Single Chip DSP Motor Control Systems
Catching on in Home Appliances
(Reprinted from Appliance magazine, October 2000)

By David Krakauer, Strategic Marketing Manager for Embedded Control Systems, Analog Devices, Inc.

Introduction

Embedded DSP motor control is revolutionizing the appliance industry, not only by delivering the highest levels of motor performance, but also by the method employed to deliver that high performance. The computing power of a DSP allows users to exploit software modeling to implement closed-loop motor control creating a shift from hardware to software that yields significant advantages for motor and appliance manufacturers, ultimately changing their relationship.

The latest generation of embedded DSP motor control ICs enables advanced control algorithms that, in turn, enable appliance manufacturers to reduce development times, costs and risks while, at the same time, enhance the efficiency, functionality, noise-reduction and performance of their products. While many processor options exist for electronic motor control, the DSP has long been acknowledged to be the best suited for motor control because of its strength in processing real world signals. Today, many appliance OEMs and motor manufacturers are rapidly adopting cost-effective DSPs as the motor control technology of choice.

Simple, Quick and Cost Effective

Appliance OEMs have discovered that today’s generation of motor control DSPs are as easy to use and as inexpensive as conventional microcontrollers (MCUs), and
they have been able to take full advantage of the DSP power to implement more advanced control algorithms. This significantly reduces system costs by modeling hardware functions in software. By eliminating hardware and focusing on software, appliance OEMs can modify and enhance their motor controls faster than ever and also create a platform of motor control solutions across an entire portfolio of white goods including refrigerators, washing machines and air conditioners.

Emerson Electric Corporation is using ADI’s DashDSP family to deliver a common platform for a large segment of their variable speed motor control products. According to Eric Wildi, Vice President of Technology at Emerson, “This commonality enables us to significantly leverage developed code and apply it in totally different applications and/or motor technology. This aspect, coupled with the flash reprogrammability, a user friendly environment, and ADI’s development tools, is accelerating our time to market and reducing our engineering expenses dramatically. We expect that modifications to existing motor controllers based on DashDSP will take a matter of days compared to weeks, if not months.”

Looking forward, the next generation of embedded DSPs will be capable of more than just motor control. This next generation of DSPs will take over more control of the entire system and will allow appliance OEMs to monitor the health of the motor and the entire appliance over a network and then schedule maintenance before breakdowns occur. The analog and digital power of the next generation will also enable wireless communications for home networking and voice recognition for improved user interfaces.
From Hardware to Software

Consumer demand is the primary force that is driving appliance OEMs to use electronic motor control. Electronic motor control allows variable speed operation that, in turn, delivers quieter operation, greater efficiency, and better overall performance to consumers. For example, a refrigerator with a variable speed compressor will use 30% less energy than one with a fixed speed compressor because the compressor operates only at the required cooling power. Another benefit is that temperatures remain more consistent so food stays fresher for longer because of less temperature cycling. In a washing machine, high spin speeds extract more water so a clothes dryer consumes less energy and finishes the laundry more quickly.

While the end consumer benefits from digital motor control, OEMs also benefit from DSP-based digital motor control because the DSP is powerful enough to allow software to model hardware. This modeling approach, accomplished through the development and implementation of advanced control algorithms, is the optimal way for OEMs to meet consumer needs.

Motor Speed

Software algorithms can significantly improve motor speeds without the use of sensors and resolvers. The faster the rotor estimation and feedback to drive the motor windings, the faster, and more accurately, the speed can be controlled. Although sensors and resolvers can be used to directly measure rotor position, these components increase cost, manufacturing complexity and decreases overall quality and reliability. The combination of high performance DSPs and analog systems allows for
the use of sensorless control software algorithms that obviate the need for such sensors without compromising performance.

**New Motor Types**

The ability to model motors in software also allows for the use of a wider variety of motor types, including AC Induction Motors (ACIM), Brushless DC Motors (BLDC) and Switched Reluctance Motors (SR). Whereas some inexpensive motors cannot be used in appliance applications because of the difficulty to precisely control them, DSPs have the capability to perform the necessary level of control. Consider, for example, the SR motor. The SR motor’s low manufacturing cost, high reliability and excellent torque characteristics have led people to speculate that it would rise to the forefront of motor types used in appliances.

However, the adoption of SR motors has been slow because these motors are difficult to control because the motor windings must be excited in the correct sequence, necessitating a high resolution of rotor position information. In addition, SR motors are highly non-linear resulting in high torque ripple and acoustic noise. A DSP-based solution solves both of these problems in software without adding cost to the system. The DSP’s fast computational power combined with a precision analog front-end to capture motor currents can not only derive the high resolution of the rotor position information required to run the motor at high speeds, but it can also be used to correct for the torque non-linearity. Until recently, SR motor control has required either the use of sensors or custom designed ASICs that increase system costs and limit the use of SR motors to high end, high price appliances. With embedded DSP motor controllers,
appliance manufacturers can now use SR motors throughout their entire appliance product portfolio.

**Benefits for Manufacturing and Supply Chains**

The change in focus from hardware to software is also changing the way appliance manufacturers work with motors. The most significant impact is due to the fact that the DSP allows for the simplification of complex motor and application modeling in software. A single model can be used for motors from different manufacturers so appliance OEMs can easily second source motors while using just one control board. Soon, software algorithms will be available that offer “adaptive tuning.” This technique allows a controller to tune itself at start-up to any motor so motors can be changed at any time during the lifetime of an appliance.

The high bandwidth of a DSP can also be used to model circuit elements in software. This reduces the total number of components used, thereby decreasing costs and simplifying manufacturing. Modeling circuit elements in software also has the beneficial effect of reducing manufacturing variability. In a similar manner, the closed-loop nature of embedded DSP motor control also makes the appliance less sensitive to manufacturing variability in the motor. In these cases, appliance manufacturers are able to deliver more consistent performance to customers at lower costs.

**Time-to-Market**

The ultimate benefit of this new method of controlling motors is that appliance OEMs can use a family of DSPs and algorithms across all products to reduce time-to-market and save investment expenses. The same algorithm that is used to control a BLDC Refrigerator compressor can also be used to control a BLDC Air Conditioner
compressor. Likewise, other software algorithms for functions such as Power Factor Correction can also be used as a common platform across all products.

Time-to-market is further reduced by the “re-use” of software from one generation of products to the next. Improving the software or adding new functionality can be done with little or no hardware modifications, thereby simplifying product qualification and certification testing.

Future Trends

While the DSP is providing considerable benefits to both appliance and motor manufacturers today, the near future presents even greater benefits as motor control DSP bandwidth will increase by more than seven times from 20 MIPS to 150 MIPS for the same price. Since motor control for white goods appliances will require between 20 to 40 MIPS of bandwidth, that leaves considerable room to handle new functions for without adding additional components to the control board or complexity to the DSP.

For example, speech recognition requires between 10 and 20 MIPS to make possible “natural language” recognition as opposed to simple “command and control.” While the latter requires the user to utter single word commands, the former allows the user to speak in a continuous flow as one normally does. “Natural language” recognition also allows the user to speak complete numbers instead of one digit at a time. For example, “515” can be spoken as “five hundred and fifteen” instead of “five-one-five.” The use of speech recognition in appliances will revolutionize the user interface and can be incorporated even in today’s motor control DSPs. But the revolution doesn’t end with speech recognition – an offshoot of this technology will be
active noise cancellation that will further reduce the noise created by appliances. This could allow appliance OEMs to use noisier, less expensive motors since the software can reduce the noise at no extra cost.

Wired or wireless communications are additional features that can be embedded in the motor control DSP. DSPs are already established as the processor of choice for communications and several applications exist on many of today’s DSP cores. A simple software modem can be included for wired communications, or RF blocks can be included in the silicon with the DSP handling the interpretation and control of the wireless signals.

Because the DSP can be used to monitor the health of an appliances motor, the inclusion of Internet communications will allow appliance OEMs to remotely monitor all of their products in use. This will have two significant and beneficial results. First, it will allow OEMs to schedule maintenance for appliances well before breakdowns occur. Second, it will allow OEMs to collect up-to-date, real-time information about the performance of the motors in their products so they can feed that information back to the motor manufacturers. The resulting data will demonstrate how the motor is actually operating in products in many different environments and will help appliance and motor manufacturers build better, more reliable products in the future.

Summary

The increasing use of DSPs to control electric motors is a signal that motor control is shifting its focus from hardware to software. This shift is due to DSPs’ superior bandwidth and their suitability to the task of processing real world signals. The
result of this shift is that appliance manufacturers now have many more options when it comes to selecting which types of motors to use in their applications. The use of software modeling, in addition to improving performance, reducing cost, and increasing reliability and efficiency, also increases appliance manufacturers’ flexibility enabling them to second source their motors.