ABSTRACT

The UCC28880 and UCC28881 devices integrate the controller and a power MOSFET into one monolithic device. Due to the integration, additional design considerations are required to stay within the safe operating area of the devices, such as the diode reverse recovery time and reverse recovery charge. These parameters, if not dictated properly, can damage the device and lead to catastrophic failure. This application note reviews the diode reverse recovery time and charge and compares diodes, displaying the effects of inadequate component selection.

Trademarks

All trademarks are the property of their respective owners.

1 Introduction

In an increasingly more electronic world, more devices are becoming “smart” and require electricity to power their intelligence. Many of these devices require less than 1-W of power and do not require electrical isolation from the input, since the circuit is inaccessible to users. Offline switchers, like the UCC28880 and UCC28881, can be configured as a buck to generate this bias power in the simplest and most cost-effective manner. While designing a buck converter with these devices is relatively simple, some design considerations must be taken into consideration to prevent catastrophic failure. One that is often overlooked is the diode.

Figure 1. UCC2888x High-Side Buck Converter Configuration
Diode Parameters

Diode selection involves more than just the blocking voltage and current rating. Consideration of the reverse recovery time ($t_{rr}$) and the reverse recovery charge ($Q_{rr}$) is just as important. When a diode is conducting in its forward bias state and is quickly reverse biased, time is required to clear the depletion region of charge carriers such that the diode can block the reverse voltage again. Reverse recovery time is how long it takes to remove the accumulated charge distribution in the diode junction before becoming a non-conducting diode. Data sheets specify under what conditions the reverse recovery time is measured. This is important because in different environments, this parameter changes. For example, reverse current increases greatly with temperature because higher temperature generates more electron-hole pairs increasing conductivity, thereby increasing $Q_{rr}$. Increased forward current increases the amount of charge on the depletion layer, again increasing $t_{rr}$.

Limitations of Internal Power MOSFET

The UCC2888x devices have a current-limit sensor between the internal 700-V power MOSFET source and the IC return (pin GND). When the current through the MOSFET reaches the current limit, $I_{\text{LIMIT}}$, the internal current limit signal goes high, turning off the MOSFET. This limit value is sensitive to temperature changes, and can increase in colder temperature environments and decrease in hotter ones.

Effect of Diode Recovery on the Power MOSFET

The UCC2888x high-side buck converter uses two diodes: the diode in the power path of the buck converter (freewheeling diode, D1) and the feedback diode (D2). During the on to off conduction transition of D1, the high $dv/dt$ of the switch node causes the diodes to undergo reverse recovery. Since the voltage across the capacitors cannot change during commutation, when diode D1 experiences a high $dv/dt$, so does diode D2, because the voltage across D2 is $V_{D2} = V_A + V_B - V_C$. This causes the internal power MOSFET to have to carry the reverse recovery current ($I_{rr}$) of both D1 and D2. If the diodes do not recover fast enough and have a large amount of reverse recovery current, then the power MOSFET sees a large current spike during this switching transition. If this total current is larger than the limitation of the power MOSFET, then the device can be damaged.
5 Diode Recovery Comparison

Figure 2 and Figure 3 demonstrate the difference of the recovery time on diode D1 (from Figure 1) with a fast diode compared to a slower diode. If the power MOSFET of the UCC2888x is operating at full load, and experiences these commutation spikes every switching cycle, there is a possibility that these current spikes force the power MOSFET outside its safe operating area and damage the device.

Doubling the recovery time of the EVM diode increased the reverse recovery current three-fold. The CMMR1U diode, rated at 100-ns maximum $t_{rr}$, takes only 50 ns to recover, as it is being placed under a different environment from initial tests.

Figure 3. Comparison of Reverse Recovery Time of the EVM Diode and a Slower Diode
6 General Design Recommendations

The data sheets for UCC28880 and UCC28881 specify diode maximum reverse recovery time that will not cause failure. In continuous mode operation, the diode reverse recovery time should be less than 35 ns (such as the STTH1R06A, which provides a 25-ns $t_{rr}$). If the device is being operated in discontinuous current mode, a slower diode with a reverse recovery time of 75 ns, or less, can be used. Generally, using faster reverse recovery diodes, those that have a $t_{rr} < 20$ ns over the entire temperature range, is recommended since doing so provides additional design margin and reduces this loss mechanism.
IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated (‘TI’) technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, “TI Resources”) are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI’s provision of TI Resources does not expand or otherwise alter TI’s applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT. AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources 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.

TI RESOURCES ARE PROVIDED “AS IS” AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include: without limitation, TI’s standard terms for semiconductor products (http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2017, Texas Instruments Incorporated