IMPROVING AC-DC POWER SUPPLY EFFICIENCY

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INTRODUCTION

Improving the efficiency of AC-DC power supplies with smaller foot print is making the task of designing the power supplies more challenging. High efficiency means how well a power supply performs without wasting power in the form of heat. We are helping our customers to reduce their cost by offering them power supplies to be certified by 80 PLUS® to Titanium efficiency, which is 96% efficient at 50% load. This can be achieved by minimizing the losses of major power dissipation components and thermal management ensuring very little heat loss without compromising on the footprint with higher switching frequencies. This application note will talk about how to improve the efficiency of a power supply with high power density.

Below are the major power dissipation components in a power supply.

LOSS COMPONENT	FACTORS
MOSFET driving loss	Function of gate charge, drive voltage and switching frequency
MOSFET switching loss	Function of Vin, Iout, FET rise and fall time and switching frequency
FET resistance	I^2 x RDS(on)
Inductor Loss	I^2 x DC resistance + AC core loss
Capacitor Loss	$IRMS^2$ x ESR

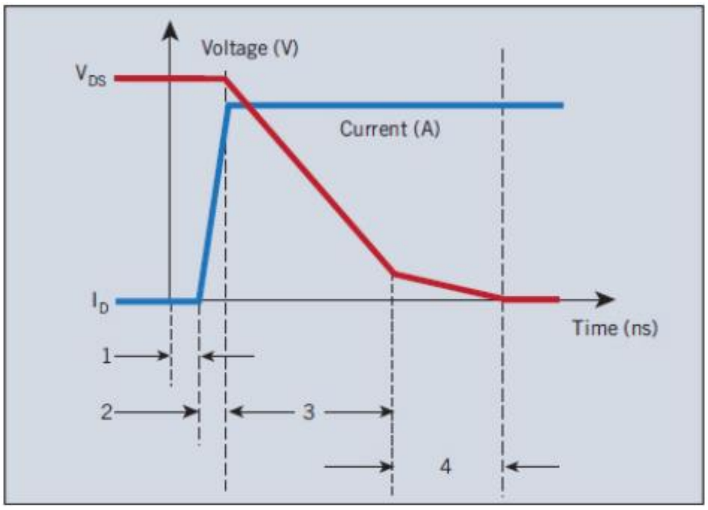
There is a trade-off between size, power and the efficiency of a power supply which should be considered during the design. Power supply with high switching frequency will have smaller footprint but higher frequency will introduce losses. With a better understanding of how these power dissipation components behave at higher switching frequency, most efficient power supply with high power density can be designed.

MOSFET LOSSES

The two major components of power loss in MOSFETs are Conduction Loss due to the finite resistance of the MOSFET and Switching Loss caused by sudden change in current due to turn the MOSFET on and off. For a MOSFET technology, the switching losses are proportional to MOSFET size while the conduction losses are inversely proportional to MOSFET size.

Minimizing MOSFET losses is not straightforward as it looks as we just see that while a large MOSFET will have less conduction loss due to lower RDS(ON), on the other hand its large area drives up the parasitic capacitance and switching losses. Reducing the conduction loss may result in much increased switching loss that it outweighs the conduction loss savings.

*Figure 1 - Showing V*I ≠ 0 during switching of power MOSFET*



INDUCTOR LOSSES

To lower an inductor's power losses at high frequencies, designers must understand the role of winding and core losses and the options available for reducing those losses. Core losses exhibit power losses in the form of hysteresis and eddy currents within the core itself and winding losses from the resistance of the winding. Inductors which are subject to high-frequency current ripple can make the effective winding resistance and the associated copper losses very high. The winding resistance of power inductors includes both the dc resistance and an AC component of resistance and at high switch-mode frequencies, the ac component of resistance can be very high, often greatly exceeding dc resistance and resulting in high copper losses. By using Litz wire, the ac resistance will greatly be reduced but drastically increase the dc resistance while Foil inductors are used to minimize the winding losses in an application of high dc current. An inductor which combines the very low dc resistance of a copper foil winding with a low ac resistance of a Litz wire winding can be the most efficient solution.

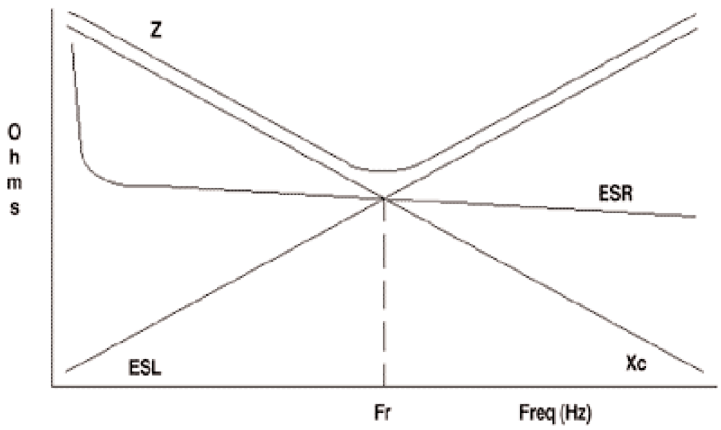
CAPACITOR LOSSES

The equivalent circuit of a capacitor is made up of three frequency dependent characteristics (Z, ESR, and ESL). Capacitor with a low equivalent series resistance (ESR) should be used to minimize the power losses. ESL is the equivalent series inductance which is the sum of all the inductive components within a capacitor. ESR, equivalent series resistance is simply the sum of all the resistive components within a capacitor and Z is the impedance of the capacitor.

$Z = \sqrt{[(ESR)^2 + (ESL - Xc)^2]}$ where, Xc = Capacitive reactance

ESR can be reduced by using a capacitor with higher capacitance and also notice that at higher frequency the ESR will change to a lower value. The low ESR aluminium electrolytic capacitor have extended life, higher ripple current rating, larger capacitance value with a variety of case sizes as compared to standard electrolytic capacitor.

Figure 2 - Frequency response characteristics of a capacitor



THERMAL MANAGEMENT

In addition to minimize the losses of all the power dissipation components of a power supply, proper thermal management should be employed to push the efficiency ever further. This can be done through creative mechanical design by avoiding hot spots and by ensuring proper air flow around the components which are going to get hot during power supply operation.

CONCLUSION

Improving the efficiency of a power supply is always the major goal of a design engineer. With combining the best design technology and creative mechanical design, the Power Supplies can reach up to 95% efficiency, a figure thought impossible few years ago. Today the engineers are talking about pushing efficiency to 100% which impossible to achieve but with years of experience and with advances in semiconductor technology we are getting close to it.

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