Delivering Efficiency in White Goods Applications

Government eco-design initiatives require domestic appliances to reduce the consumption of resources such as water and electricity while the machine is operating, making them more efficient appliances and meeting the high level of public demand for greener products.

Major appliance energy consumers

In appliances such as washing machines, refrigerators and air-conditioning units, electric motors are major energy-consuming subsystems. In particular, traditional AC induction motors driving items such as fans, pumps, compressors and the washing machine drum tend to operate at full speed when turned on, consuming more energy than is really needed. Recognising this fact appliance manufacturers are generally moving to adopt variable-speed brushless DC motors (BLDC) motors as a more energy efficient alternative. However, variable-speed control of a BLDC motor calls for more complex motor-control waveforms, generated using phase-cut devices such as triacs or an inverter with PWM input, or a more sophisticated vector-control (or field-oriented control) solution.

To enable producers of appliances and appliance-motor subsystems to deliver the innovations demanded by their target markets, power electronic components such as power transistors, triacs and high-voltage control ICs are assuming a higher profile in today's domestic appliance designs. As this trend becomes entrenched, further progress in reducing the energy consumed by modern appliances is contingent upon improvements in these components that help to boost efficiency at a cost-effective price.

In addition, stepper motors are often used in products such as high-end refrigerators, as part of built-in features such as ice makers and internal cold air regulators. Improving the performance of stepper-motor controllers can help to reduce energy losses while also increasing safety and reliability.

Power semiconductor innovation

Complementing the arrival of smarter power control ICs, ongoing improvements in devices such as metal–oxide–semiconductor field-effect transistors (MOSFETs) and insulated gate bipolar transistors (IGBTs) as used in motor-driver bridges, and triacs and relay drivers for actuating mechanisms such as valves, drains and safety locks also serve to minimise energy losses throughout the appliance.

Innovations and advances in the design of power semiconductors are focusing on increasing maximum current and voltage ratings per square millimetre of the die, and on safely integrating logic control and power-handling circuitry on the same substrate.

Progress in these areas enables device vendors to deliver new products offering intelligent functions in surface-mount packages that are smaller and easier to use. Advances in the motor-control ICs currently being positioned for appliance markets provide a good example. Double-Diffused Metal-Oxide Semiconductor (DMOS), the process technology used for making most power MOSFET devices, allows high-voltage transistors making up a motor-driver bridge to be fabricated on the same chip as the control logic, gate drivers and supporting functions for a multi-phase motor controller. The low transistor on-resistance (RDS(ON)) achievable using the DMOS process minimises the energy losses in power-control circuitry, helping to boost the operating efficiency of the appliance. In addition, there is a need to reduce standby current in order to save power even when the motor is off. ON Semiconductor has been able to deliver a measurable saving by reducing the standby current of its integrated motor controllers to 0µA.

It is worth noting also that safety and reliability goals can be fulfilled through advancing process technologies such as DMOS; in addition to reducing transistor losses, which in turn cuts down on heat generated internally allowing the die to run cooler, the best DMOS processes also have high breakdown-voltage capability, which prevents damage or destruction due to surges in the AC line.

Smoother speed control

Concerning the motor control techniques employed, there are a number of possible approaches such as phase-angle speed control using a device such as a bidirectional thyristor, or triac, which provides a low-cost alternative to vector control, a more complex technique that usually requires dedicated hardware or software running on a processor.

If using an inverter with a PWM input to control the motor speed, careful attention must be paid to the output current waveform. A distorted, non-sinusoidal current can produce unwanted effects such as audible noise and increased stress on the motor bearings. Achieving a

smoother, sinusoidal current waveform can improve the user experience of appliances such as air conditioners, refrigerators and washing machines, enabling vendors to offer quieter operation as a high-value feature, as well as increasing longevity and reducing repair costs.

Optimizing the inverter design to permit a larger commutation angle produces a waveform that more closely resembles the ideal sinusoid. Developing this approach in successive generations of motor-control ICs has enabled the inverter's commutation angle to be increased from 120° to 150° and ultimately 180° - which results in a current waveform very closely approximating to a sinusoid - allowing customers to achieve near-silent motor driving.

Another approach to appliance motor control, now entering the market in the form of single-chip control ICs, implements a low-cost vector-control scheme in hardware. This effectively relieves the burden of software development from appliance designers and third-party motor vendors, thereby allowing vector control – which enables the ultimate smooth and silent operation – to become more accessible in today's highly cost-sensitive appliance markets.

Controlling value-added features

In addition to the BLDC motors used in high-power applications such as driving compressors and washing machine drums, other motor types such as small steppers and brushed motors are needed for value-added features such as refrigerator ice makers and internal cold-air regulators. By implementing two H-bridge channels in one device, using DMOS integration, it is possible to build a controller that is equally capable of driving the forward/reverse brush motor typically used in the ice maker, or a 2-phase bipolar stepping motor as used for cold air regulation. The ability to use the same controller for either type of motor can effectively reduce design overheads for equipment producers. Stepper motors in fact have a variety of uses in the appliance space, such as air-conditioner filter cleaners, air blowers and dampers.

Conclusion

Advances in power semiconductors are enabling appliance designers to deliver new products satisfying end-user and government demands for greater energy efficiency.

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