

## Isolated DC/DC Converters ICs

# Built-in Automotive Switching MOSFET Isolated Flyback Converter ICs BD7F105EFJ-C Evaluation Board

### BD7F105EFJ-EVK-001

#### Overview

This evaluation board outputs an isolated 16.5 V voltage from an input of 8 V to 32 V, and can output a maximum output current of 0.25 A.

BD7F105EFJ-C is an isolated flyback converter that does not require a photocoupler.

Feedback circuit by the transformer's tertiary winding or photocouplers becomes unnecessary, contributing to reduction of set parts.

It also has a number of built-in protection functions that enable the design of isolated power supply applications for high reliability.

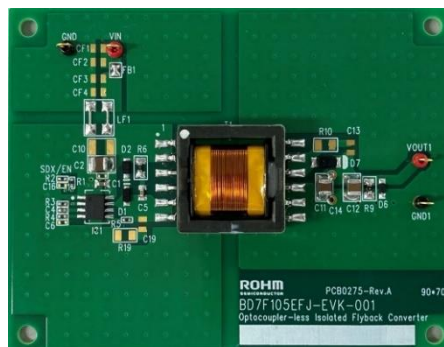


Figure 1. BD7F105EFJ-EVK-001

#### Performance Specifications

This is a typical value and does not guarantee the characteristics.

Unless otherwise specified,  $V_{IN} = 12\text{ V}$ ,  $I_{OUT} = 0.2\text{ A}$ ,  $T_a = 25\text{ }^\circ\text{C}$

Parameter	Symbol	Min	Typ	Max	Units	Conditions
Input voltage range	$V_{IN}$	8	12	32	V	
Output voltage	$V_{OUT}$	14.8	16.5	18.2	V	
Output current	$I_{OUT}$	0		0.25	A	
Maximum output power	$P_{OUT}$	-	-	4	W	
Standby power	$P_{INSTBY}$	-	40	100	mW	$I_{OUT} = 0\text{ A}$ $V_{IN} = 12\text{ V}$
Power Supply Efficiency	$\eta$	65	80	-	%	$P_{OUT} = 2\text{ W}$

## Operating Procedure

### 1. Necessary equipment

- (1) DC power supply with an output voltage of 32 V or more and an output power of 10 W / 5 A or more
- (2) Load device of 5 W or more
- (3) DC voltmeter

### 2. Connecting the Equipment

- (1) Preset the DC power supply to 8 V to 32 V and turn off the power output.  
For power supplies with slow response, connect a large capacitor to the output of the power supply.
- (2) Set the load to less than or equal to the rated current of each output and disable the load.
- (3) Connect the positive terminal of the power supply to the VIN terminal and the negative terminal to the GND terminal with a pair of wires.
- (4) Connect the positive terminal of the load to VOUT1 terminal and the negative terminal to GND1 terminal with a pair of wires.
- (5) When connecting a wattmeter, connect as shown below. (Refer to your power meter User's Manual for more information)
- (6) Connect the positive terminal of the DC voltmeter to VOUT1 terminal and the negative terminal to GND1 terminal for measuring the output voltage.
- (7) Turn on the output of the DC power supply.
- (8) Check that the DC voltmeter display is at the set voltage (16.5 V).
- (9) Activates the load.

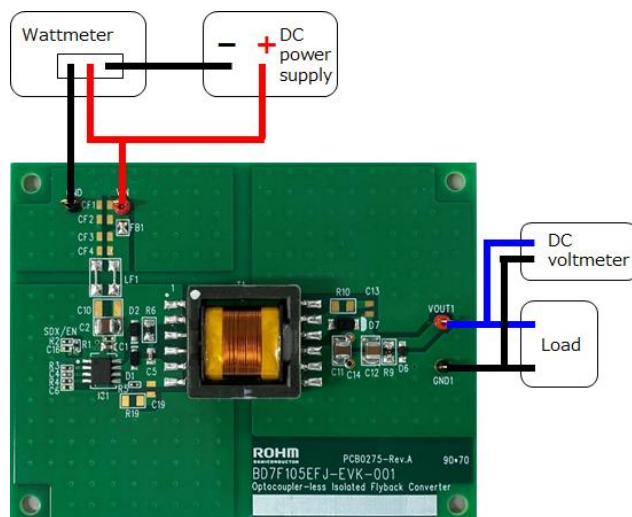


Figure 2. Connection Diagram

### Application circuit

The evaluation board operates with an average frequency 363 kHz.

Monitoring the flyback voltage due to the voltage at the output (16.5 V) provides primary-side feedback control that eliminates the need for photocouplers and auxiliary windings.

Operation starts when the VIN pin voltage exceeds UVLO detect voltage of 3.4 V (Typ) and SDXEN pin Enable pin voltage of 2.0 V (Typ).

The circuit diagram of the demonstration board is shown in the figure below, and the parts list is shown on page 9.

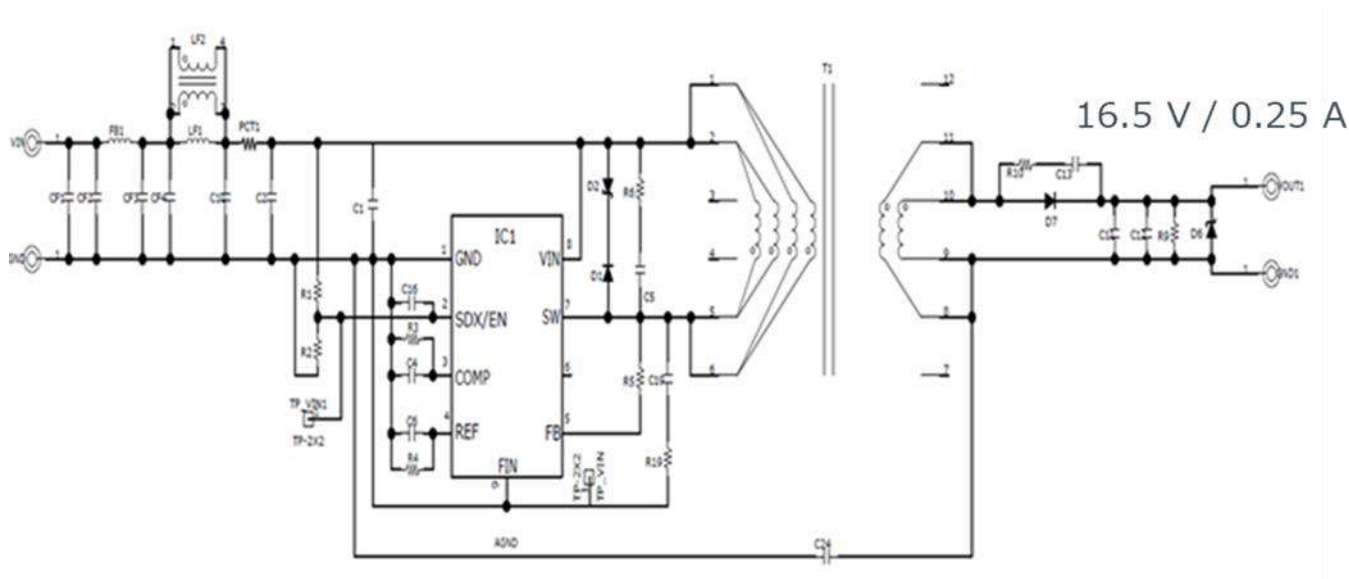


Figure 3. Circuit diagram

## Outline of BD7F105EFJ-C

### Features

- AEC-Q100 (Grade-1)
- No Need for Optocoupler and Third Winding of Transformer
- Output voltage is set by two external resistors and transformer winding ratio.
- Uses proprietary adaptive ON-time control technology
- Highly efficient light load mode (PFM operation)
- Shutdown and Enable control
- Burst voltage design possible
- 60 Built-in V-switching MOSFET
- Spread frequency spectrum
- Soft start function
- Load current compensation function
- Various protection functions
  - Undervoltage protection (UVLO)
  - Overcurrent protection (OCP)
  - Overheat protection (TSD)
  - REF pin open protection (REFOPEN)
  - Short-circuit protection (SCP)
  - Battery short-circuit protection (BSP)

### Critical Characteristics

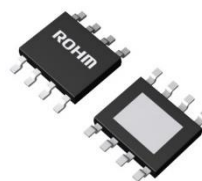
- Input voltage range :
 

VIN terminal	3.4 V to 42.0 V
SW pin	to 60 V
- Switching frequency : 363 kHz (Typ)
- Reference voltage accuracy:  $\pm 2.8\%$  (Typ)
- Shutdown current 0  $\mu$ A (Typ)
- Operating temperature range -40 °C to +125 °C

### Package W (Typ) x D (Typ) x H (Max)

HTSOP-J8

4.9 mm x 6.0 mm x 1.0 mm



### Applications

Insulated power supply for automotive use (E-Comp, Inverter etc)

Insulated power supply for industrial equipment

### Pin Layout

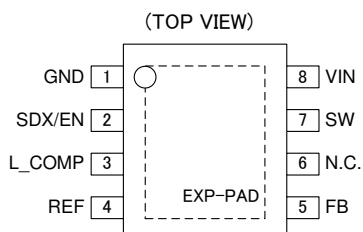


Figure 4. Pin layout drawing

### PIN ASSIGNMENT

No.	Pin name	Function
1	GND	GND terminal
2	SDX/EN	Shutdown/Enable control pin
3	L_COMP	Load current compensation value setting pin
4	REF	Output voltage setting pin
5	FB	Output voltage setting pin
6	N.C.	No Connect
7	SW	Switching output pin
8	VIN	Power input terminal
-	EXP-PAD	Rear heat dissipation pin

Measurement data

1. Load regulation

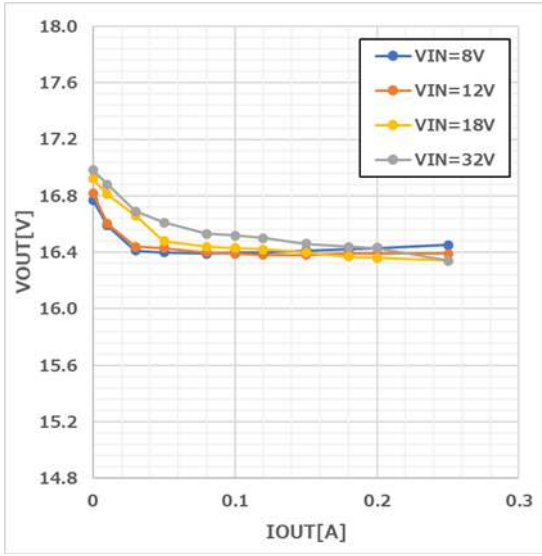


Figure 5. Output Voltage vs Output Current

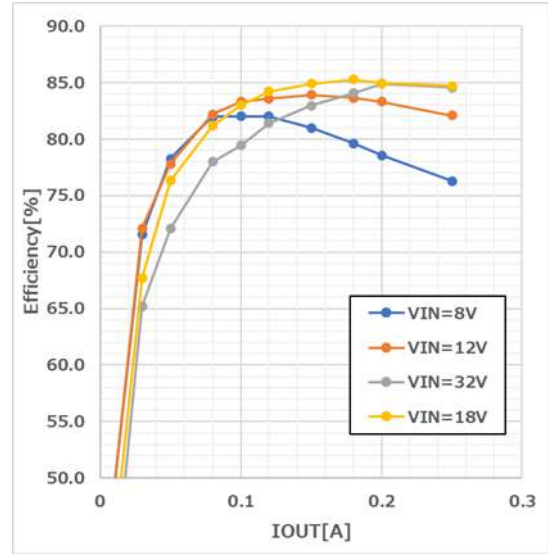


Figure 6 Efficiency vs Output Current

2. Line regulation

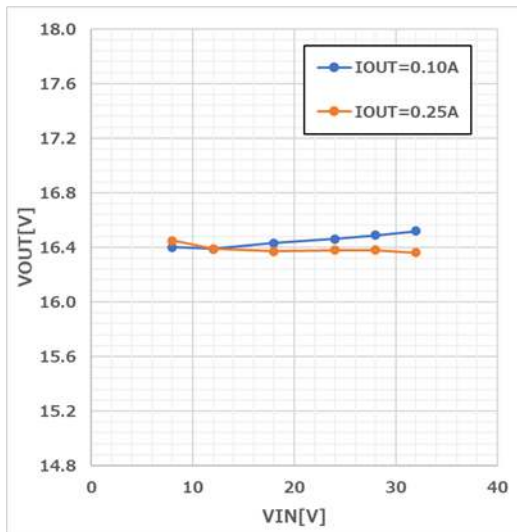


Figure 7. Output Voltage vs Input Voltage

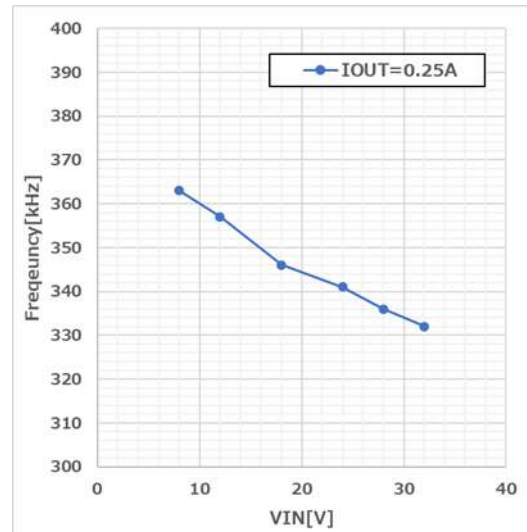
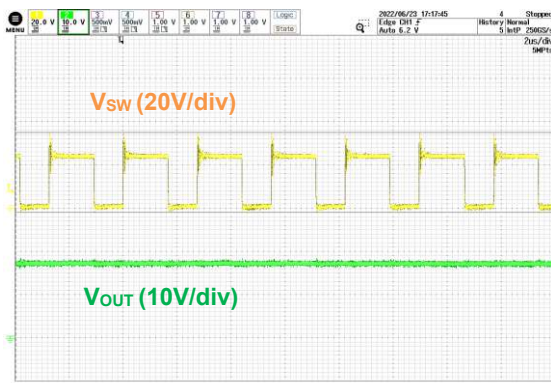


Figure 8. Frequency vs Input Voltage

Measured data-continued

3. Switching waveform



P-PC1) 37.0 V

Figure 9. MOSFET Waveform

Vin = 12 V, IO = 0.1 A

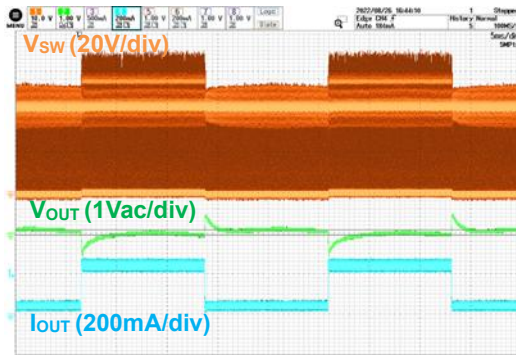


P-PC1) 41.0 V

Figure 10. MOSFET Waveform

Vin = 12 V, IO = 0.2 A

4. Load response waveform



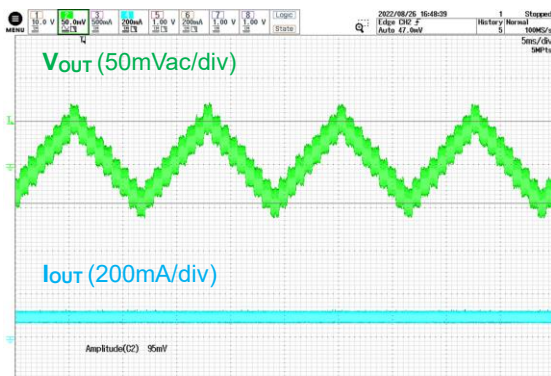
P-PC1) 37.4 V Freq(C1) 354.6099kHz Amplitude(C2) 0.13 V

Figure 11. Load response

Vin = 12 V, IO = 50 mA to 200 mA

5. Output voltage ripple waveform

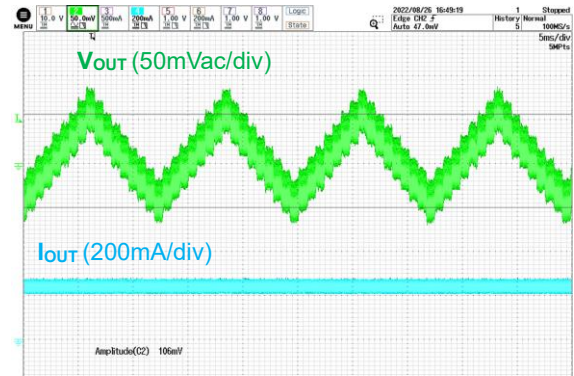
\*This ripple is due to spread spectrum.



Ampitude(C2) 95mV

Figure 12. Output Voltage ripple

VIN = 12 V / IO = 250 mA



Ampitude(C2) 106mV

Figure 13. Output Voltage ripple

VIN = 12 V / IO = 250 mA

Measured data-continued

6. Startup/stop waveform

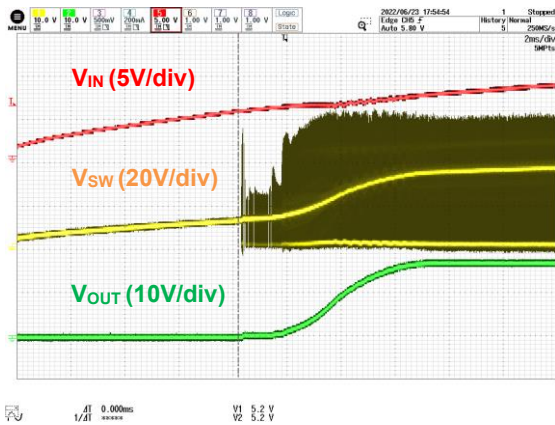


Figure 14. Start Up Waveform



Figure 15. Shut Down Waveform

7. Output short waveform

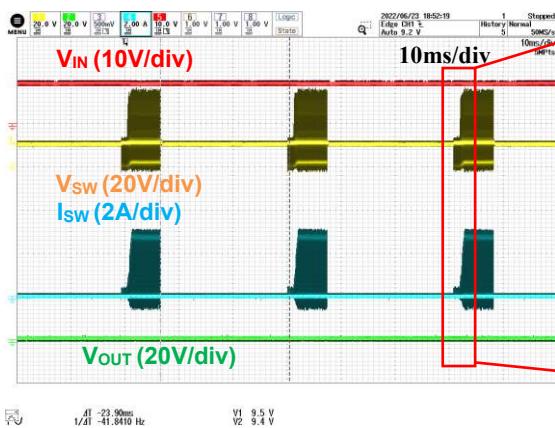


Figure 16. VOUT Short Waveform  
Vin = 8 V

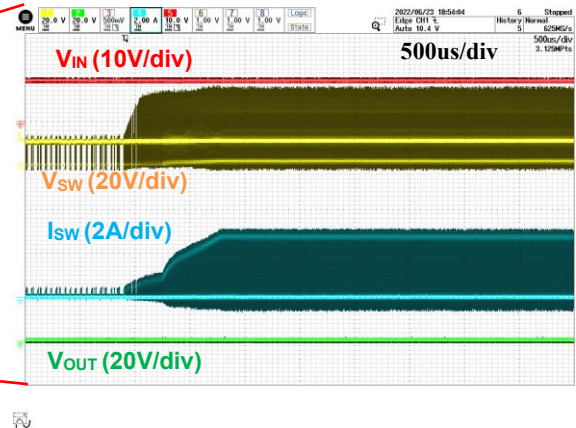


Figure 17. VOUT Short Waveform (ZOOM)  
Vin = 8 V

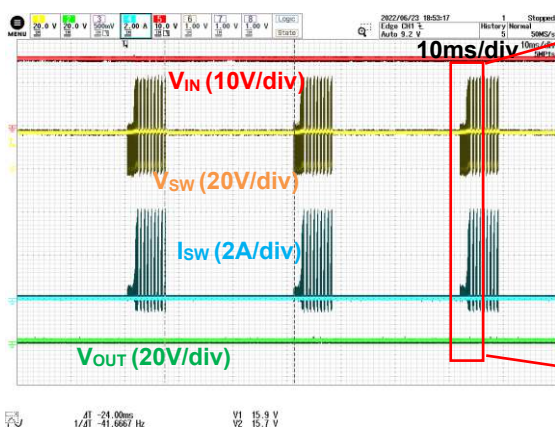


Figure 18. VOUT Short Waveform  
Vin = 15 V

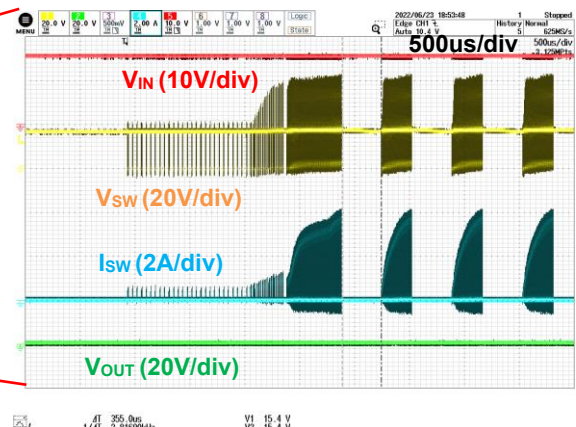


Figure 19. VOUT Short Waveform (ZOOM)  
Vin = 15 V

Measured data-continued

8. Component surface temperature

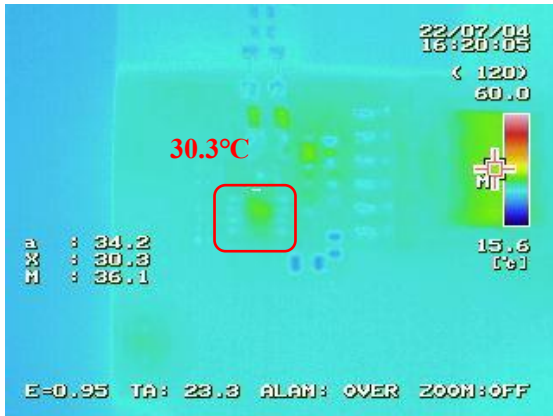


Figure 20. Surface Temperature

Vin = 8 V, IO = 250 mA (Ta = 23.3°C)

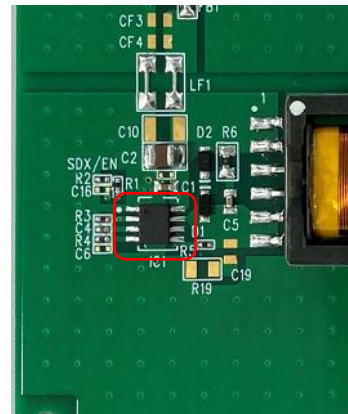


Figure 21. Surface Temperature Reference

Table 1. Tj Calculation

Item	Design	unit	comment
	BD7F105EFJ		
VIN(TYP)	8	V	
VOUT	16.5	V	
VF	0.6	V	
Pomax	4.125	W	
Io_max	0.250	A	POUT/VOUT
Np	20	-	
Ns	40	-	
Efficiency	85	%	
Iin_ave	0.607	A	POUT/EFFI/VIN
Lp	40.00	uH	
Ipeak(turnOFF)	1.32	A	Iin_ave/DUTY+VIN/LP*Ton/2
Ids(turnON)	1.03	A	Iin_ave/DUTY-VIN/LP*Ton/2
Vds	16.55	V	VIN+(Np/Ns)*(VOUT+VF)
Ron(Ta=25°C)	0.400	Ω	
Ron(Ta=120°C)	0.620	Ω	
Fsw	363	kHz	
tr	40	ns	rising time
tf	30	ns	falling time
Ton	1.423	us	1/FREQ*DUTY
DUTY	51.7	%	(Np/Ns)*(VOUT+VF)/((Np/Ns)*(VOUT+VF)+VIN)
ICC	1.0	mA	
Thermal Resistance ΨJT	13.0	°C/W	2s2p(°C/W)
①Loss calculation	0.053W	W	①P=1/6*Ipeak*Vds*tr*Fsw
②Loss calculation	0.442W	W	②P=(Ipeak-(Ipeak-IO)/2)*(Ipeak-(Ipeak-IO)/2)*Ron_total * Duty
③Loss calculation	0.041W	W	③P=1/6*Ion*Vds*tr*Fsw
④Loss calculation	0.008W	W	④P=VIN*ICC
Total loss	0.544W	W	
ΔTj	7.07	°C	
Topr_max	125	°C	
Tc	30	°C	
Tj	137.4	°C	Tj=Topr_max+ΔTj
Judge	○	-	Tj < 150°C

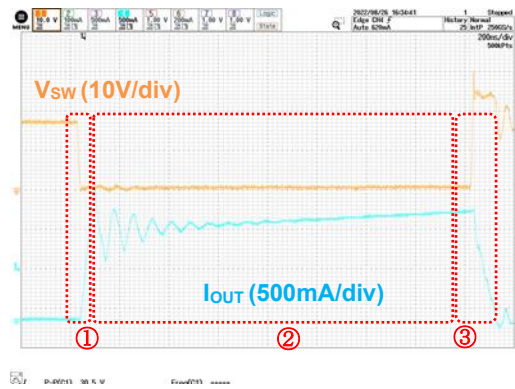


Figure 22. Peak Current Waveform

Vin = 8 V, IO = 250 mA

Tj calculation of IC is calculated using the above table.

Loss of IC is divided into 1: Turn on loss, 2: conduction loss, 3: Turn off loss, and 4: ICC.

Calculate the loss according to Table1 from the actual current waveform and power supply spec.

In this case, Tj is estimated to be 37.73 °C because Tc = 30.3 °C and ΔTj = 7.07 °C.

Tj should be designed to be 150 °C or less.

In this case, when Ta = 125 °C, Tj = 137.4 °C, and Tj = 150 °C is not reached, so it can be judged that there is no problem in the whole temperature range.



## Circuit diagrams

(Condition)  $V_{IN} = 8\text{ V to }32\text{ V}$ ,  $V_{OUT} = 16.5\text{ V}$ ,  $0.2\text{ A}$

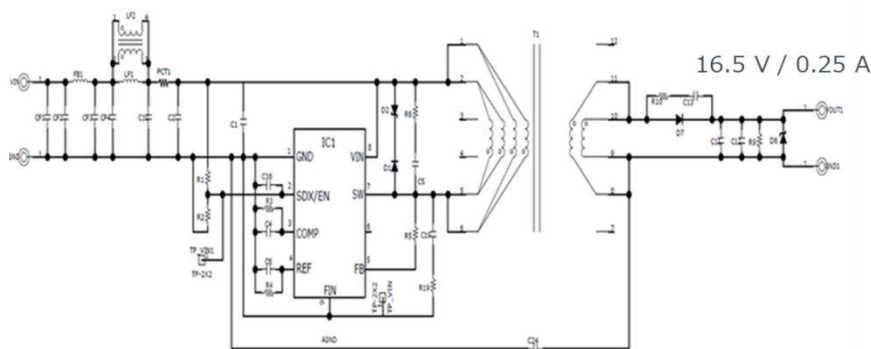


Figure 23. BD7F105EFJ-EVK-001 Schematic

## Bill of Materials

No	Item	Value	Product
CF1	Filter	0.1uF/50V	GCM188L81H104KA57D
CF2	Filter	OPEN	-
CF3	Filter	OPEN	-
CF4	Filter	OPEN	-
C10	Filter	OPEN	-
C2	Filter	0.1uF/50V	GCM188L81H104KA57D
C1	C_VIN	10uF/50V	GCM32EC71H106KA01
C4	C_LCOMP	0.1uF/50V	GCM188L81H104KA57D
C5	C_snubber1	1000pF/100V	GCM1887U2A102JA16
C6	C_REF	OPEN	-
C11	C_OUT	22uF/25V	GCM32EC71E226KE35
C12	C_OUT	22uF/25V	GCM32EC71E226KE35
C13	C_snubber2	OPEN	-
C16	C_EN	OPEN	-
C19	C_SW	OPEN	-
C24	Y_cap	OPEN	-
PCT1	-	short	-
R1	R_EN	180kΩ	MCR01MZPF1803
R2	R_EN	120kΩ	MCR01MZPF1203
R3	R_LCOMP	10kΩ	MCR01MZPF1002
R4	R_REF	2.7kΩ	MCR01MZPF2701
R5	R_FB	43kΩ	MCR01MZPF4302
R6	R_snubber1	1kΩ	MCR03MZPF1001
R9	R_OUT	2.2kΩ	ESR03MZPF2201
R10	R_snubber2	100Ω	ESR10EZPF1000
R19	R_SW	OPEN	-
FB1	Filter	short	-
LF1	Filter	OPEN	-
LF2	Filter	short	-
T1	Trans	40uH/160uH	CEFD2010_00399
D1	D_snubber	100V/1A	RB168VWM100TF
D2	D_snubber	13V	KDZV13B
D6	D_OUT	18V	UDZV18B
D7	D_secondary	150V/1A	RB168LAM150TF

\*Parts are subject to change without notice.

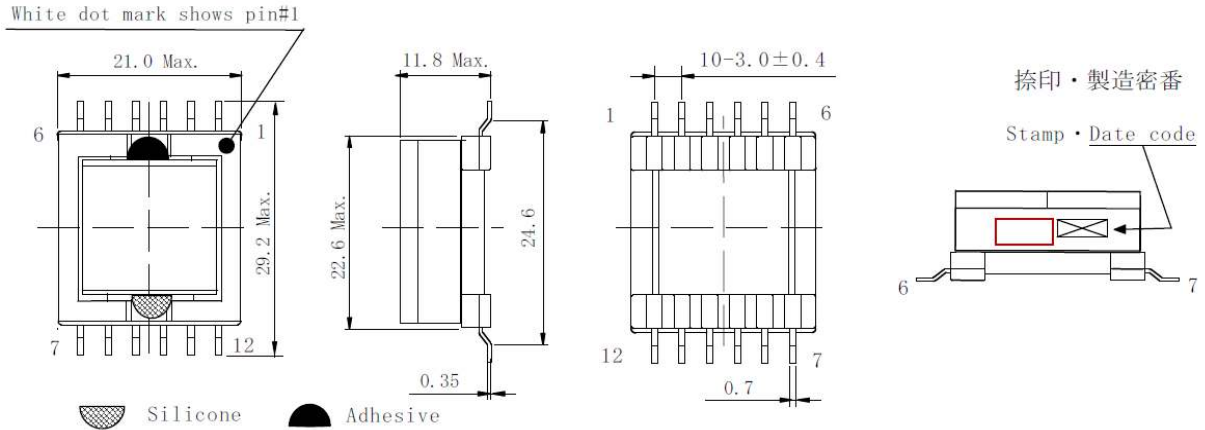
### Transformer specifications

Manufacturer : Sumida Electric Co., Ltd.

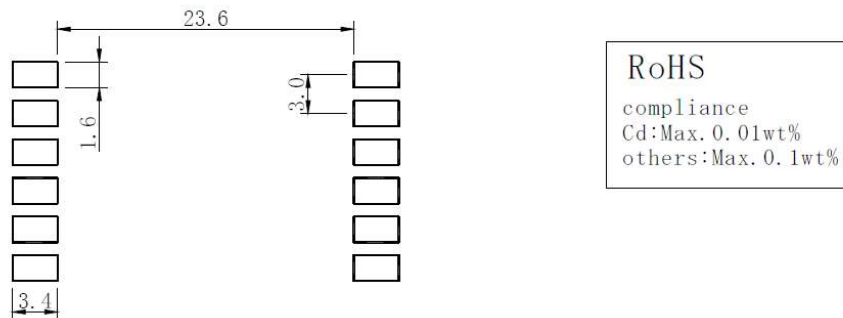
[https://job.mynavi.jp/conts/n/sp/23/54430\\_23sumida/](https://job.mynavi.jp/conts/n/sp/23/54430_23sumida/)

Product name: CEFD2010\_00399\_T379

■ External Dimensions



■ Recommended Land



■ Terminal connection diagram



“S”印は巻始めを示す。  
“S” indicates the winding start.

“.”は極性を示す。  
“.” Indicates the same polarity.

端子1-2間及び5-6間はパターンにより接続してご使用下さい。  
Pin 1-2、Pin 5-6 should be connected together when using on PCB.

## Transformer Specifications-continued

### ■ Winding wire and linear/linear type

端子番号 Terminal No.	5-2	11-8	6-1
巻数 Turns	20T	40T	20T
線径・線種 Wire (diameter & type)	0.26 UEW		

### ■ ELECTRICAL CHARACTERISTICS

項目 Item	規格 Specification	測定条件 Measuring conditions
インダクタンス Inductance (5, 6-1, 2)	40 $\mu$ H $\pm$ 10% Within	100kHz, 1V
飽和電流 Saturation Current (5, 6-1, 2)	3.5A	at 125°C
耐電圧 Withstanding voltage (1, 2, 5, 6)-(8, 11)	AC 2500Vrms 1minute	50Hz/60Hz

※ 耐電圧の規格に対して、1.2倍の電圧値で2秒間にて全数検査実施致します。

As to withstand voltage, every part should be tested with 1.2 times of standard voltage for 2 seconds.

※ 飽和電流：インダクタンスが公称値の90%に減少するときの直流電流の値。

Saturation current: The value of DC current when the inductance decreases to 90% of the nominal value.

## Application Design Example

### 1. Transformer design

#### 1.1 Determining the volume ratio $N_P/N_S$

The winding ratio is a parameter that sets the output voltage, maximum output power, duty, and SW terminal voltage.

The duty of the flyback converter is calculated by the following equation:

$$Duty = \frac{\frac{N_P}{N_S} \times (V_{OUT} + V_F)}{V_{IN} + \frac{N_P}{N_S} \times (V_{OUT} + V_F)} \quad [\%]$$

$N_P$  : Primary transformer turns

$N_S$  : Secondary transformer turns

$V_{OUT}$  : Output voltage

$V_F$  : Forward voltage of the output diode on the secondary side

$V_{IN}$  : VIN pin voltage

From the above formula, the winding ratio is calculated as follows.

$$\frac{N_P}{N_S} = \frac{D_{TYP}}{1 - D_{TYP}} \times \frac{V_{IN}}{V_{OUT} + V_F}$$

$D_{typ}$  : Duty at VIN Voltage (Typ)

It is recommended to set  $D_{TYP}$  from 30% to 50% at the VIN voltage in the middle of the operating range.

Initially, set  $D_{TYP} = 40\%$ .

In this case, the following formula is used. (Design  $V_{IN_{typ}}$  at battery voltage 12 V)

$$\frac{N_P}{N_S} = \frac{0.4}{1 - 0.4} \times \frac{12V}{16.5V + 0.6V} = 0.47$$

Therefore, we will proceed with designing with a  $N_P/N_S$  of 0.5.

The turn ratio is also limited by the maximum duty  $D_{MAX}$  determined from the minimum incoming voltage.

Make sure that  $D_{MAX}$  given by the equation below does not exceed 70%. If this is the case, set  $D_{TYP}$  so that it becomes smaller. If it exceeds 70%, the OFF time will be shortened. Therefore, the output voltage may deviate due to deviations in the flyback voltage detection.

$$\frac{N_P}{N_S} = \frac{D_{MAX}}{1 - D_{MAX}} \times \frac{V_{IN(Min)}}{V_{OUT(Max)} + V_{F(Max)}}$$

$D_{MAX}$  : Maximum duty of VIN voltage (Min) condition

$V_{OUT(Max)}$  : Maximum output voltage

$V_{F(Max)}$  : Forward voltage of secondary diode (Max.)

$$D_{MAX} = \frac{0.5}{\frac{8V}{16.5V + 0.6V} + 0.5} = 0.52 < 0.70$$

For this reason, there is no problem in this design.

$D_{MAX}$  of this designer is 0.52 and 0.70 or less, so it is judged without any problem.

**Determining the Volume Ratio  $N_P/N_S$ -continued**

The flyback voltage  $V_{OR}$  is calculated by the following equation.

$$V_{OR} = (V_{OUT} + V_F) \times \frac{N_P}{N_S} \quad [V]$$

$$V_{OR} = (16.5V + 0.6V) \times 0.5 = 8.6 V$$

Set so that the SW terminal voltage calculated below does not exceed the withstand voltage.

$$V_{SW} = V_{IN(Max)} + V_{OR} + V_{SURGE}$$

For example, if the derating against the SW pin withstand voltage is 90 %, the SW terminal voltage,  $60 V \times (100 \% - 10 \%) = 54 V$  It should be designed to be within 54 V.

This is designed with  $V_{IN(Max)} = 32 V$ ,  $V_{OR} = 8.6 V$ .

$V_{SURGE}$  at this time is as follows.

$$54 V - (32 V + 8.6 V) = 13.4 V$$

Therefore, the surge voltage must be less than 13.4 V.

$V_{SURGE}$  is caused by the leaking magnetic fluxes of the transformers.

If  $V_{SURGE}$  is large, the transformer structure needs to be reviewed and the snubber circuitry needs to be adjusted.

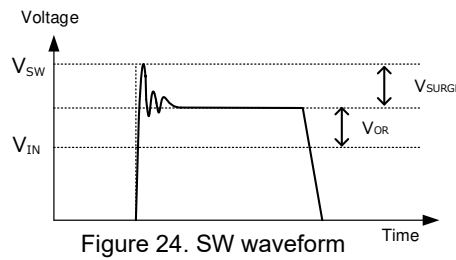


Figure 24. SW waveform

**1.2 Calculating  $L_P$ ,  $L_S$**

Set  $L_P$ ,  $L_S$  to enable continuous current mode operation.

Determine by using the current continuous-mode depth  $k$  to obtain  $L_P$ ,  $L_S$ .

$k$  is expressed from  $I_{SPK}$ ,  $I_{SB}$  of Figure 22 by the following equation.

$$k = (I_{SPK} - I_{SB}) / I_{SPK}$$

$I_{spk}$ : Secondary transformer peak current

$I_{sb}$  : Secondary transformer bottom current

$K$  : Constant representing the depth of the current continuous mode (When designing, use  $k = 0.25$  as a guide.)

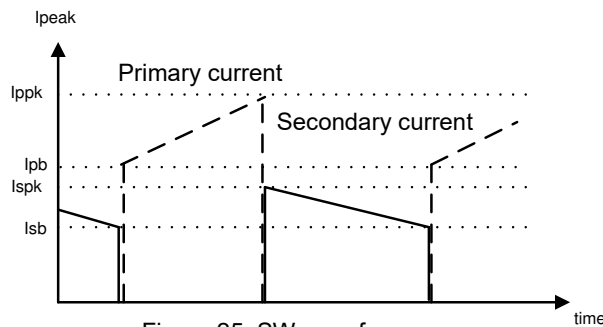


Figure 25. SW waveform

$I_{ppk}$ : Primary transformer peak current

$I_{pb}$  : Primary transformer bottom current

## Transformer design-continued

The maximum peak current on the primary side of the IC is determined by  $I_{LIMIT}$  of electrical characteristics.

$I_{LIMIT}$  minimum-value determines the secondary min-peak current  $I_{SPK1(Min)}$ .

$$I_{SPK1(Min)} = I_{LIMIT(Min)} \times \frac{N_P}{N_S} \quad [A]$$

The secondary peak current  $I_{SPK2(Max)}$  is calculated from the maximum output current  $I_{OUT(Max)}$  by the following equation.

$$I_{SPK2(Max)} = \frac{2 \times I_{OUT(Max)}}{(1 - D_{MAX}) \times (2 - k)} \times \frac{1}{\eta} \quad [A]$$

$\eta$  : Use a power supply efficiency of 70 % as a guideline.

$I_{SPK2(Max)} < I_{SPK1(Min)}$  must be met in order for  $I_{OUT(Max)}$  to be printed.

If the conditions cannot be satisfied, change  $k$  to redesign. With higher  $k$  values in discontinuous mode

The operating load area becomes wider. When  $k = 1$ , discontinuous mode operation is performed in all areas.

This IC is continuous

A low  $k$ -value is recommended to achieve high-speed response and low EMI characteristics by mode operation.

Even if the  $k$  value is high, there is no problem with power supply operation.

The secondary-side index  $L_{S(Max)}$  is calculated by the following equation.

$$L_{S(Max)} = \frac{(2 - k) \times (V_{OUT} + V_F) \times (1 - D_{MAX})^2}{2 \times I_{OUT(Max)} \times f_{sw(Max)} \times k} \quad [\mu H]$$

$$L_{S(Max)} = \frac{(2 - 0.2) \times (16.5V + 0.6V) \times (1 - 0.52)^2}{2 \times 0.25 \times 430kHz \times 0.2} = 165\mu H$$

$f_{sw(Max)}$  : Switching frequency This switching frequency should be calculated at 430 kHz.

$I_{OUT(Max)}$  : Max. secondary output current

$L_s$  is 160uH for this design

At this time, the primary inductance  $L_p$  is obtained by the following equation.

$$L_p = L_s \times \left(\frac{N_P}{N_S}\right)^2 \quad [\mu H]$$

$$L_p = 160\mu H \times (0.5)^2 = 40\mu H$$

From the above, we will proceed with the design as  $L_p$ :40uH,  $L_s$ :160uH in this design.

## Application Design Examples-continued

### 2. Output voltage

When the built-in switching MOSFET is turned OFF, the SW pin voltage  $V_{SW}$  becomes higher than the VIN pin voltage. Since the difference between the SW pin voltage and the VIN pin voltage is equal to the primary flyback voltage, the secondary output voltage is calculated from this voltage. The SW pin voltage  $V_{SW}$  at turn-off is calculated by the following equation.

$$V_{SW} = V_{IN} + \frac{N_P}{N_S} \times (V_{OUT} + V_F) \quad [V]$$

$V_{SW}$  : SW pin voltage

$V_{IN}$  : VIN pin voltage

$N_P$  : No. of primary transformer turns

$N_S$  : Secondary transformer turns

$V_{OUT}$  : Output voltage

$V_F$  : Forward voltage of the output diode on the secondary side

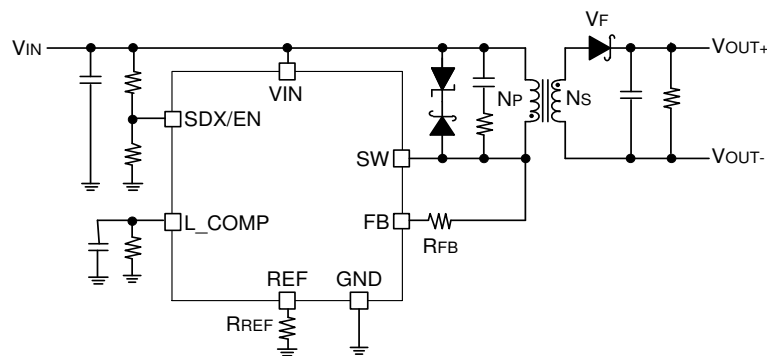


Figure 26. Application Block Diagram

The primary flyback voltage is converted to the FB-pin inrush current  $I_{FB}$  by the external resistor  $R_{FB}$  between FB-SW terminals. Since the FB pin voltage becomes almost equal to the VIN pin voltage by the IC's internal circuit, the FB pin inrush current  $I_{RFB}$  is calculated by the following equation.

$$I_{FB} = \frac{V_{SW} - V_{FB}}{R_{FB}} = \frac{V_{IN} + \frac{N_P}{N_S} \times (V_{OUT} + V_F) - V_{FB}}{R_{FB}} = \frac{\frac{N_P}{N_S} \times (V_{OUT} + V_F)}{R_{FB}} \quad [A]$$

$I_{FB}$  : FB pin inrush current

$V_{FB}$  : FB terminal voltage

$R_{FB}$  : External resistor between FB and SW pins

## 1. Output Voltage- continued

In addition, since the FB pin inrush current  $I_{RFB}$  flows to the external resistor  $R_{REF}$  between the REF terminal and GND terminal, the REF terminal voltage is calculated by the following equation.

$$V_{REF} = \frac{R_{REF}}{R_{FB}} \times \frac{N_P}{N_S} \times (V_{OUT} + V_F) \quad [V]$$

$V_{REF}$  : REF pin voltage

$R_{REF}$  : External resistor between REF pin and GND pin

Because the current that flows to the REF pin becomes  $I_{REF}$  when the REF pin voltage is  $V_{INTREF}$  for  $R_{REF}$ ,

$$R_{REF} = \frac{0.54V}{200\mu A} = 2.7 k\Omega \quad \text{The resistor must be set.}$$

The REF pin voltage is input to the comparator with the reference voltage inside the IC. The REF pin voltage is equal to the reference voltage by the internal circuit of the IC. Therefore, the output voltage and the REF pin voltage are calculated by the following equations.

$$V_{OUT} = \frac{R_{FB}}{R_{REF}} \times \frac{N_S}{N_P} \times V_{INTREF} - V_F \quad [V]$$

As can be seen from this equation, the output voltage  $V_{OUT}$  can be set by the transformer turn ratio ( $N_P/N_S$ ) on the primary and secondary sides and the resistance ratio between  $R_{FB}$  and  $R_{REF}$ .

From the above equation, the external resistor  $R_{FB}$  between the FB pin and SW terminal can be calculated by the following equation.

$$R_{FB} = \frac{R_{REF}}{V_{INTREF}} \times \frac{N_P}{N_S} \times (V_{OUT} + V_F) \quad [\Omega]$$

In this designer,  $R_{FB}$  is determined as follows.

$$R_{FB} = \frac{2.7k\Omega}{0.54V} \times 0.5 \times (16.5V + 0.6V) = 42.75 k\Omega$$

$R_{FB}$  is set to 43kohm.

However, the ESR on the secondary side of the transformer is a factor that lowers the output voltage as in  $V_F$  of the above equation.

Also, when the transformer is not coupled, the number of turns of  $N_P/N_S$  is shifted, which causes the output voltage to decrease.

Therefore, finally adjust the output voltage by checking the actual device.



## Application Design Examples-continued

### 3. Output Capacitor

Place the output capacitor as close to the secondary diode as possible.

The output capacitance value  $C_{OUT}$  is set from the output ripple voltage  $\Delta V_O$  and the start-up time.

The output ripple voltage generated by one switching is calculated as follows.

$$\Delta V_O = \frac{I_{OUT(Max)} \times D_{MAX}}{f_{SW(Max)} \times C_{OUT}} \quad [V]$$

On the other hand, when output capacitor is large, start-up time is long.

When SCP detection mask time ( $t_{MASKSCP}$ ) in start-up is passed, if REF voltage is lower than  $V_{SCP}$ , power supply cannot output. Therefore,  $C_{OUT}$  must be satisfied below condition.

$$C_{OUT} \leq \frac{1}{2} \times \frac{t_{MASKSCP(Min)} \times \left\{ \left( I_{LIMIT(Min)} \times \frac{N_P}{N_S} \right) \times (1 - Duty) - I_{OUT(Max)} \right\}}{V_{OUT} \times \left( \frac{V_{SCP(Max)}}{V_{INTREF(Min)}} \right)} \quad [\mu F]$$

$$\text{Where} = 0.762 \cdot \frac{V_{SCP(Max)}}{V_{INTREF(Min)}}$$

A large capacitor capacitance value is required to hold the output voltage during load response or power supply voltage response.

A capacitance value of 20  $\mu F$  or more is recommended as a guideline for the output voltage capacitance.

Ceramic capacitors are affected by temperature characteristics, capacitance variation, DC bias characteristics, etc.

The capacitance value may decrease. Pay attention to these points when selecting parts.

### 4. Input Capacitor

Use a ceramic capacitor for the input capacitor and place it as close to the IC as possible.

Capacitance of the capacitor should be 10  $\mu F$  or more.

## Application Design Examples-continued

### 5. Secondary output diode

A Schottky barrier diode or a fast recovery diode with low  $V_F$  is recommended because the forward voltage  $V_F$  of the secondary output diode causes an error in the output voltage. When selecting a secondary output diode, the peak of the secondary reverse voltage must not exceed the rating of the diode. The secondary RMS current  $I_{SRMS}$  must also be set so that it does not exceed the rating.

Generally, 30 % or more of the reverse-direction breakdown voltage  $V_R$  is recommended.

$$V_R = (V_{IN(Max)} \times \frac{N_S}{N_P} + V_{OUT}) \times 1.3 + V_{SURGE} \quad [V]$$

$V_R$  : Reverse voltage of the secondary output diode

$V_{IN(Max)}$ : VIN pin maximum voltage

$N_P$  : No. of primary transformer turns

$N_S$  : Secondary transformer turns

$V_{OUT}$  : Output voltage

$V_{SURGE}$ : Transformer surge voltage generated in the diode

It is recommended that the rated current of the secondary output diode be at least twice that of  $I_{SRMS}$ .

### 6. Output Resistance and Zener Diode (Minimum Load Current)

The output voltage rises when no load is applied or when light load is applied. The reason for this is that the MAXIMUM is in the OFF-time  $t_{OFF\_MAX}$  when the IC is under light load.

This is because switching is always performed at the minimum frequency determined by the minimum ON-time  $t_{ON\_MIN}$ . For the power  $P_{O\_MIN}$  determined by the switching frequency of this lowest frequency, when the secondary load is lighter than this, the output voltage is

It moves up.  $P_{O\_MIN}$  is calculated by the following equation:

$$P_{O\_MIN} = \frac{V_{IN(Max)}^2}{2 \times L_P} \times t_{ON\_MIN(Max)}^2 \times \frac{1}{t_{ON\_MIN(Max)} + t_{OFF\_MAX(Min)}} \quad [W]$$

$$I_{OUT\_MIN} = \frac{P_{O\_MIN}}{V_{OUT}}$$

Because it is an expression, it can also be obtained from  $I_{OUT\_MIN}$ .

If the rise in the secondary output voltage becomes a problem, connect a secondary output zener diode to suppress the rise in the voltage. It is also necessary to suppress the rise in the output voltage by adding a resistor to the secondary output to provide a constant loss. The output resistor  $R_{OUT}$  to be connected to the secondary side should be as follows. The resistor-loss  $P_{LOSS}$  is calculated as follows.

$$P_{loss} = \frac{V_{OUT}^2}{R_{OUT}}$$

$$R_{out} \leq \frac{V_{OUT}^2}{P_{O\_MIN}} = \frac{V_{OUT}^2}{\frac{V_{IN(Max)}^2}{2 \times L_P} \times t_{ON\_MIN(Max)}^2 \times \frac{1}{t_{ON\_MIN(Max)} + t_{OFF\_MAX(Min)}}}$$

In practice, even if  $R_{OUT}$  loads calculated by the above equation are used, the output voltage rises transiently during secondary discharging. Therefore, it should be set lower enough than this  $R_{OUT}$ . Adjust this resistance value in the actual evaluation. When selecting a resistor, pay attention to the rated power of the resistor.

## Application Design Examples-continued

### 7. Snubber circuit

Excessive on the SW pin at turn-off when the degree of coupling of the transformer is low or the large current line of the board is long, etc.

Voltage may be applied.

To suppress this, use the snubber circuitry indicated by Figure 27.

This snubber circuit clamps the voltage when the flyback voltage + surge voltage exceeds this snubber voltage.

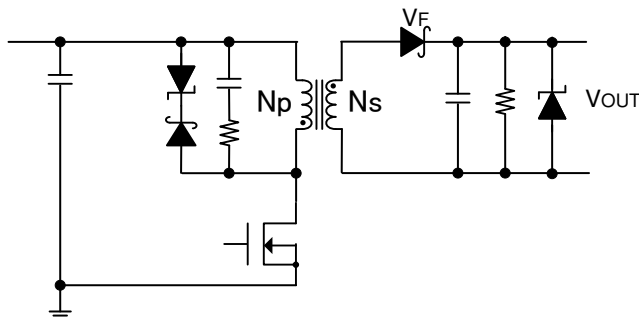


Figure 27. Snubber Circuit

The clamping voltage is determined by the following equation.

$$V_{CLAMP} = V_{F2} + V_Z \quad [V]$$

$V_{CLAMP}$  : Clamp setting voltage of snubber

$V_{F2}$  : Forward voltage of the Schottky diode

$V_Z$  : Zener voltage of the zener diode

At turn-off if the clamp setting voltage is lower than the flyback voltage  $\frac{N_P}{N_S} \times (V_{OUT} + V_F)$

A current flows through the zener. Therefore, be sure to set a voltage higher than the flyback voltage.

In addition, the snubber circuit may not be clamped at the set clamping voltage because of its operational responsiveness.

Therefore, be sure to check the clamp voltage in actual operation.

### 8. SDX/EN terminal resistor

#### 8.1 Setting Enable Voltage

After releasing VIN UVLO, Enable voltage  $V_{IN\_ENABLE}$  can be set by the following equation.

$$V_{IN\_ENABLE} = V_{EN1} \times \frac{R_1 + (R_2 // R_{SDX/EN})}{R_2 // R_{SDX/EN}} \quad [V]$$

$V_{IN\_ENABLE}$  : Target operations start VIN voltage

$V_{EN1}$  : Enable volt1

$R_2 // R_{SDX/EN}$ : Partial pressure resistance between  $R_2$  and  $R_{SDX/EN}$  inside the ICs

## Application Design Examples-continued

### 8.2 Setting Disable Voltage

Disable voltage  $V_{IN\_DISABLE}$  when the VIN pin voltage falls can be set by the following equation.

$$V_{IN\_DISABLE} = V_{EN2} \times \frac{R_1 + (R_2 // R_{SDX/EN})}{R_2 // R_{SDX/EN}} \quad [V]$$

$V_{IN\_DISABLE}$  : Intended operation stop VIN voltage

$V_{EN2}$  : Enable volt2

### 9 Output voltage compensation function using L\_COMP pin resistor

The IC can compensate for the voltage drop in the output voltage  $V_{OUT}$  in response to the increase in  $I_P$  of the primary transformer peak current.

$V_{OUT}$  changes can be caused by  $V_F$  variations in the secondary diodes or by leaking magnetic fluxes in the transformer.

An example of the output voltage compensation function is shown in Figure 26.

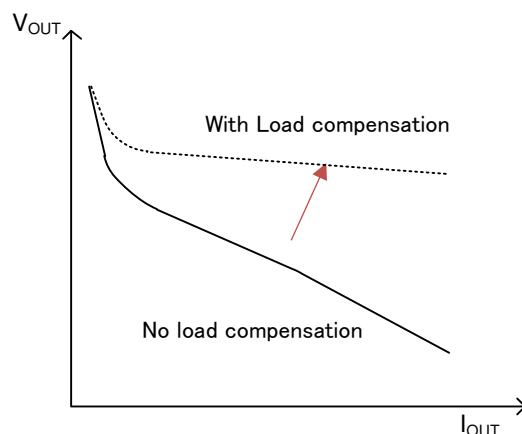


Figure 28. L\_COMP voltage compensation example

This function compensates the output voltage by adding a  $I_{REFCOMP}$  current to the REF current that determines the output voltage.

$$V_{OUT} = R_{FB} \times \frac{N_S}{N_P} \times \left( \frac{V_{INTREF}}{R_{REF}} + I_{REFCOMP} \right) - V_F \quad [V]$$

$\frac{V_{INTREF}}{R_{REF}} = 200 \mu A$  (Typ) Fixed value.  $I_{REFCOMP}$  is incremented relative to the primary current.

As a result, the output voltage is compensated according to the load current on the secondary side.

$I_{REFCOMP}$  is determined by the following equation.

$$I_{REFCOMP} = R_{L\_COMP} \times K_{L\_COMP} \times I_{SW(Ave)} \quad [\mu A]$$

$R_{L\_COMP}$  : Resistor connected to the L\_COMP pin

$I_{SW(Ave)}$  : Average current flowing through the SW pin

$K_{L\_COMP}$ : Fixed value inside the IC

## 9 Output Voltage Compensation by L\_COMP Pin Resistor-continued

The mean current  $I_{SW(Ave)}$  of the SW pin can be converted into the following equation.

$$I_{SW(Ave)} = I_{S(Ave)} \times \frac{N_S}{N_P} = I_{OUT} \times \frac{1}{\eta} \times \frac{N_S}{N_P} \quad [A]$$

$\eta$ : Efficiency (Designed at about 70% and adjust  $R_{L\_COMP}$  in the application assessment.)

As shown in this equation,  $I_{SW(Ave)}$  is proportional to  $I_{OUT}$ , so you can compensate for the above.

The compensation amount can be adjusted by the resistance value of the L\_COMP pin.

Since  $I_{SW}$  is a triangle-wave current, always use a capacitor of 0.1  $\mu$ F or more at the L\_COMP pin to smooth this.

Please connect.

The resistor of the L\_COMP pin is calculated by the following equation.

$$R_{L\_COMP} = \frac{I_{REFCOMP}}{I_{SW(Ave)}} \times \frac{1}{K_{L\_COMP}} \quad [k\Omega]$$

Be sure to check the output voltage characteristics in the application evaluation and adjust the L\_COMP terminal resistor as necessary.

When compensation is not performed, short the L\_COMP pin to GND.

**Revision history**

Date	Plate	Content of change
14.Jul.2022	001	New

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