High Efficiency Inverterised Air Conditioner Kit

The Power to Innovate

For many years, market research houses have been predicting a substantial increase in the sales of high efficiency home appliances. However, due to high costs, manufacturers resorted to selling these appliances as high-end low-volume products, so growth has been well below forecasts.

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The latest market studies continue to predict rapid market growth by indicating, for example, the variable speed drives market in major home appliances is set to double over the next five years, but this time things have changed. Now there is more confidence in the accuracy of these latest predictions due to a series of factors.

Government legislation and China's government subsidy program to stimulate the Chinese economy during the 2009 down turn are two reasons why major home appliances manufacturers are more actively implementing higher efficiency standards. Manufacturers are also using this as a chance to develop products with "unique" features to differentiate themselves from the competition.

Without doubt, Intelligent Power Modules (IPM) will enjoy market leadership in this segment, but there is a trend evident that discrete solutions will win more of the market share. Due to cost pressure, OEMs and design-houses are looking more closely at implementing discrete solutions. This has been recently seen via significant increase in requests for technical support to help with optimizing discrete solution designs.

Figure 1: Air Conditioning Inverter Kit with SMD power electronics enabling higher power densities and higher efficiency

Semiconductor solutions for home appliances

Up until 2009, IPMs used for driving inverters were the device of choice due to ease of design-in and assembly. However, due to delivery issues and cost saving programs home appliance manufacturers began adopting multiple-sourcing strategies, which allowed for flexibility in selecting different semiconductor suppliers. The discrete IGBTs enable both the cost saving potential plus second sourcing, with slightly higher design efforts.

With a discrete solution, designers are handed an extra degree of freedom over an IPM solution, so microcontrollers, gate drivers and power semiconductors can be selected and laid-out to deliver optimum thermal and electrical performance.

To help designers achieve the best from their designs with little effort, the "Air Conditioning Inverter Kit" has been released. On a single PCB, a compressor up to 1.2kW and a fan up to 200W can be simultaneously controlled. The board can run on either 110V or 230V mains voltage. The kit contains two microcontroller boards plus USB interface, two inverter stages (1.2kW and 200W), and PFC stage. An 8-bit controller (XC-878) included is capable of controlling PFC and a single motor, whilst a 16-bit controller (XE-164) is included for controlling two motors and the PFC. Figure 1 shows the kit plus contents.

A B6-full bridge configuration is used in the Air Conditioning Inverter Kit. The kit uses Infineon's most recent thin-wafer TRENCHSTOP™ and field-stop IGBT technology called RC-Drives (seen in figure 2(d)). The technology replaces conventional non-punch through and punch-through IGBTs due to low conduction and switching losses, excellent EMI behavior and cost effectiveness.

IGBTs used in inverter systems require a commutation-proof anti-parallel diode. Since the IGBT does not have an intrinsic body diode, a two chip solution in a single package is needed (Duo Pack).
Infineon's new RC-Drives technology has the diode monolithically integrated into the IGBT structure itself as can be seen in Fig. 2(d). Although integrated into IGBT, the diode is fully commutation proof diode and offers low V_F and low Q_{rr}.

With the integration of the diode, the RC-Drives enables up to a 40% shrink over the common Duo Pack solution. The shrink results in an increase of power density, which in turn allows for the use of smaller packages for the same current class. Therefore now, a TO-220 or D²PAK can be replaced with the smaller IPAK (TO-251) or DPAK (TO-252) packages, allowing for a smaller footprint on the PCB and resulting in cost- and space-saving in current classes from 4-15A.

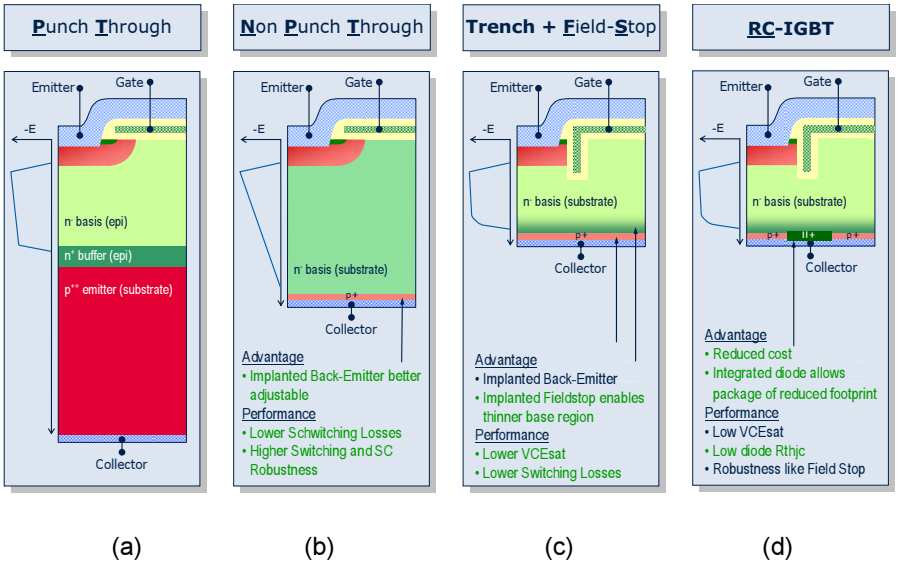

Figure 2: Vertical structures of IGBTs as a generation evolution

Higher frequencies for the customers comfort
The typical frequency range of inverters used in home appliances is between 5kHz and 16kHz, depending on which modulation technique is used. For the Air Conditioner Kit a PWM modulation technique is used and the frequency can be adjusted according to the designers requirements. Caution must be exercised when designing inverters to switch between 10kHz and 16kHz, as this is in the human audible range and the noise becomes annoying for consumers. As a result we see compressors operating below 8kHz and fans operating above 18kHz.

Thanks to Infineon's thin-wafer IGBT technology, the RC-Drives family is the perfect fit into the home appliance market, since it offers very low conduction losses ($V_{ce(sat)}$) and switching losses (E_{ts}) with a very soft turn-on/-off behavior to lower the EMI at a competitive price.

For appliances switching between 8kHz and 25kHz a new RC-Drives Fast (RC-DF) series is available in 3A and 4A in DPAK (TO-252). The new products allow for designers to increase operating frequencies above the human audible range, resulting in quieter operation for the end customer. The increase in operating frequency allows for advanced control algorithms, like field oriented control (FOC) to be implemented. The benefit of operating at higher switching frequencies means the passive component size can be reduced. The Air Conditioning Inverter Kit allows designers to use the microcontroller (XE-164) to experiment and see the efficiency benefits when using FOC (field oriented control).

A PFC stage is also included on the kit and uses the latest HighSpeed 3 IGBT technology in the boost switch. The IGBT offers an economically attractive replacement for planar MOSFETs, whilst the boost diode is the latest Infineon ThinQ! SiC-Diode. Designed to operate at 67kHz, in this combination, efficiencies of above 97% can be achieved. The benefit of the higher switching frequencies is the reduction in the size of the passive components.

Optimized control algorithms
For established open-loop control of synchronous machines, trapezoidal or block commutation with hall-elements or back EMF sensing causes noise especially at low speed and limits the maximal speed. The FOC leads to an overall system efficiency due to sinusoidal currents with a low torque ripple and a wide speed range (Figure 3). For a quick start a full tool-chain is included in the evaluation kit. The field-oriented control is implemented for both inverters using a single-shunt based feedback loop in the Air Conditioning Inverter Kit.

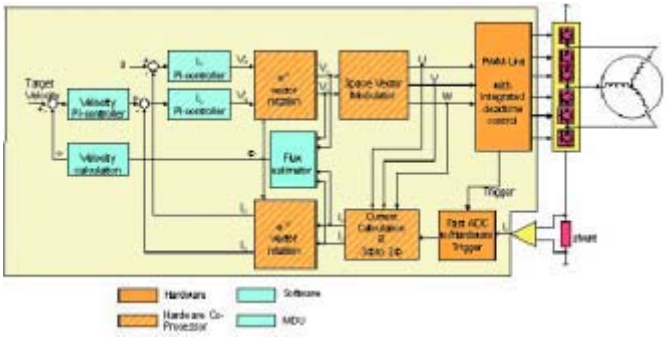

Figure 3: Block diagram of the field oriented control used in the air-conditioning system

Summary and Outlook
Application optimized power semiconductors and advanced control algorithms offer excellent energy saving and cost reduction for home appliances. The Air Conditioner Reference Kit is available as an easy entry into designing with discrete power devices and allows for experimentation with complex algorithms like FOC. The innovative thermal concept allows for high power SMD mounting, to enable easier high volume production. The kit is available to order via local sales and distribution partners.

Application notes and further information is available on:

www.Infineon.com/aircon