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MICROELECTRONICS

APPLICATION NOTE

POWER CAPABILITY OF VIPerXX0 FAMILY DEVICES

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ABSTRACT

The VIPerXX0 family devices are fully integrated switchers, intended to be used on the primary side of any off line power supply. They replace the conventional PWM driver circuit, its' associated high voltage mosfet switch, a full set of other passive components, and provide a high level of performance thanks to their current mode structure and standby operation capability.

VIPer50 and VIPer100 are presently the two available devices. They both have the same PWM functionality, but have two different sizes of mosfet switch. The main characteristics are summarized in Table 1.

Table 1. Characteristics

TYPE	Vdss	Id	Rdson
VIPer 50	600V	1.5A	5W
VIPer 100	600V	3A	2.5W

Although the name suffix (50 or 100) can give a rough idea of the output power capability of these devices, the real application will define the final power rating, depending on various parameters such as the used topology, the design of the transformer, the range of the input voltage and the efficiency of the heatsink (If any). The purpose of this note is to give a method for estimating the power dissipation of the VIPerXX0 off line switchers. The user can then define what is the reasonable maximum output power in the frame of its' own application.

DISSIPATED POWER ESTIMATION

Five factors contribute for the total dissipated power :

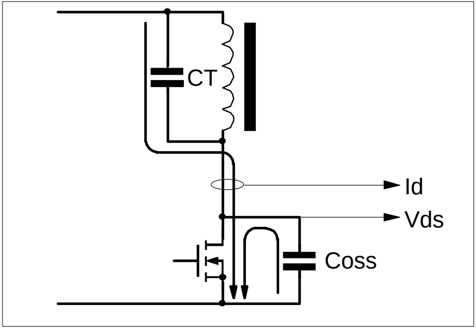
- Switch on losses.
- Switch off losses.
- Conduction losses.
- PWM consumption.
- Start up current source biasing.

Each of these factors are detailed in the following paragraphs. Note that they can be applied to any converter topology, from flyback (continuous or discontinuous) to forward.

Switch on losses

Figure 1 shows what happens at switch on. It represents the primary winding of the transformer and the mosfet switch of the VIPerXX0 device. The parasitic capacitances of these elements are also represented, as the current and voltage probes generally used for such measurements.

Figure 1. Switch on Current Flowing



At switch on, the drain voltage is decreasing down to zero, leading to the charge of the transformer parasitic capacitance CT, and the discharge of the mosfet switch one, Coss. Note that the current probe gives only the current corresponding to the transformer, and that Coss is internally discharged in the mosfet switch. This leads to an additional dissipated energy when compared to what the scope is measuring.

Figure 2. Switch on typical waveforms.

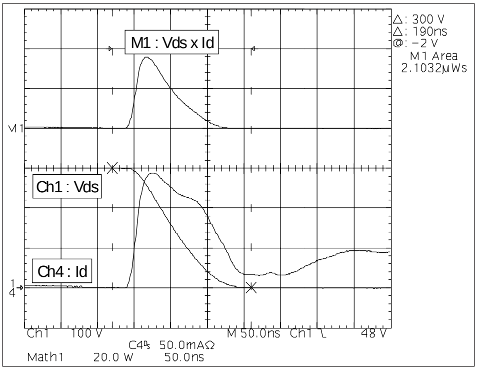
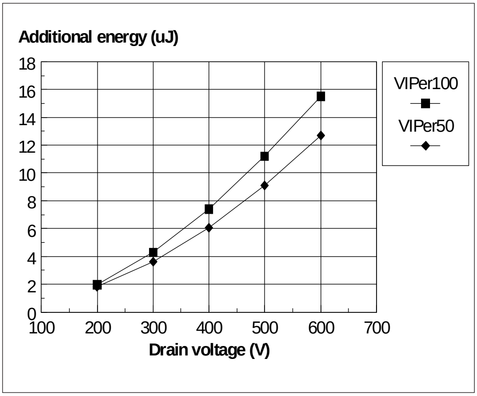


Figure 2 gives a dissipated energy of about 2.1µJ, which depends only on the characteristics of the transformer. In this case, the energy corresponds to a parasitic capacitance of about 47pF. A lower parasitic capacitance will lead to a lower dissipated energy.

As the current probe doesn't measure the internal discharging current of Coss, an additional energy term has to be added to the above scope estimation. This contribution depends on the internal output capacitance of the mosfet switch, which can be found in the datasheet. But since this capacitance is not constant (It depends on the voltage applied to the drain) and includes other capacitance like the one of the heatsink, it is simpler to use the curve of figure 3, giving the correcting energy term for VIPer50 and VIPer100 in a typical mechanical configuration (with a 15°C/W heatsink).In the case of figure 2, the drain voltage at switch on is 300V.

Figure 3. Additional switch on dissipated energy.

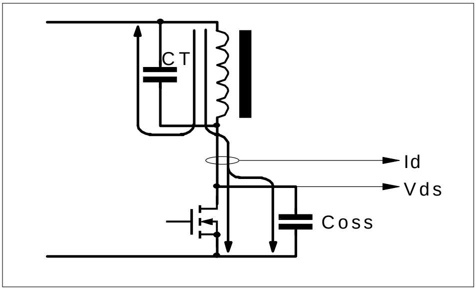


Assuming a VIPer50 is used, the above curve gives an energy of 3.6µJ to be added, leading to a total loss at switch on of about 5.7µJ.

Switch off losses

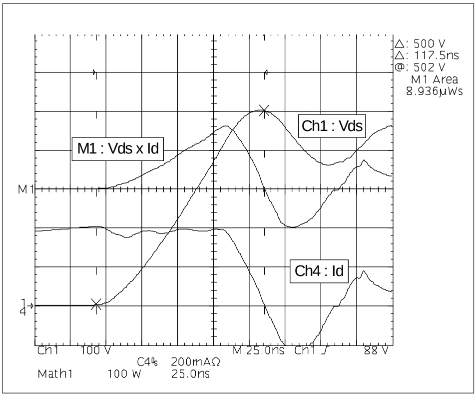
The switch off observed on a scope results from the current flow arrangement shown in figure 4. The current probe is sensing the current of the mosfet switch itself, shared between the channel of the mosfet and its' internal output capacitance. The one passing in the channel leads to dissipation, whereas the one charging Coss loses nothing: The corresponding energy is accumulated by Coss and is partially used later by the transformer, during the rest of the switching cycle. The remaining energy is dissipated at switch on, and is already taken into account at that time (See figure 3).

Figure 4. Switch off current flowing.



Therefore, the scope waveform is providing an energy which is exceeding the one really dissipated at that time. See figure 5 for a typical scope waveform.

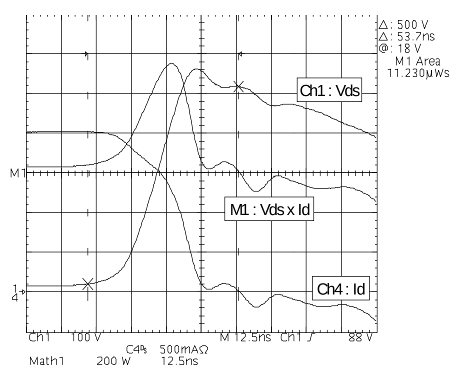
Figure 5. Switch off typical waveform.



In this case, it seems that an energy of about 8.9µJ is dissipated. But if we reconsider the correcting energy of figure 3, which also gives the energy accumulated in Coss, we find a term of about 9µJ for the VIPer50 at 500V. This means that the turn off of the mosfet switch is sufficiently fast to have most of the current charging its output capacitor, avoiding any dissipation in the channel.

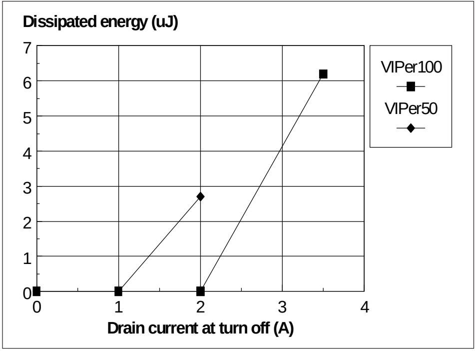
In the previous case, the drain current at switch off was about 400mA. When this current increases, the switch off is much faster and leads to real dissipation. Figure 6 gives an example with VIPer50 at 2A. The measured energy is about 11.2µJ, of which 2.2µJ are really dissipated. In this case, the pinch off of the channel is not sufficiently fast to avoid this dissipation.

Figure 6. Switch off typical waveform.



Therefore, a curve giving the real dissipation at switch off according to the drain current can be set. It can be seen in figure 7, where VIPer50 exhibits no switch off dissipation below 1A of drain current, and VIPer100 below 2A. These limits can be affected by the external circuit configuration, especially when a snubber is used. In that case, the switch off dissipation occurs for a higher value of drain current.

Figure 7. Switch off real dissipation.



The dissipated energy given in figure 7 is a rough estimation, and is convenient for a discontinuous flyback with a clamper on the drain of the device. Real measurements such as the ones shown in figure 5 or 6, corrected by the energy accumulated in Coss given by figure 3, will provide the most accurate values. It will also take into account all external parameters, like an eventual snubber, transformer parasitic capacitance, type of topology, avalanche energy, etc...

Conduction losses

These losses are due to the dissipation of the mosfet switch during its' on phase. Conventional formulas can be used to estimate this dissipation. The following one is suited for discontinuous flyback :

$$P_{COND} = R_{DSon} \bullet \frac{I_D^2}{3} \bullet d$$

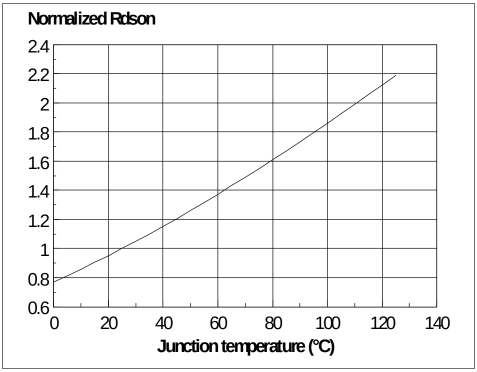
Where:

I_D is the peak drain current.

d is the duty cycle.

R_{DSon} is the on resistance of the mosfet switch. It can be found on the first page of this document, where a table gives for each device its' maximum value at 25°C. Values for higher or lower temperature can be computed by multiplying the 25°C value by the correcting coefficient in figure 8.

Figure 8. R_{DSon} correcting coefficient.



Internal PWM consumption

The internal PWM driver consumes some power from the Vdd pin. This power is generally provided by the auxiliary winding of the converter transformer, and is dissipated in the device. Because this dissipated power is the product of the voltage applied on the Vdd pin by the current consumed by the device, it depends on the type of feedback used for the regulation, and on the switching frequency.

When a secondary feedback is used, the Vdd voltage must be lower than 13V and higher than 8V. A typical value of 11V can be assumed. This value is set by the application, through the turns ratio of the transformer. For primary feedback, the regulation is done directly on the Vdd voltage, which is set to the fixed value of 13V.

The current consumed on the Vdd pin depends on both Vdd voltage and switching frequency. Figure 9 and 10 give directly the dissipated power according to the switching frequency and for both types of regulation.

Figure 9. PWM dissipated power for VIPer50.

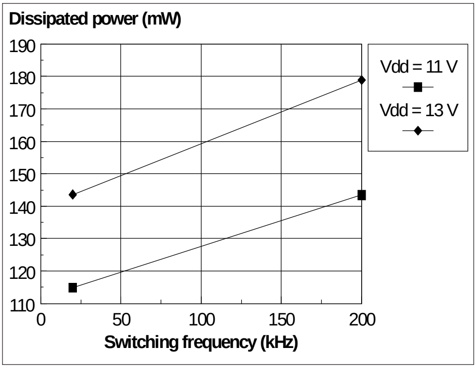
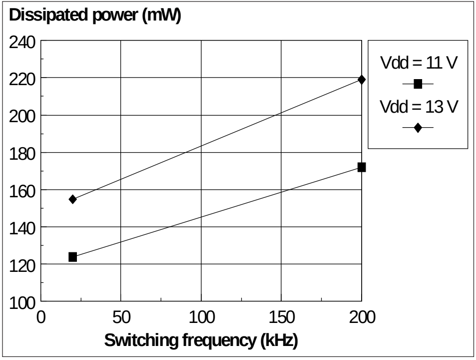


Figure 10. PWM dissipated power for VIPer100.



Start up current source biasing

Figure 11 shows the internal constitution of the start up current source. The start up of the device is insured by a high voltage mosfet delivering the start up current to the PWM and its' associated logic function. Once the converter is operating normally, this mosfet is turned off by the logic, but the biasing current remains, leading to a dissipation during the steady state operation.

This dissipation depends on the input voltage and is given in figure 12. It takes into account the rms voltage value on the drain during the normal operation of the converter, for the considered input DC voltage obtained after rectification from the mains lines.

Figure 11. Start up current source structure.

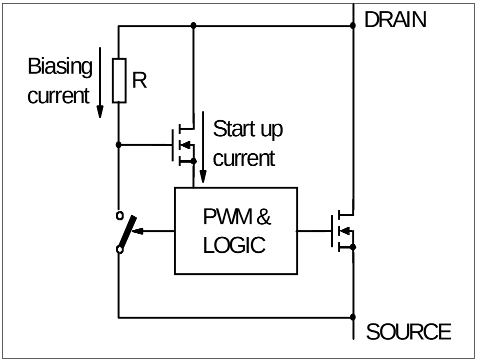
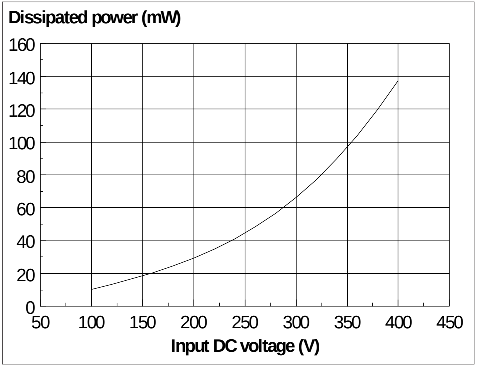


Figure 12. Biasing resistor dissipation.



Dissipated power summary

All the above contributions are summarised in table 2. They are split according to their origin, either from the device or from external components characteristics.

Table 2. Total Dissipation

	Due to Device	Due to exterrnal components
Switch on	Figure 3	Scope estimation Example: Figure 2 Note 1
Switch off	Figure 7 or scope estimation corrected by figure 3 Example: Figure 6	Note 2
Conduction	Figure 8	
PWM	Figures 9 and 10	
Biasing	Figure 12	
Total Dissipation	Sum of all internal and external contributions	

Note 1 : The transformer capacitance is the main characteristic. The corresponding energy E_T can be computed as :

$$E_T = \frac{1}{2} \bullet C_T \bullet V_{dsON}$$

C_T can be estimated by measurement, and then used for different switch on voltages. It can be assumed to be equal to the input voltage, but will differ in most cases because of the ringing of the transformer primary inductance. In any case, a scope estimation will give more accurate results. Nevertheless, the following practical examples and power capability estimations will use the above formula.

Note 2 : The curve of figure 7 is only a suggestion. The external arrangement (snubber, clamper, direct connection, transformer capacitance) can affect this result. Scope estimation is the best approach, when corrected by the accumulated energy in Coss (Figure 3). The following practical examples and power capability estimations will use the abacus of figure 7.

PRACTICAL EXAMPLES

The following paragraphs will give some practical uses of the elements previously described. Two typical situations are considered.

50W wide range flyback with VIPer100

A 100kHz switching frequency and a secondary feedback are chosen for this converter, with an input voltage between 85VAC and 264VAC. The transformer is designed in such a way that the duty cycle is 50% at the minimum input voltage, with a transition mode operation (Limit between continuous and discontinuous). The primary capacitance of this transformer is assumed to be 30pF, and the total efficiency of the converter 80%. The junction temperature will not exceed 100°C.

* Switch on losses : They are computed by adding the energy due the transformer capacitance to the one of figure 3, assuming that the drain voltage is equal to the input voltage at switch on:

- Low input voltage : 0.2 + 1 = 1.2mJ
- High input voltage : 2.1 + 6.7 = 8.8mJ

With the switching frequency of 100kHz, this gives respectively 120mW and 880mW of dissipation at switch on.

* Switch off losses : The peak primary current is computed from the following formula :

$$P_{out} = \xi \bullet \frac{I_D \bullet V_{IN}}{2} \bullet d$$ where:

P_{OUT} is the output power (50W)

ξ is the assumed efficiency (0.8)

V_{IN} is the DC input voltage (120V)

d is the duty cycle (0.5)

It comes out a peak primary current of 2.1A. According to figure 7, no switch off losses are considered.

* Conduction losses : The duty cycle is inversely proportional to the input voltage, and the peak primary current is constant. It has been computed previously. The maximum Rdson at a junction temperature of 100°C is :

1.9 (Figure 8) x 2.5 (Max, 25°C) = 4.7W

- Low input voltage: 3.5W
- High input voltage: 1.1W

* PWM dissipation : 150mW from figure 10.

* Biasing resistor dissipation from figure 12 :

- Low input voltage: 15mW
- High input voltage: 130mW

Finally, the above partial results are summed together in table 3 to find the total dissipation of the device.

Table 3. Total Dissipation

	85VAC	264VAC
On Losses	0.12	0.88
Off Losses	0	0
Cond. Losses	3.5	1.1
PWM Losses	0.15	0.15
Bias Losses	0.015	0.13
Total Dissipation	3.8W	2.3W

10W wide range flyback with VIPer50

A 70kHz switching frequency and a primary feedback are chosen for this converter, with an input voltage comprised between 85VAC and 264VAC. The transformer is designed in such a way that the duty cycle is 60% at the minimum input voltage, with a transition mode operation (Limit between continuous and discontinuous). The primary capacitance of this transformer is assumed to be 50pF, and the total efficiency of the converter 80%. The junction temperature will not exceed 80°C.

* Switch on losses :

- Low input voltage : 0.36 + 1 = 1.4mJ
- High input voltage : 3.5 + 6.7 = 10.2mJ

With the switching frequency of 70kHz, this gives respectively 100mW and 710mW of dissipation at switch on.

* Switch off losses : It comes out a peak primary current of 0.35A. No switch off losses are considered.

* Conduction losses :

The Rdson is 1.6 x 5 = 8W

- Low input voltage : 200mW
- High input voltage : 60mW

* PWM dissipation : 160mW

* Biasing resistor dissipation :

- Low input voltage : 15mW
- High input voltage : 130mW

Table 4. Total Dissipation

	85VAC	264VAC
On Losses	0.1	0.71
Off Losses	0	0
Cond. Losses	0.2	0.06
PWM Losses	0.16	0.16
Bias Losses	0.015	0.13
Total Dissipation	0.5W	1.1W

DISCONTINUOUS FLYBACK POWER CAPABILITY

It is also possible to use the above power dissipation estimation tools to compute the maximum output power capability versus the heatsink thermal resistance. The following two paragraphs discuss the results of these power limits for both the VIPer50 and VIPer100 devices. They share the same hypothetical values :

* Converter topology : Discontinuous flyback

* Converter efficiency : 80%

* Switching frequency : 100kHz

* Transformer capacitance : 30pF

* Reflected voltage : 125V

* Primary feedback

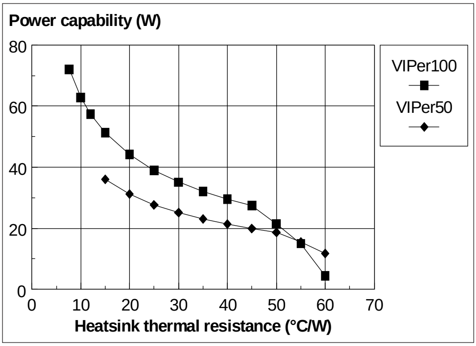
* Ambient temperature : 60°C

* Junction temperature : 130°C

Wide range operation

The input voltage ranges from 85VAC to 264VAC. Figure 13 gives the corresponding output power limit versus heatsink thermal resistance. Note that these curves are bounded for high powers by the internal current capability of the devices (See table 1 on page 1), and for low power, by the minimum free air dissipation capability of the TO220 package (About 60°C/W).

Figure 13. Wide range output power capability.

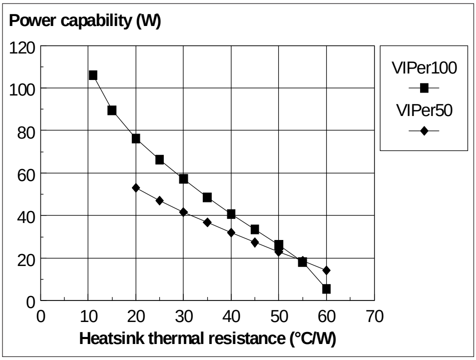


Maximum output power capabilities are 72W for the VIPer100 device with a 7.6°C/W heatsink, and 36W for the VIPer50 device with a 15°C/W heatsink.

Single range operation

The input voltage is varying now from 207VAC to 264VAC. Figure 14 presents the results, and the same comments as for the wide range operation still apply.

Figure 14. Single range output power capability



Maximum output power capabilities are 106W for the VIPer100 device with a 11°C/W heatsink, and 53W for the VIPer50 device with a 20°C/W heatsink.

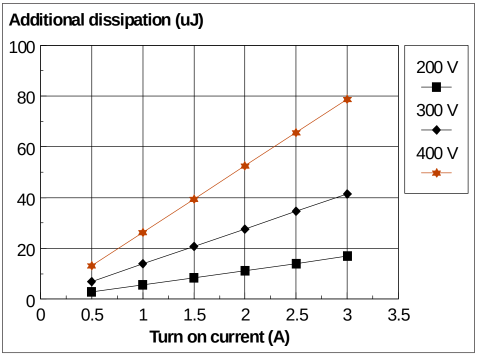
A common feature appears on the curves of figures 13 and 14 : For high thermal resistance heatsink or free air temperature, VIPer50 always has a higher power capability than VIPer100. This is due to the low power level considered in such a configuration (Less than 20W), where VIPer100 has higher switching losses than VIPer50, which are not compensated for by the lower conduction losses. For low power applications, VIPer50 is always preferable.

CONTINUOUS FLYBACK POWER CAPABILITY

These devices are also usable in continuous mode. The same method as previously described is used for the power dissipation estimation, except for switch on where the transformer capacitance is no longer sufficient. The real dissipation must be measured and depends also on the leakage inductance of the transformer, and on the recovery charge of the secondary rectifying diode.

Figure 15 gives the additional dissipation versus switch on drain voltage and current for the VIPer100. These curves have been measured with a particular transformer and output diode.The user has to measure its' own configuration by using the method described in figure 2. The correcting energy of figure 3 is still to be added to get the total switch on dissipated energy.

Figure 15. Continuous additional losses.



The same output power limit computation can be made for the VIPer100 working in continuous mode. Figure 16 displays this result. The hypothetical values are as follows :

* Converter topology : Continuous flyback

* Converter efficiency : 80%

* Switching frequency : 70kHz

* Transformer capacitance : 30pF

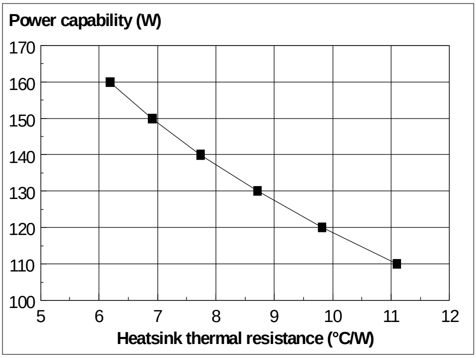
* Reflected voltage : 125V

* Primary feedback

* Ambient temperature : 60°C

* Junction temperature : 130°C

Figure 16. Single range output power capability.



Maximum output power capability is 160W for the VIPer100 device with a 6.2°C/W heatsink. This power is not limited by the internal current limitation of the device as in figures 13 and 14, but by the size of a reasonable heatsink. Larger output power can be achieved if a forced air flow is used, or a lower ambient temperature is experienced. In any case, no risk of destruction exists thanks to the thermal protection of the device.

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