

# Get Rolling with Efficient Motor-Control Designs

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*Design of efficient motor controllers requires attention to more than hardware and software design.*



To find out more about the state of motor-control design in embedded systems, I recently talked with three engineers at Texas Instruments who work with motor-related hardware and software.

"Motor control looks simple to start but it covers many disciplines so it's almost impossible to have one designer do everything," noted Miroslav Oljaca, a high-performance linear systems application engineer at Texas Instruments. "You need a team of engineers who know about power electronics, motors, EMI and RF problems, control loops, how to use ADCs properly, and so on."

Motor-control projects also require that designers know about a motor's application. "When you work with pumps, for example, you must consider how changes in liquid temperature, bearing behavior, and cavitation conditions can affect the driving motor's operations," explained Jonathan Guy, Stellaris MCU software and systems design manager at TI. "Your mechanical people might not tell you about those extreme conditions unless you ask."

### **Not All Motors Created Equal**

Other problems can arise, too. "Engineers often assume production motors will have the same characteristics as the prototypes a manufacturer gives them," said Guy. "But manufacturers often build prototypes on a special assembly line or by hand, so things can change as they go to high-volume production. You must take a close look at the first motors off the production line and adjust your design for any changes."

"The more successful companies have a close relationship with their motor suppliers and they work together on motor designs and quality control," noted Chris Clearman, TI's C2000 MCU marketing manager. "Some companies design motor-control systems and the motors so they have control over all aspects of a project."

"Sometimes, the engineers who design motor controls must face a large variation not only between prototype motors and production motors, but also among motors coming off a production line," said Oljaca. "The standard deviation on parameters

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like inductance or resistance is huge. Most electrical engineers would find it hard to believe a seven-, 10-, or 15-percent change in inductance from motor to motor, but that's acceptable to some manufacturers. In low-cost motors you see the biggest variations, so a motor-control design should be robust enough to accept these variances."

Oljaca explained that in some cases, high-speed production machines will not produce the same number of windings, so one motor might have, say, 153 windings and the next, 172. "Imperfections in the wire can cause its inductance and resistance to change," said Oljaca. "Changes in physical dimensions also can cause variations in magnetic-material characteristics. Many of those variables in AC induction motors are out of the circuit-designers' control."

### **DSPs and MCUs Offer Intelligent Motor Control**

"As a result, engineers use a digital signal processor [DSP] or a microcontroller [MCU] to create an intelligent drive that will pre-tune itself," said Oljaca. "The software measures initial motor parameters and uses them to adjust for the best motor performance. So instead of placing a winding's resistance value in firmware, the MCU measures it."

According to Clearman, in advanced drive systems, engineers choose a processor "platform" and add proprietary code to perform diagnostics, self-tuning, self startup and other tasks so a controller can work with different motors. "As motors age and their characteristics change, the controllers can adapt," said Clearman. "And the end product still performs to the system specifications."



**Fig 1. The High Voltage PFC and Motor Control Developer's Kit from Texas Instruments includes a power factor correction stage under AC-induction, brushless-DC, and permanent-magnet synchronous motors.**

To help engineers get a head start, Texas Instruments provides development kits and software aimed specifically at motor control. In January 2010, the company announced the High Voltage Motor Control and PFC Developer's Kit that works with the new controlSUITE software. The software in the kit includes full source code and documentation for closed-loop digital power-factor correction as well as complete example systems to control brushless-DC, AC-induction, or permanent magnet synchronous motors. TI offers controlSUITE at no cost. The hardware kit, TMDSHVMTRPFCKIT (\$US 599), uses a C2000 Piccolo MCU and can provide up to 750W of power to the motor-drive stage.

"These open reference designs, which engineers can copy or adapt, offer a quick start, show developers how to properly use the base algorithms, but then let them focus their efforts on adding their own value," said Guy. "The software includes a dashboard-style interface that gives them insight into what's going on. Often, engineers continue to use that interface to monitor operations even as they modify the code for their applications. And when they get a new batch of motors or move to production, they can see whether operations function as they should."

### **Build Software in Increments**

"The TI software offers an 'incremental build,' so developers can use some preset values to first get the pulse-width modulators operating with the proper pattern and at the proper switching frequency," explained Clearman. "Next, developers quickly add the feedback software to prove the ADCs sample correctly and that the controller properly captures any position information. You follow this process step by step so you verify each 'piece' of a system rather than jump into a complete

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reference design and its code and try to figure out how they work and how to adapt them to your needs."

"I want to emphasize that engineers want a proven reference design," said Clearman. "It must include well-designed signal-conditioning and protection circuits so they can focus on their own system level development."

### Don't Let 'Gotchas' Get to a Design

But even with helpful software and hardware tools and support, engineers can run into unanticipated problems.

Often, engineers must add variable-speed high-efficiency controls to older or low-tech products yet maintain much of the existing core technology. But the normal low-voltage insulation used in AC inductive motors does not respond well to the large  $dV/dt$  pulses delivered by high-frequency switching circuits, and motor insulation can fail. "A motor that worked well without a controller might have problems, so you should always look for a motor rated for 'inverter duty,'" said Guy. In some cases, companies wind motors with wire that has special pulse- or spike-resistant insulation.

The high-frequency switching also can cause a build up of electrostatic charges in the rotor that can arc over and damage the electronics or even the ball bearings. "The lubricant in the bearings provides partial insulation between the rotor and the stationary motor parts," said Guy. "So charges can build and reach a voltage high enough to arc over and damage the bearings, which affects motor performance and shortens its life."

Mechanical engineers can include shaft-grounding rings or similar components in a design to reduce or eliminate the effects of ESD events and shaft currents.

The bearing current problem is considered as the most significant remaining reliability issue for inverter driven motors that needs to be solved to achieve vibration and noise control and eliminate premature motor failure. Bearing protection technologies and their respective advantages and disadvantages should be considered to ensure the goals of reliability, long service life, and maintenance free operation are met when designing systems that use variable frequency drives to control AC induction motors. (Ref. 1)

Ten to fifteen years ago, engineers used thyristors or bipolar transistor to control motors. "Now we use MOSFETs and IGBTs, which decrease switching power dissipation," noted Oljaca. "But you pay a price for faster switching that creates higher-energy spikes related to  $dI/dt$  and  $dV/dt$ . Those spikes can damage motors, cause EMI, affect signal measurements, cause signal-conditioning problems, and so on."

"Always remember the thermal aspect of motor-controller design," cautioned Oljaca. "Motor-drive or controller circuits use many capacitors, especially in input-filter and switching stages. But engineers often underestimate how much high temperatures can influence capacitance and decrease the life of components and a

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system. That's the biggest mistake engineers make at the schematic stage--improper choice of capacitor values and characteristics."

### Reference

1. Oh, H. William and Adam Willwerth, "Shaft Grounding--A Solution to Motor Bearing Currents," ASHRAE Transactions Vol. 114, Part 2, 2008. [www.est-aegis.com/ASHRAE\\_Paper-Shaft%20Grounding-A\\_Solution\\_To\\_Motor\\_Bearing\\_Currents.pdf](http://www.est-aegis.com/ASHRAE_Paper-Shaft%20Grounding-A_Solution_To_Motor_Bearing_Currents.pdf)

### For further reading:

High Voltage PFC and Motor Control Developer's Kit:

[www.ti.com/cs\\_hvmckit-tf-pr](http://www.ti.com/cs_hvmckit-tf-pr) [1]

Coyle, Timothy, "Power Quality Part 3 Vfd/Motor Interaction," Engineered Systems, Oct, 2000. [http://findarticles.com/p/articles/mi\\_m0BPR/is\\_10\\_17/ai\\_66216307/](http://findarticles.com/p/articles/mi_m0BPR/is_10_17/ai_66216307/) [2]

"Thermal Management of Electrolytic Capacitors,"

[www.aavidthermalloy.com/technical/papers/capacitor.shtml](http://www.aavidthermalloy.com/technical/papers/capacitor.shtml) [3].

"Variable Frequency Drives--Energy Efficiency Reference Guide,"

<http://oee.nrcan.gc.ca/industrial/equipment/vfd-ref/page-04.cfm> [4]

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[1] [http://www.ti.com/cs\\_hvmckit-tf-pr](http://www.ti.com/cs_hvmckit-tf-pr)

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[3] <http://www.aavidthermalloy.com/technical/papers/capacitor.shtml>

[4] <http://oee.nrcan.gc.ca/industrial/equipment/vfd-ref/page-04.cfm>