DISCRETE SEMICONDUCTORS

APPLICATION NOTE

ZenBlock™

Zener with integrated blocking diode

Philips Semiconductors' new ZenBlock™ replaces double-diode-, RCD- or RC-snubbers in flyback convertors. The new components offer circuit designers the important benefits of lower component count and board usage, reduced EMI, optimal clamping at all loads and higher efficiency.

Clamping networks in flyback convertors

The leakage inductance of the transformer in a flyback convertor causes voltage spikes when the MOSFET is turned off. These voltages must be clamped to keep the drain voltage below the minimum breakdown voltage ($V_{(BR)DSS}$). Figure 1 shows a typical flyback convertor circuit together with three main clamping circuits. The flyback convertor is built around an off-line PWM controller with integrated MOSFET.

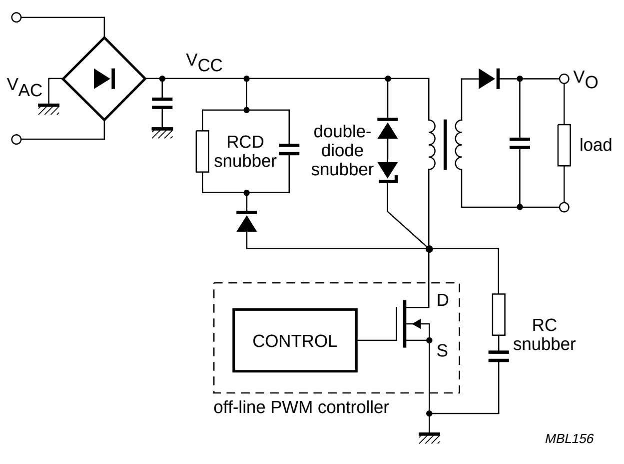

Fig. 1 Typical flyback convertor with drain clamping circuits

Both RC- and RCD-snubbers have a clamping voltage that depends on the load current and are designed for protecting the MOSFET at maximum load. The clamp voltage of the double diode is almost independent of the load current and its value can be chosen closer to $V_{(BR)DSS}$ over the whole load range. This improves the efficiency of the convertor at loads below the maximum. Figure 2 compares the clamp performance of a double-diode snubber with that of an RCD snubber.

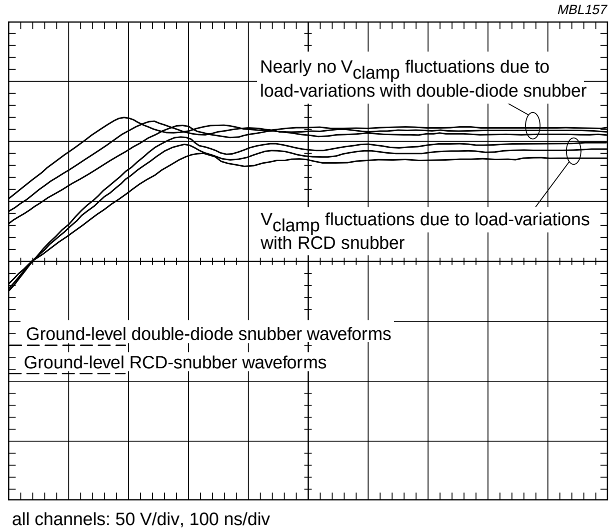

Fig.2 MOSFET drain voltage in a 90 V DC input, 3.5 W output flyback convertor at 75%, 100% and 125% load. RCD-snubber: 47 kΩ, 2.2 nF and 600 V diode. Double-diode snubber: 160 V zener and 600 V diode

Introducing the ZenBlock

The new ZenBlock combines the double diode snubber in one package. This leads to the following advantages:

- Fewer components.
- Reduced circuit board space
- Lower EMI by reducing the drain clamp circuit length and area.
- Optimal clamp performance at all loads (compared with RCD and RC snubber)
- Higher efficiency at low loads (compared with RCD and RC snubber)

For the optimal choice of ZenBlock within a given flyback convertor design the following parameters have to be determined:
- Zener voltage
- Blocking voltage
- Power rating

Operation of flyback convertor with ZenBlock (continuous mode)

The 50/60 Hz input voltage V_{AC} from Fig.1 is rectified by a bridge and a capacitor to a high DC voltage V_{CC}. The V_{CC} is connected through the primary transformer inductance L_p and the internal MOSFET to ground.

When the MOSFET is turned on, the primary current I_d rises from zero to a peak value I_p with a slope equal to V_{CC}/L_P, see Fig.3(a).

When the MOSFET is turned off, the current keeps running because of the transformer leakage inductance. The drain voltage rises to a value of:

$$V_{DS} = V_{CLM} + V_{CC} + V_{FR} \quad (1)$$

where V_{CLM} is the clamp voltage of the ZenBlock zener and V_{FR} the forward recovery voltage of the ZenBlock blocking diode (Fig.3(b)).

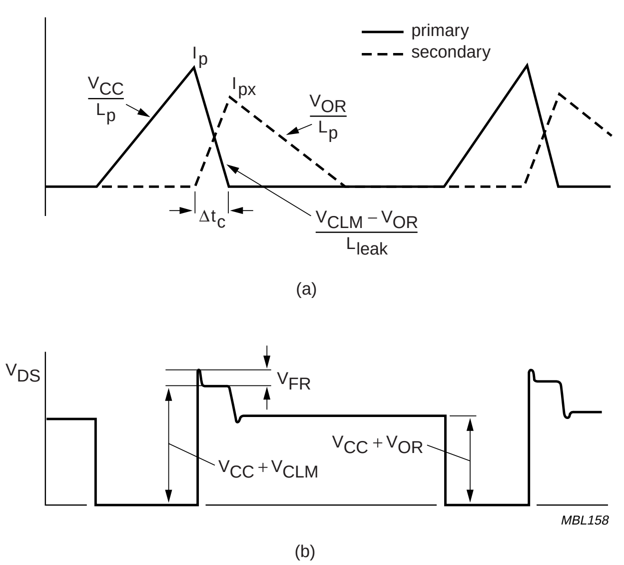

Fig.3 MOSFET switching characteristics with ZenBlock (a) Primary and secondary current (b) Drain-source voltage

After forward recovery, the drain voltage drops to $V_{CLM} + V_{CC}$. The primary current now decreases to zero with a slope equal to $(V_{CLM} - V_{OR})/L_{leak}$, where V_{OR} is the reflected output voltage given by:

$$V_{OR} = N(V_{FS} + V_O)$$

Here V_{FS} is the forward voltage of the secondary diode, V_O the output voltage of the flyback convertor and N the transformer turns ratio.

The time in which the transformer primary current drops from its peak value to zero is called the commutation time:

$$\Delta t_c = I_p L_{leak}/(V_{CLM} - V_{OR})$$

In this time the secondary current starts running and reaches a peak value of $I_{px} = I_p(1 - (L_{leak}/L_P)/(V_{CLM}/V_{OR}-1))$. For optimal convertor efficiency, I_{px} must be as high as possible which means V_{CLM} must also be as high as possible. The transformer secondary current drops to zero with a slope equal to V_{OR}/L_p. The MOSFET switches with a typical frequency f_s of 50 to 100 kHz and a duty factor of 20 to 50%.

ZenBlock design parameters

Zener voltage

The maximum drain voltage given by (1) must be lower than the minimum breakdown voltage:

$$V_{DSmax} = \sqrt{2}V_{AC\,max} + V_{CLM} + V_{FR} < V_{(BR)DSS}$$

V_{CLM} is usually taken as 1.4 times the nominal zener voltage and a maximum value for V_{FR} is 20 V. For high efficiency, V_z has to be as high a possible. When a zener has been selected, measurements have to be carried out upon the final board to confirm the safety of the drain level.

Blocking voltage

The blocking voltage has to be larger than $\sqrt{2}V_{AC\,max}$. For a 100/115 V AC input, a blocking diode of 400 V is sufficient and for a universal or a 230 V AC input, a 600 V blocking diode can be used

Table 1 gives an overview of the ZenBlock family and the available voltages. The BZD142W and BZG142 ZenBlock diodes are housed in a surface mount package. The other ZenBlock diodes (indicated by *) are leaded and will be released for supply according to market demand.

TABLE 1
ZenBlock™ zener voltage range and blocking voltage

Type	V_z (V) range	V_{BR} (V)	Package
BZD142W	50-200	700	SOD87 - surface mount
BZG142	50-300	700, 1000	SMA (SOD124) - surface mount
BZD142*	50-200	700	SOD81 - leaded
BZT142*	50-200	700	SOD57 - leaded
BZW142*	50-200	700	SOD64 - leaded
BZZ142*	50-300	700, 1000	SOD89 - leaded

Power-rating

The energy that the ZenBlock has to absorb depends on the output power of the flyback convertor, its efficiency and the leakage inductance of the transformer. The power stored in the transformer is converted to the output power P_O, which can be written as:

$$P_O = \tfrac{1}{2} L_P I_P^2 f_s \eta \qquad (2)$$

where η is the efficiency of the flyback convertor (assuming no loss in the bridge and MOSFET). The ZenBlock has to absorb the energy stored in the leakage inductance equal to:

$$P_{ZenBlock} = \tfrac{1}{2} L_{leak} I_P^2 f_s$$

From equation 2 this can be expressed as:

$$P_{ZenBlock} = P_O/\eta \,.\, L_{leak}/L_P \qquad (3)$$

With equation 3 and the maximum ZenBlock power, the maximum output power of the flyback convertor can be calculated. The maximum power that the ZenBlock can dissipate depends strongly on its mounting conditions. The method of calculating the maximum power dissipation can be found in the data handbook SC11 1999 page 57 or by visiting our www site on: http://www-eu3.semiconductors.com/handbook/various_41.html under thermal considerations.

Table 2 shows the maximum ZenBlock power and the maximum output power of the flyback convertor under specified mounting conditions.

TABLE 2
Power-ratings of ZenBlock and flyback convertor

Type	Package	*ZenBlock* power max	Flyback power max	Leads	A_{Cu}
		(W)	(W)	(mm)	(cm^2)
BZD142W	SOD87	0.5	20	X	0.4
BZG142	SMA (SOD124)	0.5	20	X	0.4
BZD142	SOD81	0.9	35	5	1.0
BZT142	SOD57	1.1	50	5	2.0
BZW142	SOD64	1.9	75	5	4.5[1)]
BZZ142	SOD89[3)]	2.8	110	5	9.0[2)]

[1)] $R_{th\ tp-a}$ = 32 K/W [2)] $R_{th\ tp-a}$ = 21 K/W
[3)] $R_{th\ j-p}$ = 5 K/W, $R_{th\ p-a}$ = 417K/W and $R_{th\ p-tp}$ = 12 K/W

The table has been constructed assuming a flyback convertor efficiency of 0.8 (without bridge and MOSFET losses), an L_{leak}/L_p value of 0.02, a maximum ambient temperature of 50 °C (inside application), a maximum tiepoint temperature of 110 °C and a copper laminate thickness of 40 µm. A_{Cu} is the copper area at each tiepoint. The maximum junction temperature is 175 °C for the BZG142 and the BZZ142 and 150 °C for the other types.

Measurements have to be carried out on the final board to confirm a safe tiepoint and junction temperature.

Application of ZenBlock with off-line PWM controllers

The ZenBlock can be used in combination with off-line PWM controllers. Table 3 gives an overview of some combinations based on the power ratings of Table 2.

TABLE 3
ZenBlock off-line PWM controller combinations

Off-line controller	Max flyback power @ 90 – 285 V (W)	ZenBlock type
TEA1401T	20	BZD142W or BZG142
TEA1501	3	
TEA1562-63	12-20	
TNY253-256	4-19	
TOP209-210	2-5	
TOP200-201	12-20	
TOP221-222Y	7-15	
TOP221-224P/G	6-20	
VIPer20	20	
MC33369-33370	12-20	
TEA1563	24	BZD142
TOP201-203	22-35	
TOP223Y	30	
MC33370-33371	25-35	
TEA1564	50	BZT142
TOP214	42	
TOP204	50	
TOP224Y	45	
VIPer50	50	
MC33371	45	
TEA1564-1565	60-75	BZW142
TOP225-226	60-75	
MC33372-33373	60-75	
TEA1565-66	80-100	BZZ142
TOP227Y	90	
VIPer100	100	
MC33374	90	

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