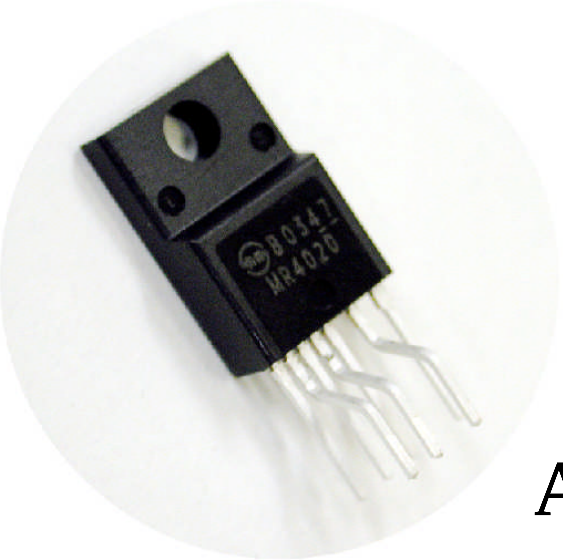
Provision for standby mode operation

Partial Resonance Power Supply IC Module

MR4000 Series



Application Note

Version 1.4

Shindengen Electric Manufacturing Co., Ltd.

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Caution	⚠	Never attempt to repair or modify the product. Doing so may lead to serious accidents. <<Electric shock, destruction of property, fire, or malfunctions may result.>>
	⚠	In the event of a problem, an excessive voltage may arise at an output terminal, or the voltage may drop. Anticipate these fluctuations and any consequential malfunctions or destruction and provide adequate protection for equipment, such as overvoltage or overcurrent protection.
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	⚠	Use only the specified input voltage. Deploy a protective element on the input line. <<Problems may result in smoke or fire.>>
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Contents

1. Overview

1.1 Introduction

The MR4000 Series IC modules incorporate a burst-mode switching function at micro-loads. These are partial resonance modules consisting of a switching device optimized for 100 V, 200 V, and auto-sensing power supply input and a control IC. The IC modules are designed to provide the following power supply characteristics:

1.2 Characteristics

1. High efficiency and low noise through partial resonance
2. Second-generation high-speed IGBT with 900-V resistance simplifies design for auto-sensing power supply input. (MR40XX series)
3. Burst mode helps reduce power consumption at micro-loads.
4. Onboard startup circuit eliminates the need for startup resistors.
5. Soft-drive circuit achieves low noise levels.
6. Overcurrent protection function (ton limit and primary current limit), overvoltage protection, and thermal shutdown function
7. Allow configuration of a power supply circuit with fewer external components.
8. Full-mold package facilitates insulation design.

1.3 Applications

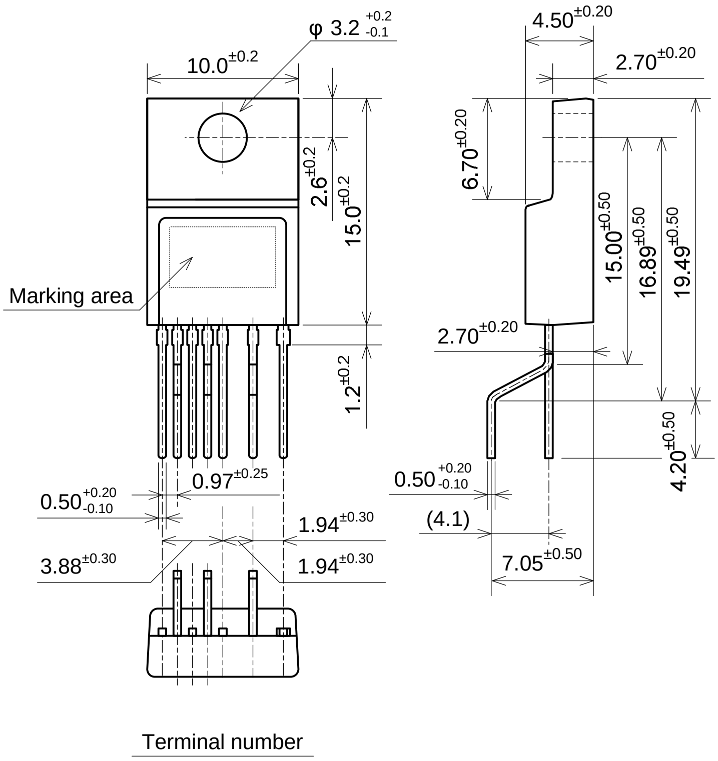
Televisions, displays, printers, video recorders, DVD, STB, refrigerators, and other appliances; various automated business machines

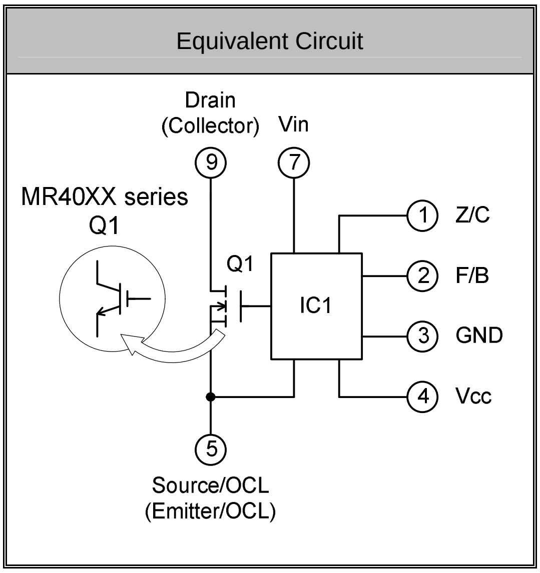
1.4 Absolute maximum ratings and reference output capacities

型 名	Main switching device		Maximum output capacity Po[W]		
		VDS/VCE [V]	Input voltage range		
			AC90 - 132V	AC180 - 276V	AC90 - 276V
MR4500	MOSFET	500	12 (20)	—	—
MR4510			25 (40)	—	—
MR4520			50 (80)	—	—
MR4530			80 (100)	—	—
MR4710		700	—	25 (40)	12 (20)
MR4720			—	50 (80)	25 (40)
MR4010	Second–generation high-speed IGBT	900	—	65	45
MR4020			—	105	70
MR4030			—	135	90
MR4040			—	180	120

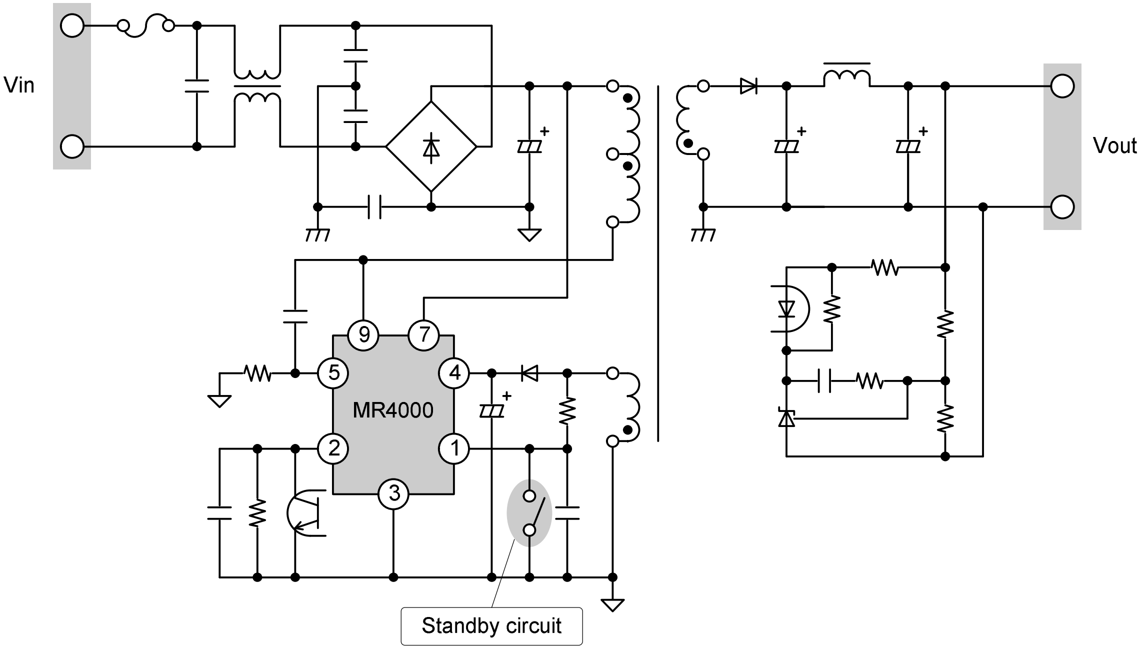
Maximum output capacity and input voltage range vary with design parameters.
Output capacities in parentheses are peak values.

1.5 Dimensions and equivalent circuit



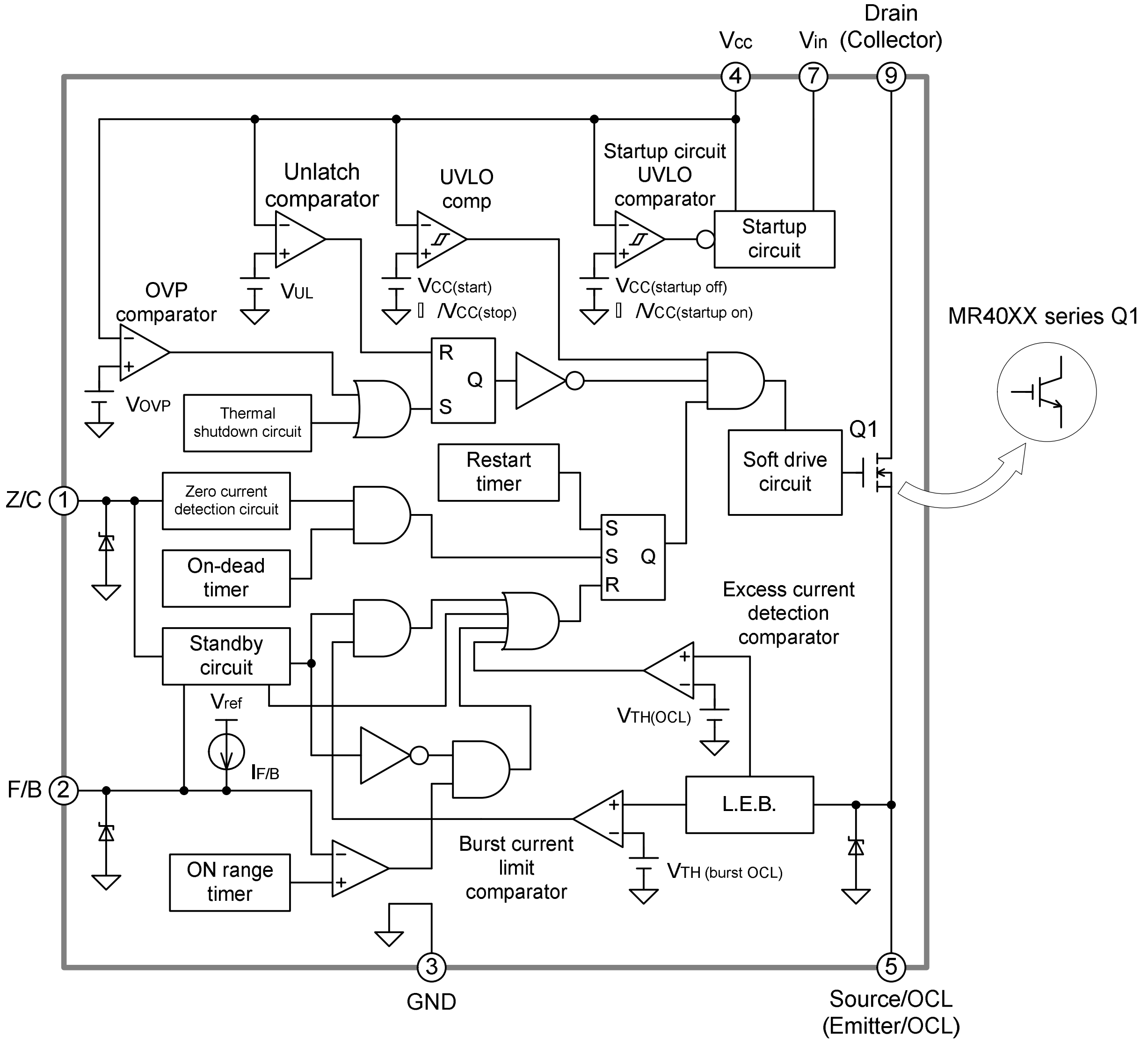


1.6 Basic circuit



2. Block diagram

2.1 Block diagram



2.2 Pin function description

Pin number	Abbreviation	Description	
1	Z/C	Zero current detection pin	
2	F/B	Feedback signal input pin	
3	GND	GND pin	
4	V_{cc}	V_{cc} (IC power supply) pin	
5	Source/OCL	MR45XX series	Main switching device source and OCL (current detection) pin
		MR47XX series	
	Emitter/OCL	MR40XX series	Main switching device emitter and OCL (current detection) pin
6	—		
7	V_{in}	Vin (startup) pin	
8	—		
9	Drain	MR45XX series	Main switching device drain pin
		MR47XX series	
	Collector	MR40XX series	Main switching device collector pin

3. Operating principles

3.1 Startup circuit

In a conventional startup circuit employing a startup resistor, an electric current continues to flow after the power supply starts, wasting power and reducing efficiency, especially during standby.
See [Conventional startup circuit] in Fig. 3.1 Comparison of startup circuits.

In the MR4000 Series startup circuit, the startup current is supplied from the input voltage and shut off when the power supply starts up.

The startup circuit supplies the $I_{startup}$ current from the constant current source in the IC until the voltage at the V_{CC} pin reaches $V_{CC(start)} = V_{CC(startup\ off)}$. This current is consumed internally in the IC and also used as the charging current for the capacitor connected externally between the V_{CC} pin and GND. This design allows stable startup with minimal dependence on the input voltage.
When the voltage at the V_{CC} pin reaches $V_{CC(startup\ off)} = V_{CC(start)}$, the startup circuit disconnects, and the startup current is halted. As soon as it stops, oscillation begins.
The current to be consumed in the IC is then supplied from the control coil.
See [MR4000 startup circuit] in Fig. 3.1 Comparison of startup circuits.
In the case of an instantaneous power failure or a load short, oscillation stops when the voltage at the V_{CC} pin reaches $V_{CC(stop)}$. When this voltage drops still further to $V_{CC(startup\ on)}$, the startup circuit begins to operate once again, and the voltage at the V_{CC} pin begins to rise. See Fig. 3.2.

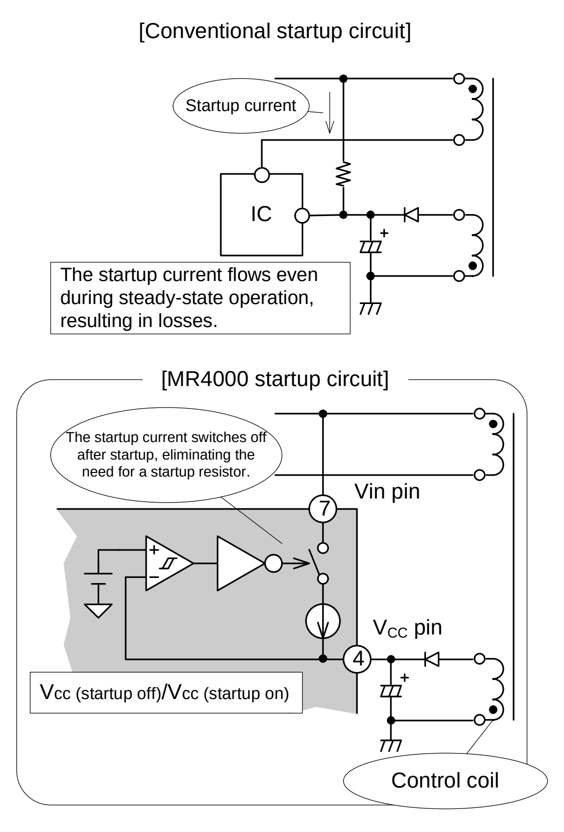


Fig. 3.1 Comparison of startup circuits

Incorporating the functions above improves efficiency, particularly during standby, and eliminates the need for a startup resistor, thereby reducing the overall number of components.

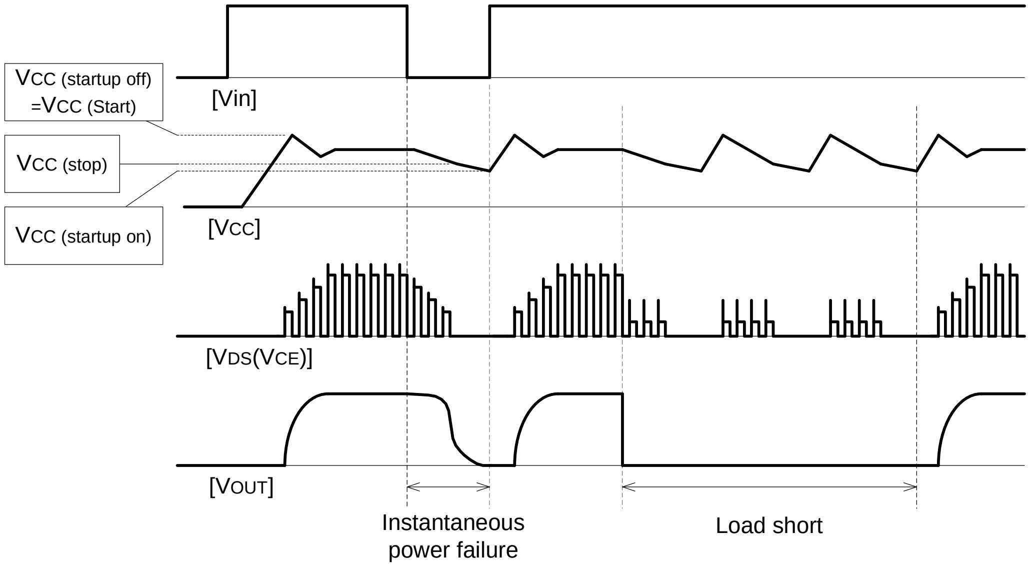


Fig. 3.2 Startup circuit operation sequence

3.2 On-trigger circuit

The MR4000 Series employs a current-critical operation system. When an energy burst to the secondary side of the main transformer is detected, the main switching device is turned on.

Energy discharge timing is detected at a negative edge of the control coil voltage waveform. The main switching device is turned on upon detection of the discharge to perform current-critical operations.
See the point with approx. 0.3 V in Fig. 3.3 On-trigger operation sequence.

The on-trigger detection voltage (approx. 0.3 V) features 50 mV hysteresis for improved noise resistance.

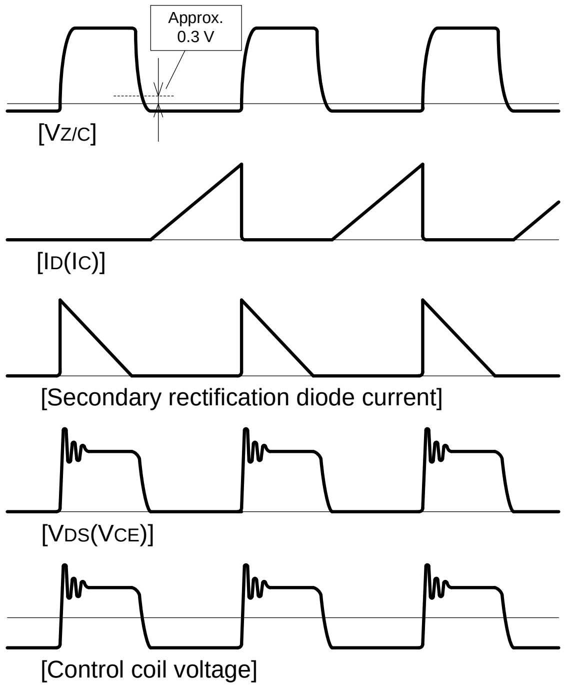


Fig. 3.3 On-trigger operation sequence

3.3 Partial resonance

In a current-critical switching power supply (RCC), when the secondary current in the circuit with a resonating capacitor connected between the drain (collector) and GND of the main switching device as shown on the right reaches 0 A, damping begins at the resonance frequency determined by the primary inductance L_P of the main transformer and the resonating capacitor C_q.

The discharge current of the resonating capacitor C_q flows through the primary coil and returns energy to the input. Adjusting the CR time constant applied to the Z/C pin (see the diagram on the right) allows the main switching device to be turned on at the trough of the damping voltage waveform, reducing turn-on losses.

In a partial resonance circuit, the energy stored in the resonating capacitor C_q during the OFF period of the main switching device is returned to the input, reducing turn-on losses. This allows the connection of a high-capacity capacitor between the drain (collector) and GND of the main switching device, thereby reducing noise.

The use of partial resonance improves efficiency and reduces noise with simple circuit configurations.

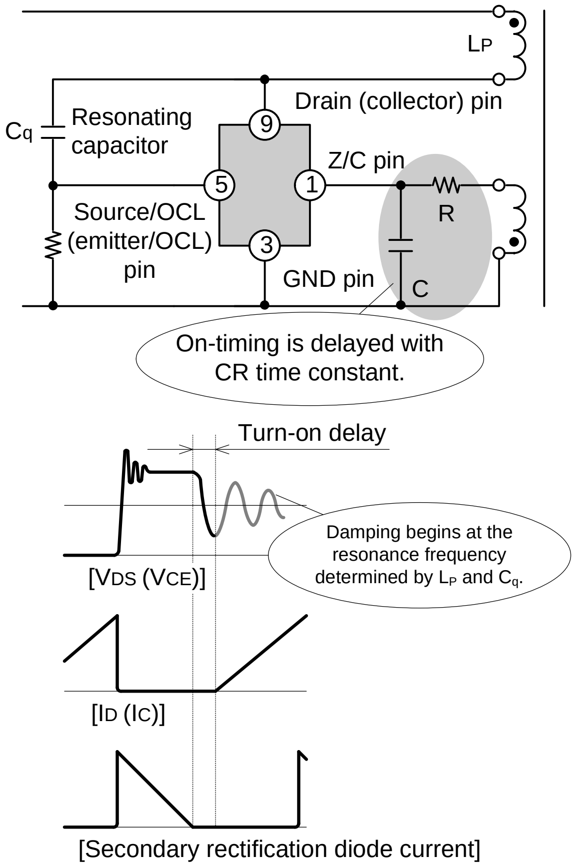


Fig. 3.4 Partial resonance

3.4 Standby mode control (patent pending)

The MR4000 Series is capable of switching between two methods of output voltage control, normal operation mode and standby mode, in a single power supply. This IC uses the burst method for standby mode. Intermittent operation is performed under light loads to reduce the oscillation frequency and reduce switching losses. The burst method effectively reduces the standby input voltage under micro-loads.

This IC uses a burst mode that performs intermittent operation without stopping IC control, thereby minimizing the output ripple. The Z/C pin is clamped to a voltage of $V_{Z/C(burst)}$ or less by an external signal to switch to standby mode control. To exit standby mode─i.e., to return to normal mode─the clamp of the Z/C pin voltage is released, and the $V_{Z/C(burst)}$ or higher voltage is applied to the pin.

In normal operation, the ON range of the main switching device is linearly controlled by voltage variations at the F/B pin. In standby mode, the current detection threshold of the Source/OCL (Emitter/OCL) pin switches from $V_{th(OCL)}$ for normal mode to $V_{th(burst\ OCL)}$ for standby mode, and the drain (collector) current is limited.
The peak value of the drain (collector) current is set by the current detection threshold, and the burst mode is selected.

In standby mode, oscillation occurs when the voltage at the F/B pin is $V_{F/B(burst\ start)}$ or higher. Oscillation stops when this voltage is $V_{F/B(burst\ stop)}$ or lower.
Since the output voltage control in standby mode sets the peak value of the drain (collector) current for each oscillation cycle, the duty ratio of the oscillating and non-oscillating intervals varies to ensure a constant voltage.

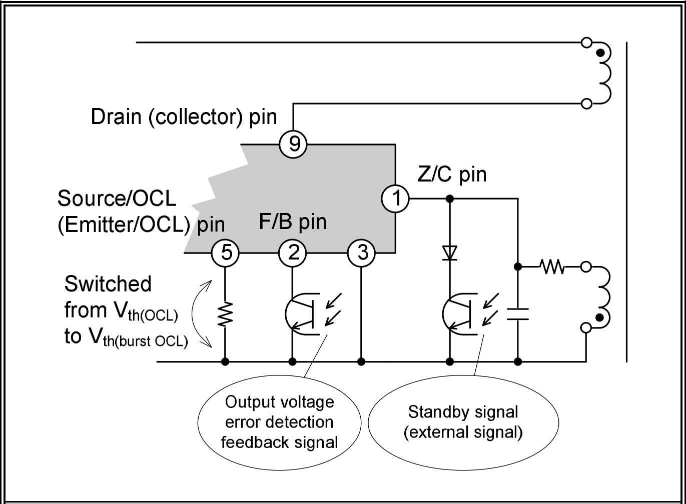


Fig. 3.5 Standby mode control

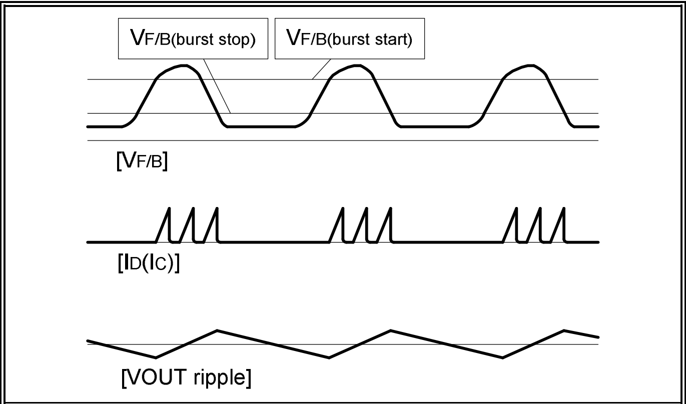


Fig. 3.6 Standby mode control sequence

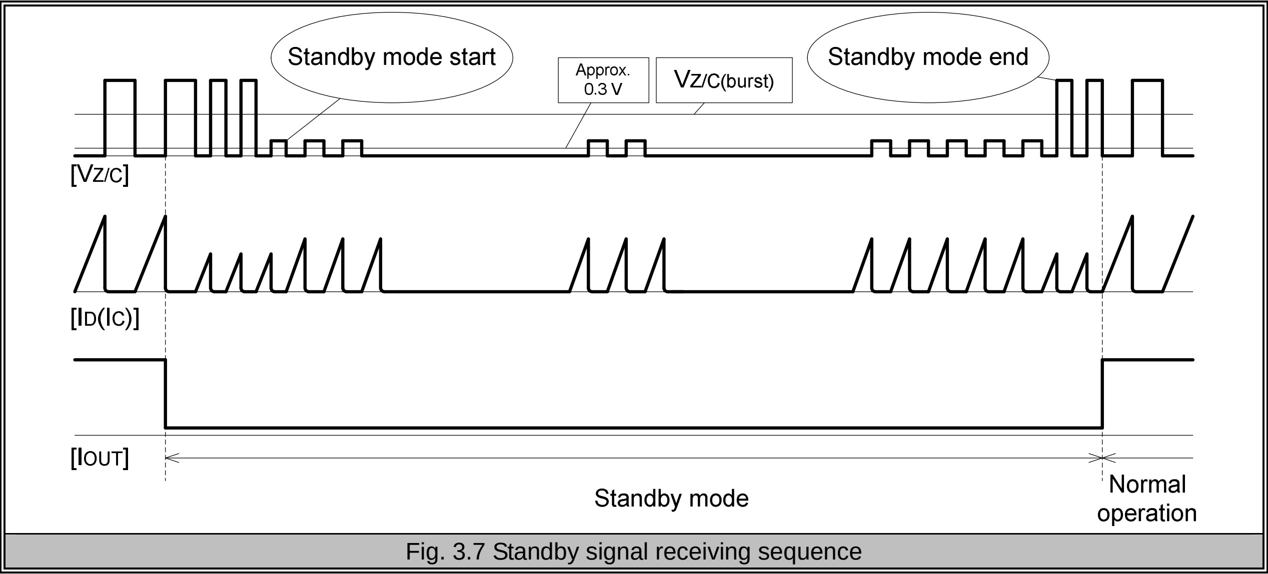


Fig. 3.7 Standby signal receiving sequence

3.5 Output voltage control (normal operation)

The MR4000 Series controls output voltage with an ON range proportional to voltage at the F/B pin.

Controlled linearly, the ON range is $t_{on(min)}$ when the voltage at the F/B pin is 1.5 V and becomes $t_{on(max)}$ when the voltage is 4.5 V. A current of IF/B flows at the F/B pin. The impedance of the photocoupler transistor connected externally between the F/B pin and GND varies depending on the control signal from the secondary output detection circuits, which controls the ON range of the main switching device to produce a constant voltage.

The maximum ON range is limited by setting the maximum value for the voltage at the F/B pin using a resistor connected externally between the F/B pin and GND. Thus, the droop point is determined.

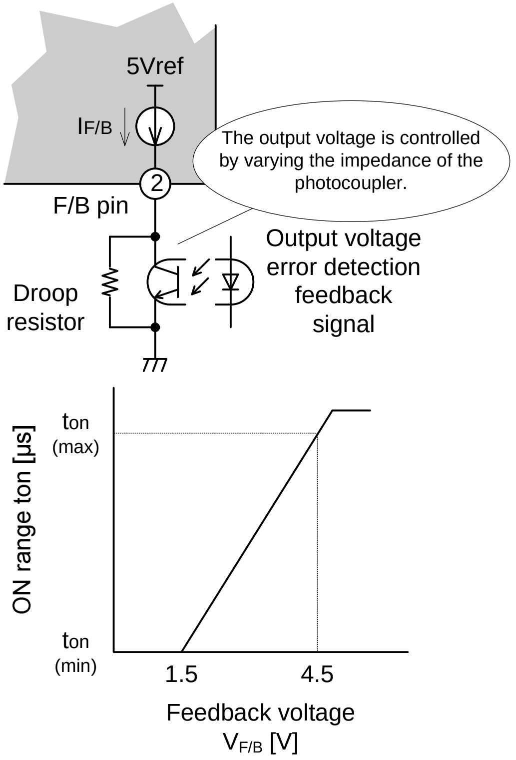


Fig. 3.8 Output voltage control

3.6 Soft drive circuit (patent pending)

The MR4000 Series supplies the main switching device gate drive voltage from two separate drive circuits.

A voltage exceeding the threshold for the main switching device is supplied from the first drive circuit at the leading edge of the drive voltage waveform to turn the main switching device on at the optimal timing.

The drive voltage is then gradually supplied from the second drive circuit (see Fig. 3.9).

The gradual supply of the drive voltage reduces drive losses and reduces noise due to the gate charge current and the current discharged when the resonating capacitor switches on.

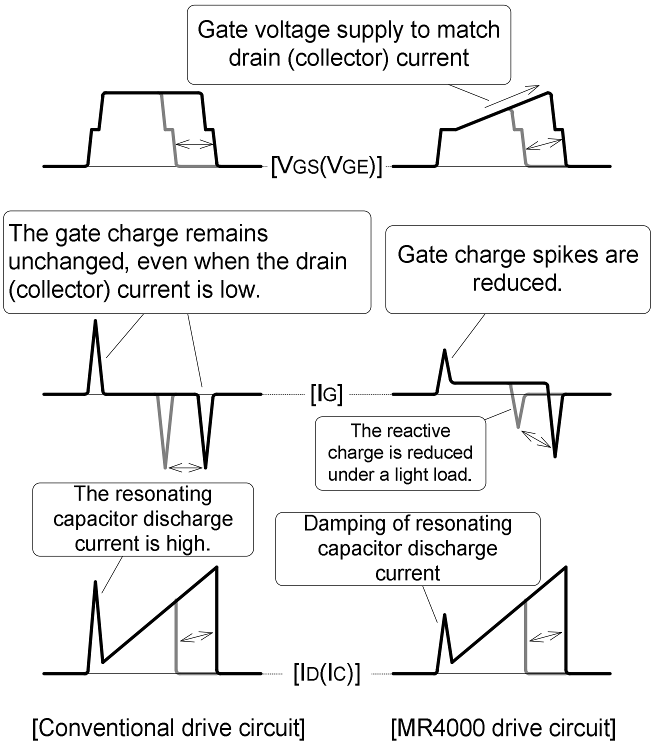


Fig. 3.9 Comparison of drive circuits

3.7 Circuit for load shorts

The MR4000 Series is designed so that voltage droop occurs under excessive load, causing the output voltage to drop, and so that the control coil voltage drops proportionally. When the control coil voltage falls below $V_{Z/C(burst)}$, the control switches to standby mode, and the Source/OCL (Emitter/OCL) pin threshold changes from $V_{th(OCL)}$ to $V_{th(burst\ OCL)}$, thereby limiting the drain (collector) current to approximately 1/10 of its previous value. This design reduces the stress on the MR4000 Series IC in the case of a load short and controls the short-circuit current to the secondary diode and the load circuit.

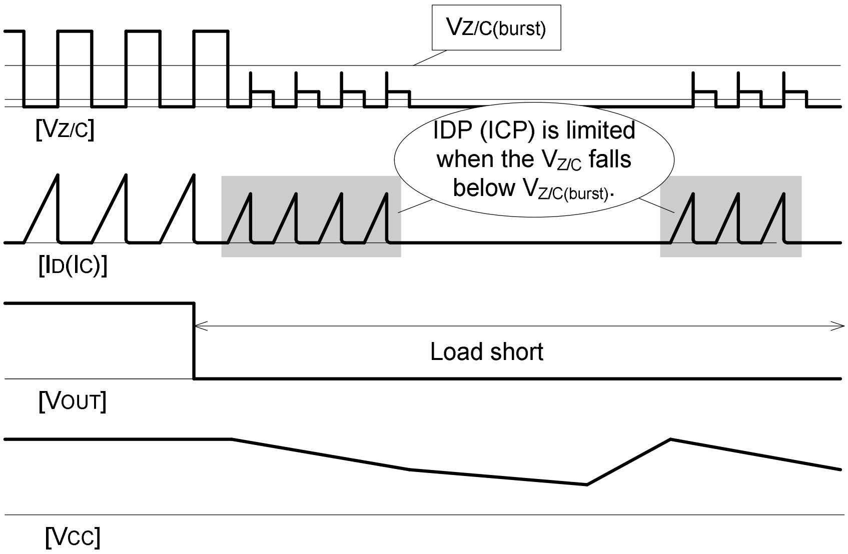


Fig. 3.10 Circuit for load shorts

3.8 Collector pin (MR40XX Series)

The collector pin on the main switching device (Pin 7)
The transformer must be designed and the resonating capacitor must be set to ensure that $V_{CE(max)}$ is less than 900 V. Depending on input conditions, the collector pin may be subject to reverse bias for a certain period during partial resonance. This IC uses the second-generation high-speed IGBT as the main switching device. Unlike MOSFETs, this device has no body diode structure and thus requires the connection of an external high-speed diode between the Collector and Emitter/OCL pins (see Fig. 3.12).

3.9 Thermal shutdown circuit (TSD)

The MR4000 Series incorporates a thermal shutdown circuit. The onboard IC is latched at 150°C (typical), after which oscillation is halted. Unlatching is achieved by momentarily dropping the voltage at the VCC pin to VUL (unlatch voltage) or lower.

3.10 Overvoltage protection circuit (OVP)

The MR4000 Series incorporates an overvoltage protection circuit (OVP). Latching occurs when the control coil voltage exceeds V_{OVP}, providing indirect overvoltage protection for the secondary output. Unlatching is achieved in the same manner as for the overheat protection circuit.

3.11 Leading edge blank (LEB)

The MR4000 Series has the leading edge blank function. This function improves the margin of noise by rejecting trigger signals from the drain current detection circuit for a certain time after the main switching device is turned on. This function prevents false detections due to the gate drive current produced the moment the main switching device is turned on or due to the discharge current of a resonating capacitor.

3.12 Malfunction prevention circuit (patent pending)

The current-critical operation of the MR4000 Series ensures that the main transformer does not become saturated as long as the droop setting is optimized.

At startup and in the event of a load short, the output voltage is significantly lower than the set voltage. Since the control coil voltage is proportional to the output voltage, it also drops significantly, and the on-trigger timing may be incorrectly detected due to the ringing voltage generated while the main switching device is OFF. The device may then be turned on before the current-critical point.

To counter this problem, the MR4000 Series incorporates a circuit to prevent on-trigger error at startup or in the event of a load short. This function disables the on-trigger for a period, t_{ondead}, after the main switching device in the IC is turned off (On-dead time). This prevents false detection due to the ringing voltage while the device is OFF.

This design permits detection of the transformer secondary current of 0 A to turn on the main switching device even at startup or in the event of a load short. This prevents the magnetic saturation of the transformer.

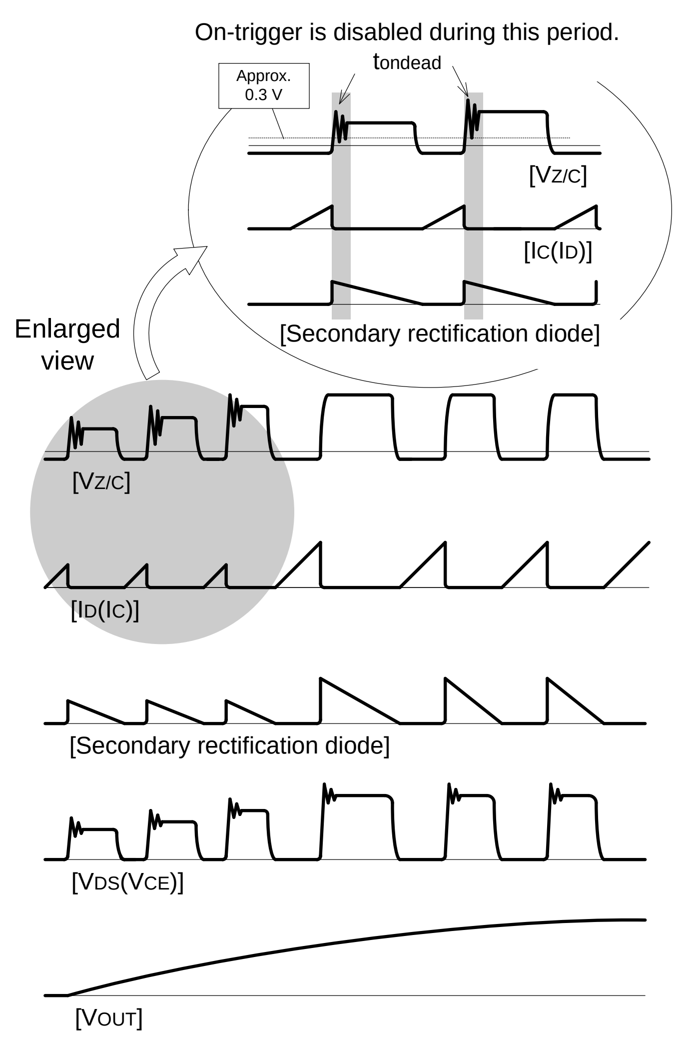


Fig. 3.11 Malfunction prevention circuit

3.13 Overcurrent protection circuit

A current detection resistor is connected between the Source/OCL (Emitter/OCL) pin and GND to detect currents between the source (emitter) of the main switching device and the source (emitter) current detection pin.
During stable operation, the main switching device current is limited by pulse-by-pulse operation with the $V_{th(OCL)}$ threshold.

During standby, the threshold changes to $V_{th(burst\ OCL)}$, and the oscillation noise from the transformer due to burst oscillation is reduced.

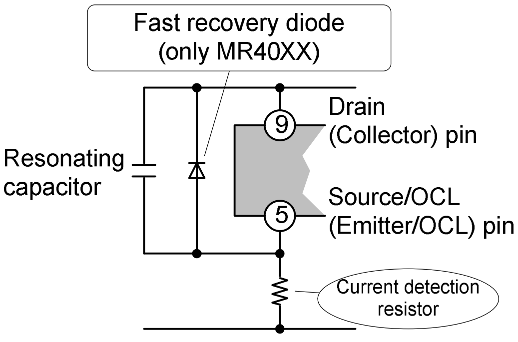
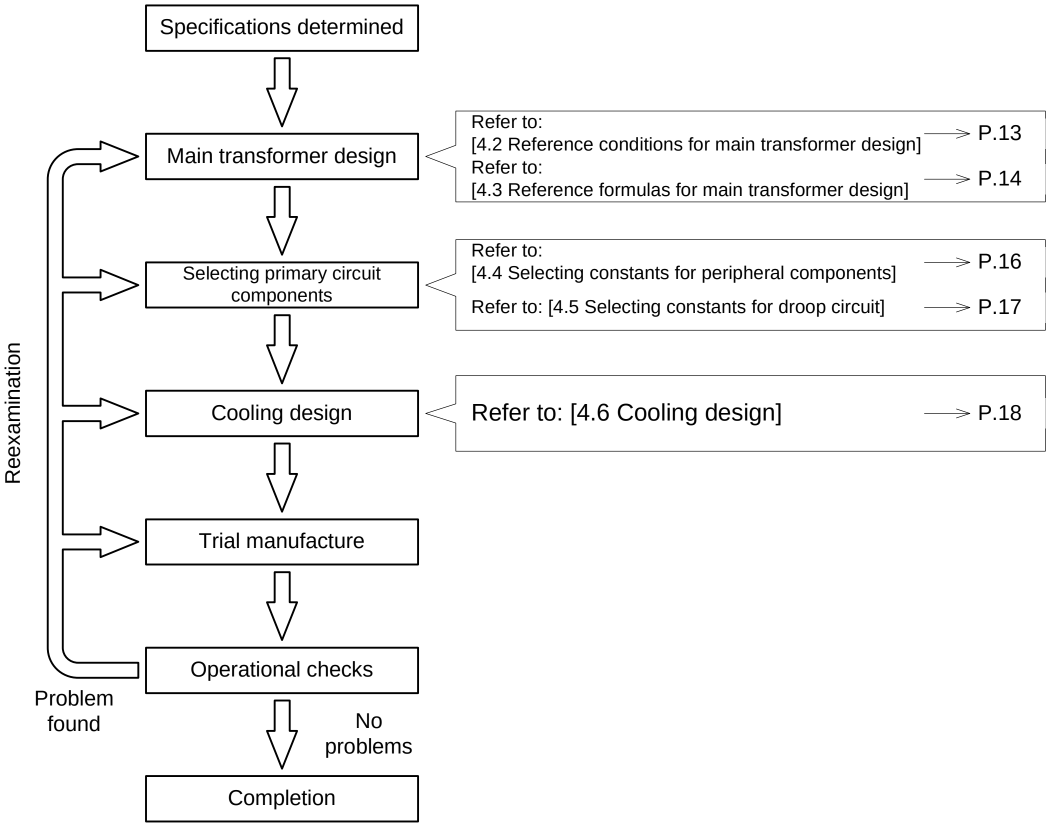


Fig. 3.12 Current detection resistor

4. Design procedure

This design procedure provides an example of an electrical design procedure. Confirm that insulation materials, insulation configurations, and structures meet the safety standards specified by the relevant authorities.

4.1 Design flow chart



4.2 Reference conditions for main transformer design

The values given below are provided for reference only. They should be adjusted to suit specific load conditions.

	Symbol	Unit	Reference value		
			MR45XX Series	MR47XX Series	MR40XX Series
Minimum input voltage	$V_{AC(min)}$	V	—		
Rated output voltage	V_o	V	—		
Rated output current	I_o	A	—		
Maximum output current	$I_{o(max)}$	A	—		
Efficiency	η		0.80 - 0.85		
Minimum oscillation frequency	$f_{(min)}$	kHz	30k - 50kHz	25k - 40kHz	25k - 50kHz
ON duty ratio	D		0.40～0.55	0.28～0.55	0.50～0.70
Control coil voltage	V_{NC}	V	15 - 17V		
Effective cross-sectional area of transformer core	A_e	mm^2	—		
Magnetic flux density variation	ΔB	mT	250 - 320mT		
Coil current density	α	A/mm^2	4 - 6A/mm^2		

4.3 Reference formulas for main transformer design

1	Minimum DC input voltage	$V_{DC(min)} = 1.2 \times V_{AC(min)}$	[V]
2	Maximum DC input voltage	$V_{DC(max)} = \sqrt{2} \times V_{AC(max)}$	[V]
3	Oscillation cycle	$T_{(max)} = \frac{1}{f_{(min)}}$	[s]
4	Maximum ON Period	$t_{on(max)1} = \frac{D}{f_{(min)}}$	[s]
5	Maximum OFF period	$t_{off(max)} = \frac{N_{S1} \times V_{DC(min)} \times t_{on(max)1}}{N_P \times (V_{O1} + V_{F1})} + t_q$	[s]
6	Resonance period	$t_q = \frac{2\pi\sqrt{L_P \times C_q}}{2}$ (Resonance cycle $\times \frac{1}{2}$)	[s]
7	Maximum load power	$P_{O(max)} = V_O \times I_{O(max)}$	[W]
8	Maximum output power (reference value)	$P_L = 1.3 \times P_{O(max)}$	[W]
9	Peak drain (collector) current	$I_{DP}(I_{CP}) = \frac{2 \times P_L}{\eta \times V_{DC(min)} \times D}$	[A]
10	Primary coil inductance	$L_P = \frac{V_{DC(min)} \times t_{on(max)1}}{I_{DP}(I_{CP})}$	[H]
11	Number of turns in primary coil	$N_P = \frac{V_{DC(min)} \times t_{on(max)1} \times 10^9}{\Delta B \times A_e}$	[Turn]
12	Core gap	$l_g = \frac{4\pi \times 10^{-10} \times A_e \times N_P^2}{L_P}$	[mm]

The gap Ig is the center gap value.
Review the transformer core size and oscillation frequency and redesign if Ig is 1 mm or greater.

13	Number of turns in control output coil	$N_{S1}=\dfrac{(V_{O1}+V_{F1})\times N_P\times(\dfrac{1}{f_{(min)}}-t_{on(max)1}-t_q)}{V_{DC(min)}\times t_{on(max)1}}$	[Turn]
14	Number of turns in non-control output coil	$N_{S2}=N_{S1}\times\dfrac{V_{O2}+V_{F2}}{V_{O1}+V_{F1}}$	[Turn]
15	Number of turns in control coil	$N_C=N_{S1}\times\dfrac{V_{NC}+V_{FNC}}{V_{O1}+V_{F1}}$	[Turn]

Consider the secondary diode forward voltage V_F for each output when determining the number of turns in an output coil.
V_{FNC} is the control coil voltage rectification diode forward voltage.
The reference value for determining the control coil voltage $V_{NC(min)}$ is 15 V to 17 V.

If the $V_{NC(min)}$ is too small, startup characteristics may degrade, making startup difficult.
If the $V_{NC(min)}$ is too large, the overvoltage latch stop voltage V_{OP} may be reached relatively easily.
Check the $V_{NC(min)}$ voltage within an actual circuit at the design stage to determine the optimal value.

16	Primary coil size	$A_{NP}=\dfrac{2\times\sqrt{D}\times P_O}{\alpha\times\sqrt{3}\times\eta\times V_{DC(min)}\times t_{on(max)1}\times f_{(min)}}$	[mm^2]
17	Secondary coil size	$A_{NS}=\dfrac{2\times\sqrt{1-D-(t_q\times f_{(min)})}\times I_O}{\alpha\times\sqrt{3}\times(t_{off(max)}-t_q)\times f_{(min)}}$	[mm^2]

A_{NC} = 0.2 mm dia. is recommended for the N_C coil to simplify calculations.

4.4 Selecting constants for peripheral components

The table below gives constants for MR4000 peripheral components.

Component		Reference value		
		MR45XX Series	MR47XX Series	MR40XX Series
C112	This capacitor determines the resonance frequency. Select the value based on noise, efficiency, and other factors.	1200p - 3300pF	- 330pF	820pF - 2200pF
C113	This is the power supply voltage rectification capacitor. If the value is small, operation at startup easily becomes intermittent. If this is too large, startup time will lengthen.	47 - 100µF		
C114	This is the partial resonance adjustment capacitor. Adjust this capacitor with R115 so that turn-on occurs at the resonance trough.	10p - 330pF		
C115	This capacitor is used to reduce noise at Pin 2. It is also beneficial for gain phase adjustments. If the value is too large, the frequency response may degrade.	4700pF	100p - 2200pF	
R113	This is the current limiting damper resistor for C108. Select the value after considering noise, efficiency, and other factors.	0 to several ohms		
R114	This is the overcurrent detection resistor. It determines the droop point.	See [4.5 Selecting constants for droop circuit].		
R115	This resistor limits the Z/C pin current.	Approximately 20 kΩ		
R116	This resistor limits the Z/C pin current.	Approximately 10 kΩ		
R117	Adjust the value according to the droop characteristics. Set to a value slightly higher than the droop point set with R114.	Tens of kΩ		
R151	This resistor compensates for droop based on the input voltage. Adjust the value based on droop characteristics.	Not required	Approximately 50 kΩ	
D111	Select a high-speed diode in the 900 V and 1A class.	Not required	High-speed diode, 900 V and 1 A class	
DZ151	This zener diode compensates for droop based on the input voltage.	Not required	See Section 4.5.	

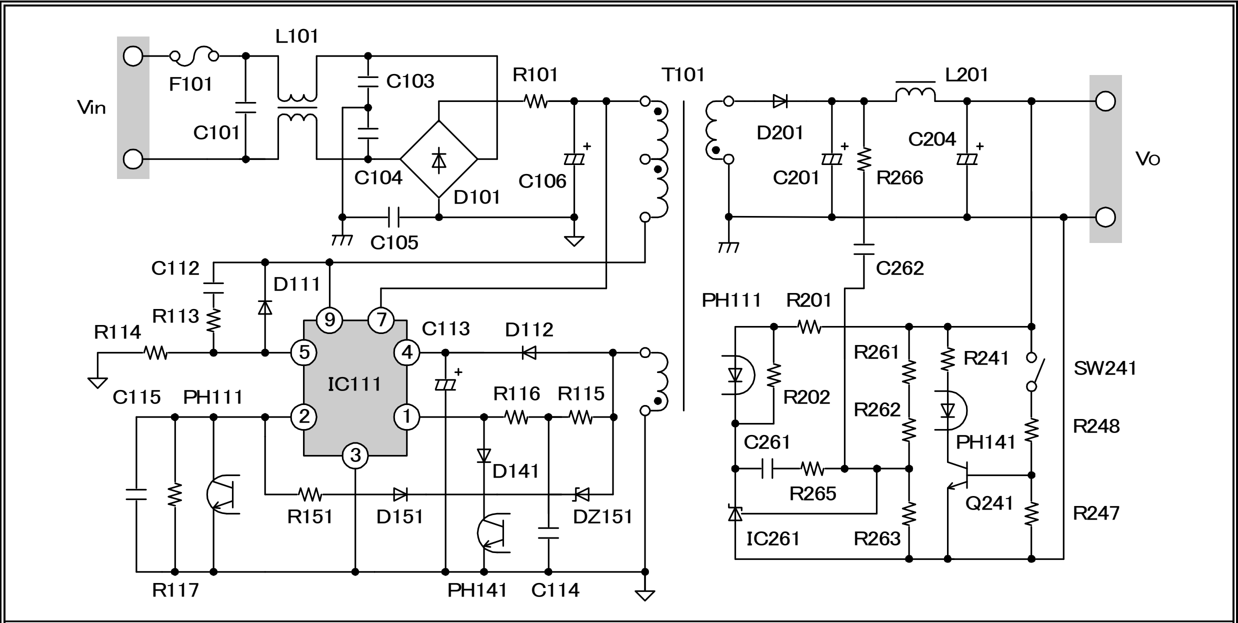


Fig. 4.1 MR4000 Series reference power supply circuit

R151, D151 and DZ151 are additional components for auto-sensing input specifications.

4.5 Selecting constants for droop circuit

The following are methods of determining the constant of a droop circuit. They are recommended for the MR4000 Series standard power supplies.

4.5.1 MR45XX Series

The following is the method recommended for the MR45XX Series standard circuit.

(1) Apply the following formula to calculate the overcurrent detection resistance R114:

$$R114 = \frac{V_{th(OCL)}}{I_{DP}(I_{CP})} \quad [\Omega]$$

$V_{th(OCL)}$	Overcurrent limit threshold voltage
$I_{DP}(I_{CP})$	Drain (Collector) peak current at maximum output power

(2) Adjust R117 on an actual board.
Set a droop point slightly higher than that set with R114.
This value will be on the order of several tens of kΩ.

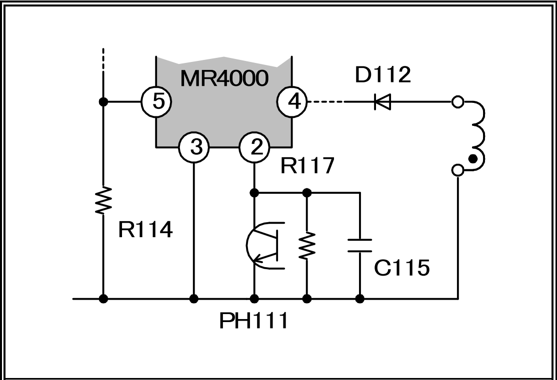


Fig. 4.2 MR45XX Series droop circuit

4.5.2 MR40XX Series

The following method is recommended for the MR40XX Series standard circuit.

(1) Apply the following formula to calculate the overcurrent detection resistance R114:

$$R114 = \frac{V_{th(OCL)}}{I_{DP}(I_{CP})} \quad [\Omega]$$

$V_{th(OCL)}$	Overcurrent limit threshold voltage
$I_{DP}(I_{CP})$	Drain (Collector) peak current at maximum output power

(2) Adjust R117 on an actual board.
Set a droop point slightly higher than that set with R114.
This value will be on the order of several tens of kΩ.

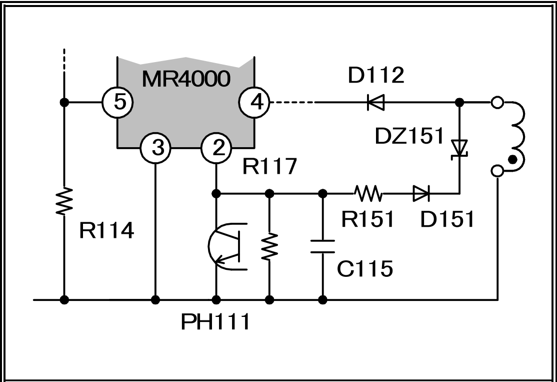


Fig. 4.3 MR40XX Series droop circuit

(3) Select the voltage for DZ151, a zener diode that compensates for droop based on the input voltage.
Apply the following formula to calculate the zener voltage:
The compensation beginning voltage is assumed to be 150 V.

$$\text{Zener voltage} = 1.3 \times 150 \times \frac{N_C}{N_P} \quad [V]$$

(4) Adjust R151, a resistor that compensates for droop based on the input voltage, on an actual board.
The value of R151 is approximately 50 Ω.

(5) Set C115 at about 2200 pF.

4.6 Cooling design

Tj(max) for the MR4000 Series is 150°C. Since the operation of the MR4000 Series is accompanied by an increase in temperature associated with power losses, you must carefully consider the type of heat sink needed. Additionally, if the design must ensure that Tj(max) is not exceeded, you must also consider the thermal shutdown function (TSD = 150°C (typical)). The extent to which Tj is derated in a design is critical for improving reliability.

4.6.1 Junction temperature and power losses

Most power losses that occur while the devices in the MR Series operate are associated with the internal MOSFET. If most power losses are considered ON losses, they may be expressed as follows:

$$P_D = V_{DS} \times I_D$$

The temperature increase ΔTj attributable to power losses PD is expressed as follows:

$$\Delta T_j + T_a \leqq T_{j(max)}$$

If $T_{SD(min)}$ is assumed to be 120°C, considering TSD = 150°C (typical), PD is constrained to satisfy the following equation:

$$\Delta T_j + T_a \leqq T_{SD(min)}$$

4.6.2 Junction temperature and thermal resistance

T_j may be calculated as follows using thermal resistance θ_{ja}.

$$T_j = (P_D \times \theta_{ja}) + T_a$$

θ_{ja}, the junction-to-ambient thermal resistance, is expressed as follows:

$$\theta_{ja} = \theta_{jc} + \theta_{cf} + \theta_{fa}$$

	Symbol	Unit
Junction-to-ambient thermal resistance	θ_{ja}	°C /W
Junction-to-case thermal resistance	θ_{jc}	°C /W
Case-to-fin thermal resistance (contact thermal resistance)	θ_{cf}	°C /W
Fin-to-ambient thermal resistance (fin thermal resistance)	θ_{fa}	°C /W

4.6.3 Cautions for cooling design

The thermal shutdown (T_{SD}) protective function stops and latches operation at 150°C in the event of abnormal heat buildup in the MR Series. This means circuit design must incorporate a cooling design whereby the temperature is sufficiently derated. Shindengen recommends setting a cooling design target so that the case temperature will not exceed 100°C.

6. Supplementary design information

This chapter provides supplementary information for MR4000 Series power supply circuits. Use this information when designing or evaluating MR4000 Series power supply circuits.

Supplementary design information: Contents

6.1 Supplementary notes on design

6.1.1 V_{CC} control

Since the IC control current is very low, V_{CC} can be significantly affected by the ringing voltage caused by transformer leakage inductance. This will increase the V_{CC} voltage of the MR4000 Series beyond the design value. Under certain load conditions, the IC may be latched and stopped or the V_{CC} may become too low. The ringing voltage caused by the transformer leakage inductance is reduced with a DCR snubber circuit. Several other solutions are also available, as shown below.

(1) Increasing the damper resistance

Increasing this resistance reduces voltage variations. Increasing the resistance will affect V_{CC}. Make sure the design accounts for possible stoppage of MR4000 Series products due to a fall in V_{CC}. Set the resistance on an actual board between several ohms and tens of ohms.

Note that a light load may decrease efficiency under certain circumstances.

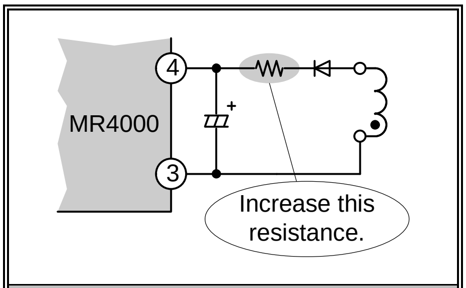


Fig. 6.1 Damper resistance

(2) N_C coil winding method

Bring the N_C coil into closer contact with a secondary coil that has limited contact with the primary coil. Doing so will reduce the ringing generated in the N_C coil. This is our recommended winding method.

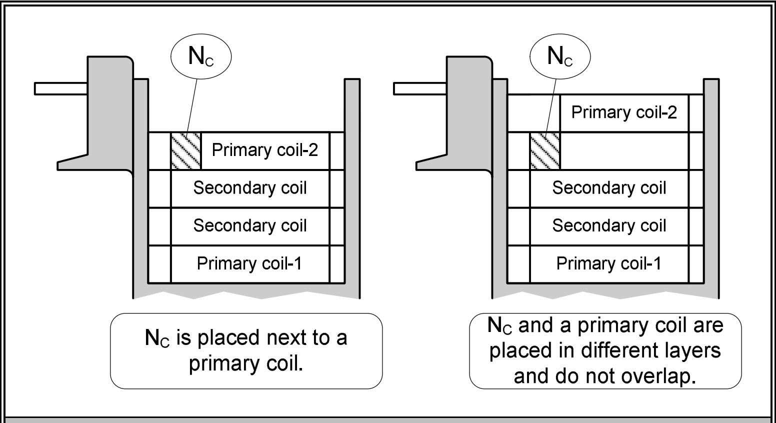


Fig. 6.2 Transformer winding to improve contact

(3) Adding a dummy resistor

If using a dummy resistor increases power consumption and decreases efficiency, this circuit will improve these performance somewhat.

If the V_{CC} voltage exceeds the level determined by the zener diode, the dummy resistor will control the voltage increase. We recommend a zener diode for 16 V or higher.

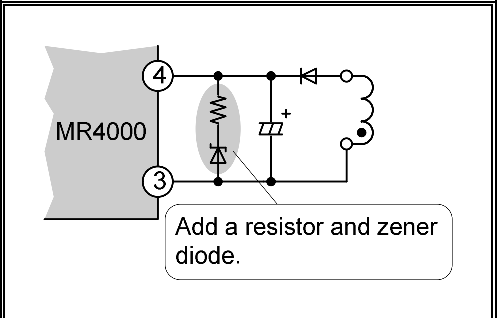


Fig. 6.3 Adding a dummy resistor

6.1.2 Ringing voltage at turn-off of main switching device

A significant voltage surge component is generated in the main switch if the transformer leakage inductance is too large or if a relatively high current is output. The most effective way to reduce the voltage surge component is to reduce the leakage inductance. The voltage surge component can be also reduced by a clamp circuit. Reducing the voltage surge component protects the main switch. In the case of a multi-output power supply, it also improves cross regulation in the outputs.

(1) Transformer leakage inductance

When the main switching device is turned off, a ringing voltage is added to the voltage, as shown in Fig. 6.4, due to the leakage inductance of the transformer primary coil.

The voltage applied to the main switching device must be designed to accommodate the ringing voltage. The leakage inductance of the primary coil is measured as shown in Fig. 6.4.

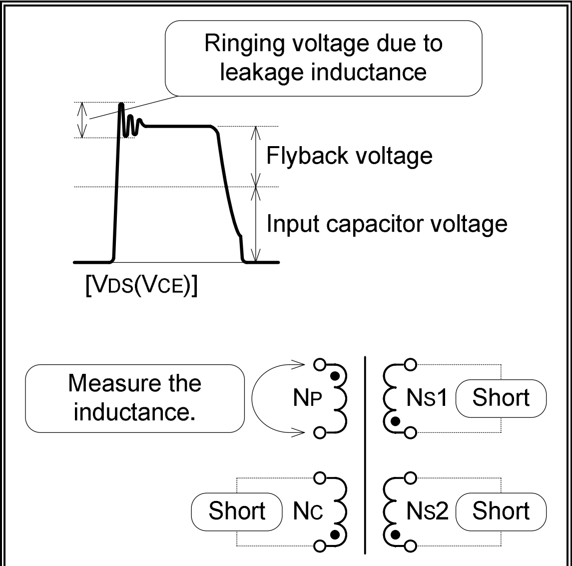


Fig. 6.4 Leakage inductance

(2) Clamp circuit

A clamp circuit may be required if the withstand voltage limit of the main switching device is exceeded due to load or other conditions or if the design margin is insufficient due to a ringing voltage caused by the leakage inductance.

We recommend a DCR snubber circuit as a clamp circuit. See the next page for DCR snubber circuit design procedures.

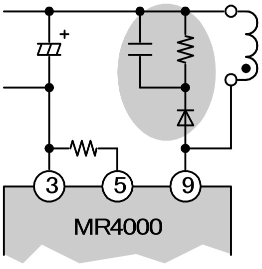


Fig. 6.5 DCR snubber circuit

Design of DCR snubber circuit

Use the following formulas to estimate the constants for a DCR snubber circuit:
If all the energy of the leakage inductance L_l is assumed to be consumed in the snubber circuit, the following formula holds true:

$$\frac{1}{2} \times L_l \times I_{DP}(I_{CP})^2 = \frac{1}{2} \times C_S \times \left(1.2V_{NP} - V_{NP}\right)^2 \quad \ldots(1)$$

Energy of leakage inductance L_l = Energy of snubber capacitor C_S $R_S \times I_S = 1.2 \times V_{NP}$ …(2)

Voltage of snubber resistor R_S = Charging voltage of snubber capacitor C_S $R_S \times I_S{}^2 = \frac{1}{2} \times L_l{}^2 \times I_{DP}(I_{CP})^2 \times f$ …(3)

Power consumption of snubber resistor R_S = Power of leakage inductance L_l
If we assume that L_l is 2.5% of the primary inductance L_P and that the charging voltage of snubber capacitor C_S is 1.2 times V_{NP}, C_S is given as follows:

From formula (1), $C_S = 0.625 \times L_P \times \frac{I_{DP}(I_{CP})^2}{V_{NP}{}^2}$ [F]

From formulas (1) and (3), we obtain formula (4). $R_S \times I_S{}^2 = \frac{1}{2} \times C_S{}^2 \times \left(1.2V_{NP} - V_{NP}\right)^2 \times f$ …(4)

Formula (2) is equivalent to formula (5). $I_S = 1.2 \times \frac{V_{NP}}{R_S}$ …(5)

When we substitute formula (5) into formula (4), we obtain formula (6). $\frac{1}{R_S} = \frac{1}{72} \times C_S \times f$ …(6)

We substitute C_S into formula (6) to obtain R_S. $R_S = 115.2 \times \frac{V_{NP}{}^2}{f \times L_P \times I_{DP}(I_{CP})^2}$ [Ω]

P_{RS}, power consumption in R_S is: $P_{RS} = R_S \times I_S{}^2$ [W]

These values assume that L_l is 2.5% of the primary inductance L_P and that the charging voltage of snubber capacitor C_S is 1.2 times the value of V_{NP}. Adjustments must be made on an actual board.

L_l	Leakage inductance
$I_{DP}(I_{CP})$	Peak current of main switching device
C_S	Snubber capacitor
L_P	Primary inductance of transformer
V_{NP}	Flyback voltage generated with primary inductance L_P
R_S	Snubber resistor
I_S	Current flowing to snubber resistor
f	Oscillation frequency of power supply

* Calculation example
When oscillation frequency f = 25 kHz, L_P = 0.5 mH,
I_{DP} = 5 A and V_{NP} = 200V;
C_S = 0.2 uF, R_S = 14.7 kΩ and P_{RS} = 3.9 W.

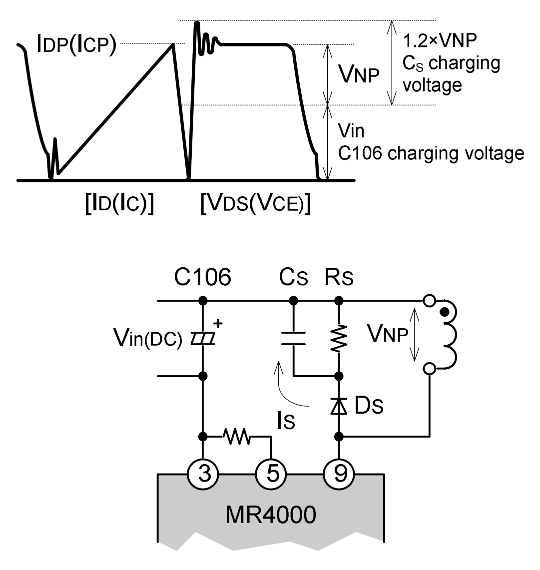


Fig. 6.6 Design of DCR snubber circuit

6.1.3 Resonating capacitor

(1) Selecting the resonating capacitor

The resonating capacitor must have the following characteristics:

1) The withstand voltage is significantly greater than that of the main switching device.
2) Tangent of loss angle tan δ is small.
3) The upper temperature limit is high.

Ideally, use a mica or polypropylene capacitor. A low-loss ceramic capacitor should also be adequate. Consult with the manufacturer before using this capacitor type.

(2) Capacity of resonating capacitor

Noise is reduced by the resonance determined by the resonating capacitor and the primary coil inductance. This has both favorable and adverse effects, as shown in the table below. Consider these effects when setting the capacity of the capacitor.

Item	Small ← Capacitor capacity → Large	
Efficiency during standby	Increases	Decreases
Heat buildup in the transformer	Decreases	Increases
Ringing voltage at turn-off of main switching device	Increases	Decreases
Noise	Increases	Decreases
Operating frequency	Increases	Decreases

6.1.4 Constants of components around Z/C pin in the circuit

At the design stage, keep in mind the following aspects of the constants for the components around the Z/C pin (Pin 1) in the circuit.

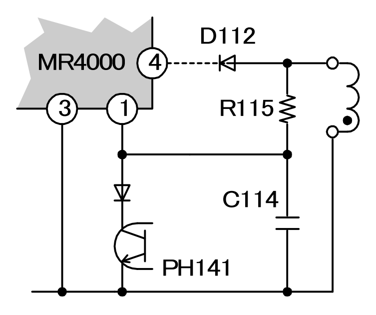


Fig. 6.7 Circuit around Z/C pin

(1) Partial resonance capacitor C114

The capacity of C114 capacitor should be around 100 pF. Since the Z/C pin (Pin 1) is susceptible to noise, the capacity should not be lower.

(2) Partial resonance resistor R115

Keep in mind the following when determining the value for R115:

1) $\frac{V_{CC}}{R_{115}} < 5mA$ and $\frac{V_{in} \times N_C}{R_{115} \times N_P} < 5mA$

The absolute maximum rating for the Z/C pin (Pin 1) is ±5 mA. Current flowing to the pin cannot exceed this level. (Vin represents the input capacitor voltage when the maximum input voltage is applied.)

2) Determine R115 so that the main switching device is turned on at the trough of its partial resonance.

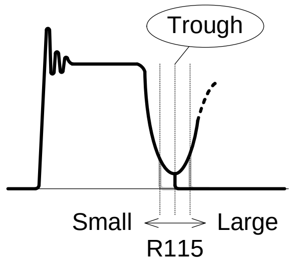


Fig. 6.8 Adjusting the resonance trough

(3) Z/C pin current limiting resistor R116

If requirements 1) and 2) of Section (2) above cannot be met simultaneously, add R116 as shown in Fig. 6.9. R116 should be around 10 kΩ.

R115 is used to set the partial resonance trough of the main switching device. Set in the same way as described in Section (2) above.

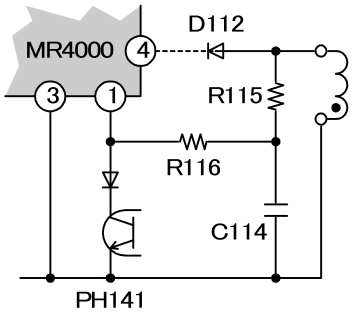


Fig. 6.9 Addition of R116

6.1.5 Enhancing the peak surge current of V_{CC} pin

This measure helps enhance resistance against surge currents applied from external sources.

Add a capacitor between the V_{CC} pin (Pin 4) and GND pin (Pin 3).

Use a capacitor with good frequency characteristics. Place the capacitor as close as possible to the V_{CC} and GND pins (Pins 4 and 3).

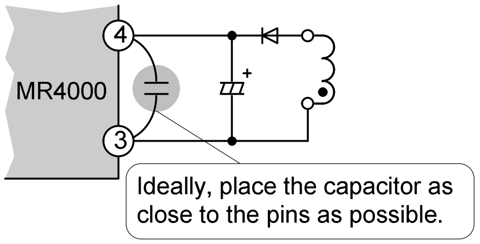
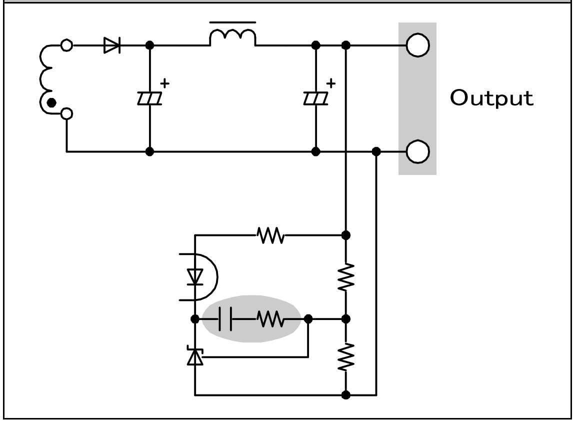


Fig. 6.10 Capacitor between V_{CC} pin and GND pin

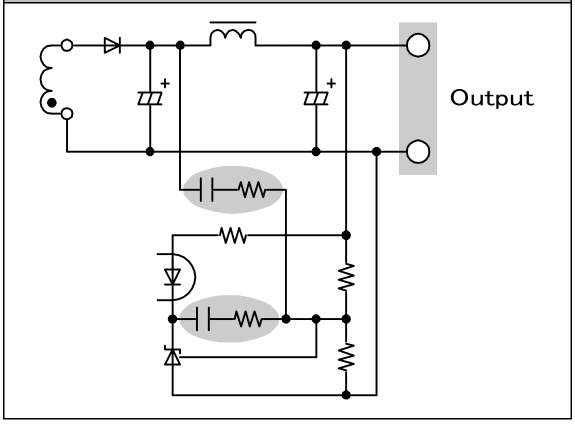
6.1.6 Phase correction

In an RCC circuit, delays in the phase of the photocoupler, capacitor, or coil may result in hunting. If so, oscillations may become audible or output voltage ripples may become very large. The following countermeasures are available:

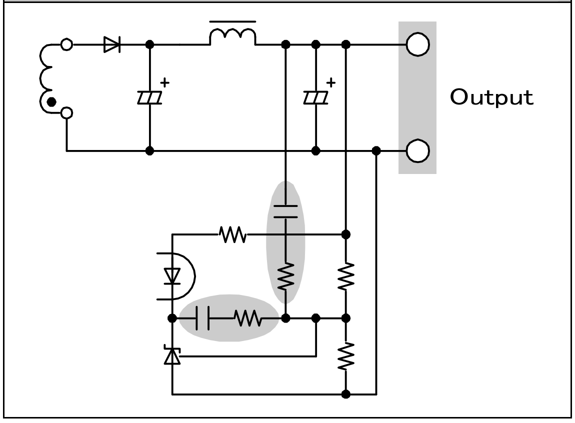
(1) Insert C and R between the cathode and REF of the shunt regulator.



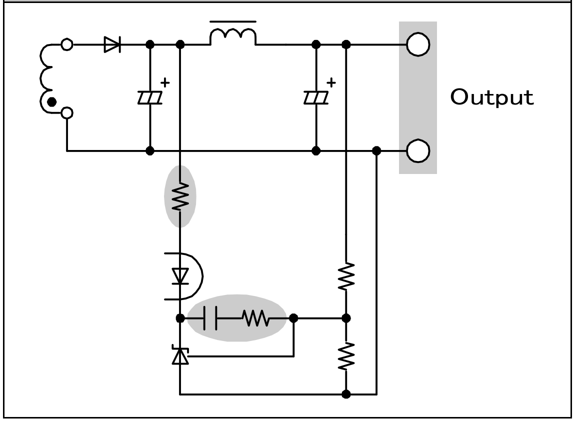
(2) Insert C and R between the front of the secondary LC filter and REF of the shunt regulator.



(3) Insert C and R between the rear of the secondary LC filter and REF of the shunt regulator.



(4) Place the power supply side of the photocoupler in front of the LC filter.



If the oscillation tends to be intermittent under light load, one solution is to lower the feedback gain. Insert a resistor as shown in Fig. 6.11. Set the resistor to 2.2 kΩ or less.

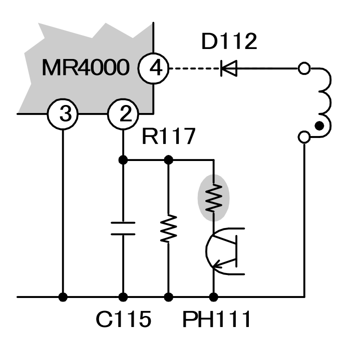


Fig. 6.11 Lowering feedback gain

6.2 Noise reduction

This section describes noise reduction methods for the MR4000. Check these methods on an actual board to determine the best combination of methods.

6.2.1 Redesigning the transformer

Redesign the transformer to reduce noise, considering the following factors. Proceed carefully with respect to the withstand voltage, operating frequency, and other relevant parameters of the main switching device.

(1) Improve coil contact.
That will reduce ringing at turn-off and reduce noise.
(2) Increase the ON duty ratio.
Taking full advantage of the partial resonance function will reduce surge currents at turn-on and reduce noise.
(3) Decrease the operating frequency.
That will reduce noise attributable to fundamental waves or harmonics thereof.

6.2.2 Changing Y capacitor

We can reduce noise not only by changing the location of a Y capacitor or adding a Y capacitor, but by also changing the capacity. The effect varies with PCB patterns. Check carefully with an actual board.

(1) Try changing the location of the Y capacitor at the filter.
(2) Connect to ground from the negative side of the input capacitor.
(3) Connect to ground from the positive side of the input capacitor.

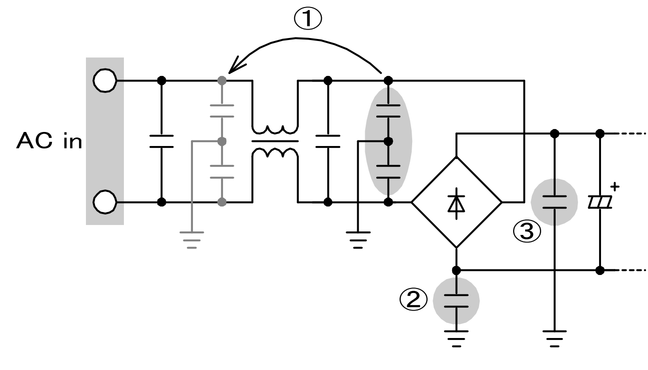


Fig. 6.12 Considerations for Y capacitor

6.2.3 Using a snubber circuit

(1) Add a DCR snubber.
That will lower the peak of a ringing voltage at turn-off and reduce noise.
(2) Add a damping resistor.
Connect to the resonating capacitor in series. This will advance the damping of a ringing voltage at turn-off and reduce noise.
(3) Connect a capacitor in parallel to the DCR snubber diode.
This will reduce noise from the diode handling switching.

Ideally, use a mica or polypropylene capacitor as the capacitors in (2) and (3). A low-loss ceramic capacitor should also prove adequate. Consult with the manufacturer before using this type of capacitor.

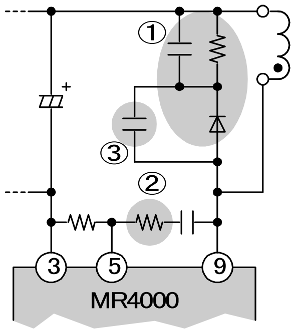


Fig. 6.13 Snubber circuit

6.2.4 Connecting a capacitor to a secondary diode in parallel

The secondary diode handles switching. Add a capacitor to reduce noise.

Try the diodes on an actual board to determine which is most effective. It may help to connect a damping resistor to this capacitor in series.

Ideally, use a mica or polypropylene capacitor. A low-loss ceramic capacitor should also prove adequate. Consult with the manufacturer before using this type of capacitor.

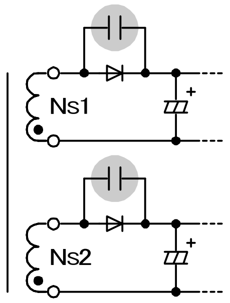


Fig. 6.14 Adding a capacitor to the secondary side

6.2.5 Capacitive coupling

You can also couple the primary GND and the secondary GND with a capacitor. Take great care to consider the leakage current between the primary and secondary and the safety standards.

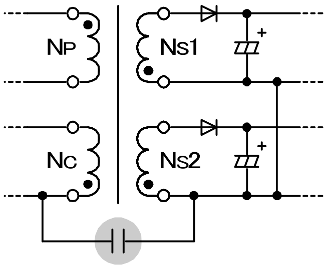


Fig. 6.15 Capacitive coupling

6.2.6 Other measures

(1) Place bead cores around the drain (collector) pin (Pin 9).
(2) Place bead cores around the secondary diode.

6.3 Supplemental information on surface mounting

6.3.1 Greasing

When using a radiation fin (heat sink), apply a thin uniform film of silicon grease between the MR4000 Series and the fin. This will reduce contact thermal resistance and enhance the heat radiation effect.

6.3.2 Screws

Use M3 round head, pan head, binding head, or fillister head screws. Avoid countersunk head screws. Use plain washers and spring washers to keep the screws tight. Use small, plain 3-mm washers. Do not use washers that are 3.5 mm or larger or washers with one polished side.

6.3.3 Radiation fin

The mounting surface of the radiation fin for the MR4000 series must be flat and free of any unevenness, torsion, or warping to protect the device from excessive stress and to avoid impairing radiation effects. Make sure the edge of the mounting hole is free of burrs. Use a long fin positioned laterally. This shape results in more effective radiation than other shapes.

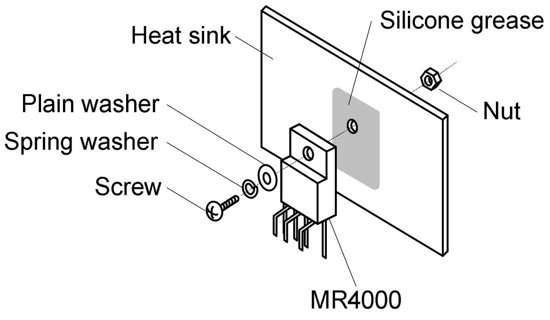


Fig. 6.16 Mounting the radiation fin

6.4 Precautions for waveform measurements

6.4.1 Isolating the AC line

When measuring the MR4000 Series or a peripheral circuit using an oscilloscope or other such instrument, isolate the AC line between the circuit to be measured and the measuring instrument to prevent electric shock and leakage.

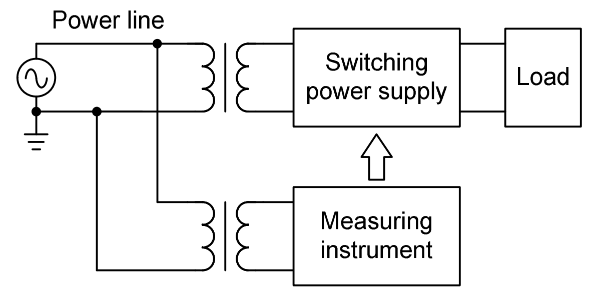


Fig. 6.17 Isolating the AC line

6.4.2 Simultaneous measurement of primary and secondary sides

In the case of a power supply using the MR4000 Series, the AC input (primary) side and the DC output (secondary) side are isolated from each other by a transformer. Do not use a measuring instrument on the primary and secondary sides simultaneously. Otherwise, GNDs of different potentials may be connected; this can affect the operation of the power supply or measurement results. (Example of method to avoid: Measure the primary and secondary waveforms simultaneously using the voltage probe of an oscilloscope.)

To check both the primary and secondary waveforms simultaneously, use a differential probe for one of the two.

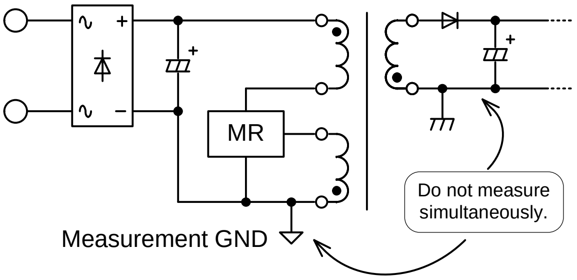
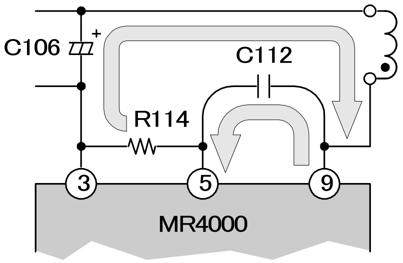


Fig. 6.18 Simultaneous measurement of primary and secondary sides

6.5 Notes on pattern design

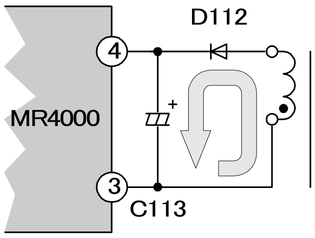
Patterns must be as short as possible to make the loops as small as possible. Keep the following in mind at the design stage:

6.5.1 Pattern design for primary side



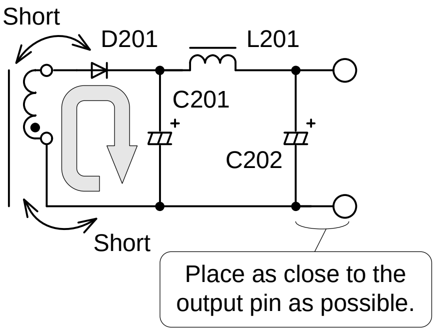
A high-speed switching current flows through the loop. Reducing the loop area will reduce noise.

6.5.2 Pattern design around Nc coil



Make the loop connecting the transformer, D112, and C113 thick and short.

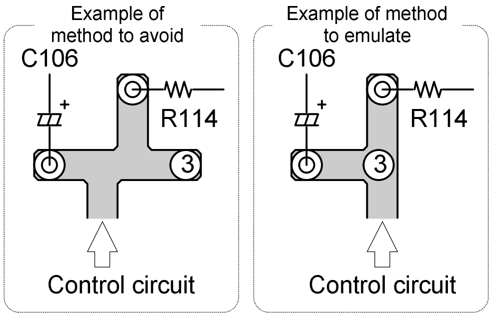
6.5.3 Pattern design for secondary side



Place as close to the output pin as possible.

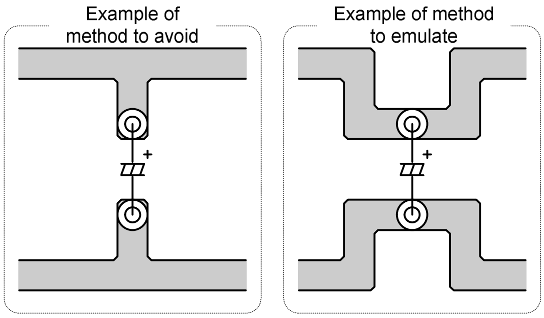
Make the loop connecting the transformer, rectification diode, and output capacitor thick and short. Place the capacitor at the rear of the output choke coil as close to the output pin as possible.

6.5.4 Pattern design around GND pin



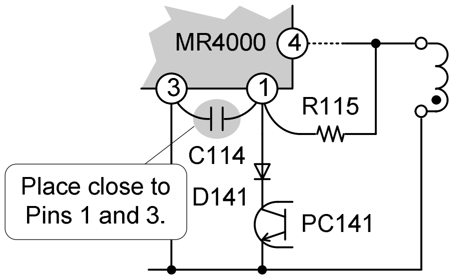
Connect the GND pin (Pin 3) directly to the negative side of C106. Do not connect any other component. Do not place the end of the control circuit inside R114 (closer to GND pin).

6.5.5 Connecting a capacitor



Make sure the pattern passes through the capacitor pads.

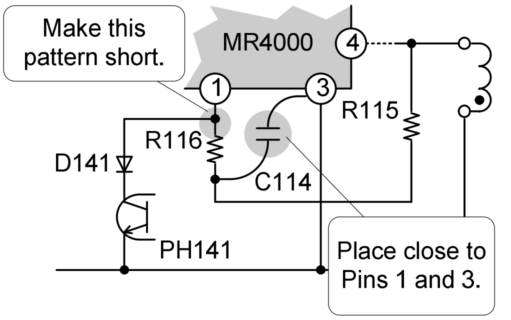
6.5.6 Pattern of C114



Place close to Pins 1 and 3.

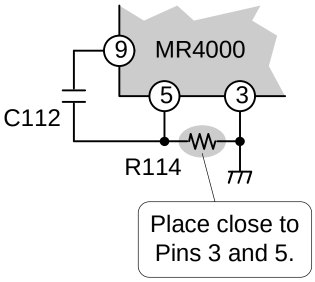
The Z/C pin (Pin 1) is susceptible to noise. Connect the pattern near the Z/C pin (Pin 1) and GND pin (Pin 3).

6.5.7 Pattern of R116



For patterns incorporating R116, make the pattern short as shown in the diagram above.

6.5.8 Location of OCL resistor



Place the current detection resistor as close as possible to the OCL pin (Pin 5) and GND pin (Pin 3). The OCL detection level is low and readily affected by the inductance or resistance component of the current detection loop wire. Placing R114 close to Pins 3 and 5 will help prevent errors due to noise and increase detection accuracy.

6.6 Application circuit examples

6.6.1 Indirect control

If output voltage precision is not an issue, a constant voltage control can be provided at the primary side without using a photocoupler. Figure 6.19 shows an example of 12 V output design.

(1) Circuit configuration
The circuit consists of a transistor and a current control resistor that control the F/B pin (Pin 2) and a zener diode that detects voltage. In cases where an increase in voltage under light load is an issue, add a dummy resistor on the secondary side.

(2) Circuit operation
The zener diode in the additional component for indirect control surrounded in a frame in the diagram detects the output voltage of the control coil. The detection signal controls the F/B pin (Pin 2) directly via the transistor.

(3) Problem
A ringing voltage attributable to transformer leakage inductance can result in significant variations in voltage precision. This can also increase the output voltage under a light load.

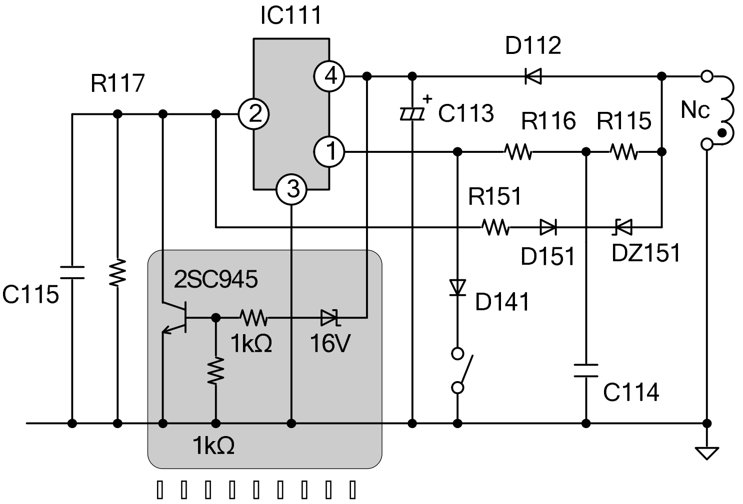


Fig. 6.19 Indirect control

6.6.2 Oscillation stop circuit in case of low voltage input

This protection circuit prevents input from a 100 V group power source to a 200 V group power supply. The circuit monitors input voltages. On detecting an input of 100 V, the circuit stops the oscillation of the MR4000 series. On detecting an input of 200 V, the circuit allows regular oscillation.

(1) Circuit configuration
The circuit consists of a transistor Q1 that short-circuits the input voltage detection resistor and the F/B pin (Pin 2), a transistor Q2 that turns Q1 off, and a zener diode that corrects for variations in VBE of Q2 and temperature characteristics.

(2) Circuit operation
The transistor Q1 short-circuits the F/B pin (Pin 2) of the MR4000 Series until the input voltage Vin exceeds 138 V (a maximum voltage in the 100 V group), thereby keeping the MR from oscillating. When Vin reaches 170 V (a minimum voltage in the 200 V group), Q2 is turned on, turning Q1 off. The MR4000 Series begins oscillating.

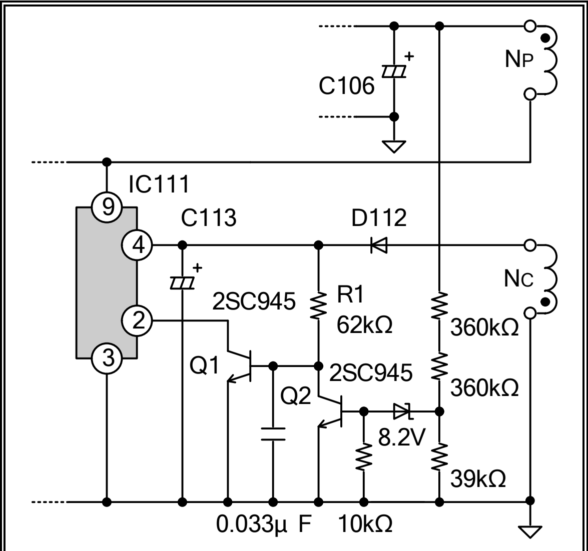


Fig. 6.20 Oscillation stop circuit in case of low voltage input

(3) Problem
Efficiency is reduced during standby. Standby characteristics are decreased due to the current required for the input voltage detection circuit and the current flowing to Q1 and Q2. If the resistor R1 is set to 56 kΩ or less, the IC can not start up.

(4) Precautions
If resistor R1 is set to 56 kΩ or less, the IC may not start up.
Carefully consider the startup characteristics if a resistor or any other component is connected to the V_{CC} pin (Pin 4) of the MR4000 Series for other purposes.

6.6.3 Remote ON/OFF circuit for MR4000 Series

The oscillation of MR4000 Series devices can be turned on and off with an external ON/OFF signal.

(1) Circuit configuration
The circuit consists of a transistor that short-circuits the F/B pin (Pin 2) and an external ON/OFF signal on the primary side. The external signal can be input from the secondary side using a photocoupler instead of the transistor.

(2) Circuit operation
Upon receipt of the external signal, the transistor is turned on, short-circuiting the F/B pin (Pin 2) and halting the power supply. When a low external signal is input, the transistor is turned off, and oscillation resumes.

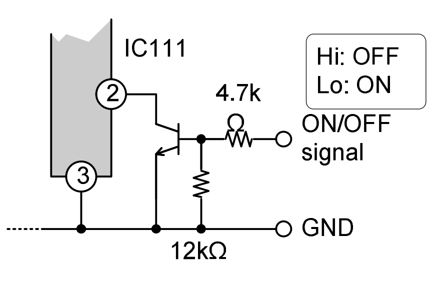


Fig. 6.21 MR4000 Series ON/OFF circuit

(3) Problem
If the power supply has been turned off by the external signal, the built-in startup circuit will continue charging and discharging the V_{CC}, resulting in losses.

6.6.4 OVP latch circuit by secondary side detection using auxiliary coil

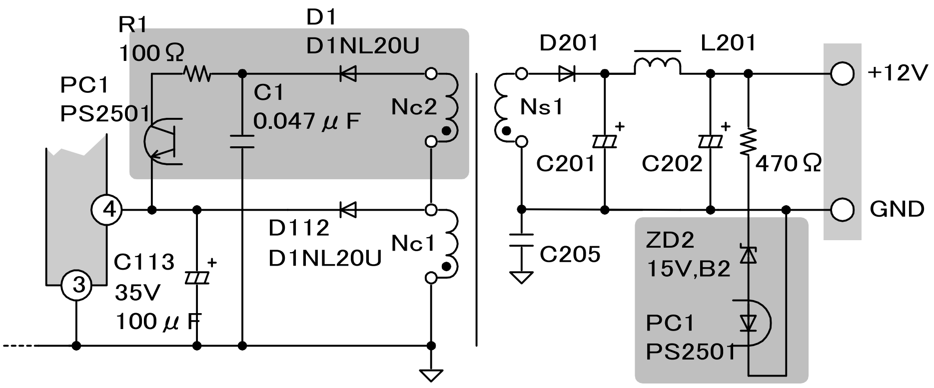


Fig. 6.22 OVP circuit using auxiliary coil

(1) Circuit configuration

This circuit consists of N_C2, an auxiliary coil; PC1, a photocoupler for OVP; R1; C1; D1; and ZD2, a zener diode for secondary output detection.

(2) Circuit operation

Set the N_C2 coil voltage to 22 V ($V_{CC(OVP)}$ x 1.1) or greater. If the output voltage exceeds the zener voltage, as the F/B pin is opened, the photocoupler will activate. As a result, the N_C2 coil voltage is applied to the V_{CC} pin (Pin 4) of the MR4000 Series, the V_{CC} voltage exceeds 20 V, and the IC is latched and stopped for OVP.

(3) Precautions

Take steps to ensure the circuit does not exceed 21 V, the absolute maximum rating for the withstand voltage of the IC. Proceed carefully while referring to the constants of the components in the diagram above.

6.7 Troubleshooting list

The table below shows common problems with power supply designs using the MR4000 Series, possible causes, and solutions.

Problem		Possible cause	Solution
1	Does not start up.	The polarity of the transformer is incorrect.	Check winding directions for N_P, N_S, and N_C.
		The droop compensation circuit is inadequate.	Adjust the droop compensation circuit.
			The ON range setting (resistance between the F/B pin and GND pin) is small.
		A constant current load or constant power load is used.	Change to a constant resistance load.
		The overvoltage latch is on.	Adjust the number of turns in the N_C coil.
			Review the transformer coil structure.
			Combine a zener diode and a resistor to clamp V_{CC}.
			Insert a resistor between the N_C coil and rectification diode.
		The input to the Z/C pin is incorrect.	Review the circuit around the Z/C pin.
		The IC is activated under a heavy load.	Startup under a light load is recommended for the MR4000 Series.
		$T_{on(max)}$ has reached the limit value.	Review the transformer design.
		There are too few turns in the N_C coil.	Adjust the number of turns in the N_C coil.
2	MR4000 Series is defective.	The transformer is causing magnetic saturation.	Review the core ΔB.
			Adjust the resistance between the F/B pin and GND pin.
		The droop compensation circuit is inadequate.	Adjust the droop compensation circuit.
			Adjust the resistance between the F/B pin and GND pin.
		The voltage exceeded the withstand level of the main switching device.	Provide a snubber circuit.
			Review the transformer design.
			Review the transformer coil structure.
3	A control output voltage rises.	Adjust the current limiting resistance of the photodiode.	Adjust the current limiting resistance of the photodiode.
4	A non-control output voltage rises.	Peak charging to the output capacitor due to a surge voltage	Add a dummy resistor or damper resistor at the output end.
			Review the transformer design.
5	The output voltage or current does not reach the desired level.	The constants for the output voltage detection circuit are inappropriate.	Reexamine the output voltage detection resistance.
		The droop compensation circuit is inadequate.	Adjust the resistance between the F/B pin and GND pin.
			Adjust the OCL resistance.
		$T_{on(max)}$ has reached the limit value.	Increase the oscillation frequency.
			Set the ON duty ratio lower.
6	MR4000 Series generate excessive heat.	The heat sink is too small or missing.	Provide a heat sink or replace with a larger one.
		The switching loss is large.	Reduce the oscillation frequency.
			Use a smaller resonating capacitor.
		The tightening torque is insufficient.	Tighten at the torque recommended by Shindengen.
		Contact with the heat sink is poor.	Apply silicone grease.
			Insert a radiation sheet.
		Timing for partial resonance is incorrect.	Adjust the delay setting for partial resonance.
		The partial resonance trough is high.	Increase the ON duty ratio.
7	Intermittent oscillation occurs under a light load.	The oscillation frequency is high.	Reduce the oscillation frequency.
		The phase compensation circuit is inadequate.	Adjust the circuit around the shunt regulator.
		The feedback gain is high.	Increase the current limiting resistance on the diode side of the photocoupler.
			Connect a resistor in series with the transistor side of the photocoupler.

Problem		Possible cause	Solution
8	Abnormal oscillation during steady-state operation This results in hunting.	The phase has shifted.	Place the secondary F/B pin in front of L.
			Adjust the circuit around the shunt regulator.
			Adjust the circuit around the photocoupler.
9	The droop operation is ineffective.	The droop circuit is inadequate.	Adjust the OCL resistance.
			Adjust the resistance between the F/B pin and GND pin.
10	V_{DS} or V_{CE} exceeds the withstand level.	The ON duty ratio is large.	Redesign ON duty ratio.
		The transformer coupling is poor.	Review the transformer coil structure.
		The ratio of numbers of turns in coils is inappropriate.	Review the transformer design.
		The surge is large.	Adjust the resonating capacitor.
			Provide a snubber circuit.
			Add a power clamper.
			Connect a resistor in series with the resonating capacitor.
11	The IC cannot enter standby mode.	The current to the photodiode is too low.	Adjust the current-limiting resistance of the photodiode.
		Noise is superimposed on the Z/C pin.	Increase the capacity of the capacitor between the Z/C pin and GND pin.
			Improve the PCB pattern.
12	The oscillation halts when the output load is increased.	The overvoltage latch is on.	Adjust the number of turns in the N_C coil.
			Review the transformer coil structure.
			Combine a zener diode and a resistor to clamp V_{CC}.
			Add a damper resistor for V_{CC}.
13	The transformer generates an oscillating tone in standby mode.	Transformer vibrations	Reinforce impregnation (e.g., double impregnation, use of adhesive)
			Optimize the load.
14	The input power is large in the case of a load short.	Noise is superimposed on the Z/C pin.	Increase the capacity of the capacitor between the Z/C pin and GND pin.
		The VF of the secondary diode is large.	Increase the current rating of the diode.
			Use a Schottky diode.
		The transformer coupling is poor.	Review the transformer coil structure.
15	The droop point varies.	The resistor between the F/B pin and GND pin is operating.	Make sure the voltage droops only with the OCL pin resistance.
16	The standby power is large.	The tan δ of the resonating capacitor is large.	Use a capacitor with a smaller tan δ.
		The capacity of the resonating capacitor is large.	Adjust the resonating capacitor (carefully monitor VDS or VCE to ensure that the withstand level is not exceeded.)

6.8 Glossary

This section provides a glossary of terms used in the MR Series Application Note, power supply reference data, and other technical materials. It provides various definitions for technical use, such as power supply design and IC functions.

6.8.1 Power supply operation

[Resonating capacitor]

A capacitor for a damper snubber circuit in a power supply circuit using partial resonance
→ *Damper snubber*

[Clamper snubber]

A snubber circuit consisting of diode, capacitor, and resistor at the primary coil end (DCR snubber) or a snubber circuit using a power zener diode
→ *Snubber circuit*

[Gain and phase]

Important parameters for a feedback control circuit.

[Conducted emissions]

Conducted noise fed back to the input side; also called input feedback noise

[Output ripple voltage]

Output voltage is not completely DC and has various superimposed frequency components.
General ripple voltage components result from commercial and switching frequencies.

[Droop characteristics]

Output characteristics when an overcurrent protection function activates

[Droop compensation circuit]

A compensation circuit used to minimize the dependence of the droop function on input voltage

[Snubber circuit]

A circuit used to reduce stress on a switching device. Snubber circuits are divided into clamper snubber and damper snubber.

[Damper snubber]

A CR snubber circuit consisting of a resistor and a capacitor between the drain and the source or between the collector and the emitter of a main switching device. In a partial resonance power supply circuit, C represents a resonating capacitor and R a damper resistor.
→ *Snubber circuit*

[Current-critical system]

A power supply control system for an isolated flyback transformer in which the main switching device activates when the secondary diode is turned off

[Input feedback noise]

Conducted noise fed back to the input side; also called conducted emissions

[Burst mode]

Control mode for a switching power supply using intermittent oscillation
With the MR Series, the drain current peak value during intermittent oscillation is limited to $I_{DP(burst\ limit)}$.

[Hunting]
A situation in which the gain or phase in a feedback control system is not adequate, resulting in abnormal oscillations

[Feedback]
Signal fed back to the primary control circuit upon detection of the output voltage
Feedback is used for constant voltage control.

[Radiated emissions]
Disturbance field strengths released into the air; also called radiated noise

[Partial resonance]
A soft-switching method or technology used in a circuit that reduces switching losses at startup of the main switching device in a switching power supply

[Radiated noise]
Disturbance field strengths broadcast into the air; also called radiated emissions

[Ringing voltage]
In this application note, it refers in particular to the oscillation voltage immediately after the main switching device is turned off.

6.8.2 Transformer design

[Duty ratio]
A ratio of the ON range to the oscillation period; sometimes referred to as D.

[TON-T ratio]
The same as duty ratio

[ON duty ratio]
The same as duty ratio

[Core gap]
A gap in a transformer core
In a flyback power supply, this gap is used to adjust inductance.

[Control coil]
A coil used to supply the source voltage to the internal IC of the MR Series and to output the Z/C signal.

[Magnetic saturation]
State in which the maximum magnetic flux density of a transformer is exceeded
If magnetic saturation occurs, the inductor will not function; a sudden excessive current may flow and damage the power supply.

[Magnetic flux density]
The magnetic flux per unit area generated at the core by an excitation current

6.8.3 IC functions

【LEB】
See Leading edge blank.

[OCP]
See overcurrent protection.

[OVP]
See overvoltage protection.

[TSD]
See thermal shutdown.

[Under voltage lock out]
A function that incorporates several volts of hysteresis into startup characteristics. This function stabilizes startup characteristics; sometimes referred to as UVLO.

[UVLO]
See Under voltage lock out.

[On-dead timer]
A function that disables the main switching device for a certain period to prevent unintended operation due to the ringing voltage when turned off

[On-trigger]
With the MR Series, the Z/C pin (Pin 2) detects a falling edge of the control coil signal and uses it as a trigger signal to turn on the main switching device.

[On-trigger disabled period]
In switching operations, this refers to a period during which the turn-on signal is not accepted to prevent unintended operations due to ringing voltage when turned off.

[Overvoltage protection]
A function that limits the output voltage to prevent damage to the power supply sometimes referred to as OVP

[Overcurrent protection]
A function that limits the output current to prevent damage to the power supply; sometimes referred to as OCP

[Thermal shutdown]
A function that limits the IC junction temperature to prevent damage to the IC. If the temperature exceeds a certain level, the IC is latched and stopped; sometimes referred to as TSD; also referred to as overheat protection.
→ *Latch stop*

[Soft drive]
A drive system of the main switching device of a switching power supply that reduces noise and enhances efficiency under a light load. Shindengen has applied for a patent on this technology.

[Negative edge]
A falling edge of a rectangular wave

[Latch stop]
One of IC’s stop modes following activation of a protection function; in this mode, the IC will not restart unless power is applied again.

[Leading edge blank]

A function that prevents the main switching device from being turned off for a certain period to prevent unintended operations due to a surge voltage at turn-on; sometimes referred to as LEB

[Restart timer]

The MR Series re-oscillates in standby mode or at startup if it does not receive a trigger signal for a certain period of time. The restart timer determines this duration.

6.8.4 Other

[Ultra fast IGBT]

A switching device developed by Shindengen that offers sufficient speed characteristics for switching power supplies; employed as the main switching device in the MR2900 Series, MR40XX Series, and MR5000 Series.

Guides for MR Series Applications

We offer various applications that make it easier to design power supply circuits using the MR Series. We will continue to update and add new data and know-how. Please contact our sales department to order reference materials or to inquire about the latest editions.

Selection guide
Lists the line-up of MR Series and provides product overviews. (We are currently working to include the MR4000 Series.)

Application note	
MR1000 Series	Presents MR1000 Series operating principles, design procedures for power supply circuits, and supplemental design information.
MR2000 Series	Presents MR2000 Series operating principles, design procedures for power supply circuits, and supplemental design information.
MR4000 Series	Presents MR4000 Series operating principles, design procedures for power supply circuits, and supplemental design information.
MR5000 Series	Presents MR5000 Series operating principles, design procedures for power supply circuits, and supplemental design information.

Power supply reference data	
MR1000 Series	Provides power supply reference data for MR1000 Series and abnormal test tables.
MR2000 Series	Provides power supply reference data for MR2000 Series and abnormal test tables.
MR4000 Series	In preparation
MR5000 Series	In preparation