Crop here for Mid-Atlantic paper size

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.

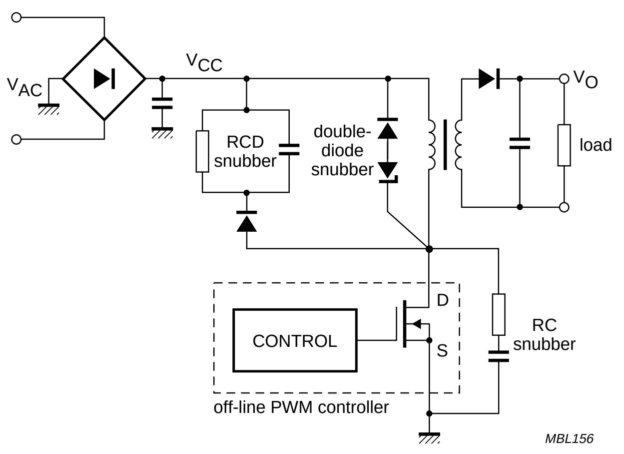

Fig. 1 Typical flyback convertor with drain clamping circuits

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.

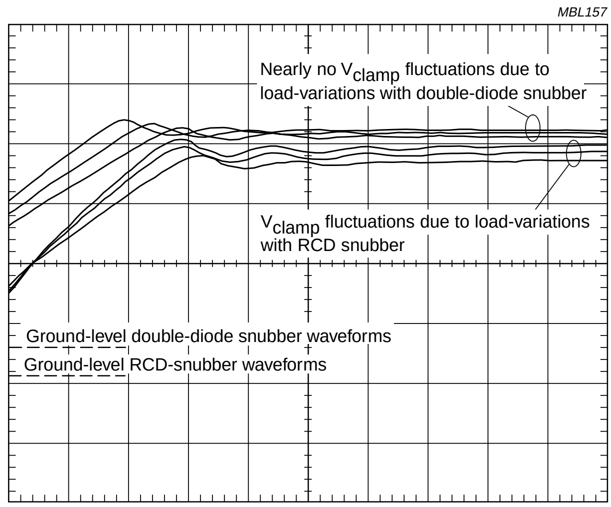

Fig.2 MOSFET drain voltage in a 90 V DC input, 3.5 W output flyback convertor at 75%, 100% and 125% load. RCD-snubber: 47 kΩ, 2.2 nF and 600 V diode. Double-diode snubber: 160 V zener and 600 V diode

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)).

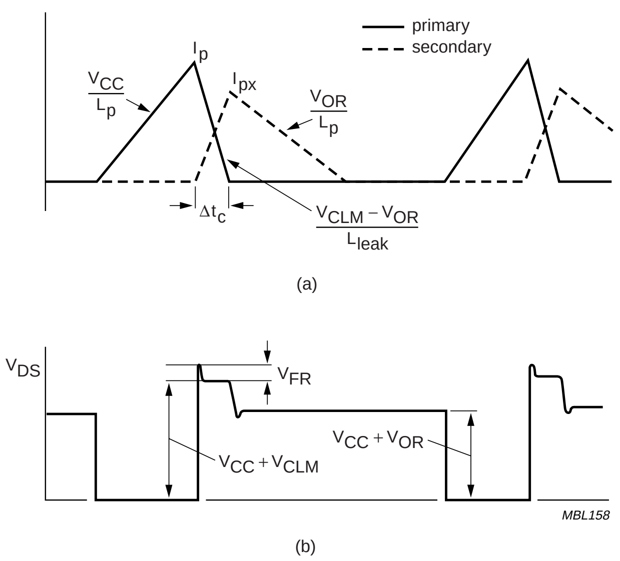

Fig.3 MOSFET switching characteristics with ZenBlock (a) Primary and secondary current (b) Drain-source voltage

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:

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

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

Philips Semiconductors – a worldwide company

Argentina: see South America

Australia: 3 Figtree Drive, HOMEBUSH, NSW 2140,
Tel. +61 2 9704 8141, Fax. +61 2 9704 8139

Austria: Computerstr. 6, A-1101 WIEN, P.O. Box 213,
Tel. +43 1 60 101 1248, Fax. +43 1 60 101 1210

Belarus: Hotel Minsk Business Center, Bld. 3, r. 1211, Volodarski Str. 6,
220050 MINSK, Tel. +375 172 20 0733, Fax. +375 172 20 0773

Belgium: see The Netherlands

Brazil: see South America

Bulgaria: Philips Bulgaria Ltd., Energoproject, 15th floor,
51 James Bourchier Blvd., 1407 SOFIA,
Tel. +359 2 68 9211, Fax. +359 2 68 9102

Canada: PHILIPS SEMICONDUCTORS/COMPONENTS,
Tel. +1 800 234 7381, Fax. +1 800 943 0087

China/Hong Kong: 501 Hong Kong Industrial Technology Centre,
72 Tat Chee Avenue, Kowloon Tong, HONG KONG,
Tel. +852 2319 7888, Fax. +852 2319 7700

Colombia: see South America

Czech Republic: see Austria

Denmark: Sydhavnsgade 23, 1780 COPENHAGEN V,
Tel. +45 33 29 3333, Fax. +45 33 29 3905

Finland: Sinikalliontie 3, FIN-02630 ESPOO,
Tel. +358 9 615 800, Fax. +358 9 6158 0920

France: 51 Rue Carnot, BP317, 92156 SURESNES Cedex,
Tel. +33 1 4099 6161, Fax. +33 1 4099 6427

Germany: Hammerbrookstraße 69, D-20097 HAMBURG,
Tel. +49 40 2353 60, Fax. +49 40 2353 6300

Hungary: see Austria

India: Philips INDIA Ltd, Band Box Building, 2nd floor,
254-D, Dr. Annie Besant Road, Worli, MUMBAI 400 025,
Tel. +91 22 493 8541, Fax. +91 22 493 0966

Indonesia: PT Philips Development Corporation, Semiconductors Division,
Gedung Philips, Jl. Buncit Raya Kav.99-100, JAKARTA 12510,
Tel. +62 21 794 0040 ext. 2501, Fax. +62 21 794 0080

Ireland: Newstead, Clonskeagh, DUBLIN 14,
Tel. +353 1 7640 000, Fax. +353 1 7640 200

Israel: RAPAC Electronics, 7 Kehilat Saloniki St, PO Box 18053,
TEL AVIV 61180, Tel. +972 3 645 0444, Fax. +972 3 649 1007

Italy: PHILIPS SEMICONDUCTORS, Via Casati, 23 - 20052 MONZA (MI),
Tel. +39 039 203 6838, Fax +39 039 203 6800

Japan: Philips Bldg 13-37, Kohnan 2-chome, Minato-ku,
TOKYO 108-8507, Tel. +81 3 3740 5130, Fax. +81 3 3740 5057

Korea: Philips House, 260-199 Itaewon-dong, Yongsan-ku, SEOUL,
Tel. +82 2 709 1412, Fax. +82 2 709 1415

Malaysia: No. 76 Jalan Universiti, 46200 PETALING JAYA, SELANGOR,
Tel. +60 3 750 5214, Fax. +60 3 757 4880

Mexico: 5900 Gateway East, Suite 200, EL PASO, TEXAS 79905,
Tel. +9-5 800 234 7381, Fax +9-5 800 943 0087

Middle East: see Italy

Netherlands: Postbus 90050, 5600 PB EINDHOVEN, Bldg. VB,
Tel. +31 40 27 82785, Fax. +31 40 27 88399

New Zealand: 2 Wagener Place, C.P.O. Box 1041, AUCKLAND,
Tel. +64 9 849 4160, Fax. +64 9 849 7811

Norway: Box 1, Manglerud 0612, OSLO,
Tel. +47 22 74 8000, Fax. +47 22 74 8341

Pakistan: see Singapore

Philippines: Philips Semiconductors Philippines Inc.,
106 Valero St. Salcedo Village, P.O. Box 2108 MCC, MAKATI,
Metro MANILA, Tel. +63 2 816 6380, Fax. +63 2 817 3474

Poland: Al.Jerozolimskie 195 B, 02-222 WARSAW,
Tel. +48 22 5710 000, Fax. +48 22 5710 001

Portugal: see Spain

Romania: see Italy

Russia: Philips Russia, Ul. Usatcheva 35A, 119048 MOSCOW,
Tel. +7 095 755 6918, Fax. +7 095 755 6919

Singapore: Lorong 1, Toa Payoh, SINGAPORE 319762,
Tel. +65 350 2538, Fax. +65 251 6500

Slovakia: see Austria

Slovenia: see Italy

South Africa: S.A. PHILIPS Pty Ltd., 195-215 Main Road Martindale,
2092 JOHANNESBURG, P.O. Box 58088 Newville 2114,
Tel. +27 11 471 5401, Fax. +27 11 471 5398

South America: Al. Vicente Pinzon, 173, 6th floor,
04547-130 SÃO PAULO, SP, Brazil,
Tel. +55 11 821 2333, Fax. +55 11 821 2382

Spain: Balmes 22, 08007 BARCELONA,
Tel. +34 93 301 6312, Fax. +34 93 301 4107

Sweden: Kottbygatan 7, Akalla, S-16485 STOCKHOLM,
Tel. +46 8 5985 2000, Fax. +46 8 5985 2745

Switzerland: Allmendstrasse 140, CH-8027 ZÜRICH,
Tel. +41 1 488 2741 Fax. +41 1 488 3263

Taiwan: Philips Semiconductors, 6F, No. 96, Chien Kuo N. Rd., Sec. 1,
TAIPEI, Taiwan Tel. +886 2 2134 2886, Fax. +886 2 2134 2874

Thailand: PHILIPS ELECTRONICS (THAILAND) Ltd.,
209/2 Sanpavuth-Bangna Road Prakanong, BANGKOK 10260,
Tel. +66 2 745 4090, Fax. +66 2 398 0793

Turkey: Yukari Dudullu, Org. San. Blg., 2.Cad. Nr. 28 81260 Umraniye,
ISTANBUL, Tel. +90 216 522 1500, Fax. +90 216 522 1813

Ukraine: PHILIPS UKRAINE, 4 Patrice Lumumba str., Building B, Floor 7,
252042 KIEV, Tel. +380 44 264 2776, Fax. +380 44 268 0461

United Kingdom: Philips Semiconductors Ltd., 276 Bath Road, Hayes,
MIDDLESEX UB3 5BX, Tel. +44 208 730 5000, Fax. +44 208 754 8421

United States: 811 East Arques Avenue, SUNNYVALE, CA 94088-3409,
Tel. +1 800 234 7381, Fax. +1 800 943 0087

Uruguay: see South America

Vietnam: see Singapore

Yugoslavia: PHILIPS, Trg N. Pasica 5/v, 11000 BEOGRAD,
Tel. +381 11 3341 299, Fax.+381 11 3342 553

For all other countries apply to: Philips Semiconductors,
International Marketing & Sales Communications, Building BE-p, P.O. Box 218,
5600 MD EINDHOVEN, The Netherlands, Fax. +31 40 27 24825

Internet: http://www.semiconductors.philips.com

Printed in The Netherlands

Date of release: March 2000

Document order number: 9397 750 06903