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Using Integrated Modules to Improve Efficiency, Reliability and Size of Home Appliance Motor Drives

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According to the United States Department of Energy (DOE), appliance motors consume approximately 20% of all electric energy consumption in the typical household. As the home appliance industry is forced to address energy conservation efforts, semiconductor manufacturers likewise need to provide innovative techniques and product technologies to optimize efficiency. Motor drive solutions are an integral part of this innovation. Inverter motor driving architectures have now become popular due to a 40% energy savings over non-inverter based architectures. For inverter based systems there is increasing demand for compactness, built-in control, and lower overall cost. Inverter drive modules meet those needs and are a conventional alternative to discrete-based inverters. This article discusses the latest integrated module devices that ensure high efficiency, reliability, smaller packaging, and greater design flexibility for these energy-restricted applications.

Limits of Non-Integrated Motor Solutions

Inverter motors are used in home appliances such as air conditioners, washing machines and fan motors. Inverter drive applications are increasingly popular because they deliver precise frequency-control, starting current control and high efficiency. Frequency control translates to efficiency because it gives designers the ability to have different cycles that conserve energy in such applications. For lower power appliances, such as fan motors, water suppliers and air purifiers, the traditional approach for driving inverter-based systems has been to use a discrete solution comprising IGBTs and gate driver ICs. However, system designers face a number of challenges when designing these devices in a non-integrated fashion; namely design flexibility, packaging and reliability.

Traditional solutions using IGBTs and gate driver ICs can pose a problem to end-applications. For instance, IGBTs are not designed specifically for the gate driver ICs that are driving them, making board design more complex and timely. Since electrical noise from the motor and system can create a parasitic interference problem requiring more external filtering components, using a number of discrete components increases design time because each device must be designed in. Furthermore, if any compatibility problems are found between the discrete IGBTs and ICs, time-to-market will be extended, which in turn, adds costs for the manufacturer.

Integrated Solution for Increasing Design Flexibility

Design flexibility in motor control enables the use of inverter-based systems for a wide range of applications. Realizing the importance of design flexibility, semiconductor suppliers are adapting their motor drive solutions accordingly. For example, Fairchild Semiconductor offers the Smart Power Module (SPM™), which incorporates a number of flexibility features. As sensor-less vector control and other increasingly sophisticated control methods are applied to general industrial and consumer appliances, there is a growing need to measure inverter phase current. To solve this challenge, the SPM family offers products with a 3-N terminal structure in which IGBT inverter bridge emitter terminals are separated. In this type of structure, a shunt resistance can then be used in each 3-N terminal to easily detect inverter phase current.

Compact packaging and low power loss are the primary goals of low-power modules used in inverter applications. However, in recent years, attempting to reduce power loss through excessively fast-switching speeds has given rise to a number of corresponding challenges. Excessive switching speed increases the IGBT and power diode dv/dt , di/dt , and recovery currents creating problems such as excessive conducted and radiated EMI (Electromagnetic Interference), excessive surge voltage, and high magnitude motor leakage currents. These problems not only increase system cost, but can also impact the motor life.

To solve these concerns, the ability to adjust the switching dv/dt becomes essential. Technologies such as SPM devices provide switching below 3kV/ μ sec (typical) through advanced gate drive impedance design. Depending on how the impedance cell is designed, the high-side switching slope can be adjusted so that EMI problems may be easily remedied. To further reduce EMI, these modules provide an integrated low loss IGBT, low forward voltage Fast Recovery Diodes (FRD), and gate drivers to optimize the switching speeds while reducing total power loss. It is the integration of these parts that allows the optimization of each component, thus reducing design time while still providing design flexibility.

Improvements to Packaging and Reliability

Through control board standardization, overall manufacturing costs will be substantially reduced as users are able to simplify materials purchasing and maintain manufacturing consistency. By using Smart Power Modules, for example, the wire-to-chip junctions and the chip-to-frame junctions are enforced in a transfer mold package to make it endure severe thermal stress. In particular, the wire-to-chip junction endurance of rapid temperature swings caused by load variation has been substantially improved. Power cycle results show that smart modules are capable of over ten million power cycles at an average chip junction temperature swing of 25°C. This makes the modules suitable not only for home appliances, which usually work under a relatively constant load, but also for typical servo applications characterized by frequent and dramatic load changes.

The module structure is relatively simple: power chips and the IC chips are directly die-bonded on the copper lead frame and the bare ceramic material is attached to the frame and then molded into epoxy resin. This structure greatly minimizes the parts count and material types, optimizing assembly process and overall cost. The design concept is based on providing a product with smaller size but a higher power rating. Of the low power modules released to date, Fairchild's SPM has high power density with a wide current rated product built into a single package outline.

Conclusion

As global energy supplies dwindle, government and agency regulators are continuing to look for ways to mitigate high energy consumption. Accordingly, the home appliance industry is adjusted by adopting inverter-based, 3-phase motors for a significantly more efficient approach compared to traditional motor drive solutions. The semiconductor devices used to drive these inverter-based systems have evolved into highly integrated power modules that meet these efficiency demands while also improving manufacturing and time-to-market costs.

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