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DIODE EFFECTS ON EFFICIENCY OF POWER CONVERTER

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ABSTRACT

The choice of diode technology is dependent on the power losses incurred by the diode in the design of a power converter. The conduction and the reverse power losses in the diode influences the degradation of efficiency of the power converter, especially in low voltage electronic applications. This paper presents the conduction and reverse power losses associated with the two diode technologies; the Ultra-Fast, and the Schottky diode technologies, for a given application. The paper also highlights the effect of the power losses on the efficiency of the converter using both circuit and datasheet parameters.

Keywords: *Conduction Loss, Converter, ON-time, OFF-time, Reverse Power Loss, Schottky Diode*

INTRODUCTION

The performance of an electronic appliance is mostly dependent on the stability of the power supply. This is because, the fluctuations and voltage spikes in the power supply affect not just the performance, but also the safety and reliability the entire system. The power supply design industry with the aim to insure designing power sources free of voltage fluctuations have developed several technologies (Unitrode Corporation, 1988), including ; the zener diode; the linear regulators; and the switching power supplies. But all these technologies have limitations for low voltage applications.

Again, due to more stringent load performance requirements, and the developments in the semiconductor industry, the linear power regulator was introduced. While the linear regulators embed comparators, power switches and operational amplifiers within them in providing the requirements as demanded by the electronic load, the linear regulator have some unbearable limitations including; low efficiency, high power loss, and limited power supply application, as they can only be applied in step-down applications (ON Semiconductor, 2014). The linear power supplies operate in the linear mode of the power switch, there is a very high conduction loss, leading to the heat buildup within the regulator, necessitating the unavoidable attachment of heat sinks. But the heat sink does not improve the efficiency beyond 65% in the performance of the system, but rather increasing the weight and cost of the overall system. The switching power supply offers not just higher efficiency and reduced power loses, but also ensures reduced system weight, and greater design flexibility. The advantage of the switching power supply is that the power switch is not in continuous operation, but is operated rapidly between saturation and cutoff, increasing the efficiency of these power supplies ranging from 65% to 95%, and the recent advances in inductors, and semiconductors have made the switching power supplies even more popular in the power supply industry (ON Semiconductor, 2014) . But they also have few losses within the power devices used in the converters (ON Semiconductor , 2008). This paper presents the comparison of the conduction and the reverse power losses contributed by different rectifier diode technologies to the overall power supply unit losses. The results would assist power supply designers decide on the choice of diode technology for a typical low voltage power converter.

Power Losses In Switching Converters.

There are basically three classes of loss in the power supply (Khersonsky, Robinson, & Guteirrez, 1992); the conduction loss; the reverse loss, and the switching loss. While the conduction loss and the reverse loss have to do with the product of voltages and currents, the switching loss has to do with the response time of the power devices. In a switching power supply, although conduction loss is contributed by three sub-components; the conduction loss in the transistor (or MOSFET), the conduction loss in the rectifier diode, and the conduction loss in the inductor, the switching loss is majorly comprised of; the switching loss in the transistor and the switching loss in the diode. There are basically four rectifier diode technologies (ON Semiconductor, 2014), but only the Ultra-fast recovery and the Schottky diode technologies are presented, and performance compared.

DESIGN APPROACH

In ascertaining the combined power loss of a diode, both the conduction loss and the reverse power loss are evaluated, using the circuit and the datasheet parameters.

(A) Diode Conduction Loss

The conduction loss contributed by the rectifier diode in the designing of power converters is the product of the diode forward voltage (V_f), and the load current multiplied by the OFF time period. That is;

$$P_{c\,(diode)} = V_f I_L t_{OFF} \quad (1)$$

$$P_{c\,(diode)} = V_f I_L (1 - D)\,T \quad (2)$$

(B) Reverse power loss

In addition to the forward conduction loss of the diode, there is the loss due to the reverse bias of the diode, and it given by;

$$P_R = V_R I_R t_{ON} \quad (3)$$

In power converter applications, the choice of a diode is dependent on the power losses incurred by the diode. And therefore, the need to compare different diodes, and their effects on the system efficiency, so that power supply designer can carrying out power converter design and make adequate components selection for the designed power converter.

(C) Design Problem

Using the Ultra-Fast diode and the Schottky diode, the Power converter was designed with the following specifications and the conduction and reverse power losses obtained.

V_O = 5
I_L = 3
V_S = 15
f = 100 kHz

The duty ratio $D = \frac{V_o}{V_s} = \frac{5}{15} = 0.33$

(I) Ultra-fast diode

Using the RURD4120 datasheet,

$the\ forward\ voltage\ (V_f)$ = 2.1V
$the\ forward\ current\ (I_f)$ = 3A
$the\ reverse\ current\ (I_R)$ = 100μA
$the\ reverse\ voltage\ (V_R)$ = 1200V

(i) **the conduction loss**

From equation (1), the conduction loss is;

$$P_c = V_f\ X\ I_o t_{OFF}$$

But $t_{OFF} = T - t_{ON}$
Where

$$T = \frac{1}{f} = \frac{1}{100\ x\ 10^3} = 10\mu s$$

And $t_{ON} = D\ T = 0.33\ (10\mu s) = 3.3\mu s$
Therefore, $t_{OFF} = (10 - 3.3)\mu s = 6.7\mu s$
The conduction loss becomes;

$$P_c = 2.1\ X\ 3\ X\ 6.7\ x10^{-6} = 42.2\mu W$$

(ii) The reverse power loss

From equation (3), the reverse power loss of the diode is;

$$P_R = V_R I_R\ t_{ON}$$
$$= 1200\ X\ 100\ X10^{-6}\ X\ 3.3\ X10^{-6} = 0.396\ \mu W$$

Therefore, the combined power loss using the Ultra-fast diode, is obtained from;

$$P_{ult} = P_C + P_R$$
$$= 42.2\mu W + 0.396\ \mu W$$
$$= 42.59\mu\ W$$

(II) Schottky Diode

Using the 1N5822 datasheet,

$$V_F = 0.525$$
$$I_F = 3\ amp$$
$$V_R = 40\ V$$
$$I_R = 20\ mA$$

(i) The conduction loss

Also from equation (1),

$$P_c = V_f\ X\ I_o[t_{OFF}]$$
$$P_c = 0.525\ X\ 3\ X\ 6.7\ x10^{-6} = 10.5525\mu W$$

(ii) The reverse power loss

Also from equation (3), the reverse power loss is;

$$P_R = V_R I_R\ t_{ON}$$
$$= 40\ X\ 20\ X10^{-3}\ X\ 3.3\ X10^{-6} = 2.64\ \mu W$$

Therefore, the combined power loss for the Schottky diode is;

$$P_{skt} = P_c + P_R = 13.19\ \mu W$$

RESULT ANALYSIS

The power losses for the Ultra-fast and the Schottky diode technologies as applied on the converter designed for load requirements ranging from 500mA to 3000mA is as shown in Table 1.

Table 1: Diode power loss for typical applications

Diode Technology	Load Current (mA)	Total power loss (μW)
Ultra fast	500	7.63
	1000	14.47
	2000	28.54
	3000	42.59
Schottky	500	4.39
	1000	6.16
	2000	9.68
	3000	13.19

EFFECT ON EFFICIENCY /DISCUSSION OF RESULTS

The power loss in the diode actually affects the efficiency of the power converter. Although, the diode power loss is made up of several components, the conduction loss is the major contributor. As the converter is applied on increasing load requirements, the diode conduction loss is significantly increased, irrespective of diode technology, degrading the efficiency of the converter. In low voltage applications, with comparable load requirements, the effect on the efficiency is more pronounced in the converters adopting the Ultra-Fast diode technology.

CONCLUSION

When a power converter is designed and developed, any electrical load that is not beyond the designed load requirement can be applied on the converter. As the diode power loss is significantly impacted with increasing load requirements as clearly shown in the results, the Schottky diode technology is preferred in low voltage buck converter applications, provided the load requirements are within the specifications of the Schottky diode technology.

REFERENCES

Khersonsky, Y., Robinson, D., & Guteirrez, D. (1992). *International Rectifier.* Retrieved April 16, 2020, from International Rectifier Web site:https://www.scribd.com/doc/242623214/The-HEXFRED-Ultrafast-Diode-in-Power-Switching-Circuits-pdf

ON Semiconductor . (2008, November). Retrieved September 26, 2019, from ON Semiconductor Web site: www.onsemi.com

ON Semiconductor. (2014, April 4). Retrieved March 21, 2020, from ON Semiconductor Web site: www.onsemi.com

Unitrode Corporation. (1988). *Unitrode Applications Handbook.*