Application Note

Secondary Side Synchronous Rectification Controller IC

BM1R001xxF series Technical Design

BM1R00146F BM1R00147F BM1R00148F BM1R00149F BM1R00150F

This application note describes an example of how to design the secondary-side synchronous rectification circuit with the BM1R001xxF series.

General Description

The BM1R001xxF series ICs are the synchronous rectification controller ICs having built-in low-consumption and high-accuracy shunt regulators. The synchronous rectification controllers support all of the discontinuous, critical and continuous modes and allow application to the PWM converters. Adoption of the high-voltage 120 V process has enabled monitoring the drain voltage directly. The shunt regulators reduce consumption of circuit current and contribute to reduction in standby power requirement, and these two functions construct an independent circuit in the IC and enable supporting various applications such as only using the synchronous rectification controller.

Features

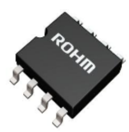
- ■Built-in Low Consumption Shunt Regulator Reducing Standby Power Consumption
- ■Synchronous Rectification MOSFET Supports High and Low Sides
- ■120 V High Voltage Process DRAIN Terminal
- ■Supports various driving methods such as the PWM, quasi-resonant, LLC, etc.
- ■Built-in Overvoltage Protection for SH_IN and SH_OUT Terminals
- ■Built-in Thermal Shutdown Function
- ■Built-in Auto Shutdown Function
- ■SOP8 Package being compatible with flow-type soldering

Key Specifications

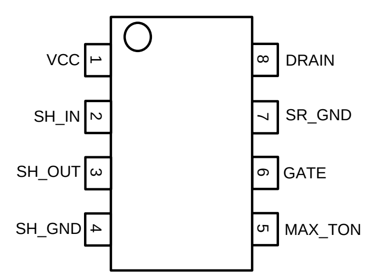
- ■Input Voltage Range: 2.7 V to 32 V
- ■Operating Circuit Current (No Switching): 800 uA (Typ)
- ■Circuit Current (Auto Shutdown): 120 uA (Typ)
- ■DRAIN Terminal Absolute Voltage: 120 V
- ■Operating Temperature Range: -40°C to +105°C

Package

	W (Typ) x D (Typ) x H (Max)
SOP8	5.00 mm x 6.20 mm x 1.71 mm



Pin Configuration



Lineup Table

Part Number	Compulsion ON Time (Typ.) [us]	Compulsion OFF Time (Typ.) [us]	SH_IN OVP	SH_OUT OVP	TSD	SLEEP MODE
BM1R00146F	NONE	1.3	Auto Restart	Auto Restart	Auto Restart	Yes
BM1R00147F	NONE	2.0				
BM1R00148F	NONE	3.0				
BM1R00149F	NONE	3.6				
BM1R00150F	NONE	4.6				

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Design Procedure

The description below is the design procedure for replacing the secondary-side rectifying diode and shunt regulator with any of the BM1R001xxF series.

1. Synchronous rectification circuit

1-1. Selecting MOSFET for synchronous rectification

The MOSFET for synchronous rectification that replaces the rectifying diode should be selected first. Refer to the reverse voltage V_R and the forward current I_F that are generated on the rectifying diode and select the replacement MOSFET while taking into account its maximum drain-to-source voltage, peak current, loss caused by ON-resistance (Ron), maximum power dissipation of the package, etc. Be sure to check with the MOSFET mounted on the product and disperse heat by using a heatsink, etc. if necessary.

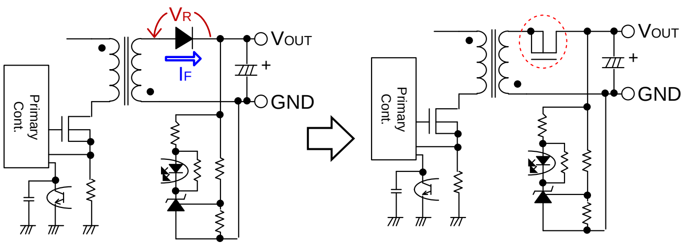
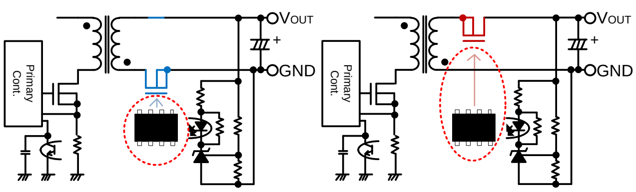


Figure 1. Design Procedure - Selecting MOSFET

1-2. Selecting the IC

In order to support different types of power supplies, we have developed a lineup of the compulsion OFF time. Select the appropriate IC by referring to the reverse voltage V_R and the forward current I_F that are generated in the rectifying diode checked in the above section 1-1., and calculate the maximum ON time t_{MAX_ON} of the secondary-side MOSFET. In case of the BM1R001xxF series, the MOSFET can be located on either the high side or the low side for synchronous rectification.



(Low Side Type) (High Side Type)

Figure 2. Design Procedure - Selecting IC

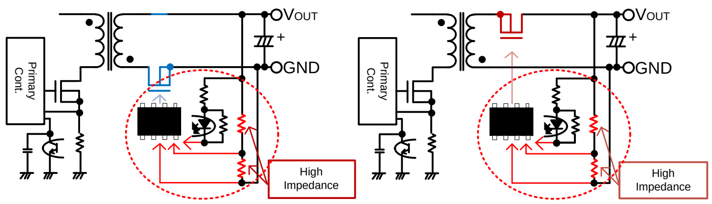
1-3. Selecting peripheral circuit components

Measures should be taken with regards to the DRAIN pin in order to avoid erroneous detection caused by the surge voltage generated at the time of switching the MOSFET. Also, set the power supply circuit to the IC power supply pin, VCC.

2. Shunt regulator circuit

The BM1R001xxF series have built-in low-consumption and high-accuracy shunt regulator and contribute to reduction in power consumption of shunt regulator sections. As the shunt regulator and the synchronous rectification controller in an IC are completely separated from each other, the shunt regulator can be used on the basis of GND even in the high-side type flyback application.

When the IC's built-in shunt regulator is not used, the pins (SH_IN, SH_OUT and SH_GND) in the regulator section should be open.



(Low Side Type) (High Side Type)

Figure 3. Design Procedure - Selecting shunt regulator

Design Example

Described below is a design example of replacing the secondary-side rectifying diode and shunt regulator with any of the BM1R001xxF series in the following power supply specification:

<Power supply specification>

・Input voltage (VIN) 400 Vdc

・Output voltage (VOUT) 5 V

・Output current (IOUT) 10 A

・Power supply method: Insulated type with PWM flyback converter. 130 kHz switching frequency.

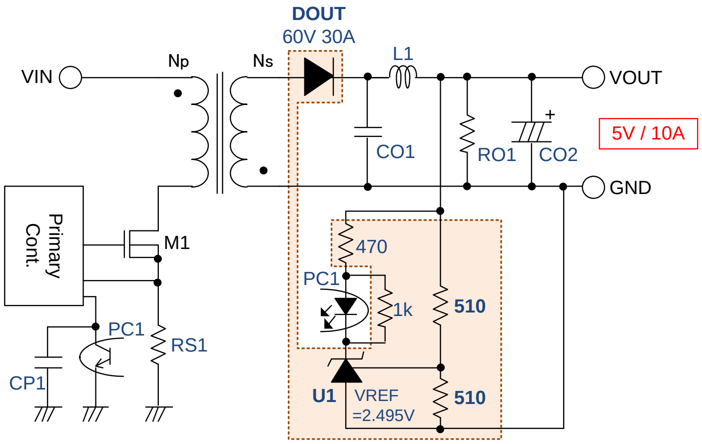


Figure 4. Circuit before replacement with any of the BM1R001xxF series

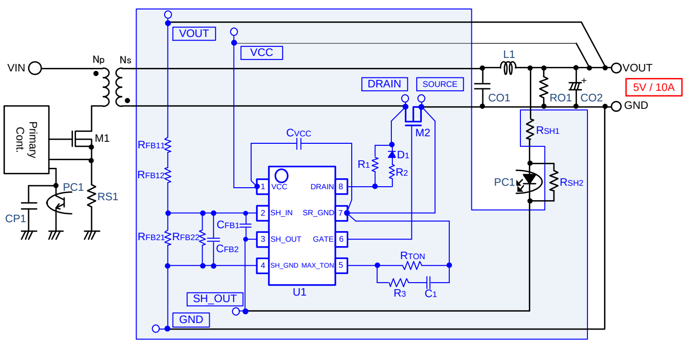


Figure 5. Circuit after replacement with any of the BM1R001xxF series

(Low Side Type)

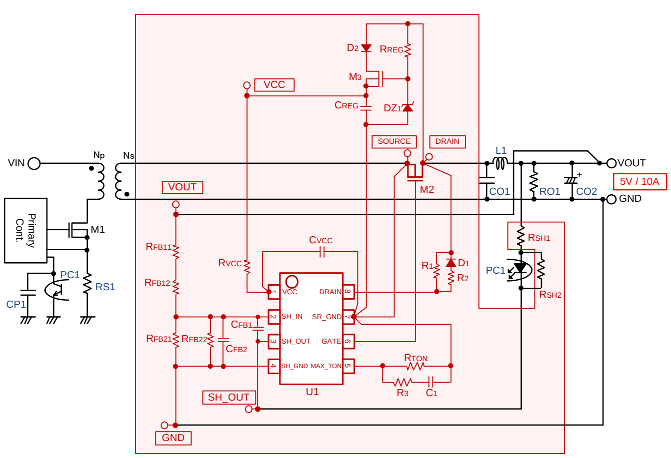


Figure 6. Circuit after replacement with any of the BM1R001xxF series

(High Side Type)

1. Synchronous rectification circuit

1-1. Selecting MOSFET M2 for synchronous rectification

The MOSFET M2 for synchronous rectification that replaces the secondary-side rectifying diode DOUT should be selected. The reverse voltage V_R and the forward current I_F that are generated in the rectifying diode DOUT should be checked before replacement.

<Waveform example>

VIN=400 Vdc

IOUT=10 A (MAX)

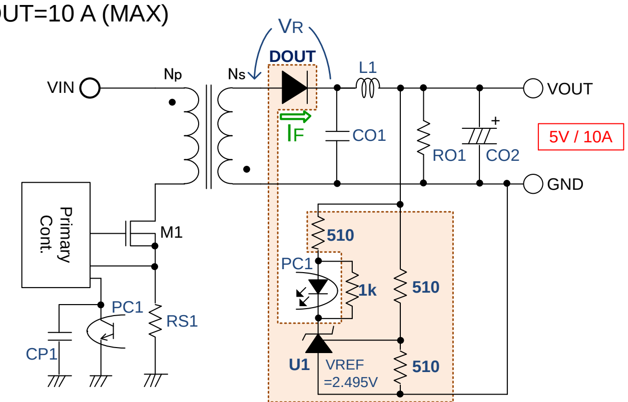


Figure 7. Reverse voltage V_R and forward current I_F of rectifying diode

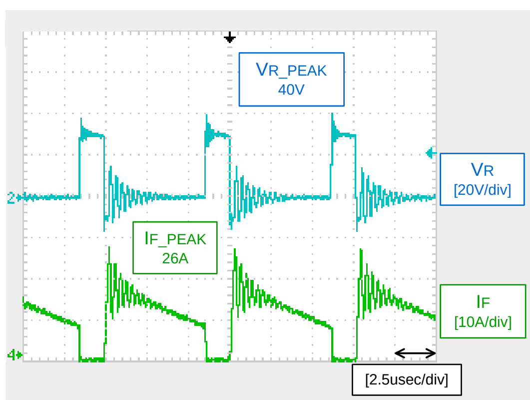


Figure 8. Waveforms of reverse voltage V_R and forward current I_F of rectifying diode

When you consider the maximum drain-to-source voltage V_{DS} and the drain current I_D of the replacement MOSFET, use the measured reverse voltage V_R and forward current I_F of the rectifying diode as a guide for selection. At the time of selection, also take into account the loss caused by ON-resistance (Ron), the package's maximum power dissipation P_D, etc. When the Ron of the MOSFET M2 is too high, the MOSFET may generate abnormal heat. Check with the MOSFET mounted on the product and disperse heat by using a heatsink etc., if necessary.

(Example of M2 selection: V_{DS}=60 V, I_D=50 A, Ron=4 mΩ, P_D=120 W)

ROHM's MOSFET lineup has a wide selection and can meet the requirements of various applications. Please visit our website where you can use the MOSFET selection tool in our customer support page.

Note: Absolute maximum rating of the DRAIN pins of the BM1R001xxF series is 120 V (Ta=25℃). Check that the voltage applied to the ICs' DRAIN pins does not exceed the absolute maximum rating. If the voltage that exceeds the absolute maximum rating is applied to any of the DRAIN pins, see the following paragraph below "3. When V_{DS2} is influenced by surge and exceeds the V_{DS} breakdown voltage of the secondary-side MOSFET" of the section "Troubleshooting in the flyback application" in page 13. When a transformer needs to be designed, please visit our website and refer to the various design examples in the AC/DC Design Library of the customer support page.

1-2. Selecting the IC

The BM1R001xxF series provide the Compulsion OFF Time that enable their application to various power supplies.

<Compulsion OFF time>

The compulsion OFF time is the masking time to prevent the resonant waveform generated on the DRAIN pin from turning on the gate of the secondary-side MOSFET.

<Standard for determining the compulsion OFF time in the continuous-mode operation>

When you select the IC, you should consider the switching frequency of the primary-side controller and the ON time of each of the primary-side and secondary-side MOSFETs.

Select the IC according to the following procedure:

1. Check waveforms of the reverse voltage V_R and the forward current I_F that are generated in the rectifying diode DOUT before replacement.
(Measure the ON time of the primary-side MOSFET M1 (t1) and the cycle time of the primary-side controller (tp).)

2. Set the maximum ON time t_{MAX_ON} of the secondary-side MOSFET.
(Set t_{MAX_ON} to prevent breakage that is caused when the primary-side and secondary-side MOSFETS are turned ON simultaneously at the time of heavy loading in the continuous-mode.)

3. Selecting the IC
(Calculate the necessary compulsion OFF time t_{OFF} according to the following formula.)

$$t_{OFF}[\mu \sec] < t_p[\mu \sec] - (t_{MAX\_ON}[\mu \sec] - t_1[\mu \sec])$$

For the method to calculate the compulsion OFF time when the continuous-mode operation is not conducted, see the following section below "Reference: How to calculate the compulsion OFF time when the continuous-mode operation is not conducted" in page 6.

1-2-1. Checking waveforms of the reverse voltage V_R and the forward current I_F that are generated in the rectifying diode DOUT before replacement

<Example of waveforms>

VIN=400 Vdc

IOUT=10 A (MAX)

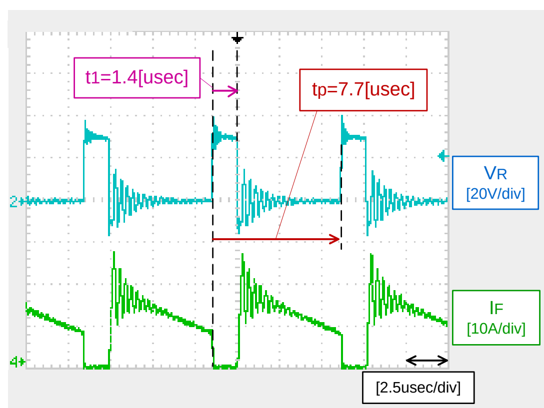


Figure 9. Rectifying diode's reverse voltage V_R and forward current I_F
(In the continuous-mode operation)

We can see from the waveforms of Figure 9 that the ON time of the primary-side MOSFET M1 (t1) is 1.4 usec and the cycle time of the primary-side controller (tp) is 7.7 usec.

1-2-2. Setting the maximum ON time t_{MAX_ON} of the secondary-side MOSFET

Set the maximum ON time t_{MAX_ON} by using the MAX_TON pin. Counting operation starts when the DRAIN pin voltage detects the rise edge exceeding VCC (= output voltage VOUT) × 1.4 V (Typ). When the maximum ON time t_{MAX_ON} that was set with the resistor R_{TON} has elapsed, the secondary MOSFET M2 is turned OFF forcibly.

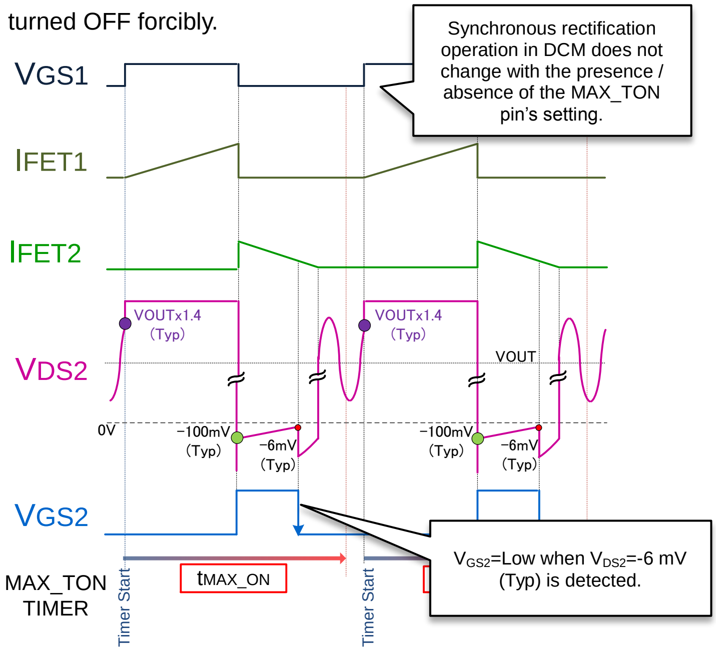


Figure 10. Operation of MAX_TON in DCM

(Light load / non-continuous mode)

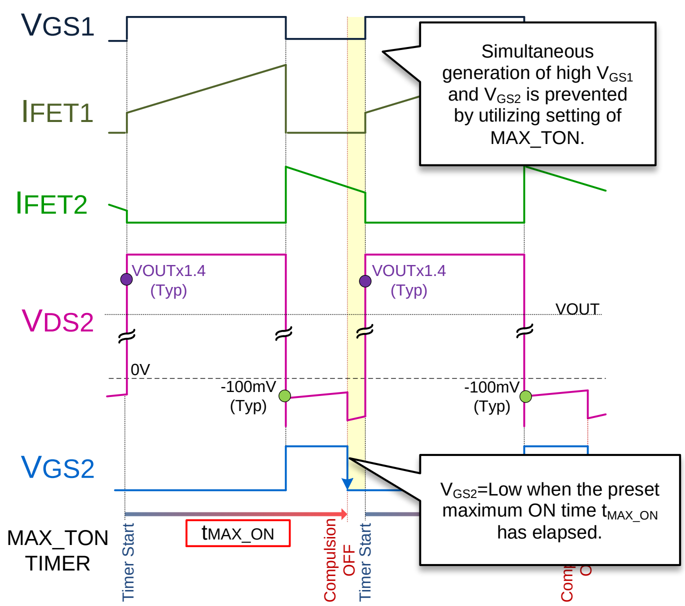


Figure 11. Operation of MAX_TON in CCM

(Heavy load / continuous-mode operation)

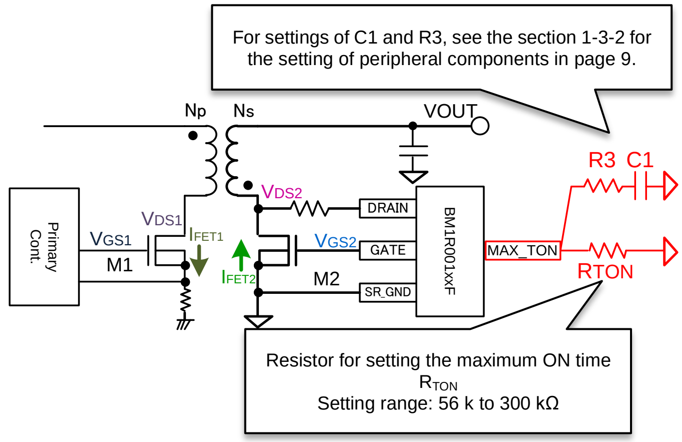


Figure 12. Setting of MAX_TON pin

(In continuous-mode operation)

The maximum ON time t_{MAX_ON} must be set so that it is always shorter than the cycle time of the primary-side controller total period (tp). Setting range of the resistor R_{TON} is 56 k through 300 k and the maximum ON time t_{MAX_ON} is proportionate to the resistance value. Accuracy is improved as the set maximum ON time comes close to 10 usec (R_{TON}=100 kΩ).

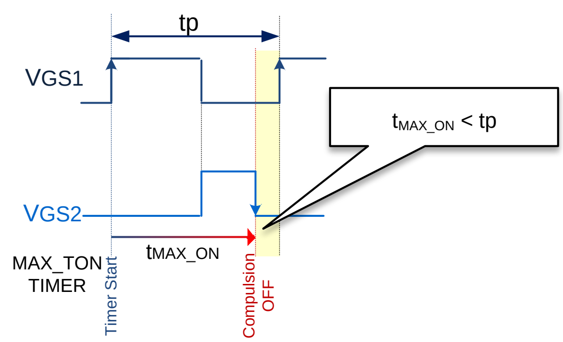


Figure 13. Setting of maximum ON time t_{MAX_ON}

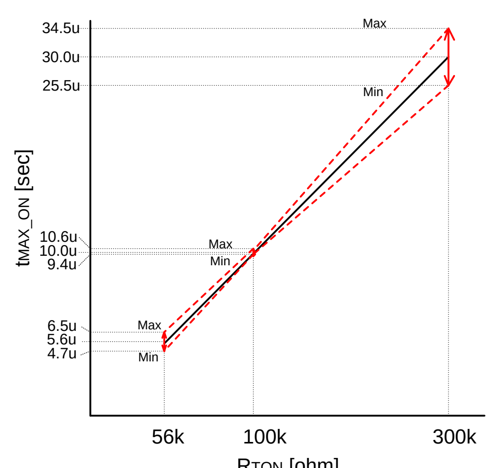


Figure 14. Setting of t_{MAX_ON} – R_{TON}

When the primary-side controller is in accordance with the PWM control method, the R_{TON} setting method that takes variation into account is expressed as the formula below.

$$R_{TON}[k\Omega] < \frac{10000[k\Omega \cdot kHz]}{(1+\Delta T_{MAX\_TON}[\%]+\Delta R_{TON}[\%]+\Delta F_{MAX}[\%]) \times F_{MAX}[kHz]}$$

- F_{MAX} [kHz]: Primary-side maximum frequency
- ⊿F_{MAX} [%]: Primary-side maximum frequency accuracy
- ⊿T_{MAX_ON} [%]: Time accuracy of Secondary-side MAX_TON timer
- ⊿R_{TON} [%]: Secondary-side MAX_TON resistance accuracy

According to the following values of the design example this time,

- F_{MAX} = 130 [kHz]
- ⊿F_{MAX} =5[%]
- ⊿T_{MAX_ON} =7[%]
- ⊿R_{TON} =1[%]

R_{TON} is calculated as the formula below.

$$R_{TON}[k\Omega] < \frac{10000[k\Omega \cdot kHz]}{(1+7[\%]+1[\%]+5[\%]) \times 130[kHz]} = 68.1[k\Omega]$$

Based on the above result, setting of R_{TON} in this design example should be less than 68 kΩ. Note that this formula is expressing the ideal state. Therefore, please check the operation sufficiently with the actual equipment at the time of selection. In this design example, the value shall be 68kΩ. When R_{TON}=68 kΩ, the maximum ON time t_{MAX_ON} calculated according to the following formula is 6.8 usec.

$$t_{MAX\_ON}[\mu\sec] = \frac{R_{TON}[k\Omega]}{10[k\Omega/\mu\sec]} = \frac{68[k\Omega]}{10[k\Omega/\mu\sec]} = 6.8[\mu\sec]$$

[Reference: When the primary-side controller has the built-in jitter function]

The R_{TON} setting method that takes variation into account is expressed as the formula below.

$$R_{TON}[k\Omega] < \frac{10000[k\Omega \cdot kHz]}{(1+\Delta T_{MAX\_TON}[\%]+\Delta R_{TON}[\%]+\Delta F_{MAX}[\%]) \times (F_{MAX}[kHz]+F_{JITTER}[kHz])}$$

- F_{MAX} [kHz]: Primary-side maximum frequency
- ⊿F_{MAX} [%]] Primary-side maximum frequency accuracy
- F_{JITTER} [kHz]: Primary-side jitter frequency
- ⊿T_{MAX_ON} [%]: Secondary-side MAX_TON timer time accuracy
- ⊿R_{TON} [%]: Secondary-side MAX_TON resistance accuracy

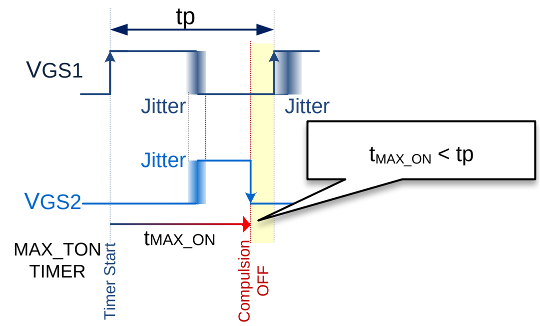


Figure 15. Setting of the maximum ON time T_{MAX_ON}

(When the controller has the jitter function)

[Reference: Setting the MAX_TON pin when the continuous-mode operation is not conducted]

Setting the MAX_TON pin is not required in the non-continuous mode, under the quasi-resonant control or in the LLC application where the continuous-mode operation is not conducted. In such a case, the function can be disabled by pulling up the MAX_TON pin to VCC. When the MAX_TON pin is pulled up to VCC, connecting components to the pin is not required.

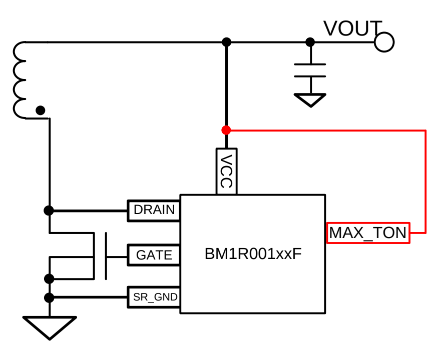


Figure 16. Setting of MAX_TON pin

(When the continuous-mode operation is not conducted)

[Reference: How to calculate the compulsion OFF time when the continuous-mode operation is not conducted]

As setting the maximum ON time t_{MAX_ON} is not required, t_{MAX_ON} does not need to be calculated. Instead, measure the time (t_{ON}) before the forward current I_F becomes 0 after the rectifying diode is turned ON. The necessary compulsion OFF time t_{OFF} is expressed with the following formula:

$$t_{OFF}[\mu\sec] < t_p[\mu\sec] - t_{ON}[\mu\sec]$$

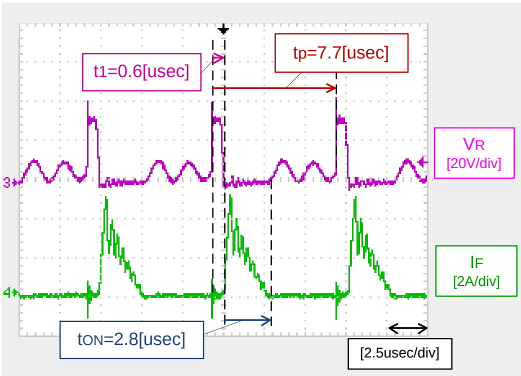


Figure 17. Rectifying diode's reverse voltage V_R and forward current I_F

(When the continuous-mode operation is not conducted)

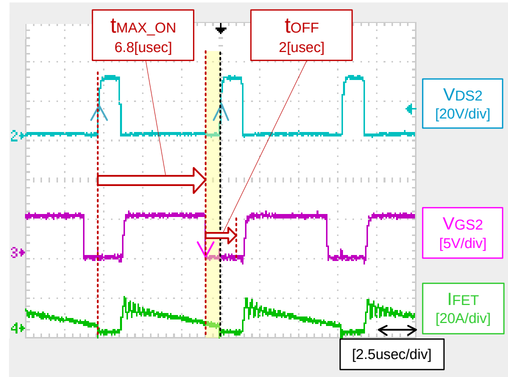


Figure 18. Waveforms of secondary-side synchronous rectification under heavy loading when BM1R00147F is selected and R_{TON}=68 kΩ

1-2-3. Selecting the IC

The necessary compulsion OFF time t_{OFF} is expressed with the following formula by using the ON time of the primary-side MOSFET M1 (t1) and the cycle time of the primary-side controller (tp) measured in 1-2-1 and the maximum ON time t_{MAX_ON} calculated in 1-2-2:

$$t_{OFF}[\mu\text{sec}] < t_p[\mu\text{sec}] - (t_{MAX\_ON}[\mu\text{sec}] - t_1[\mu\text{sec}])$$

$$7.7[\mu\text{sec}] - (6.8[\mu\text{sec}] - 1.4[\mu\text{sec}]) = 2.3[\mu\text{sec}]$$

Based on the result of the above calculation and in consideration of variation, this design example selects BM1R00147F with the compulsion OFF time t_{OFF} of 2 usec (Typ.). (Variation of the compulsion OFF time is ±9%.) Note that this formula is expressing the ideal state. Therefore, please check the operation sufficiently with the actual equipment when selecting the IC.

Table 1. Lineup table

Part Number	Compulsion ON Time (Typ.) [us]	Compulsion OFF Time (Typ.) [us]
BM1R00146F	NONE	1.3
BM1R00147F	NONE	2.0
BM1R00148F	NONE	3.0
BM1R00149F	NONE	3.6
BM1R00150F	NONE	4.6

1-3. Selecting peripheral circuit components

1-3-1. DRAIN pins D1, R1, and R2

Gate of the secondary-side MOSFET is controlled by utilizing the DRAIN pin voltage. As the DRAIN pin VDS2 detection level is as low as several millivolt, even a small surge voltage at the time of MOSFET switching causes erroneous detection. Therefore, it is required to take measures to absorb surge for the DRAIN pin.

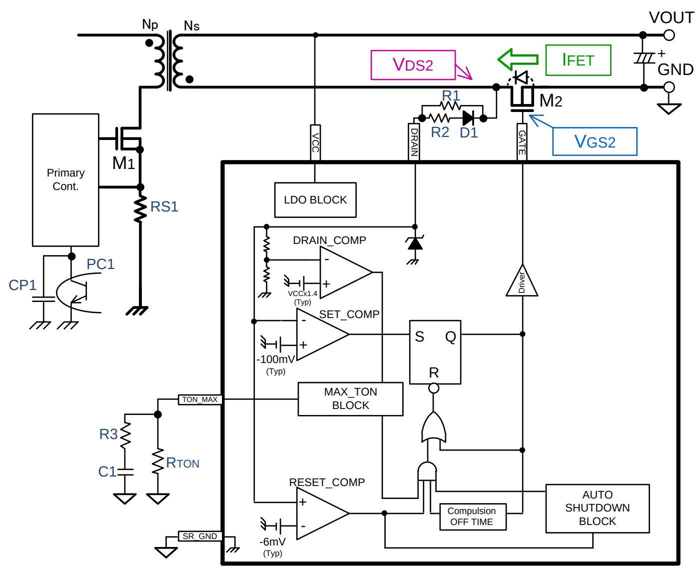


Figure 19. Block diagram of secondary-side synchronous rectification section

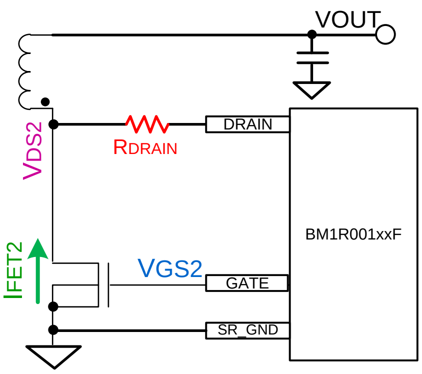


Figure 20. Circuit of DRAIN pin section
(With no measures for surge)

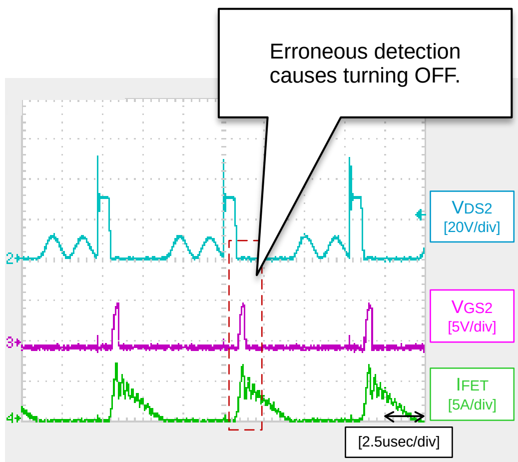


Figure 21. Waveforms of secondary-side synchronous rectification (With no measures for surge)

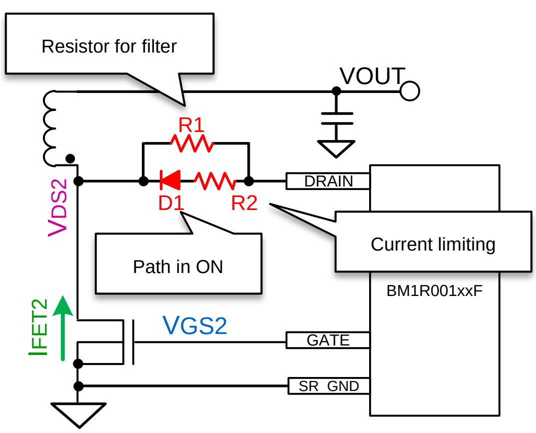


Figure 22. Circuit of DRAIN pin section
(With measures for surge)

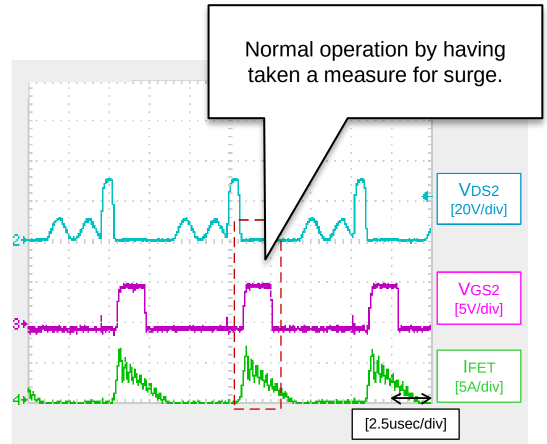


Figure 23. Waveforms of secondary-side synchronous rectification (With measures for surge)

Select the small-signal Schottky-barrier diode D1 with low forward voltage V_f. Because of high impedance of the DRAIN pin, D1 does not need to withstand the voltage exceeding V_{DS2} and the diode with low withstanding voltage can be selected. For this design example, we select ROHM's RB751VM-40 (V_R=30 V, I_O=30 mA, $V_{f\ MAX}$=0.37 V).

R1 is a resistor for the V_{DS2} detection filter. Insert a resistance of about 300 Ω to 2 kΩ. Determine the R1 constant setting by checking the V_{DS2} waveform and the V_{GS2} waveform in reference to the following paragraph below "1. When the secondary-side MOSFET is turned OFF instantaneously" of the section "Troubleshooting in the flyback application" in page 10. For this design example, we select 1 kΩ.

R2 is a current limiting resistor. The moment when the current I_{FET2} starts to flow through the secondary-side MOSFET M2, the I_{FET2} flows through the secondary-side MOSFET's body diode because the secondary-side MOSFET is turned OFF and it causes V_{DS2}=-V_{f_M2}. As negative voltage is input to the IC's DRAIN pin, the current I_d is sourced from the IC. Insert R2 so that the current I_d that flows in this situation does not exceed 6 mA for protection of the IC. R2 is calculated according to the following formula:

$$R_2[\Omega] > \frac{V_{f\_M2\_MAX}[V] - V_{f\_D1\_MIN}[V] - V_{f\_ESD\_MIN}[V]}{6[mA]}$$

R_2>100Ω when the maximum value of V_f of M2, $V_{f\_M2\_MAX}$, is 1.2 V, the minimum value of V_f of D1, $V_{f\_D1\_MIN}$, is 0.2 V and the minimum value of V_f of ESD diode, $V_{f\_ESD\_MIN}$, is 0.4 V. We select 150 Ω by taking into account a margin.

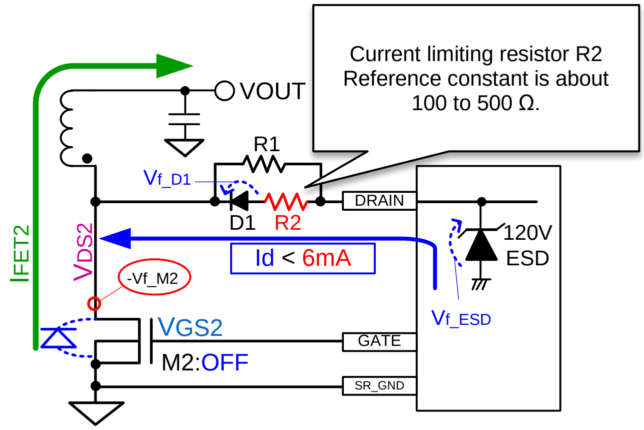


Figure 24. Setting the current limiting resistor R2 - circuit diagram

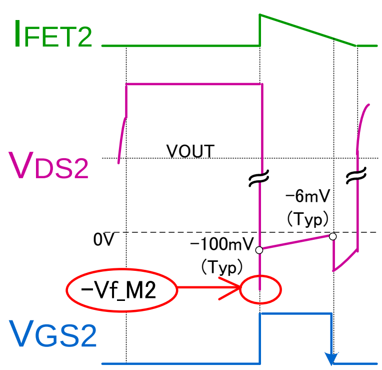


Figure 25. Setting the current limiting resistor R2 - operation waveforms

1-3-2. C1 and R3 for the MAX_TON pin

The MAX_TON pin voltage is output as 0.4 V (Typ). In order to reduce the effects of the switching noise, connect the capacitor C1 and the resistor R3 in series. Be sure to connect C1 and R3 as they also serve as phase compensation of the MAX_TON pin. About 1000 pF and 1 kΩ are recommended for C1 and R3 respectively.

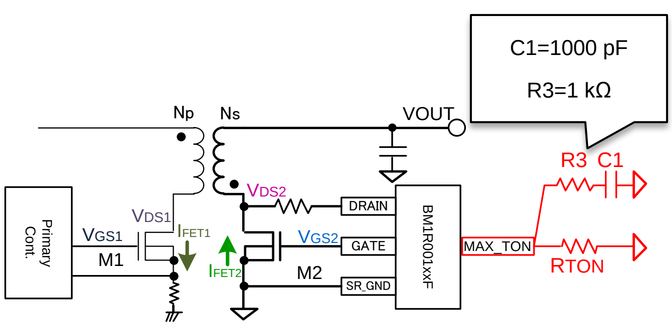


Figure 26. Setting C1 and R3 for the MAX_TON pin (In the continuous-mode operation)

1-3-3. VCC pin

It is the IC’s power supply pin. Operation is started when VCC is at least 2.3 V (Typ) and shuts down when VCC is less than 2.25 V (Typ). As the secondary-side output V_{OUT} of this design example is 5 V, the simplest power supply of connecting to the VCC is possible as shown in Figure 27 in the case of the Low Side Type.

In the case of the High Side Type where the secondary-side GND and the IC’s GND pin SR_GND are not sharing the supply voltage, prepare the additional supply voltage by adding an auxiliary power supply circuit as shown below in Figure 28 or providing the auxiliary winding on the secondary side of the transformer as shown below in Figure 29.

For stable operation of the IC, select at least 1 uF capacitor as the VCC pin’s capacitor C_{VCC}. Be careful not to select an excessively large capacity as it leads to long start-up time. We select 10 uF for this design example.

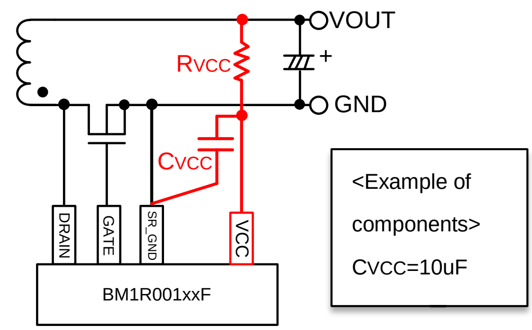


Figure 27. Example of VCC power supply method 1 (Low Side Type)

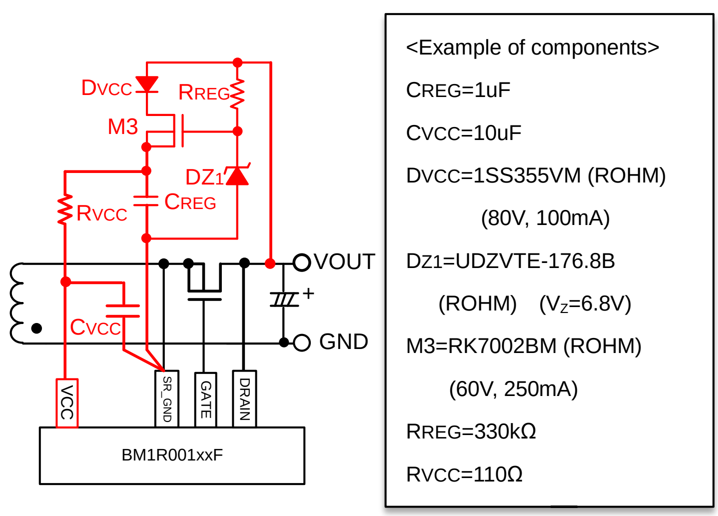
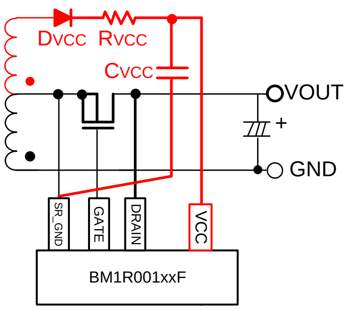


Figure 28. Example of VCC power supply method 2 (High Side Type)



<Example of components>
CVCC=10 uF
DVCC= RF05VAM2S (ROHM)
(200 V, 500 mA)
RVCC=10 Ω

Figure 29. Example of VCC power supply method 3 (High Side Type)

2. Shunt regulator circuit

The relevant models have built-in low-consumption and high-accuracy shunt regulators. The circuit uses the resistances R_{FB1} and R_{FB2} for setting the output voltage VOUT. As the built-in shunt regulators are of the CMOS structure, it is not required to set the base current. As a result, high impedance can be provided by using the resistances R_{FB1} and R_{FB2}, and the standby power is reduced. For a stable operation, determine the resistances R_{FB1} and R_{FB2} so that I_{FB} is about 10 uA. Relation with the built-in shunt regulator's reference voltage V_{REF}=0.8 V (Typ) is expressed as the formula below.

$$VOUT[V] = \left(1 + \frac{R_{FB1}[\Omega]}{R_{FB2}[\Omega]}\right) \times V_{REF}[V]$$

For this design example, we calculate R_{FB1} and R_{FB2} according to the following formula in order to set VOUT=5 V.

$$VOUT = \left(1 + \frac{420[k\Omega]}{80[k\Omega]}\right) \times 0.8[V] = 5[V]$$

$$R_{FB1} = 420[k\Omega]$$

$$R_{FB2} = 80[k\Omega]$$

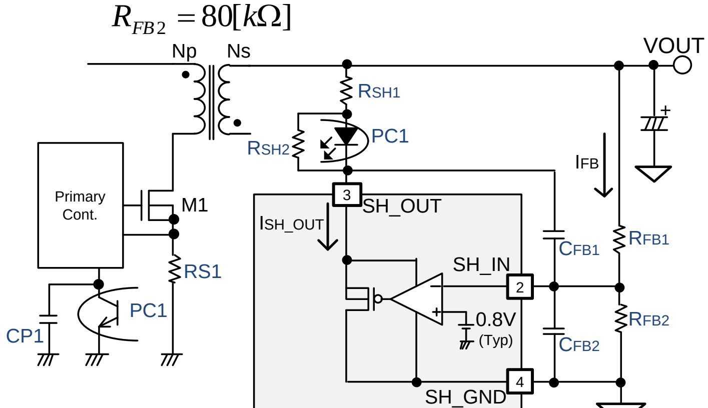


Figure 30. Built-in shunt regulator section - circuit diagram

C_{FB1} is a capacitor for phase compensation. Select a capacitor of about 1000 pF.

C_{FB2} is a capacitor for eliminating noise from the SH_IN pin. As a rough indication, its capacitance is about 100 to 470 pF. It is 220 pF in this design example.

The output load response can be adjusted by using the resistance R_{SH1}. By reducing R_{SH1}, load fluctuation can be suppressed, but as there is a trade-off relationship with stability, please consider well when selecting the resistance. It is 510 Ω in this design example.

Resistance R_{SH2} is used for setting the circuit current of the built-in shunt regulator. As the maximum value of the SH_OUT pin current $I_{SH\_OUT\_max}$ when SH_IN=Low is 75 uA, the relationship between R_{SH2} and the minimum Vf value of the photocoupler PC1 Vf_min should satisfy the following formula:

$$R_{SH2}[\Omega] < \frac{V_{f\_min}[V]}{75[\mu A]}$$

If Vf_min of the photocoupler PC1 used for this design example is 1.1 V,

$$R_{SH2}[\Omega] < \frac{1.1[V]}{75[\mu A]} = 14.7[k\Omega]$$

R_{SH2} is calculated to be less than 14.7 kΩ. Considering a margin, we select 12 kΩ.

Troubleshooting in the flyback application

1. When the secondary-side MOSFET is turned OFF instantaneously:

Because of a noise generated by the DRAIN pin voltage, the secondary-side MOSFET may be turned OFF.

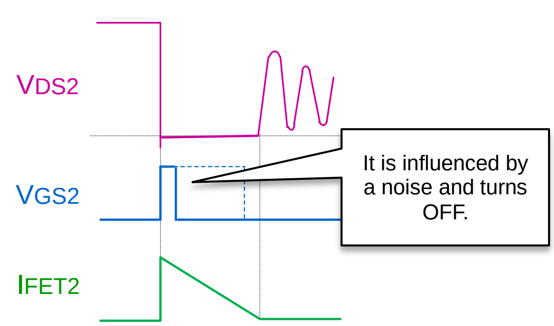


Figure 31. Waveform of secondary-side MOSFET that turns OFF instantaneously

<Countermeasure 1-① : Increasing the resistance R1 connected to the DRAIN pin by inserting the ferrite bead B1>

Erroneous detection can be avoided by inserting the ferrite bead B1 for absorption of surge or increasing the value of the resistor R1 for the filter.

The type of ferrite bead B1 that has high impedance in the low-frequency range is recommended.

(Example of component: MPZ1608S102AT (TDK))

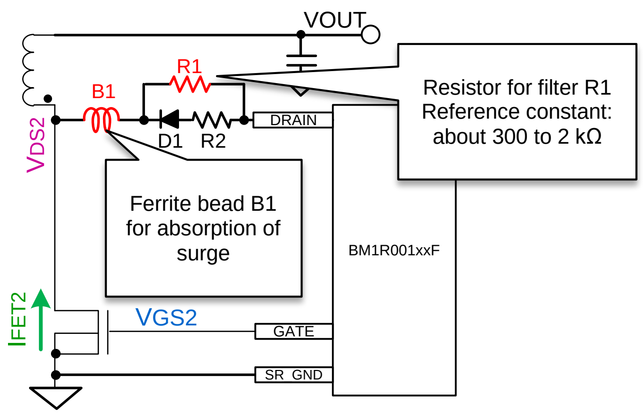


Figure 32. Countermeasure 1-① Inserting B1 and adjusting R1 resistance

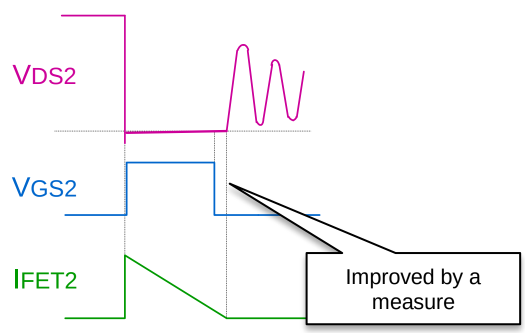


Figure 33. Operation waveform after implementing countermeasure 1-①

■Countermeasure 1-① Contradictory event

If impedance caused by B1 and R1 is too large, the secondary-side MOSFET may be turned ON under the light load because of resonant operation. Therefore, checking the operation under the light load is necessary. (See the above paragraph “2. When the secondary-side MOSFET is turned ON under the light load because of resonant operation” of the section “Troubleshooting in the flyback application” in page 11.)

2. When the secondary-side MOSFET is turned ON under the light load because of resonant operation:

When the value of the resistor for the filter R1 is too large, the secondary-side MOSFET may be turned ON under the light load.

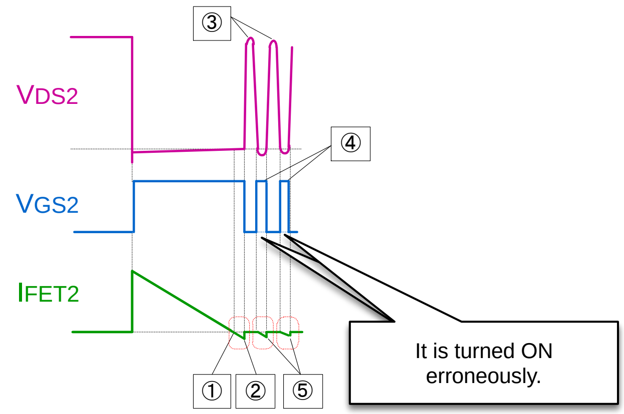


Figure 34. Waveform of erroneous detection under the light load

① As the resistance R1 that determines the OFF timing is large, detection of the DRAIN pin voltage is delayed and V_{GS2} does not change to “Low.”

② Reverse flow of I_{FET2} continues until V_{GS2} becomes “Low.”

③ Resonant amplification of V_{DS2} becomes large as the secondary-side MOSFET is turned OFF after accumulation of reverse flow status.

④ V_{DS2} becomes the negative voltage again and V_{GS2} changes to “High.” (Secondary-side MOSFET is turned ON erroneously.)

⑤ Similar to ②, reverse flow of I_{FET2} occurs.

Then, ③, ④ and ⑤ are repeated.

<Countermeasure 2-① : Decreasing the resistance R1 connected to the DRAIN pin>

By decreasing the value of the resistor for the filter R1, resonant amplification of V_{DS2} is lowered and the operation that turns ON the secondary-side MOSFET erroneously can be avoided.

■Countermeasure 2-① Contradictory event

If R1 is decreased excessively, effects of the noise filter are also reduced and the secondary-side MOSFET may be turned OFF instantaneously because of a noise generated by the DRAIN pin voltage. Therefore, checking the operation is necessary. (See the above paragraph “1. When the secondary-side MOSFET is turned OFF instantaneously” of the section “Troubleshooting in the flyback application” in page 10.)

<Countermeasure 2-②: Change to the model with longer compulsion OFF time>

The operation that turns ON the secondary-side MOSFET erroneously can be masked by selecting from the lineup, the model with the compulsion OFF time that is longer than the time before a resonance cycle ends after the secondary-side MOSFET is turned OFF.

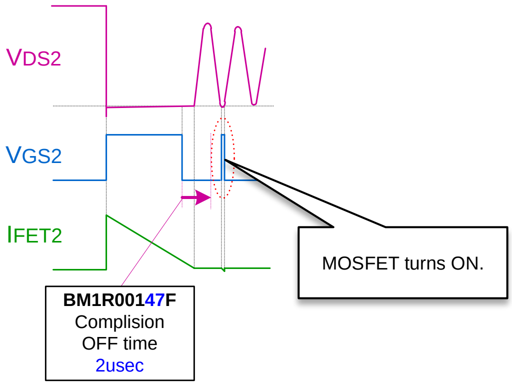


Figure 35. Operation waveform before implementing countermeasure 2-②

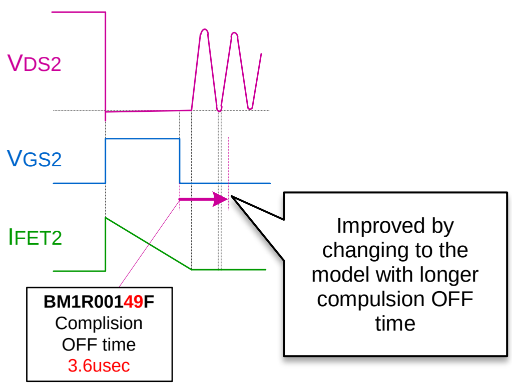


Figure 36. Operation waveform after implementing countermeasure 2-②

■ Countermeasure 2-② Contradictory event

If the compulsion OFF time is too long, the timing when the secondary-side MOSFET is turned ON under the heavy loading may be delayed because of the compulsion OFF time. Therefore, checking the operation under heavy loading is necessary.

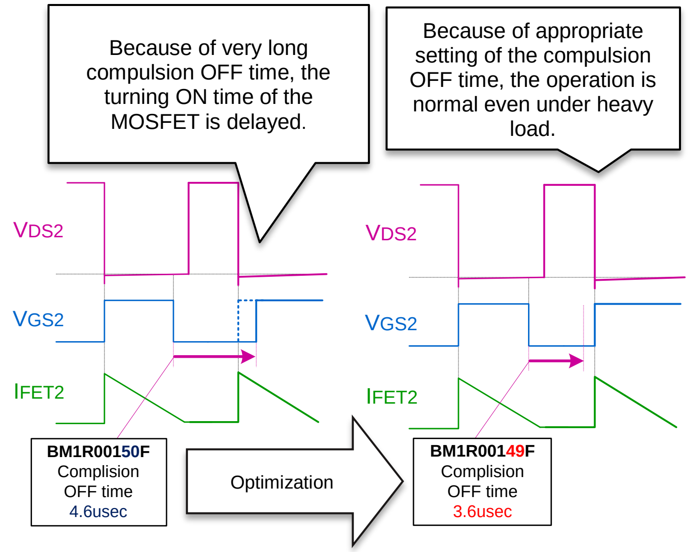


Figure 37. Countermeasure 2-② Contradictory event

< Countermeasure 2-③: Adding snubber circuit between the secondary-side MOSFET's DRAIN and SOURCE>

Amplitude of V_{DS2} is attenuated by adding a snubber circuit.

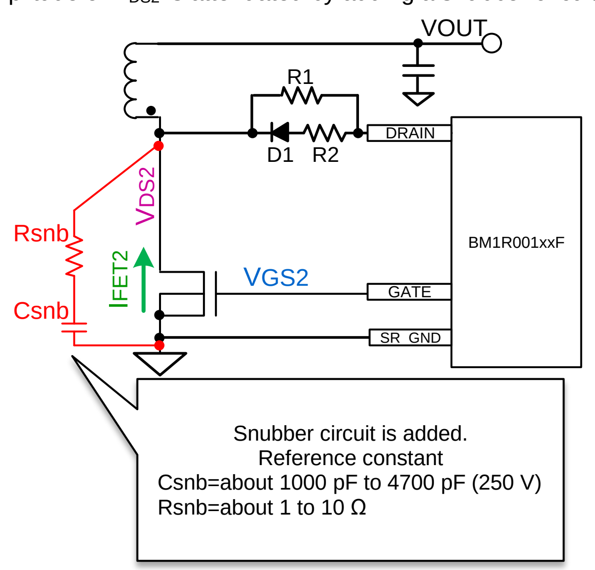


Figure 38. Countermeasure 2-③ Adding snubber circuit

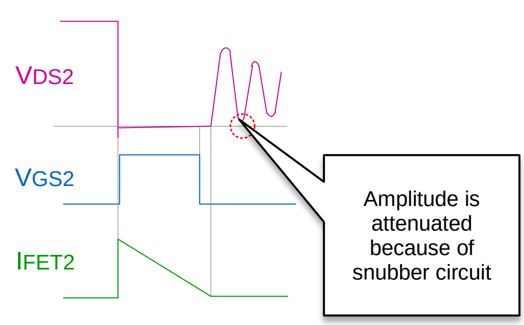


Figure 39. Operation waveform after implementing countermeasure 2-③

■ Countermeasure 2-③ Contradictory event

Checking characteristics is necessary as the standby power and efficiency in the range where the resonant operation occurs (no load to medium load) deteriorate by adding a snubber circuit.

<Countermeasure 2-④: Reducing transformer's winding ratio Ns / Np>

Amplitude of V_{DS2} is attenuated by changing transformer's winding ratio.

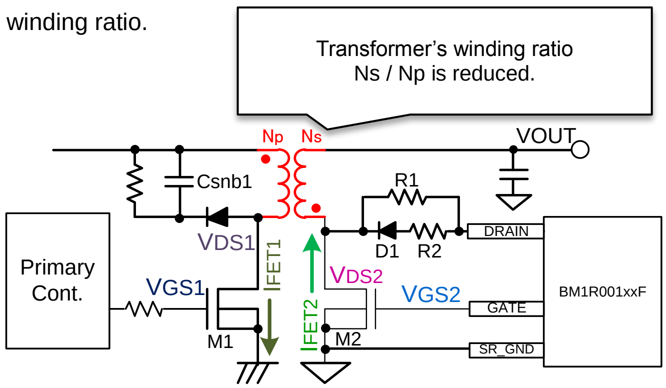


Figure 40. Countermeasure 2-④ Adjusting transformer's winding ratio

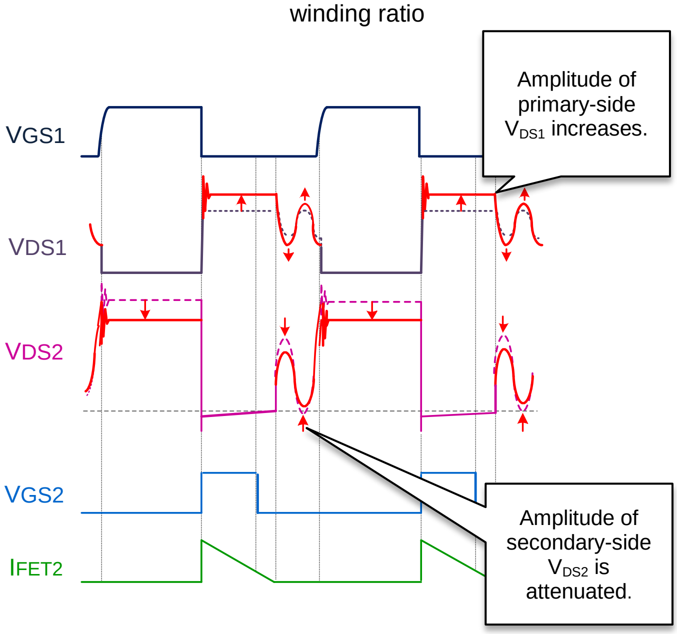


Figure 41. Operation waveform after implementing countermeasure 2-④

■Countermeasure 2-④ Contradictory event

As V_{DS1} of the primary-side MOSFET increases, the VDS withstanding margin of the primary-side MOSFET M1 is reduced. Adjust the transformer's winding ratio so that V_{DS1} does not exceed the breakdown voltage.

3. When V_{DS2} is influenced by surge and exceeds the V_{DS} breakdown voltage of the secondary-side MOSFET, the voltage exceeding the breakdown voltage of the secondary-side MOSFET's V_{DS} may be applied to the V_{DS2} because of surge.

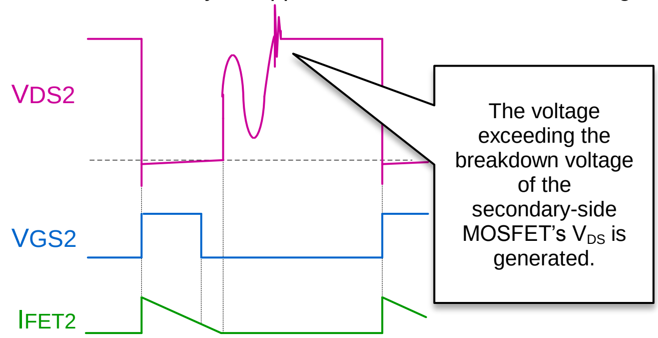


Figure 42. Operation waveform when V_{DS2} surge voltage is generated

<Countermeasure 3-①: Inserting a capacitor between the secondary-side MOSFET's DRAIN and SOURCE>

Overshoot V_{DS2} is smoothed by inserting a capacitor between the secondary-side MOSFET's DRAIN and SOURCE.

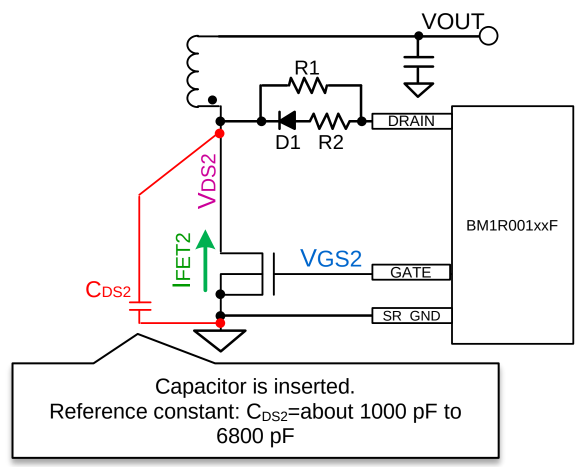


Figure 43. Countermeasure 3-① Insertion of capacitor

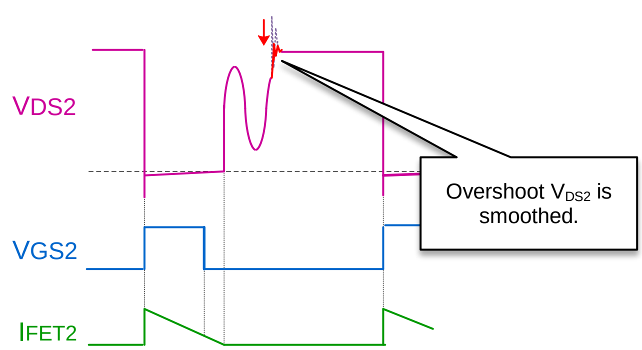


Figure 44. Operation waveform after implementing countermeasure 3-①

■Countermeasure 3-① Contradictory event

Checking characteristics is necessary as efficiency in the range where resonance occurs (no load to light load) deteriorates by adding a capacitor.

<Countermeasure 3-②: Increasing the primary-side FET's GATE resistance>

Overshoot on the secondary-side V_{DS2} can be reduced by increasing the GATE resistance R_{GATE1} of the primary-side FET M1 and delaying the rise time of V_{GS1}.

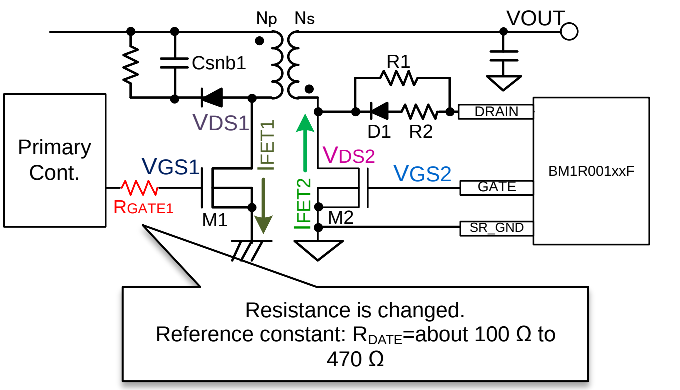


Figure 45. Adjusting resistance R_{GATE}

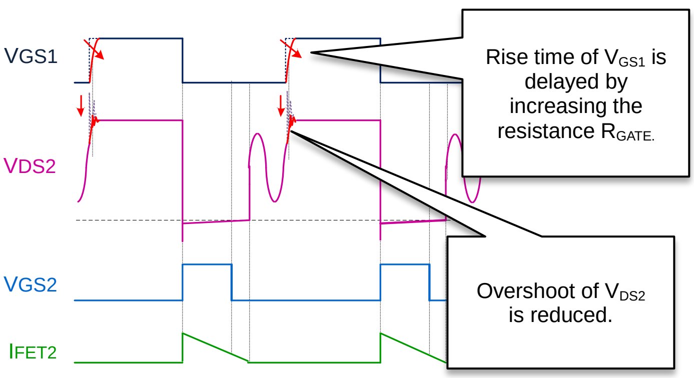


Figure 46. Operation waveform after implementing countermeasure 3-②

■Countermeasure 3-② Contradictory event

Checking characteristics is necessary as deterioration in efficiency and generation of heat on the primary-side MOSFET M1 are the concerns when the value of R_{GATE1} is increased.

<Countermeasure 3-③: Reducing transformer's winding ratio Ns / Np>

Amplitude of V_{DS2} is attenuated by changing transformer's winding ratio.

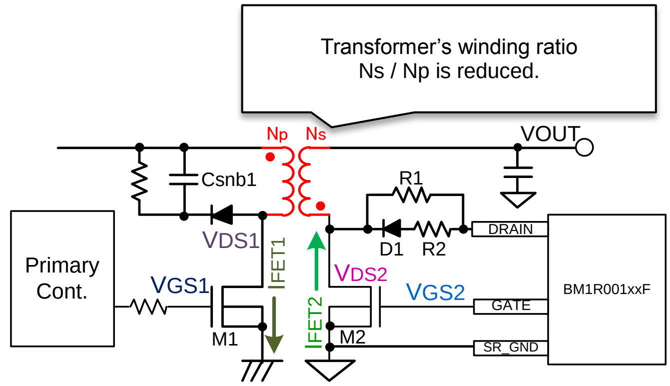


Figure 47. Countermeasure 3-③ Adjusting transformer's winding ratio

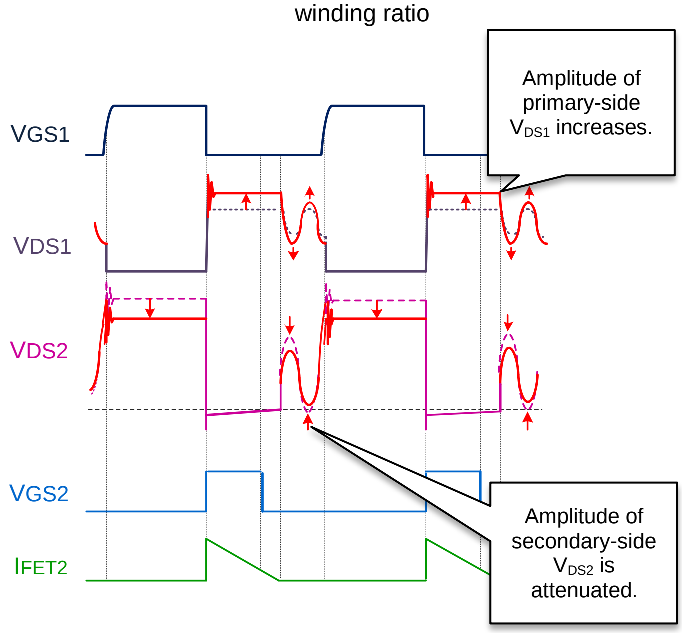


Figure 48. Operation waveform after implementing countermeasure 3-③

■Countermeasure 3-③ Contradictory event

As V_{DS1} of the primary-side MOSFET increases, the VDS withstanding margin of the primary-side MOSFET M1 is reduced. Adjust the transformer's winding ratio so that V_{DS1} does not exceed the breakdown voltage.

Evaluation characteristics data

Comparison of efficiency of the three following evaluation boards

Input VIN=400Vdc

Output VOUT=5 V, IOUT=0 - 10 A (MAX) sweep

・Before replacement rectifying diode installed

・After replacement with BM1R00147F (High Side Type)

・After replacement with BM1R00147F (Low Side Type)

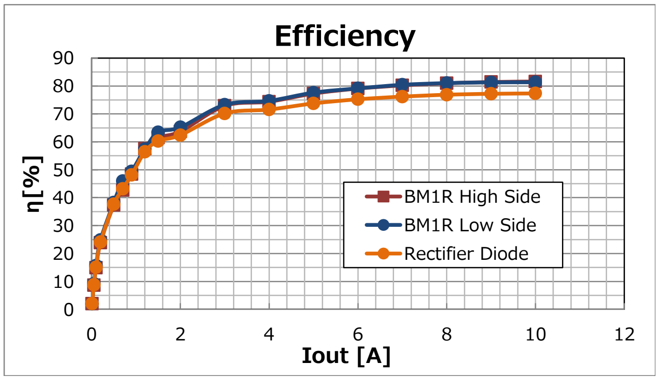


Figure 49. Data of efficiency

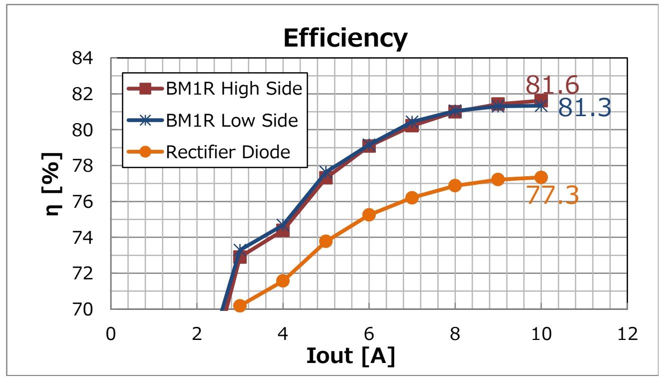


Figure 50. Enlarged data of efficiency

Evaluation Circuit

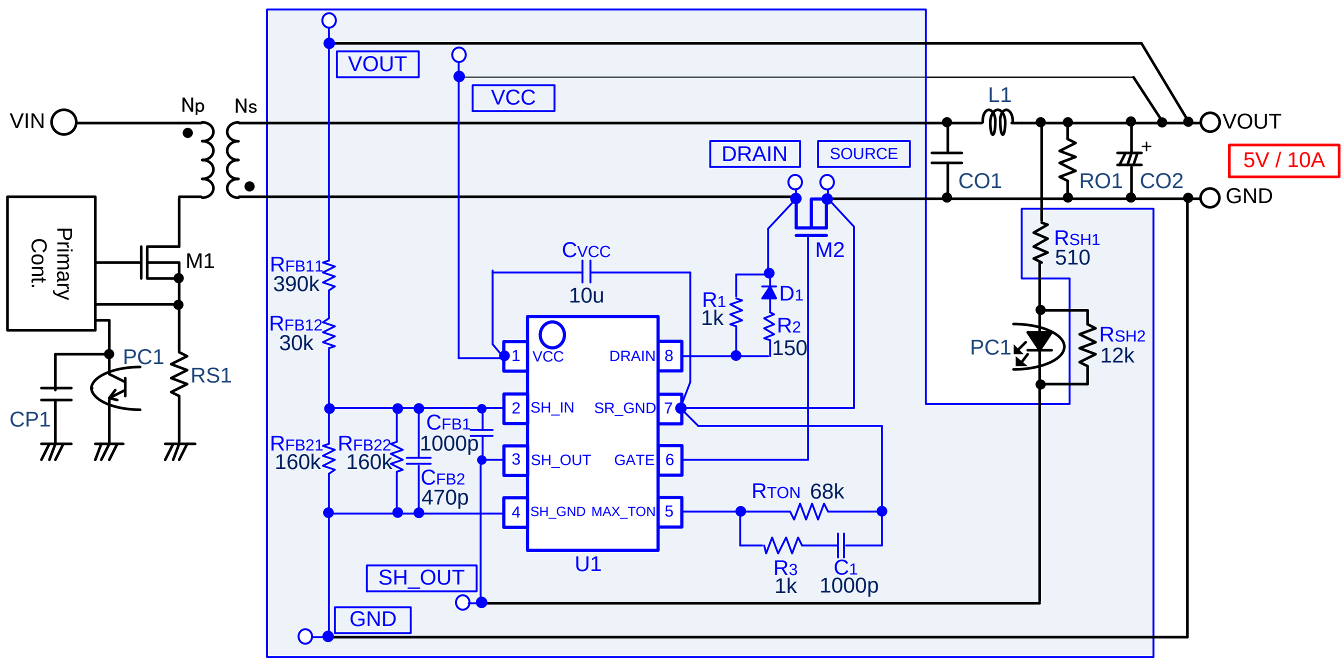


Figure 51. BM1R100147F Evaluation Circuit

(Low Side Type)

Table 2. BM1R100147F Evaluation Circuit BOM List

(Low Side Type)

No	Symbol	Type	Value	Rating	Part Number	Manufacturer
1	C1	Capacitor	1000pF	50V	GRM188R71H102KA01D	MURATA
2	CFB1	Capacitor	1000pF	50V	GRM188R71H102KA01D	MURATA
3	CFB2	Capacitor	220pF	50V	GRM188R71H221KA01D	MURATA
4	CVCC	Capacitor	10uF	50V	GRM31CB31H106KA12L	MURATA
5	D1	Diode	-	40V / 30mA	RB751VM-40	ROHM
6	R1	Resistor	1kΩ	1/10W	MCR03EZPFX1001	ROHM
7	R2	Resistor	150Ω	1/10W	MCR03EZPFX1500	ROHM
8	R3	Resistor	1kΩ	1/10W	MCR03EZPFX1001	ROHM
9	RFB11	Resistor	390kΩ	1/10W	MCR03EZPFX3903	ROHM
10	RFB12	Resistor	30kΩ	1/10W	MCR03EZPFX3002	ROHM
11	RFB21	Resistor	160kΩ	1/10W	MCR03EZPFX1603	ROHM
12	RFB22	Resistor	160kΩ	1/10W	MCR03EZPFX1603	ROHM
13	RREG	Resistor	330kΩ	1/10W	MCR03EZPFX3303	ROHM
14	RSH1	Resistor	510Ω	1/10W	MCR03EZPFX5100	ROHM
15	RSH2	Resistor	12kΩ	1/10W	MCR03EZPFX1202	ROHM
16	RTON	Resistor	68kΩ	1/10W	MCR03EZPFX6802	ROHM
17	RVCC	Resistor	10Ω	1/4W	MCR18EZPF10R0	ROHM
18	U1	IC	-	-	BM1R00147F	ROHM

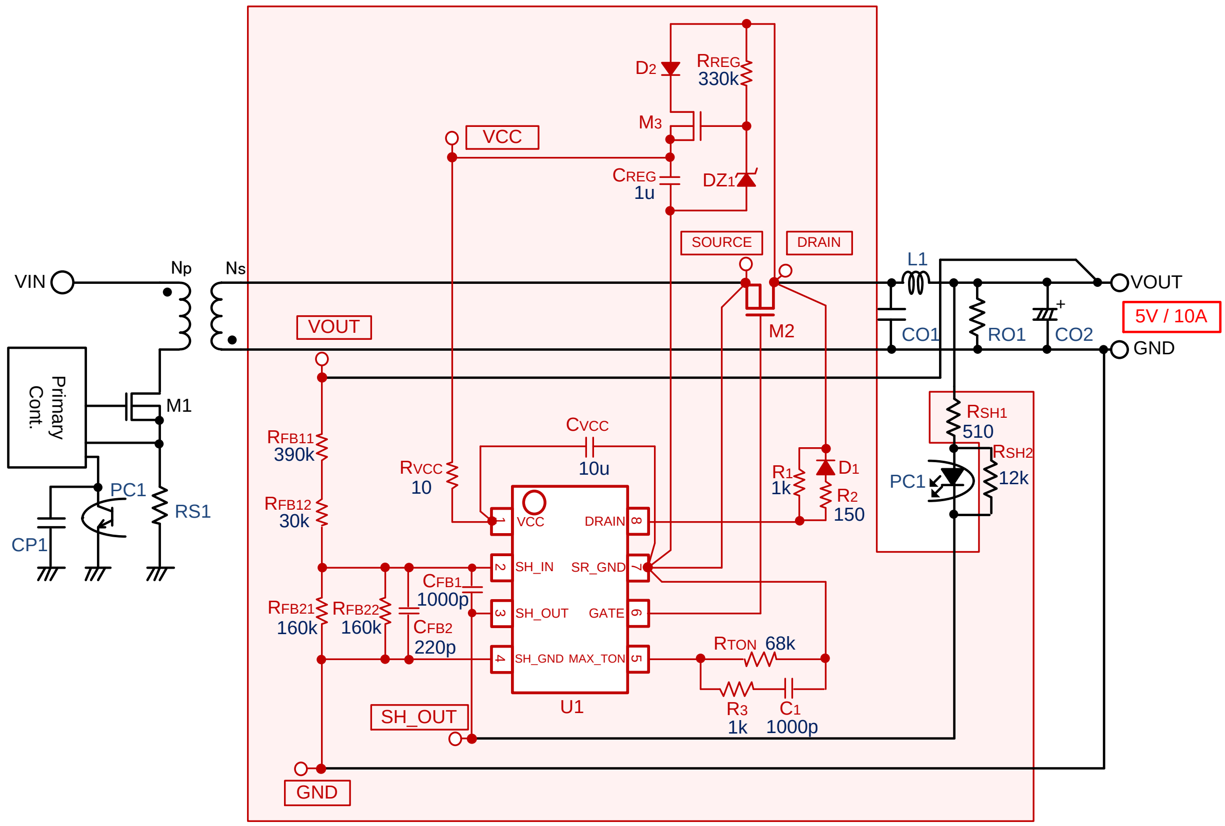


Figure 52. BM1R100147F Evaluation Circuit

(High Side Type)

Table 3. BM1R100147F Evaluation Circuit BOM List

(High Side Type)

No	Symbol	Type	Value	Rating	Part Number	Manufacturer
1	C1	Capacitor	1000pF	50V	GRM188R71H102KA01D	MURATA
2	CFB1	Capacitor	1000pF	50V	GRM188R71H102KA01D	MURATA
3	CFB2	Capacitor	220pF	50V	GRM188R71H221KA01D	MURATA
4	CREG	Capacitor	1uF	25V	GRM188R71E105KA12D	MURATA
5	CVCC	Capacitor	10uF	50V	GRM31CB31H106KA12L	MURATA
6	D1	Diode	-	40V / 30mA	RB751VM-40	ROHM
7	D2	Diode	-	80V / 100mA	1SS355VM	ROHM
8	DZ1	Zener Diode	-	6.8V	UDZVTE-176.8B	ROHM
9	M3	MOSFET	-	60V / 0.25A	RK7002BM	ROHM
10	R1	Resistor	1kΩ	1/10W	MCR03EZPFX1001	ROHM
11	R2	Resistor	150Ω	1/10W	MCR03EZPFX1500	ROHM
12	R3	Resistor	1kΩ	1/10W	MCR03EZPFX1001	ROHM
13	RFB11	Resistor	390kΩ	1/10W	MCR03EZPFX3903	ROHM
14	RFB12	Resistor	30kΩ	1/10W	MCR03EZPFX3002	ROHM
15	RFB21	Resistor	160kΩ	1/10W	MCR03EZPFX1603	ROHM
16	RFB22	Resistor	160kΩ	1/10W	MCR03EZPFX1603	ROHM
17	RREG	Resistor	330kΩ	1/10W	MCR03EZPFX3303	ROHM
18	RSH1	Resistor	510Ω	1/10W	MCR03EZPFX5100	ROHM
19	RSH2	Resistor	12kΩ	1/10W	MCR03EZPFX1202	ROHM
20	RTON	Resistor	68kΩ	1/10W	MCR03EZPFX6802	ROHM
21	RVCC	Resistor	10Ω	1/4W	MCR18EZPF10R0	ROHM
22	U1	IC	-	-	BM1R00147F	ROHM

Notes on the PCB Layout

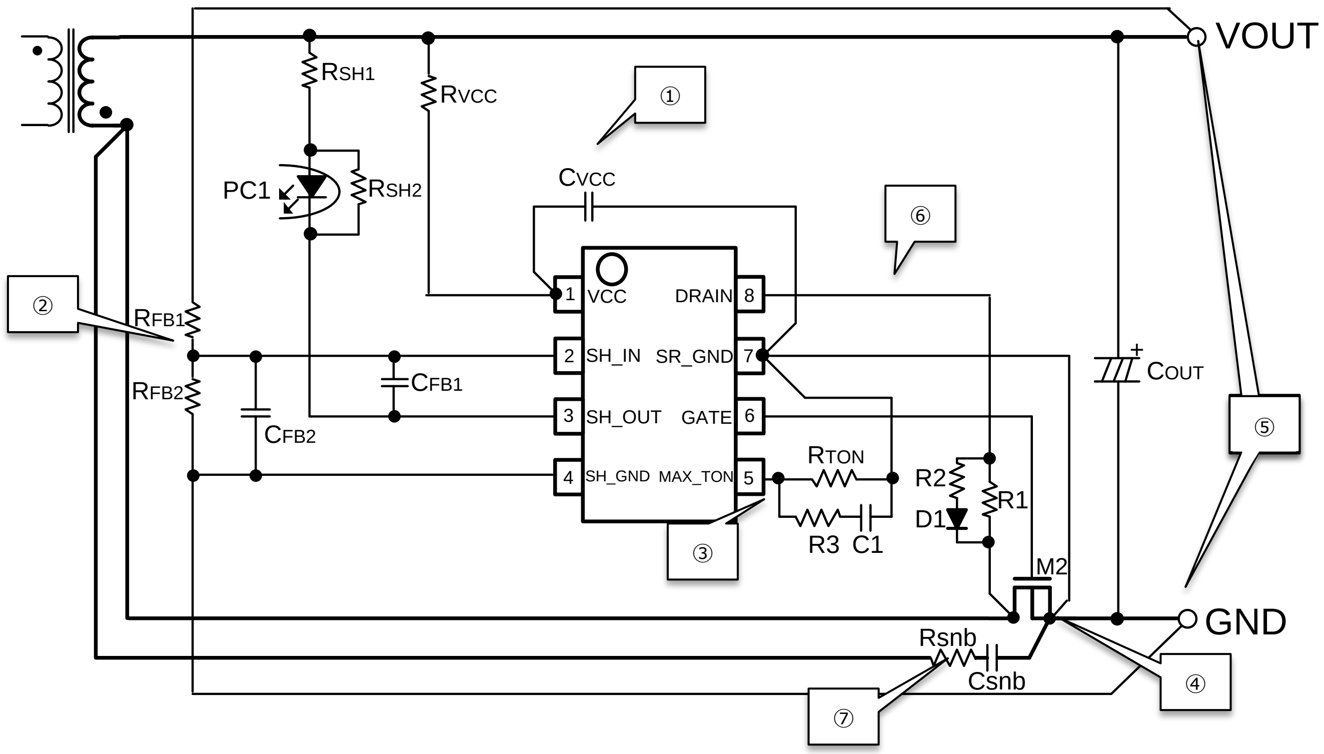


Figure 53. Notes on the PCB Layout

①VCC line may malfunction under the influence of switching noise. Therefore, it is recommended to insert a capacitor C_{VCC} between the VCC and SR_GND terminal.

②SH_IN terminal is a high impedance line. To avoid crosstalk, electrical wiring should be as short as possible and not in parallel with the switching line.

③ MAX_TON terminal has a 0.4V output. The external components of the MAX_TON terminal affects the compulsion OFF time due to switching. Thus, R_{TON}, R1 and C1 should be connected to MAX_TON terminal as near as possible. It is also recommended to use an independent electrical wiring in connection with SR_GND terminal.

④The synchronous rectification controller IC must accurately monitor the V_{DS} generated in the FET. Accordingly, the electrical wiring between the DRAIN to DRAIN and SR_GND to SOURCE of the IC and FET respectively should be connected independently.

⑤The SH_GND of the shunt regulator and the feedback resistors of VOUT are recommended to be connected to the GND of the output with an independent electrical wiring.

⑥The DRAIN terminal is a 0↔100V switching line. Use a narrow wiring and connect as short as possible.

⑦Use an independent wiring if connecting a snubber circuit between the DS of the FET. The connection of the transformer output and the SOURCE of the FET should be thick and short as possible.

Revision History

Date	Revision	Changes
14.Jun.2017	001	Rev.001 Release
7.Feb.2019	002	Page 8: Changed the formula of R2. Page 9: Changed the Figure 24. Page 16: Changed the Figure 51 and Table 2. (Low Side Type) Page 17: Changed the Figure 52 and Table 3. (High Side Type)

Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications :

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors.
Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Poducts beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

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7) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative : transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

8) Do not use our Products in applications requiring extremely high reliability, such as aerospace equipment, nuclear power control systems, and submarine repeaters.

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