SANKEN ELECTRIC CO., LTD.

Selection Guide

Diode

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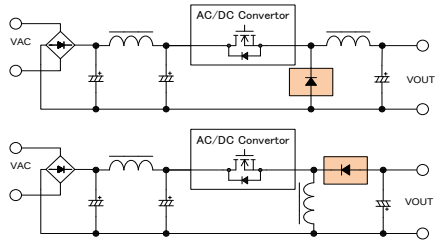
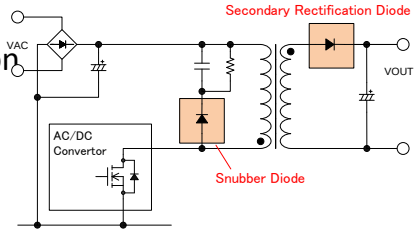
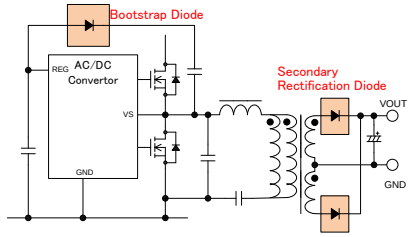
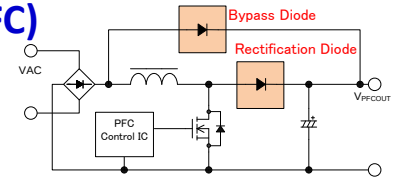
http://www.sanken-ele.co.jp/en

Diodes according to Application

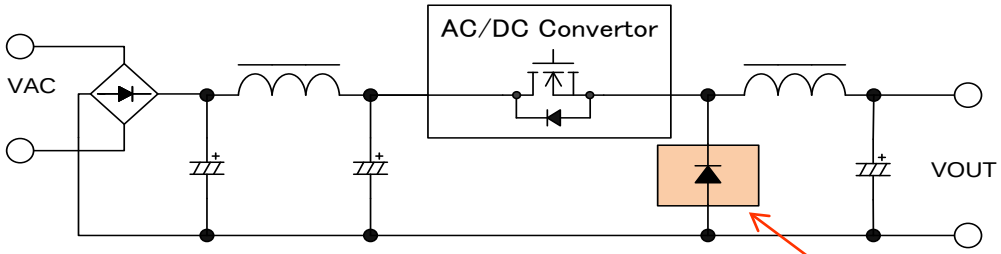
Diodes for power supply circuit.
for more information, refer to Sanken's website.

Power Supply Application	Diode Application	page
Non-isolated Buck/Buck-boost Circuit ➢ Low power application ➢ For motor control ➢ Auxiliary power supply ➢ LED lighting, etc. 	**Freewheeling Diode (FRD)**	P.3
Fly-back Circuit ➢ Low to middle power application ➢ Adapter ➢ Auxiliary power supply ➢ LED lighting, etc. 	**Snubber Diode (SARS)**	P.6
	Secondary Rectification Diode ▪ SBD: VRM = 40 V to 100 V ▪ FRD: VRM = 200 V to 600 V	P.8
LLC Circuit ➢ High power application ➢ OA , AV ➢ Industrial equipment ➢ LED street light, etc. 	**Bootstrap Diode (FRD)**	P.13
Power Factor Correction (PFC) ➢ Application for 75W or more ➢ Industrial equipment ➢ LED lighting, etc. 	**For PFC** • **Bypass Diode** (Acceptable large current) • **Rectification Diode (FRD)**	P.14

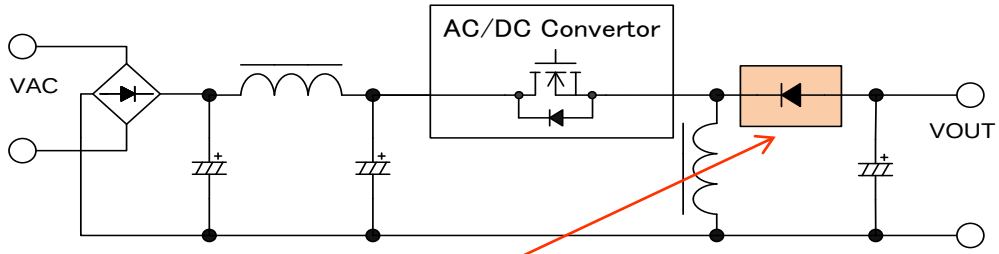
Freewheeling Diode
For Non-Isolated Buck and Buck-boost Circuit

Offline converter ICs for a buck and buck boost circuit operate with high frequency. Thus, the freewheeling diode needs the fast recovery characteristic. To improve the efficiency of circuit, select the diode that has a low VF.

Buck Circuit



Buck-boost Circuit



Freewheel Diode

V_{RM}	I_F	Features	Page
200 V to 400 V	1 A to 10 A	Fast recovery trr ≤ 100 ns	P. 4
500 V to 600 V	1 Ato10 A	Fast recovery trr ≤ 100 ns	P. 5

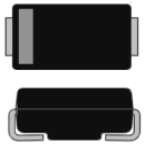
Fast Recovery Diode (1/2)

- Fast Recovery: trr ≤ 100 ns
- V_{RM} = 200 V to 400 V
- I_F = 1 A to 10 A

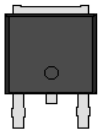
Package

Axial

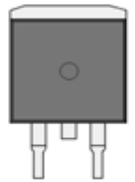
SJP



TO252-2L



TO263-2L



V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr
					I_F : I_R=1:1
200 V	1.0 A	**SJPL-D2**	SJP	0.98 V	50 ns
	1.5 A	**SJPX-F2**		0.98 V	30 ns
	2.0 A	**SJPL-H2**		0.98 V	50 ns
	3.0 A	**SJPL-L2**		0.98 V	50 ns
	10 A	**MPL-102S**	TO263-2L	0.98 V	40 ns
		SPXS-2102S	TO252-2L	1.25 V	30 ns
300 V	2.0 A	**SJPX-H3**	SJP	1.3 V	30 ns
400 V	0.7 A	**AG01**	Axial(ϕ2.4/ϕ0.6)	1.8 V	100 ns
		EG01	Axial(ϕ2.7/ϕ0.6)	2.0 V	100 ns
	0.8 A	**EG1**	Axial(ϕ2.7/ϕ0.78)	1.8 V	100 ns
	1.5 A	**SJPL-F4**	SJP	1.3 V	50 ns
	3.0 A	**SJPL-L4**		1.3 V	50 ns

Fast Recovery Diode (2/2)

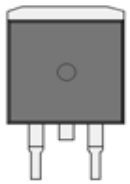
- Fast Recovery:
  trr ≤ 100 ns
- V_{RM} = 500 V to 600 V
- I_F = 1 A to 10 A

Package

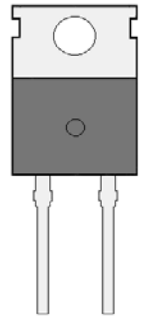
Axial

SJP

TO263-2L



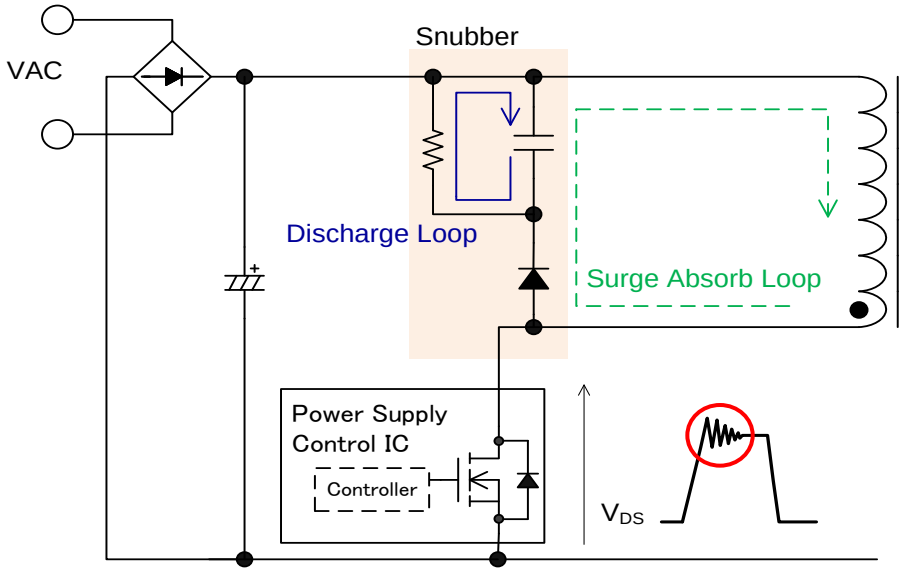
TO220-2L



V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr
					I_F : I_R=1:1
500 V	1.0 A	**SJPD-D5**	SJP	1.4 V	40 ns
	3.0 A	**SJPD-L5**		1.4 V	50 ns
600 V	0.5 A	**AG01A**	Axial(ϕ2.4/ϕ0.6)	1.8 V	100 ns
		EG01A		2.0 V	100 ns
	0.6 A	**EG1A**	Axial(ϕ2.7/ϕ0.78)	2.0 V	100 ns
	2.0 A	**SJPL-H6**	SJP	1.5 V	50 ns
		SJPX-H6		1.5 V	30 ns
	3.0 A	**MPL-1036S**	TO263-2L	1.75 V	50 ns
	10 A	**DENS-1106S**	TO220-2L	1.3 V	100 ns
		DEXS-1106S		1.6 V	30 ns

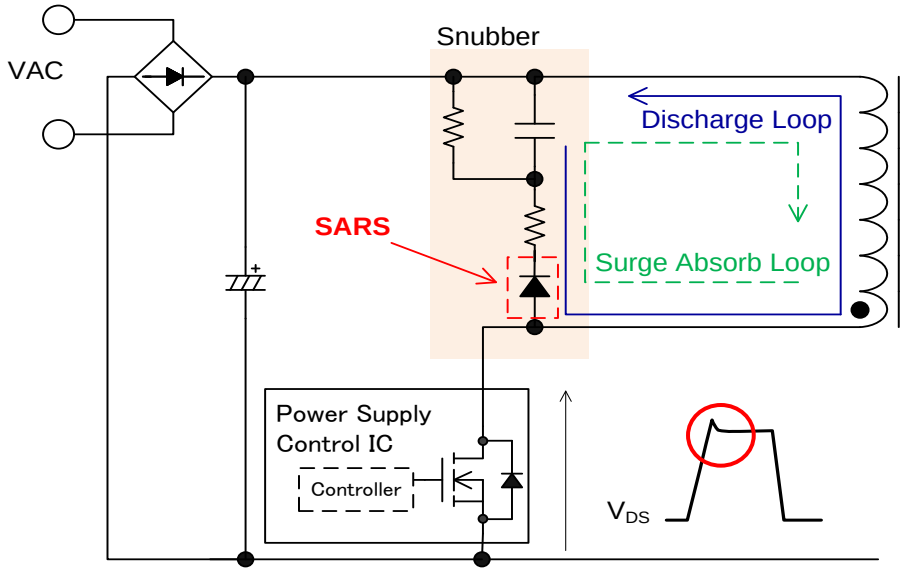
SARS Diode for Snubber Circuit

Using FLR Diode



When a power MOSFET turns off, surge current flows on "Surge Absorb Loop", and is absorbed by the capacitor. The electrical charge of capacitor is discharged through "Discharge Loop". This energy is not transferred to the secondary side, and becomes power dissipation. When the capacitor is discharged, the recovery current of the diode flows to the power MOSFET. For reducing damage of the power MOSFET, use a fast recovery diode whose trr is short. Note that using a fast recovery diode may cause noises, and may increase components of input filter.

Using SARS



When SARS is used, the electrical charge of the capacitor is discharged through "Discharge Loop" in recovery period of SARS, and is transferred to the secondary side. This results in improvement of circuit efficiency.
When the capacitor is discharged, the instantaneous recovery current of the diode flows to the power MOSFET. To reduce the damage of power MOSFET by the instantaneous current, add a resistor in series with SARS (Patented circuit) .

SARS: Diode for Snubber Circuit

- Low noise:
  Prevention of ringing at Power MOSFET turn-off
- PCB area saving:
  Reducing number of filter circuit components
- High circuit efficiency

Package

SJP

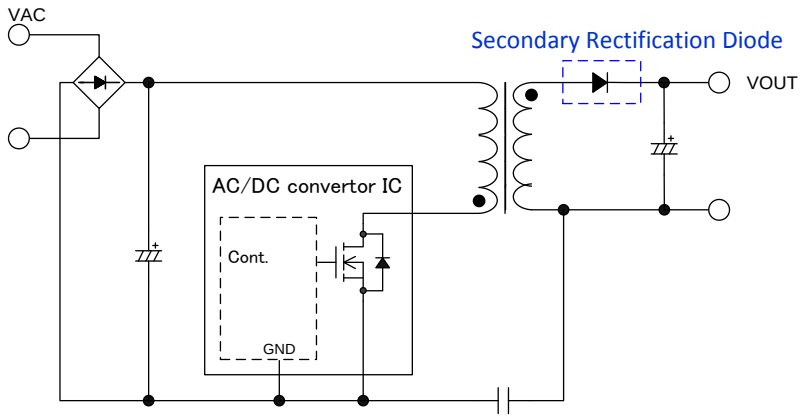
Axial

Products	V_{RM}	$I_{F(AV)}$	I_{FSM} 50Hz Half-wave	V_F		trr I_F:I_R=1:1	Package
				V_F (max.)	I_F		
SARS01	800 V	1.2 A	110 A	0.92 V	1.2 A	2 µs to 18 µs	Axial ϕ2.7 / ϕ0.60
SARS05	800 V	1.0 A	30 A	1.05 V	1.0 A	2 µs to 18 µs	SJP (SMA:4.5×2.6)

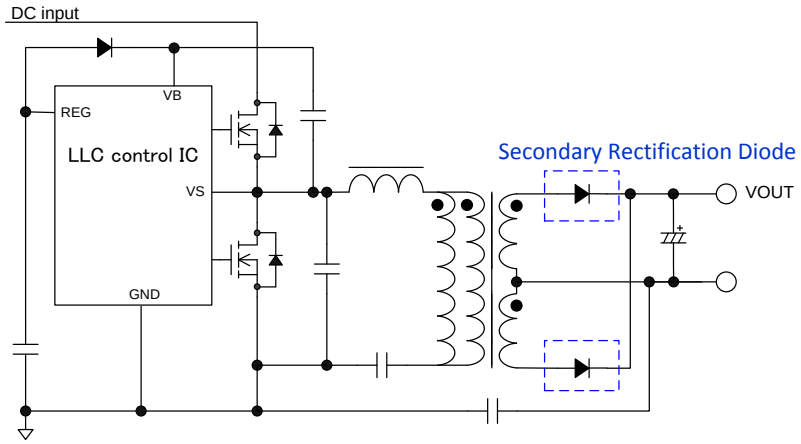
Secondary Rectification Diode

Two types current, which are forward current for charging to a secondary electrical capacitor and recovery current, flow through the secondary rectification diode. To improve the efficiency of circuit, select the diode that has a low VF and short trr characteristics.

◆ Flyback Type



◆ Half bridge Type



Type	Package	V_{RM}	$I_{F(AVG)}$	V_F	trr	Page
Schottky	SMD, Through-hole	60 V to 100V	1 A to 30 A	≤ 0.98 V	–	P.9
Fast Recovery	SMD	200 V to 600 V	1 A to 10 A	≤ 1.75 V	≤ 50 ns	P.10
Fast Recovery	Through-hole	200 V to 600 V	20 A to 60 A	≤ 1.70 V	≤ 150 ns	P.11 P.12

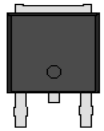
Schottky Diode

- V_{RM} = 60 V to 150 V
- I_F = 1 A to 30 A
- $V_F \leq 0.92$ V

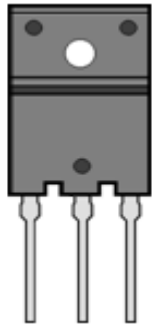
Package

SJP

TO252-2L



TO3PF-3L



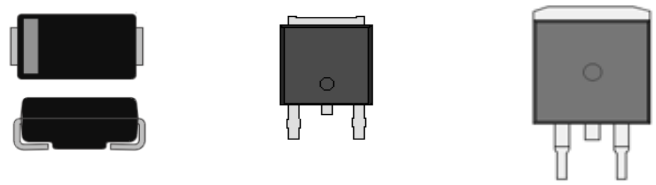
V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	I_R	H・I_R
60 V	1.0 A	**SJPB-D6**	SJP	0.68 V	0.1 mA	30 mA
	1.5 A	**SJPW-F6**		0.70 V	1.0 mA	70 mA
	2.0 A	**SJPB-H6**		0.69 V	0.2 mA	55 mA
	3.0 A	**SJPB-L6**		0.70 V	0.3 mA	70 mA
	30 A	**FMW-4306**	TO3PF-3L	0.70 V	3.0 mA	350 mA
90 V	1.0 A	**SJPB-D9**	SJP	0.85 V	0.1 mA	30 mA
	2.0 A	**SJPB-H9**		0.85 V	0.2 mA	55 mA
100 V	10 A	**SPEN-210A**	TO252-2L	0.85 V	0.1 mA	50 mA
	30 A	**FMEN-430A**	TO3PF-3L	0.85 V	0.3 mA	150 mA

SMD Type Fast Recovery Diode

- V_{RM} = 200 V to 600 V
- I_F = 1 A to 10 A
- trr ≤ 50 ns
- V_F ≤ 1.75 V

Package

SJP TO252-2L TO263-2L

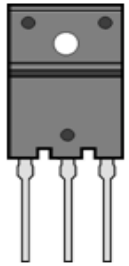


V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr
					I_F : I_R=1:1
200 V	1.0 A	**SJPL-D2**	SJP	0.98 V	50 ns
	1.5 A	**SJPX-F2**		0.98 V	30 ns
	2.0 A	**SJPL-H2**		0.98 V	50 ns
	3.0 A	**SJPL-L2**		0.98 V	50 ns
	10 A	**SPXS-2102S**	TO252-2L	1.25 V	30 ns
		MPL-102S	TO263-2L	0.98 V	40 ns
300 V	2.0 A	**SJPX-H3**	SJP	1.30 V	30 ns
400 V	1.5 A	**SJPL-F4**	SJP	1.30 V	50 ns
	3.0 A	**SJPL-L4**		1.30 V	50 ns
500 V	1.0 A	**SJPD-D5**	SJP	1.40 V	40 ns
	3.0 A	**SJPD-L5**		1.40 V	50 ns
600 V	2.0 A	**SJPL-H6**	SJP	1.50 V	50 ns
		SJPX-H6		1.50 V	30 ns
	3.0 A	**MPL-1036S**	TO263-2L	1.75 V	50 ns

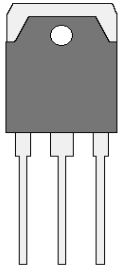
Through-hole Type Fast Recovery Diode (1/2)

Package

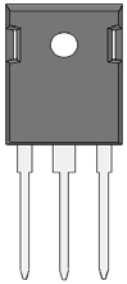
TO3PF-3L



TO3P-3L



TO247-3L



- V_{RM} = 200 V to 400 V
- I_F = 20 A to 60 A
- trr ≤ 100 ns
- V_F ≤ 1.4 V

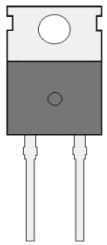
V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr I_F : I_R=1:1
200 V	20 A	**CTXA-4202S**	TO3P-3L	1.20 V	25 ns
		CTXS-4202S		1.05 V	30 ns
		FML-4202S	TO3PF-3L	0.98 V	40 ns
		FMX-4202S		0.98 V	30 ns
		FMXS-4202S		1.05 V	30 ns
	45 A	**CTXS-4452S**	TO3P-3L	1.10 V	35 ns
300 V	20 A	**FMX-4203S**	TO3PF-3L	1.30 V	30 ns
		FMXA-4203S		1.30 V	25 ns
	60 A	**CTNS-4603S**	TO3P-3L	1.20 V	100 ns
		CTXS-4603S		1.40 V	50 ns
		CTNS-6603S	TO247-3L	1.20 V	100 ns
400 V	20 A	**CTLD-4204S**	TO3P-3L	1.40 V	50 ns
		FMD-4204S	TO3PF-3L	1.40 V	50 ns
		FML-4204S		1.30 V	50 ns
		FMLB-4204S		1.30 V	50 ns

Through-hole Type Fast Recovery Diode (2/2)

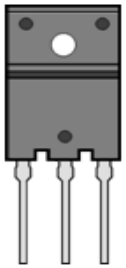
- V_{RM} = 600 V
- I_F = 10 A to 60 A
- trr = 150 ns
- $V_F \leq 0.7$ V

Package

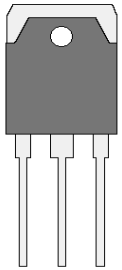
TO220-2L



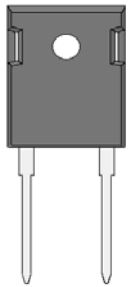
TO3PF-3L



TO3P-3L



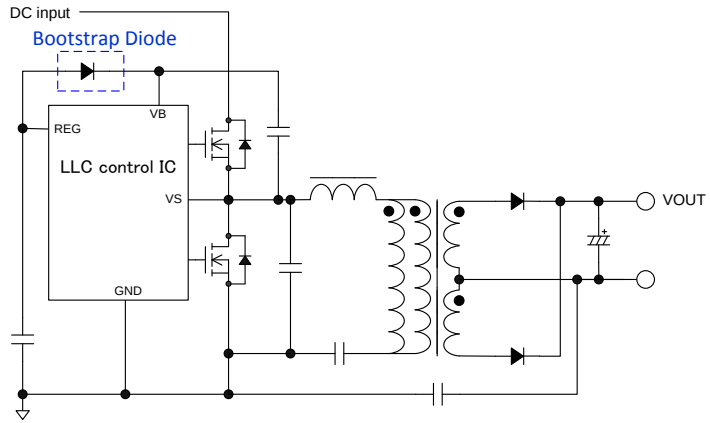
TO247-2L



V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr I_F : I_R=1:1
600 V	10 A	**DENS-1106S**	TO220-2L	1.30 V	100 ns
		DEXS-1106S		1.60 V	30 ns
	15 A	**DENS-1156S**	TO220-2L	1.30 V	100 ns
		DEXS-1156S		1.60 V	30 ns
	20 A	**FMD-4206S**	TO3PF-3L	1.70 V	50 ns
	30 A	**FMN-4306S**	TO3PF-3L	1.30 V	100 ns
		CTNS-4306S	TO3P-3L	1.30 V	100 ns
		CTXS-5306S	TO247-2L	1.70 V	35 ns
	60 A	**CTNS-4606S**	TO3P-3L	1.30 V	100 ns
		CTXS-4606S		1.70 V	35 ns
		CTXS-5606S	TO247-2L	1.70 V	50 ns
		FMNS-4606S	TO3PF-3L	1.30 V	150 ns

Bootstrap Diode

Bootstrap Diode is used for a high-side driver circuit.
Since the recovery current flows to the diode depending on the switching frequency of the driver IC, select a diode that has fast recovery characteristic. When the bootstrap diode is selected, the applied voltage to a power MOSFET and the high-side sink current should be taken into account.

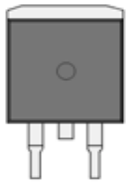


Package

Axial

SJP

TO263-2L

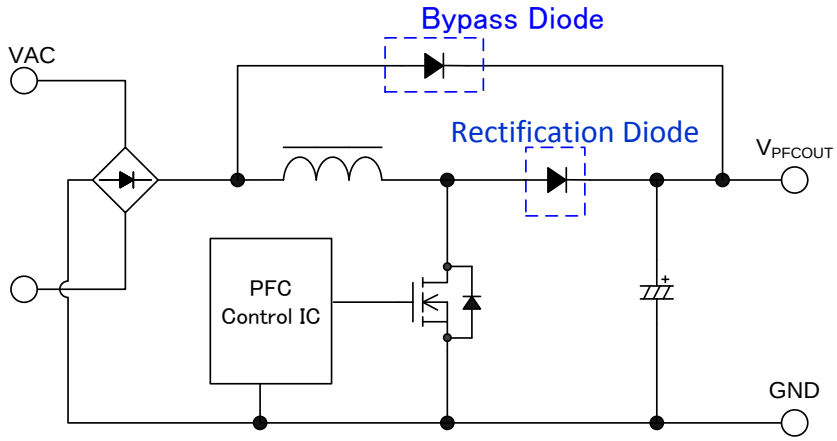


V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr I_F : I_R=1:1
600 V	0.5 A	**AG01A**	Axial(ϕ2.4/ϕ0.6)	1.8 V	100 ns
		EG01A	Axial(ϕ2.7/ϕ0.6)	2.0 V	100 ns
	0.6 A	**EG1A**	Axial(ϕ2.7/ϕ0.78)	2.0 V	100 ns
	2.0 A	**SJPL-H6**	SJP	1.5 V	50 ns
		SJPX-H6	SJP	1.5 V	30 ns
	3.0 A	**MPL-1036S**	TO263-2L	1.75 V	50 ns
1000 V	0.5 A	**EG01C**	Axial(ϕ2.7/ϕ0.6)	3.3 V	100 ns

For PFC Circuit

PFC circuit consists a bypass diode and a rectification diode. Each diode should be selected according to their use.

- Selection guide for bypass diode: P.15
- Selection guide for Rectification diode: P.16



Type	Operation Mode	Features	Page
Bypass Diode	—	High power: I_{FSM} > 35 A Low forward voltage: V_F ≤ 1.05 V	P.17
Rectification Diode	DCM CRM	Low forward voltage: V_F ≤ 1.3 V	P.18
	CCM	Fast recovery: trr ≤ 50 ns	P.19
		Low noise type Fast recovery: trr ≤ 100 ns	P.20

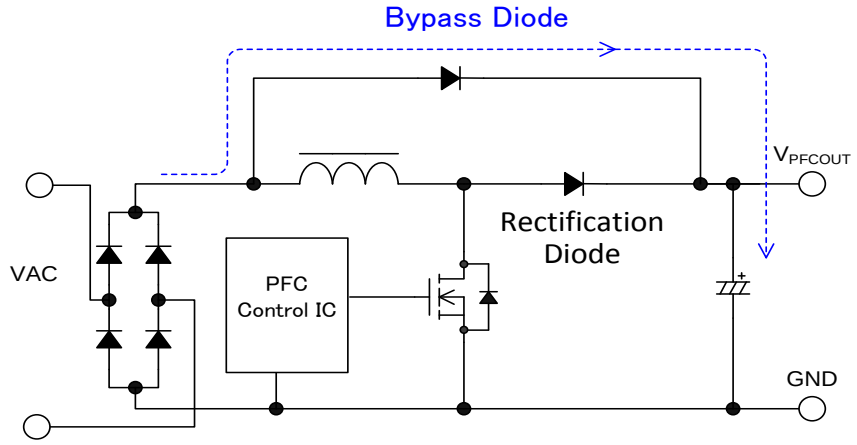
Selection Guide for Bypass Diode

1. Bypass Diode Operation

➢ **For Protecting power MOSFET and Rectification Diode from Inrush Current**

When the inductance is saturated by an inrush current, large current flows to the rectification diode, and may cause to break the diode. In addition, when the power MOSFET turns on during saturation state of the inductance, the power MOSFET may be broken. Thus, flow the inrush current to the bypass diode.

This prevents the inductance saturation, and protects the power MOSFET and the rectification diode.



➢ **For protecting Bridge Diode from Lightning Surge**

If the lightning surge is added to the circuit, bridge diode may be broken. To prevent this, the lightning surge is charged to the electrolytic capacitor through the bypass diode.

2. Electrical Characteristics of Bypass Diode

To flowing inrush current and lightning surge current to the bypass diode, select the diode that VF of bypass diode is lower than its of the rectification diode.

For the bypass diode, the pulse current and VF characteristic should be taken into account. While the PFC output voltage is higher than the input voltage, the bypass diode turns off (i.e., No caring about trr).

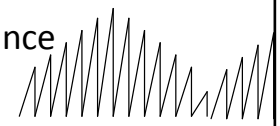
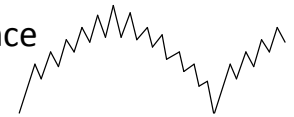
Key points of bypass diode selection:

1) Large current capability in short period: I_{FSM} > 35 A

2) VF lower than rectification diode: $V_F \leq 1.05$ V

Selection Guide for PFC Rectification Diode

Select the PFC rectification diode according to the PFC operation mode.

	Discontinuous Conduction Mode (DCM)	Critical Conduction Mode (CRM)	Continuous Conduction Mode (CCM)
Features	■ There is a period that the current flows through inductor becomes zero ■ Small inductance I_L 	■ The current that flows through inductor becomes zero for a moment (fixed on time) ■ Medium inductance I_L 	■ No period that the current flows through inductor becomes zero (fixed frequency) ■ Large inductance I_L 
Advantages	■ Power MOSFET tarns on when the diode current is zero. ✓ No recovery current of the rectification diode ✓ Small switching noise ■ To improve the circuit efficiency, select low VF diode.		■ Peak current of power MOSFET is small ■ Ripple of input current is small ■ Normal mode noise is small
Disadvantages	■ Peak current of power MOSFET is large ■ Ripple of input current is large ■ Normal mode noise is large		■ Power MOSFET tarns on when current flows through the diode. ✓ Recovery current loss increases ✓ Switching noise is large ■ To reduce the losses, select the diode that has low VF and fast trr characteristics.

Key points in selecting a rectifier diode:
- **DCM, CRM: Low VF diode, $V_F \leq 1.3V$**
- **CCM: Low VF and fast recovery diode, trr ≤ 50 ns**

Rectification Diode, $V_F \leq 0.95$ V, $V_{RM} = 600$ V

Package

Axial

- $V_F \leq 1.05$ V
- V_{RM} = 600 V to 1000 V
- I_{FSM} = 35 A to 80 A

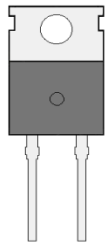
V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	I_{FSM} 50Hz Half wave
600 V	1.0 A	**AM01A**	Axial(ϕ2.4/ϕ0.6)	0.98 V	35 A
	1.0 A	**EM01A**	Axial(ϕ2.7/ϕ0.6)	0.97 V	45 A
	1.0 A	**EM1A**	Axial(ϕ2.7/ϕ0.78)	0.97 V	45 A
	1.2 A	**EM2A**	Axial(ϕ2.7/ϕ0.78)	0.92 V	80 A
800 V	1.0 A	**EM1B**	Axial(ϕ2.7/ϕ0.78)	1.05 V	35 A
	1.2 A	**EM2B**	Axial(ϕ2.7/ϕ0.78)	0.92 V	80 A
1000 V	1.0 A	**EM1C**	Axial(ϕ2.7/ϕ0.78)	1.05 V	35 A

Fast Recovery Diode, $V_F \leq 1.3$ V, $V_{RM} = 600$ V

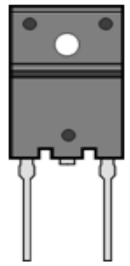
- for DCM and CRM
- $V_F = 1.3$ V
- $V_{RM} = 600$ V
- trr ≤ 150 ns

Package

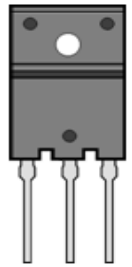
TO220-2L



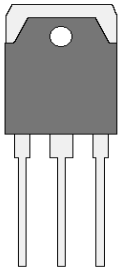
TO3PF-2L



TO3PF-3L



TO3P-3L



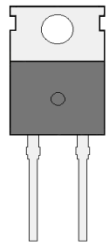
V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr
					I_F : I_R=1:1
600 V	10	**DENS-1106S**	TO220-2L	1.3 V	100 ns
	15	**DENS-1156S**	TO220-2L	1.3 V	100 ns
	30	**FMN-3306S**	TO3PF-2L	1.3 V	150 ns
		FMN-4306S	TO3PF-3L	1.3 V	100 ns
		CTNS-4306S	TO3P-3L	1.3 V	100 ns
	60	**CTNS-4606S**	TO3P-3L	1.3 V	100 ns
		FMNS-4606S	TO3PF-3L	1.3 V	150 ns

Fast Recovery Diode, trr ≤ 50 ns, V_{RM} = 600 V

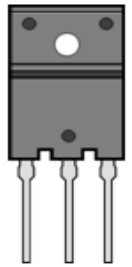
- For CCM Mode
- trr ≤ 50 ns
- V_{RM} = 600 V
- I_F = 10 A to 60 A

Package

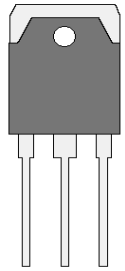
TO220-2L



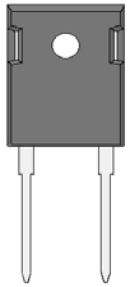
TO3PF-3L



TO3P-3L



TO247-2L



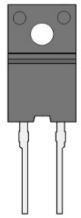
V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr
					I_F : I_R=1:1
600 V	10 A	**DEXS-1106S**	TO220-2L	1.6 V	30 ns
	15 A	**DEXS-1156S**	TO220-2L	1.6 V	30 ns
	20 A	**FMD-4206S**	TO3PF-3L	1.7 V	50 ns
	30 A	**CTXS-5306S**	TO247-2L	1.7 V	35 ns
	60 A	**CTXS-4606S**	TO3P-3L	1.7 V	35 ns
		CTXS-5606S	TO247-2L	1.7 V	50 ns

Low Noise Fast Recovery Diode, trr ≤ 100 ns, V_{RM} = 600 V

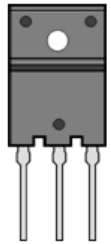
- For CCM Mode
- Low Noise
- trr ≤ 100 ns
- V_{RM} = 600 V
- I_F = 20 A to 60 A

Package

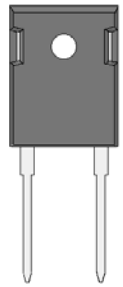
TO-220F



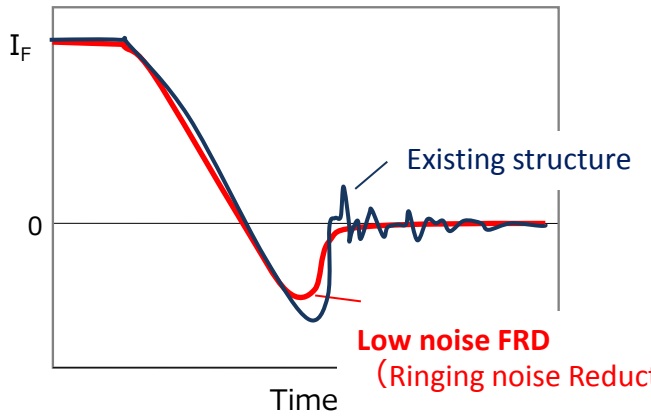
TO-3PF



TO-247



Switching Current Waveform



V_{RM}	$I_{F(AV)}$	Products	Package	V_F (max.)	trr *
600 V	20 A	**FMXR-1206S-CG**	TO220F-2L	2.5 V	60 ns
		FMXR-4206S-SP	TO3PF-3L	2.5 V	60 ns
	30 A	**FMXR-4306S-SP**	TO3PF-3L	2.5 V	70 ns
		CTXR-5306S-SP	TO247-2L	2.5 V	70 ns
	40 A	**FMXR-4406S-SP**	TO3PF-3L	2.5 V	60 ns
		CTXR-5406S-SP	TO247-2L	2.5 V	75 ns
	60 A	**FMXR-4606S-SP**	TO3PF-3L	2.5 V	70 ns
		CTXR-5606S-SP	TO247-2L	2.5 V	80 ns

* $I_F = I_{F(AV)}$, di/dt = 200 A/µs, 100% recovery point

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