

Extending Efficiency

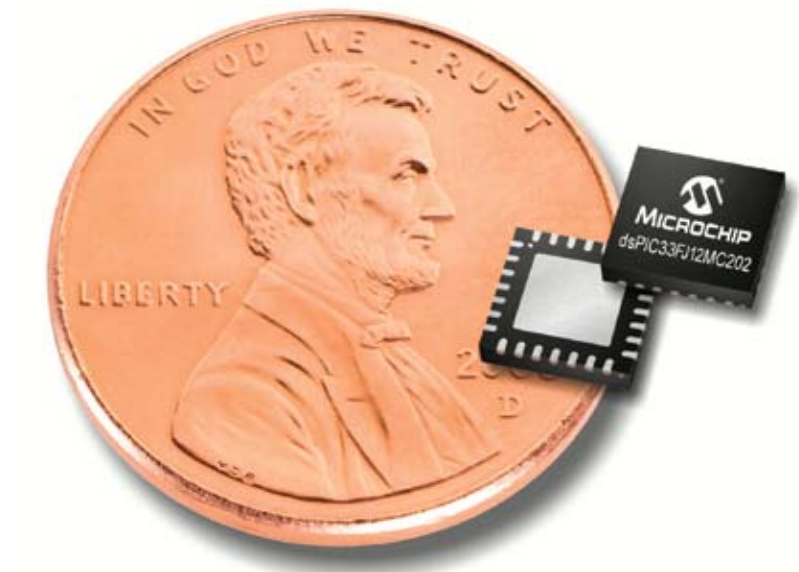
Advanced control methods more accessible to wider range of appliances.

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Advanced motor-control techniques are a practical necessity because they enable more efficient and quieter appliances. In the past, these advanced control techniques were only available as proprietary solutions, and hence were limited in scope to a few high-end appliances. Given the drive toward efficient appliances running on “green” power, which is mandated by regulations and customer preferences, these motor-control algorithms are now being sought by designers of all classes of appliances. Thanks to the new generation of digital-signal-controllers (DSCs), the cost-effective implementation of advanced motor-control algorithms has become a reality.

From the slew of advanced motor-control techniques available today, the Field-Oriented Control (FOC) algorithm has solid claims on being the leading technique for helping to save energy and building quieter appliances. DSC-based FOC control over a Permanent-Magnet Synchronous Motor (PMSM) will serve as an example. Sensor-less FOC control has advantages over the sensor-based version, because it overcomes impediments in some applications that cannot afford to deploy position or speed sensors. In certain compressor applications, for example, the motor is flooded in oil, making wire-harness placements difficult.

Today’s motor-control solutions rely on costly custom ASICs to implement a FOC algorithm. Further compounding the difficulty is the fact that these ASIC-based FOC algorithms and related



A Microchip dsPIC digital signal controller.

libraries are inflexible — users cannot tailor the FOC algorithm based on the application requirements. Additionally, delivering green power to the appliance requires the addition of a Power Factor Correction (PFC)

circuit. Existing appliance power stages are also dependent on costly custom ASICs to implement the PFC block.

Versatile DSCs are suitable for implementing advanced motor-

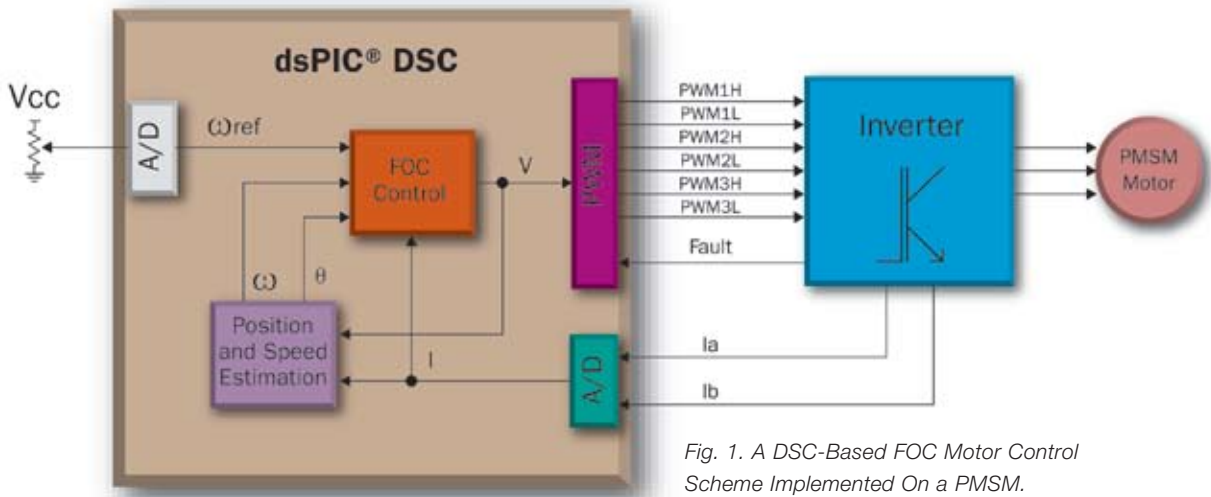


Fig. 1. A DSC-Based FOC Motor Control Scheme Implemented On a PMSM.

control algorithms such as FOC, and also double as system controllers in appliances. This is because DSCs feature peripherals tailored for motor control, such as Pulse Width Modulators (PWMs), Analog-to-Digital Converters (ADCs) and quadrature-encoder interfaces. When executing controller routines and implementing digital filters, DSCs help designers optimize code execution by being able to execute the MAC instructions and fractional operations in a single cycle.

The system-controller aspect of appliance design can be comfortably handled through DSCs. General-purpose I/O lines on the DSC can be used to interface switches and displays. Serial ports on the DSC can also be used for system calibration and diagnosing system faults. The dsPIC DSCs from Microchip Technology also provide fault and

diagnostics interfaces that include input lines, with the ability to shut down the PWMs in case of catastrophic faults in the system.

In particular, Microchip's dsPIC33FJ12MC202 DSC is a good fit for applications requiring PFC control with 3-phase load control, such as appliances using PMSM motors or ACIM motors. The dsPIC DSC's fast and flexible ADC supports current sensing and offers useful triggering options. The dsPIC33FJ12MC202 features four PWM generators, where three of these PWM generators work on one time base and the fourth on an independent time base. This is extremely handy in applications that require different frequencies for PFC and 3-phase load control. Additionally, these highly capable DSCs come in compact 6 x 6 mm QFN package sizes — enabling designers to put DSCs on compact motor-control boards for placement inside motor housings.

Current sensing is a crucial function in motor control, and it requires fast and flexible on-chip ADCs. The dsPIC DSC family features ADCs that are capable of converting input samples at a 1 Msps rate, and capturing up to four inputs simultaneously. Multiple trigger options on the ADCs enable the use of inexpensive current-sense resistors, to measure motor phase-winding currents. Using PWM modules, it is possible to trigger A/D conversions — which results in an inexpensive current-sensing circuit — by sensing inputs at specific times where switching transistors allow current to flow through the sense resistors.

PMSM example

Given their motor-control specific peripherals, DSCs can be deployed in appliances with variable-speed motor drives. In these applications, DSC-based

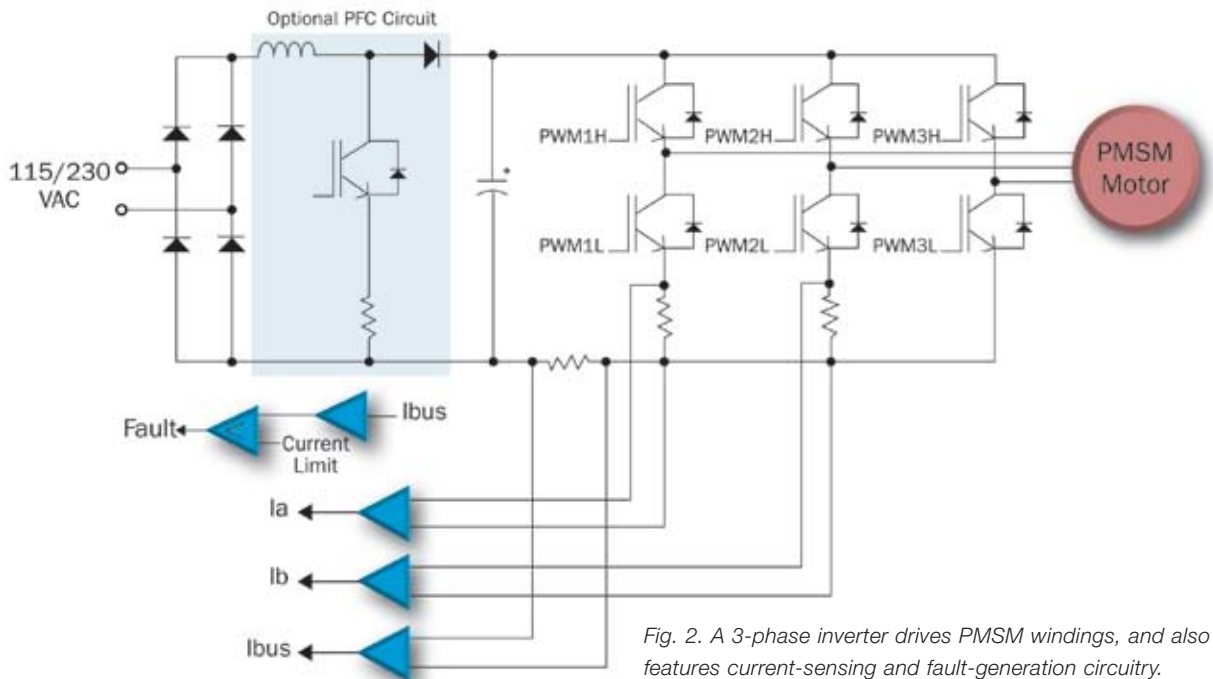


Fig. 2. A 3-phase inverter drives PMSM windings, and also features current-sensing and fault-generation circuitry.

FOC control makes practical and economic sense, because modifying the hardware for implementing motor control is minimal. These appliances feature a three-phase inverter, which is used as the power stage to drive the motor windings. By adding a DSC (see Fig. 1) and current-sensing circuitry (see Fig. 2) through the help of two low-cost resistors, software on the DSC improves the motor efficiency through FOC control. The sensorless control technique implements the FOC algorithm by estimating the position of the motor without using position sensors (as shown in Fig. 1). The FOC algorithm — which is executed at the same rate as the PWM — is configured by ensuring that the PWM triggers ADC conversions for the

two windings, using two shunt resistors. Then, a potentiometer is used to set the reference speed of the motor. The ADC Interrupts are enabled, to execute the algorithm.

The position estimator (see Fig. 1) is based on the currents and voltages of the motor, and uses a motor model to measure the motor position indirectly, via an observer. The motor position can be estimated by assuming that the PMSM model is the same as that of a DC motor. A current-observer model aids in the measurement of the back EMF, indirectly, by feeding the motor and its model with the same input. Since the motor model has a closed-loop observer, it works to ensure that the estimated value matches the measured value.

FOC is accomplished by keeping the stator magnetic field ninety degrees ahead of the rotor, at all times. This requires constant rotor-position information. In FOC, designers need to deploy a different algorithm to detect or estimate rotor position. FOC results in better torque production and less torque-ripple generation by the motor.

Using the 3-phase voltage, the FOC algorithm generates a vector to control the 3-phase stator current. Converting the physical current into a rotational vector using transforms makes the torque and flux components time-invariant. This time invariance enables control with conventional Proportional and Integral (PI) controllers, as with a DC motor.

Using the FOC technique, the motor currents are transformed to 2-axis vectors, as seen in a DC motor. The FOC process begins by measuring the three-phase motor currents. In practice, since the instantaneous sum of the three current values will be zero, by measuring only two of the three currents, the value of the third can be determined. Also, the hardware cost is reduced, because only two current sensors are required.

This FOC technique will work with asynchronous motors, as well. A synchronous motor differs from an asynchronous motor in the relationship between the mechanical speed and the electrical speed. In a synchronous motor, the supplied voltages have the same frequency as the mechanical motor speed. In an asynchronous motor, the final mechanical speed is different from the input frequency, and the relationship between input frequency and mechanical speed varies, depending on the mechanical load applied to the motor.

A major advantage of deploying DSCs in motor control is the practicality of a common design platform, which makes the production of appliances more efficient. Even with different varieties of motors, such as PMSM and ACIM, appliance makers can use the same motor-control board and only need to change the software on the DSC. Therefore, a single design platform can handle multiple types of motors, and appliance makers

only need to develop different motor-control IP to handle many varieties of motors. As a result, appliance makers now have an economical way to offer a range of appliance models that use PMSMs, or other motor types, with sensor-less FOC algorithm control.

Firmware IP protection is a major issue for manufacturers who frequently deploy appliance design teams that collaborate across many geographic regions. It is easy to imagine a scenario where multiple design teams based in different locations could work in tandem to implement FOC firmware, develop the appliance front panel, and get the final system integration done.

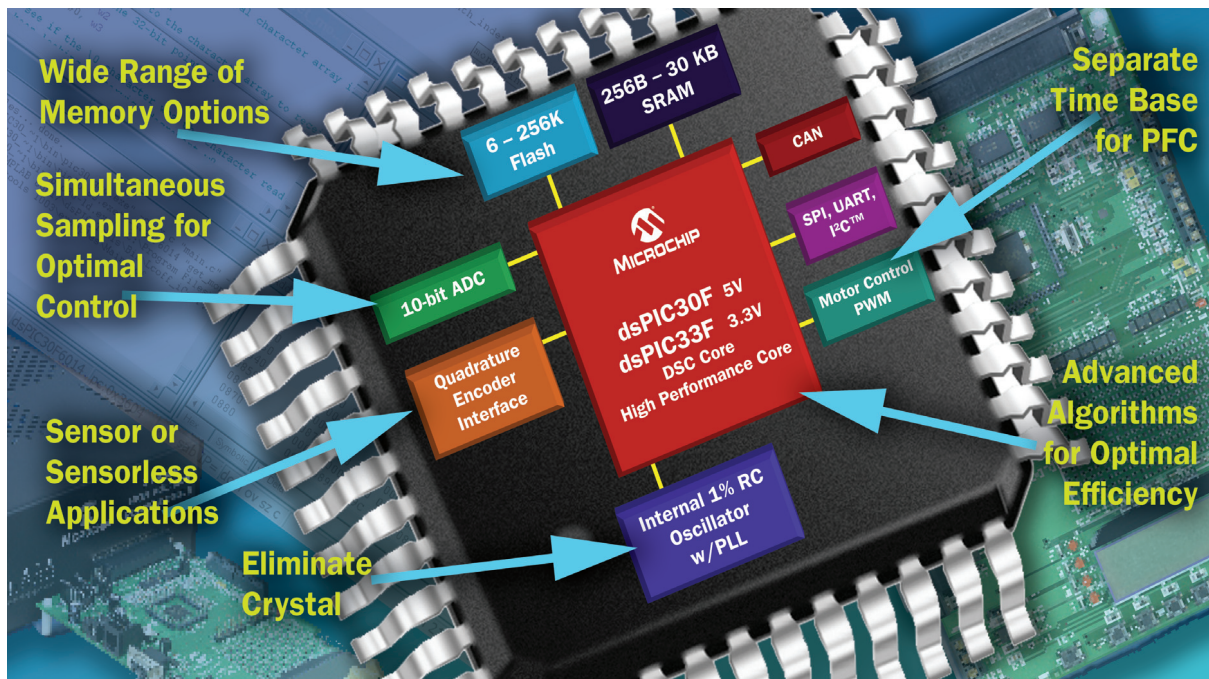
While developing their firmware and designs, these teams will have claims to their own IP. Microchip's dsPIC DSC family offers the CodeGuard security feature, which helps to protect IP in collaborative design environments by securing IP segments separately. CodeGuard security enables multiregional IP development, where each team develops its IP, and locks out that portion of DSC memory. In another example, when motor manufacturers sell motor-control algorithms to appliance manufacturers; using CodeGuard security, these drivers can be housed in a protected section on the DSC memory.

In a clear departure from existing motor-control solutions that rely on costly custom ASICs to implement FOC and the PFC

block, appliance makers now have a better choice. To enhance the efficiency of appliances and reduce their audible noise, controllers such as Microchip's dsPIC DSCs can be deployed. These DSCs make it easy for appliance makers to efficiently and economically implement advanced algorithms such as FOC, on a wider range of appliances than ever before. Microchip provides a free FOC algorithm, with full source code.

For more information, email: appliance@microchip.com

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