Combining Inrush Current Limiting with PFC for White Goods Motor Applications

Devices that execute multiple application functions to reduce system complexities

When Europe mandated the requirement that electric loads of 80W or above draw current in a high power factor manner, it was another incremental step towards conservation and a greener environment. Many of the consumer products affected include white goods appliances. Many of these appliances such as air conditioners, refrigerators, washers and dryers have complex loads due to the inverter for the electric motor drive. In principle, complex loads generally have poor power factors. By mandating that these appliances be power factor corrected (PFC) the transmission lines power delivery is better utilized, saving energy and reducing both the cost of electricity and the release of carbon emissions from the burning of fossil fuels. Around the world today, many government regulatory agencies have mandated similar requirements for PFC in these applications.

The front end of a motor drive circuit without PFC looks very similar to a switch mode power supply where bulk storage capacitance resides that smooths out the DC from the rectified mains. When initially energizing the motor drive circuit, the mains input looks essentially like a short circuit because there is no charge on the bulk capacitors. When power is applied this condition results in high inrush currents to charge the capacitor. If this inrush current is not controlled or limited, the current draw from the line will surge to magnitudes higher than its normal RMS operating current (Figure 1). These excessive currents potentially can damage or stress both mechanical and electrical elements such as fuses, solder joints or electronic components, just to name a few.

Most white goods motor manufacturers have adopted the use of a negative temperature coefficient resistor (NTC) to limit inrush current. The NTC operation is very simple. Under cold or initial start up conditions the NTC is a high resistance device and limits the current quite well. After start-up or a few moments into normal operating conditions, the NTC gets warmer due to power dissipation. As it gets warmer its resistance significantly decreases, making it a more efficient path for current to flow through. In most embedded motor drive circuits the NTC is placed somewhere in the high current path, either on the AC side or just after the bridge rectifier (See Figure 2). There are some inherent shortfalls with the NTC approach that can adversely affect the embedded motor’s drive reliability. As previously mentioned, the NTC’s efficiency depends on the temperature. The hotter it becomes, the more efficient it is. An NTC cannot be overheated to conduct the heat away; otherwise it will not work as intended. This dissipation is left to heat the surrounding environment where the other semiconductor components reside. In the embedded environment the problem is exacerbated. An increase of just 10C can reduce the semiconductors expected life or mean time between failures (MTBF) by as much as half, significantly reducing the drive’s reliability.

Another major problem with the NTC is its thermal mass or time response. A problem could arise if the mains voltage were to momentarily dropout or severely brownout for a period just long enough where significant change is depleted from the bulk capacitors. When the line voltage recovers, the NTC may not have had enough time to cool down, and is in its low resistance state. The inrush currents associated with the line recovery in this event allow even higher surge currents than normally present, even higher than those at initial start up. In this case there is no protection. These unusually high currents could damage power train elements such as fuses, solder joints, traces or all the elements in the path.

Figure 3 shows a simplified schematic of the industries first single chip dual-phase interleaved PFC pre-regulator, the UCC28070 from Texas Instruments. Interleaving two phases 180o apart provides ripple current cancellation. This enables the use of a smaller electro...
By Gary Aw, Product Manager, Gate Drive Optocouplers, Avago Singapore

IGBT Gate Drivers in High-Frequency Induction Cookers

Efficiency of induction cookers is 84 percent

Today, with the constant demand for energy saving devices, high-frequency induction cookers, already a trend in Europe, are gaining popularity in the rest of the world. These kitchen devices offer high efficiency that reduces energy usage, reduces cooking time and, simultaneously, improves user safety, particularly among children, since all heat is localized to the pan itself.

According to the U.S. Department of Energy, the typical efficiency of induction cookers is 84% compared to the 40 percent of gas cookers. In this article, two typical induction cooker designs, the half-bridge series-resonant and the quasi-resonant topology, are discussed. The merits and disadvantages of these two high-frequency inverter topologies along with three gate driver circuits, discrete transistors, optocouplers integrated circuit and transformers for high frequency operation are also discussed.

What is induction cooking?

In an induction cooktop, a magnetic field transfers electric energy directly to the object to be heated. By inducing an electric current into the ferrous cooking utensil, heat is generated in the object, and the cooking surface only gets hot from the heat reflected from the object being heated: no heat is directly transferred.

How does an induction cooker work?

Figures 1 and 2 show two circuit topologies for induction cookers: the half-bridge series resonant converter, Fig. 1, and the quasi-resonant converter, Fig. 2. In both topologies, there exist the resonant elements Lr and Cr. For circuit simplification, the load pot, R, is assumed to be a purely resistive element. In both

Figure 1: Half-bridge series-resonant topology for induction cookers.

Figure 2: Quasi-resonant topology for induction cookers.

www.powersystemsdesign.com

www.ti.com
**IMPORTANT NOTICE**

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifiers</td>
<td>Audio</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Automotive</td>
</tr>
<tr>
<td>DSP</td>
<td>Broadband</td>
</tr>
<tr>
<td>Clocks and Timers</td>
<td>Digital Control</td>
</tr>
<tr>
<td>Interface</td>
<td>Medical</td>
</tr>
<tr>
<td>Logic</td>
<td>Military</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Optical Networking</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Security</td>
</tr>
<tr>
<td>RFID</td>
<td>Telephony</td>
</tr>
<tr>
<td>RF/I and ZigBee® Solutions</td>
<td>Video &amp; Imaging</td>
</tr>
<tr>
<td></td>
<td>Wireless</td>
</tr>
</tbody>
</table>

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright 2008, Texas Instruments Incorporated