates all of the control and analogue-interface functions necessary for accurate, sensorless, sinusoidal control of PMSMs using DC-link current measurements. Sinusoidal-current control ensures quiet operation while allowing designers to maximise the efficiency benefits of a PWM-based design. In addition, the functionality provided by the control IC ensures smooth pump start-up. On the chip are a differential amplifier, dual sample and hold circuits and a 12-bit A/D converter to sample the low-voltage signal across the DC-link shunt. Motor-control functionality is provided by a patented motion-control engine (MCE), which is an algorithm editor that eliminates coding. Chip functionality is completed by an 8-bit, 8051 microcontroller operating independently from the MCE. This device executes the application-layer software, releasing system resources from handling interrupts or internal registers.

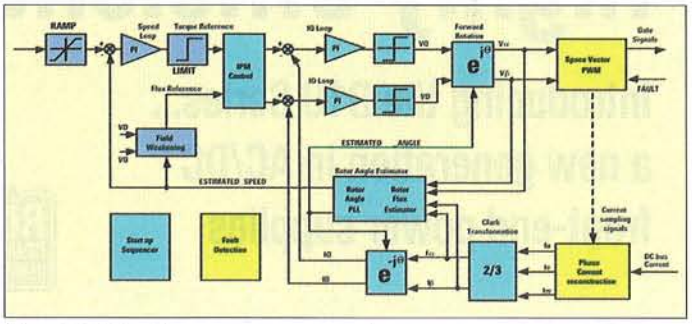

Figure 1: Full intelligent-pump motor-control system.

Motor-control soft IP

A library of motor-control-function blocks is available as selectable soft IP, and you program the MCE via a graphical compiler tool (integrated into the MatLab/Simulink development environment). This approach helps reduce design errors and allows delivery of optimised control applications with extremely quick design cycles. Developers select key functions from the available MCE control elements - including proportional plus integral, vector rotator, angle estimator, multiply/divide, low-loss low-EMI space-vector PWM and single-shunt IFB - and then use the compiler to link them together as appropriate. Sequencing, user-interface, host-communication and upper-layer control tasks can be implemented in the microcontroller, which is equipped with a JTAG port for emulation and debugging. The MCE is configurable to meet individual motor-control requirements. For example, one additional function implements reluctance-torque control for an interior permanent-magnet motor (IPM). Reluctance torque is a torque component resulting from the IPM's construction and is not present in surface permanent-magnet motors (SPMs). IPM control allows the designer to maximise the IPM's torque output by adjusting the phase advance. A designer simply excludes the block for designs that do not use IPMs. A full intelligent-pump motor-control system can be implemented by combining the IC with IR's IRAMS06UP60B intelligent power module (Figure 1). This module comprises a three-phase inverter and driver to provide the power stage in a compact SIP1 package. The power stage provides shut-down- and over-current-protection features to ensure safe operation under fault conditions. The module also includes the requisite shunt resistors, minimising the need for external components.

Sample algorithm

A sample-algorithm implementation demonstrates the operation of the function-block arrangements of the motor-control IC. The MCE converts the three rotor-current values from the DC-link measurements into equivalent two-phase values using a Clarke-transform function. The rotor flux estimator then derives the flux functions using the two-phase circuit equations and the voltage values that result from the forward vector-rotation function ($e^{j\theta}$). The rotor phase PLL then ensures accurate estimates for rotor angle and speed. The field-oriented control (FOC) blocks decouple the transforms of the AC motor-winding currents into two DC components representing torque (IQ) and flux (ID). This simplifies the controller as current-loop tuning no longer depends on rotor speed. The speed loop then becomes an outer loop, calculating the torque-reference command for the IQ loop from the speed error. The RAMP function maintains motor acceleration within specified limits, and the LIMIT function prevents the motor current from exceeding the manufacturer's recommended maximum.

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