Auxiliary Switch Diodes for Snubber

SARS01, SARS02, SARS05, SARS10

Data Sheet

Description

The SARS[1] is an auxiliary switch diode especially designed for snubber circuits, which are used in the primary sides of flyback switched-mode power supplies.

Being capable of reducing the ringing voltage generated at power MOSFET turn-off, the SARS-incorporated snubber circuits allow better cross regulation of multiple outputs.

The SARS can also improve power supply efficiency by partially transferring such ringing voltage into the secondary side of a power supply unit.

Features

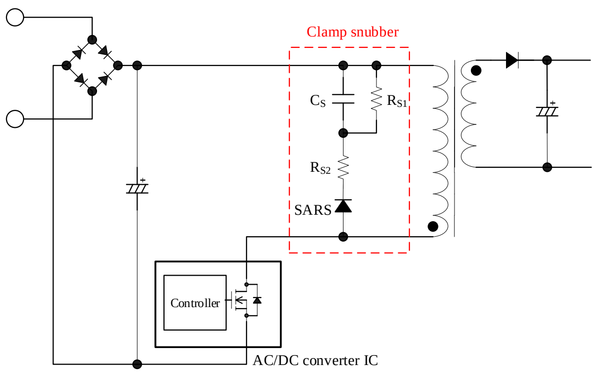
- Improves Cross Regulation
- Reduces Noise
- Improves Efficiency

Applications

For switched-mode power supplies (SMPS) with flyback topology such as:

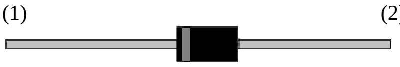
- White Goods
- Adaptor
- Industrial Equipment

Typical Application



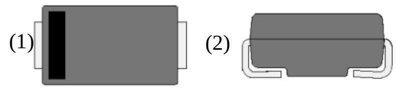
Package

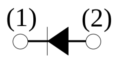
SARS01 (Axial φ 2.7 / φ 0.60)



SARS02 (Axial φ 4 / φ 0.78)

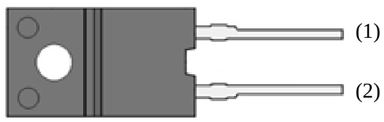
SARS05 (SJP 4.5 mm × 2.6 mm)

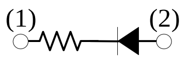




(1) Cathode
(2) Anode

SARS10 (TO220F-2L)





(1) Cathode side
(2) Anode

Not to scale

Selection Guide

R_{S2}	Part Number	$I_{F(AV)}$	V_F (max.)	Power Supply Output Power, P_O*
External Resistor	SARS01	1.2 A	0.92 V	up to 50 W
	SARS02	1.5 A	0.92 V	up to 100 W
	SARS05	1 A	1.05 V	up to 50 W
Built-in 22 Ω	SARS10	0.3 A	13 V	up to 300 W

* P_O represents a reference value for product selection. When using the product, you should monitor temperature rises during actual operation.

(1) The "SARS" represents any one of the SARSxx devices listed in this document.

Contents

Absolute Maximum Ratings

Unless otherwise specified, T_A = 25 °C, only the SARS10 incorporates a resistor (22 Ω).

Parameter	Symbol	Conditions	Rating	Unit	Remarks
Transient Peak Reverse Voltage	V_{RSM}		800	V	
Peak Repetitive Reverse Voltage	V_{RM}		800	V	
Average Forward Current[2]	$I_{F(AV)}$		1.2	A	SARS01
			1.2		SARS02
			1.0		SARS05
			0.3		SARS10
Surge Forward Current	I_{FSM}	Half cycle sine wave, positive side, 10 ms, 1 shot	110	A	SARS01
			100		SARS02
			30		SARS05
		1 ms, square pulse, 1 shot	1.5		SARS10
I^2t Limiting Value	I^2t	1 ms ≤ t ≤ 10 ms	60.5	A^2s	SARS01
			50		SARS02
			4.5		SARS05
			—		SARS10
Junction Temperature	T_J		−40 to 150	°C	SARS01/02/05
			−20 to 125		SARS10
Storage Temperature	T_{STG}		−40 to 150	°C	SARS01/02/05
			−20 to 125		SARS10
Power Dissipation	P		3.0	W	SARS10

(2) See the derating curves of each product.

Electrical Characteristics

Unless otherwise specified, T_A = 25 °C, only the SARS10 incorporates a resistor (22 Ω).

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	Remarks
Forward Voltage Drop	V_F	I_F = 1.2 A	—	—	0.92	V	SARS01
		I_F = 1.5 A	—	—	0.92		SARS02
		I_F = 1.0 A	—	—	1.05		SARS05
		I_F = 0.5 A	—	—	13		SARS10
Reverse Leakage Current	I_R	$V_R = V_{RM}$	—	—	10	µA	SARS01
			—	—	10		SARS02
			—	—	5		SARS05
			—	—	10		SARS10
Reverse Leakage Current under High Temperature	$H \cdot I_R$	$V_R = V_{RM}$, T_J = 100 °C	—	—	50	µA	SARS01/02/05
		$V_R = V_{RM}$, T_J = 125 °C	—	—	100		SARS10
Reverse Recovery Time	t_{rr}	$I_F = I_{RP}$ = 100 mA, T_J = 25 °C, 90% recovery point	2	—	18	µs	SARS01
			2	—	18		SARS02
			2	—	19		SARS05
			1	—	9		SARS10
Thermal Resistance	$R_{th(J-L)}$	(3)	—	—	20	°C/W	SARS01
			—	—	15		SARS02
			—	—	20		SARS05
	$R_{th(J-C)}$	(4)	—	—	15	°C/W	SARS10

(3) $R_{th(J-L)}$ is thermal resistance between junction and lead.
(4) $R_{th(J-c)}$ is thermal resistance between junction and case.

SARS01 Rating and Characteristic Curves

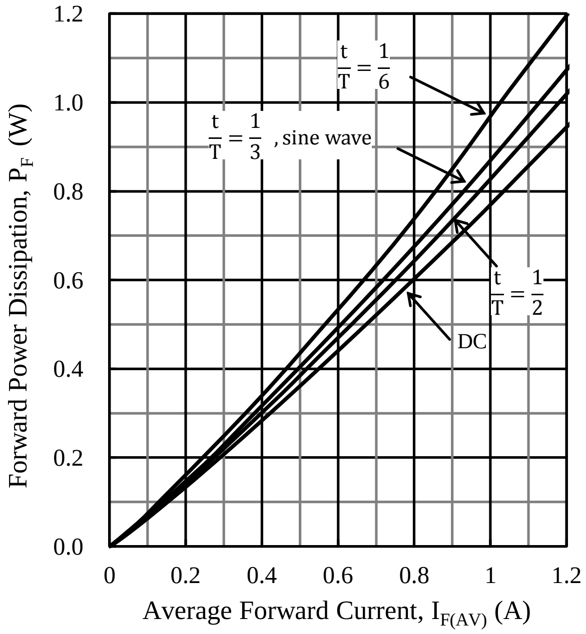


Figure 1. $I_{F(AV)}$ vs. P_F Power Dissipation Curves
(T_J = 150 °C)

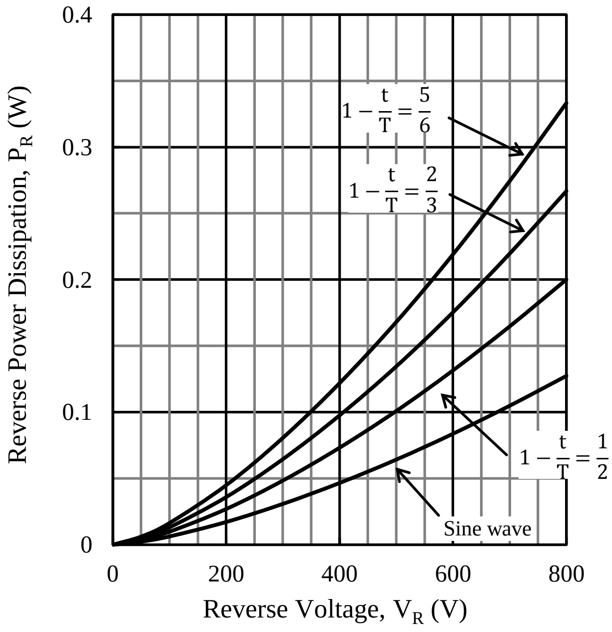


Figure 2. V_R vs. P_R Power Dissipation Curves
(T_J = 150 °C)

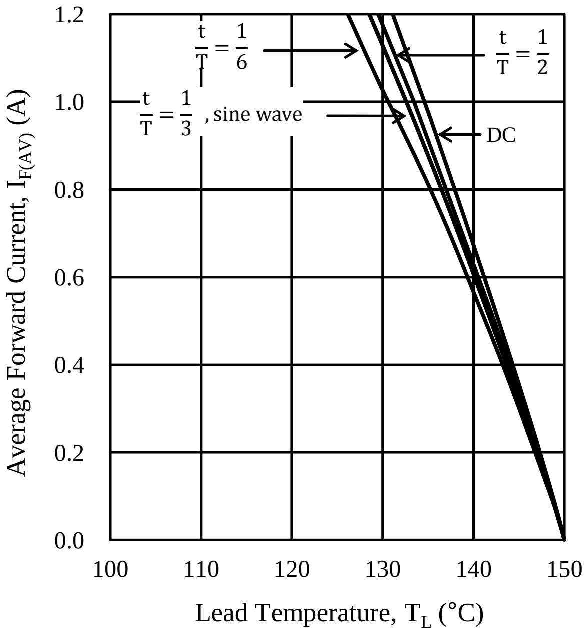


Figure 3. T_L vs. $I_{F(AV)}$ Derating Curves
(V_R = 0 V, T_J = 150 °C)

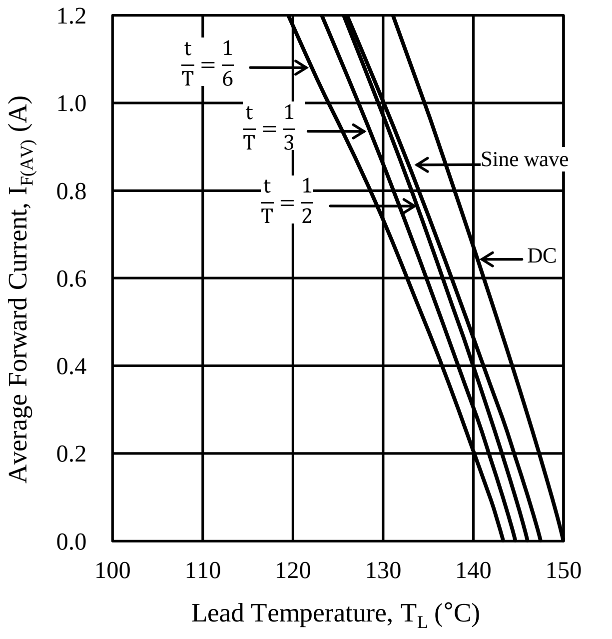


Figure 4. T_L vs. $I_{F(AV)}$ Derating Curves
(V_R = 800 V, T_J = 150 °C)

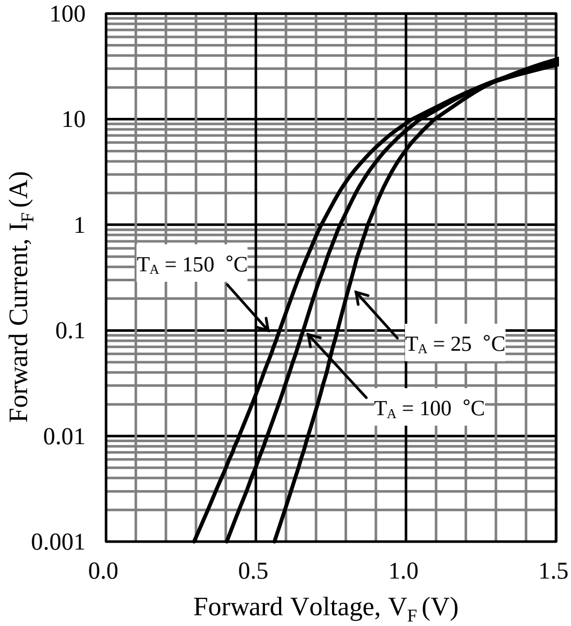


Figure 5. V_F vs. I_F Typical Characteristics

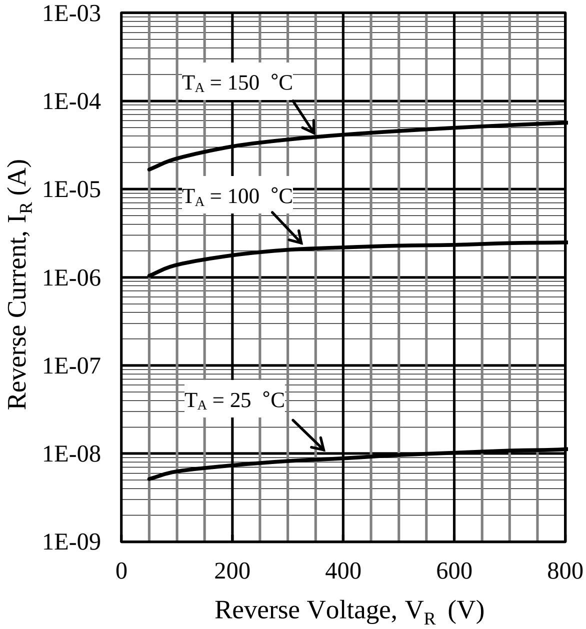


Figure 6. V_R vs. I_R Typical Characteristics

SARS02 Rating and Characteristic Curves

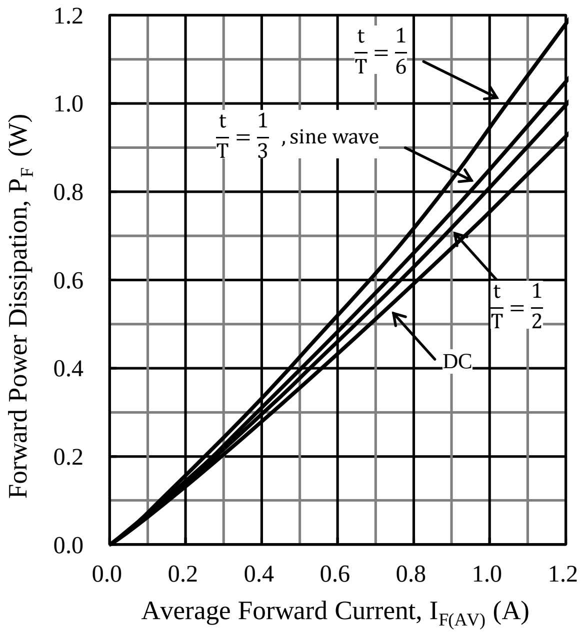


Figure 7. $I_{F(AV)}$ vs. P_F Power Dissipation Curves (T_J = 150 °C)

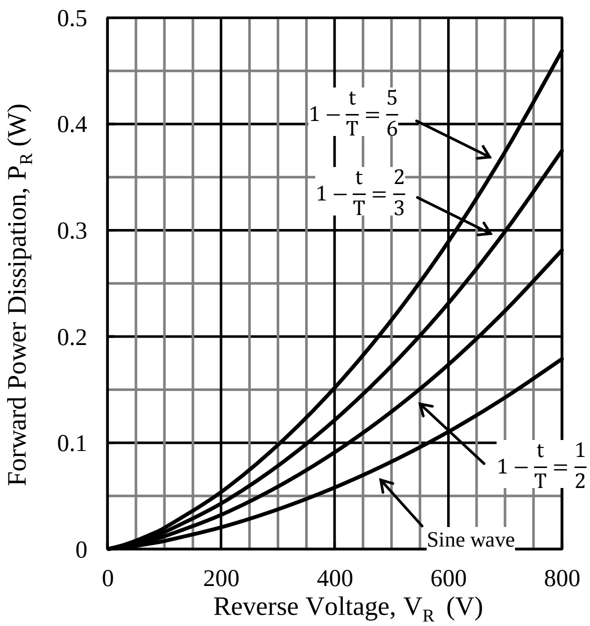


Figure 8. V_R vs. P_R Power Dissipation Curves (T_J = 150 °C)

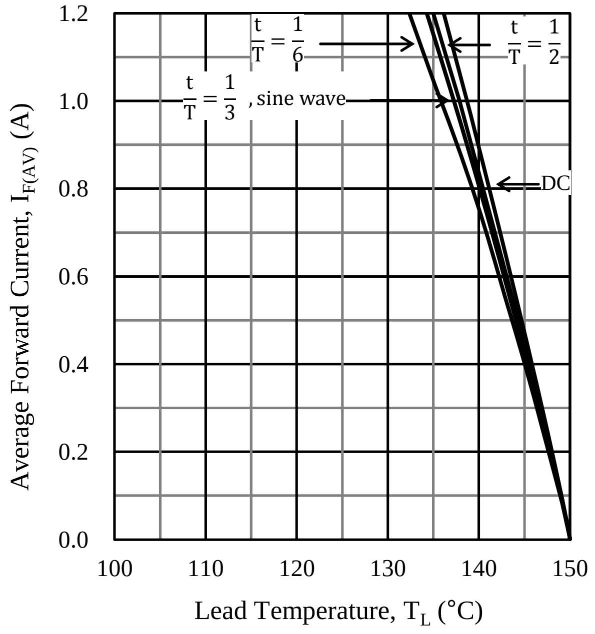


Figure 9. T_L vs. $I_{F(AV)}$ Derating Curves
(V_R = 0 V, T_J = 150 °C)

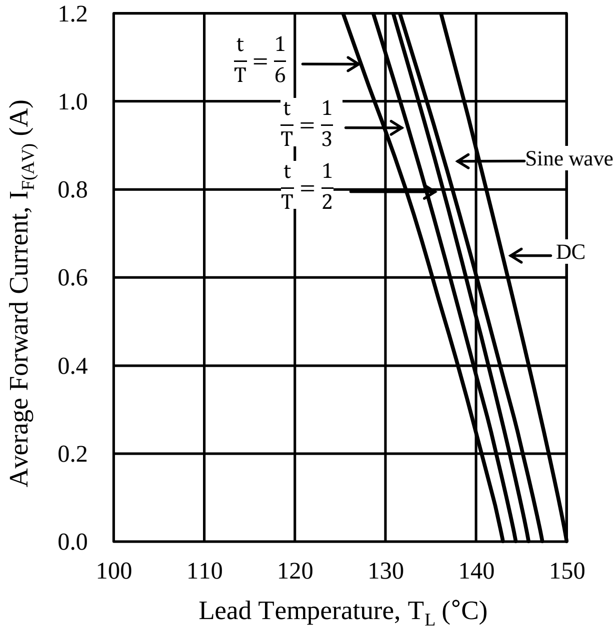


Figure 10. T_L vs. $I_{F(AV)}$ Derating Curves
(V_R = 800 V, T_J = 150 °C)

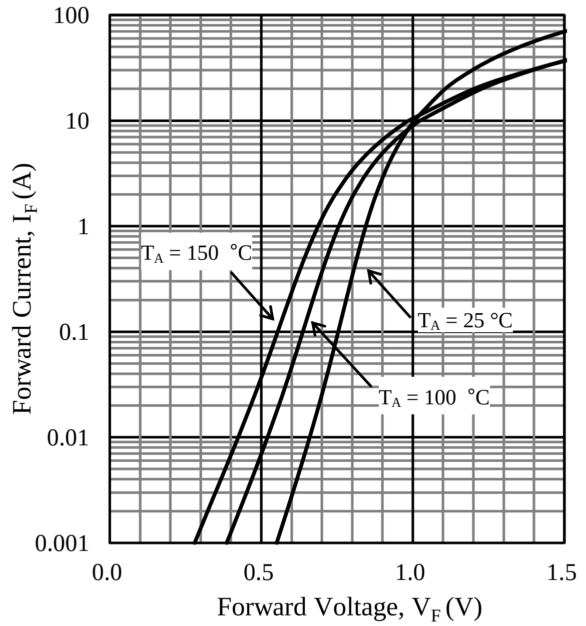


Figure 11. V_F vs. I_F Typical Characteristics

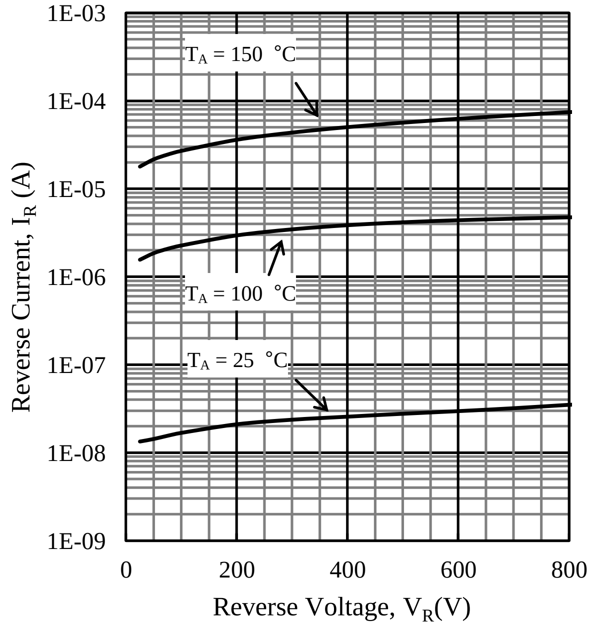


Figure 12. V_R vs. I_R Typical Characteristics

SARS05 Rating and Characteristic Curves

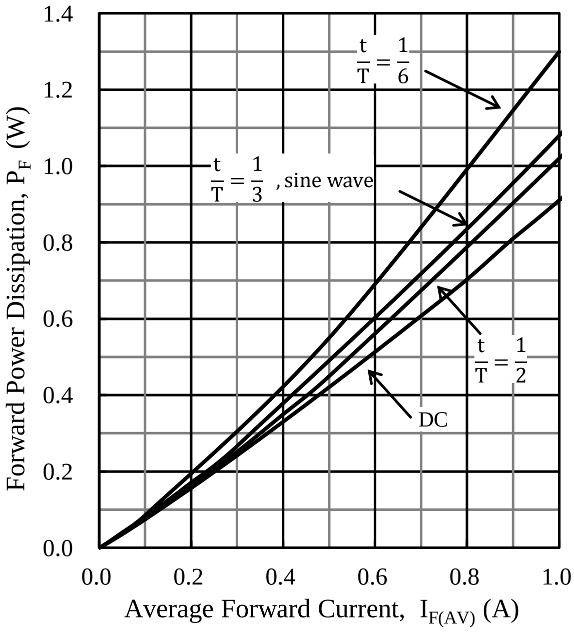


Figure 13. $I_{F(AV)}$ vs. P_F Power Dissipation Curves (T_J = 150 °C)

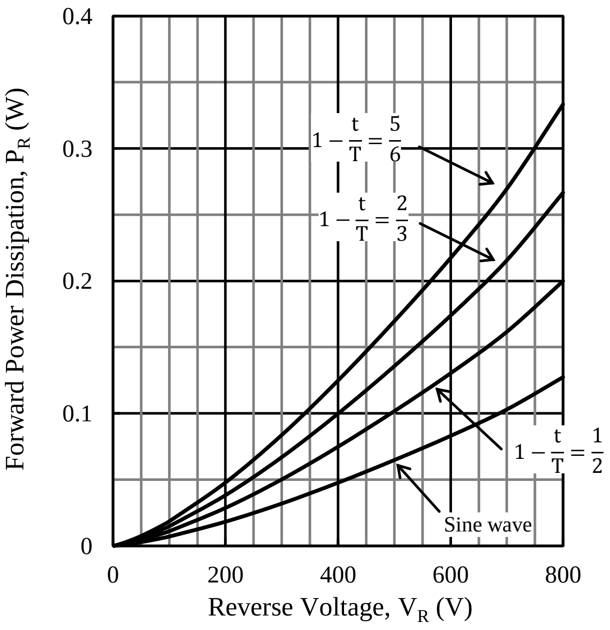


Figure 14. V_R vs. P_R Power Dissipation Curves (T_J = 150 °C)

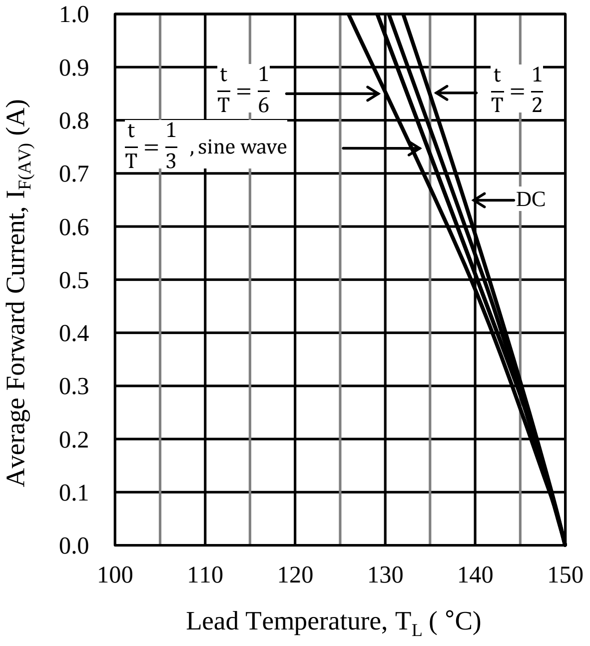


Figure 15. T_L vs. $I_{F(AV)}$ Derating Curves (V_R = 0 V, T_J = 150 °C)

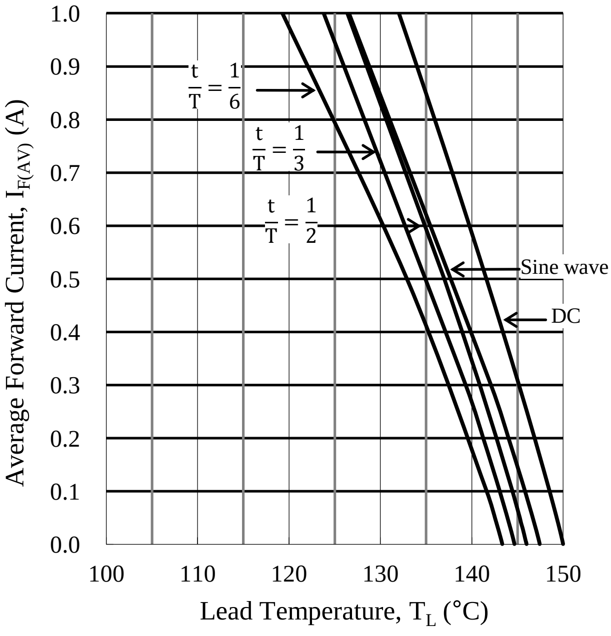


Figure 16. T_L vs. $I_{F(AV)}$ Derating Curves (V_R = 800 V, T_J = 150 °C)

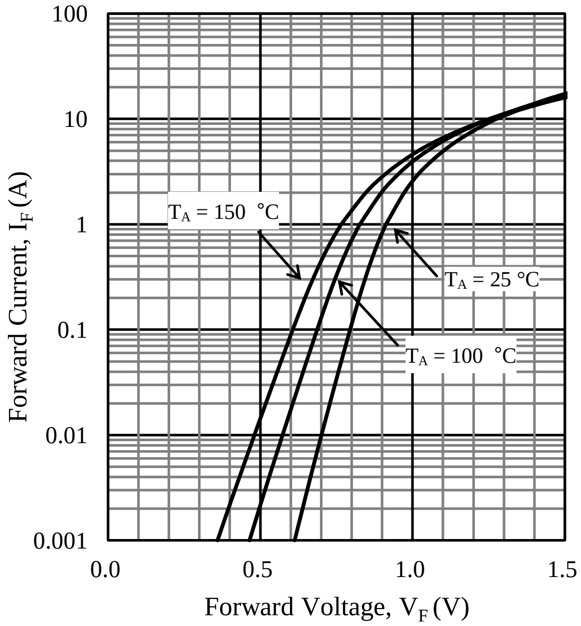


Figure 17. V_F vs. I_F Typical Characteristics

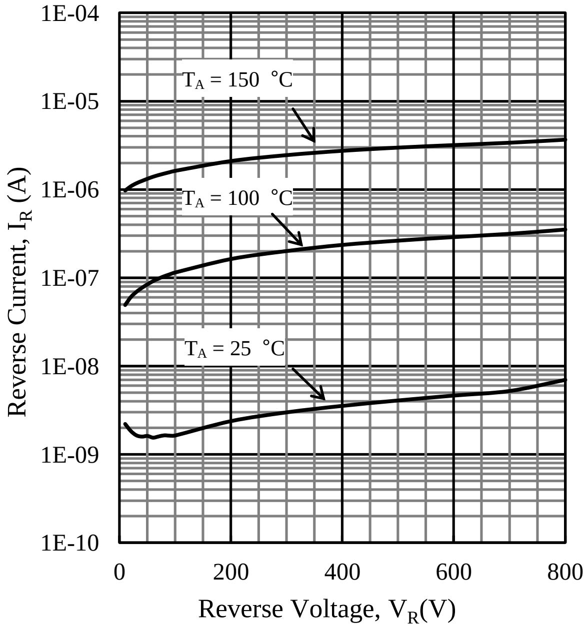


Figure 18. V_R vs. I_R Typical Characteristics

SARS10 Rating and Characteristic Curves

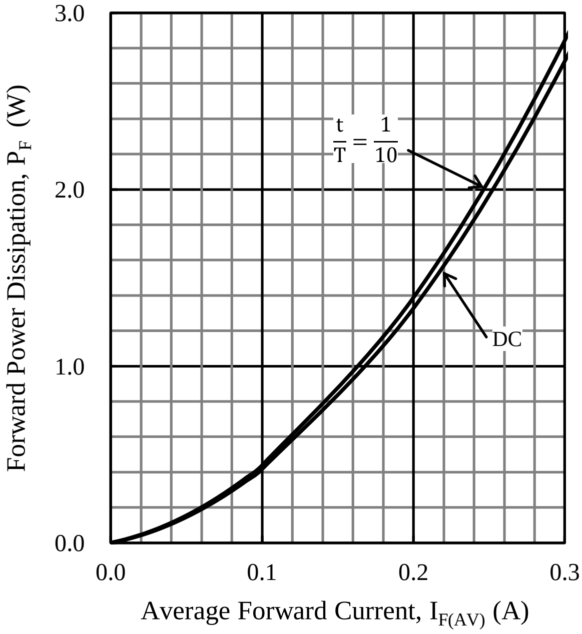


Figure 19. $I_{F(AV)}$ vs. P_F Power Dissipation Curves (T_J = 125 °C)

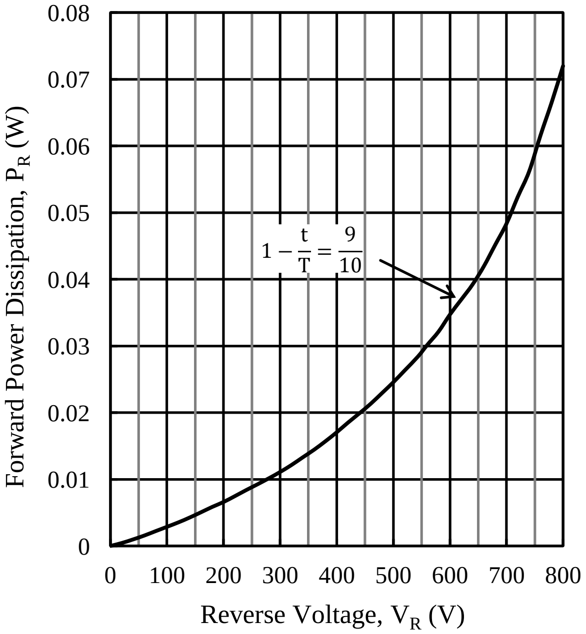


Figure 20. V_R vs. P_R Power Dissipation Curve (T_J = 125 °C)

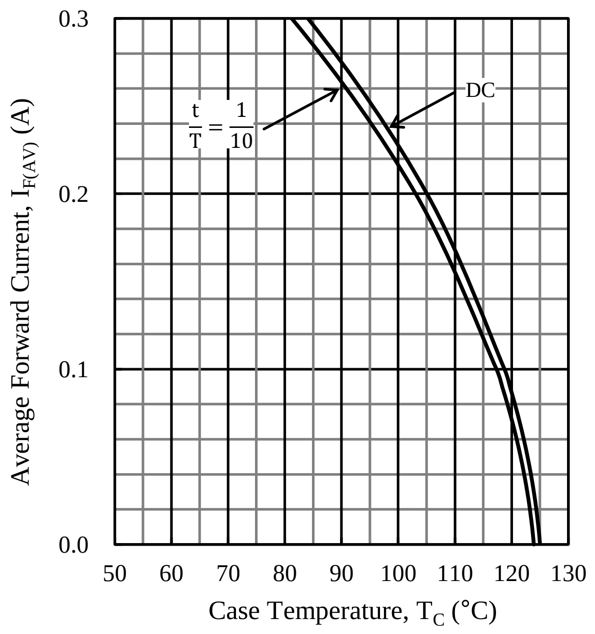


Figure 21. T_C vs. $I_{F(AV)}$ Derating Curves
(V_R = 800 V, T_J = 125 °C)

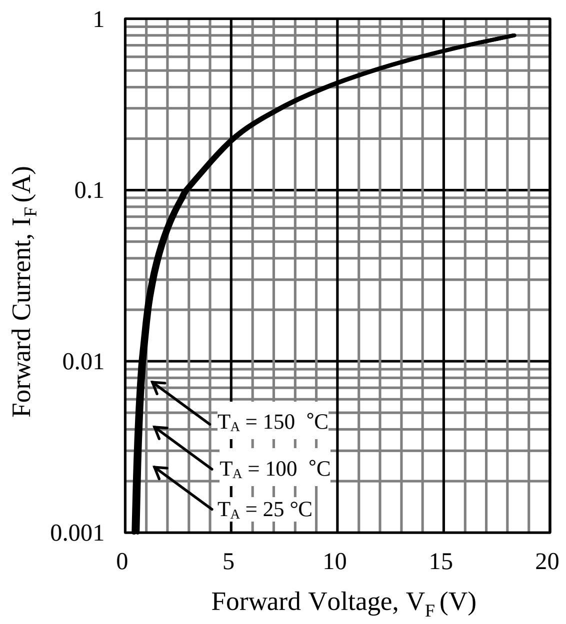


Figure 22. V_F vs. I_F Typical Characteristics

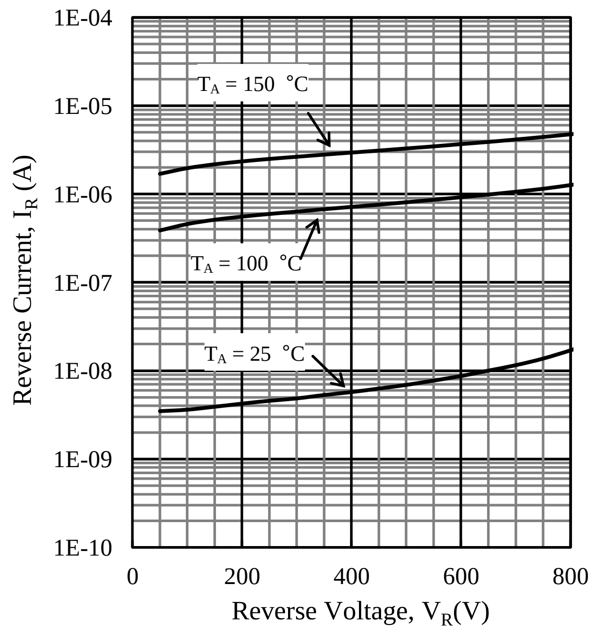
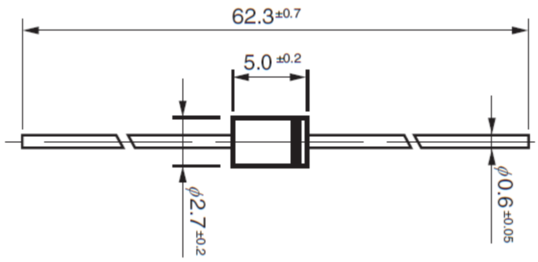


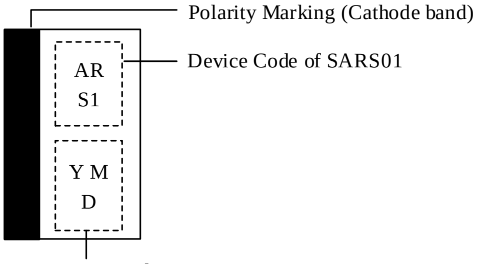
Figure 23. V_R vs. I_R Typical Characteristics

Physical Dimensions and Marking Diagrams

- **SARS01**

  Axial (φ 2.7 / φ 0.6)



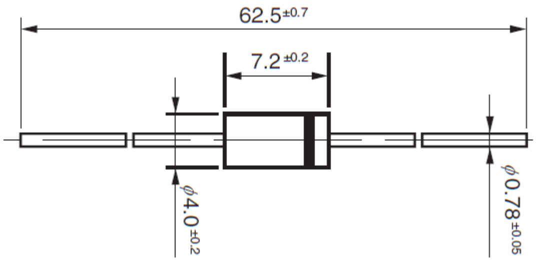


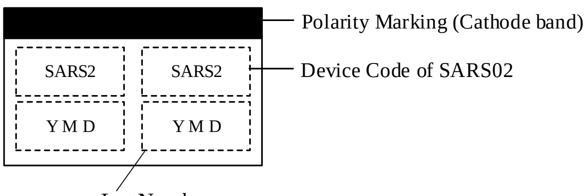
Lot Number:
Y is the last digit of the year of manufacture (0 to 9)
M is the month of the year (1 to 9, O, N, or D)
D is a period of days:
"•" is the first 10 days of the month (1st to 10th)
"• •" is the second 10 days of the month (11th to 20th)
"• • •" is the last 10–11 days of the month (21st to 31st)

NOTES:
- Dimensions in millimeters
- Bare lead: Pb-free (RoHS compliant)
- When soldering the products, be sure to minimize the working time, within the following limits:
  Flow: 260 ± 5 °C / 10 ± 1 s, 2 times
  Soldering Iron: 380 ± 10 °C / 3.5 ± 0.5 s, 1 time (Soldering should be at a distance of at least 1.5 mm from the body of the products.)

- **SARS02**

  Axial (φ 4 / φ 0.78)





Lot Number:
Y is the last digit of the year of manufacture (0 to 9)
M is the month of the year (1 to 9, O, N, or D)
D is a period of days:
"•" is the first 10 days of the month (1st to 10th)
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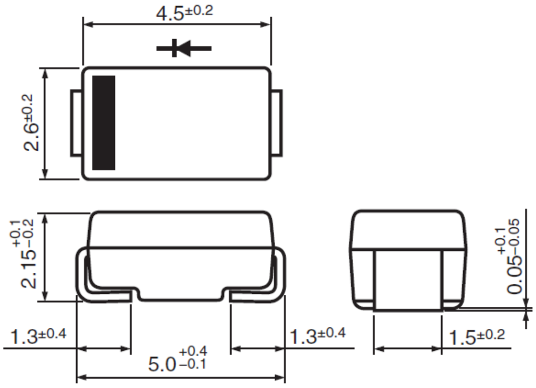
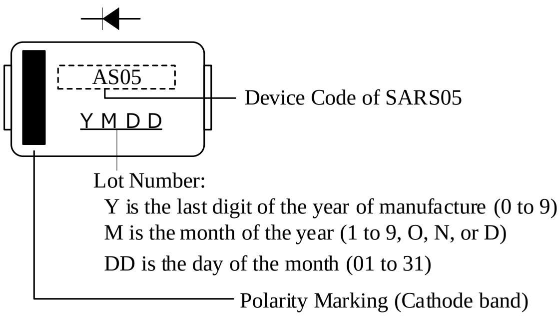
"• • •" is the last 10–11 days of the month (21st to 31st)

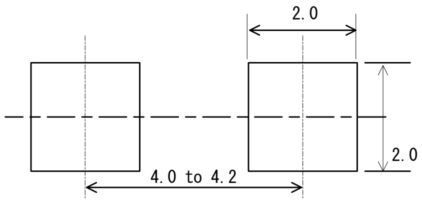
NOTES:
- Dimensions in millimeters
- Bare lead: Pb-free (RoHS compliant)
- When soldering the products, be sure to minimize the working time within the following limits:
  Flow: 260 ± 5 °C / 10 ± 1 s, 2 times
  Soldering iron: 380 ± 10 °C / 3.5 ± 0.5 s, 1 time (Soldering should be at a distance of at least 1.5 mm from the body of the products.)

- **SARS05**
  SJP 4.5 mm × 2.6 mm



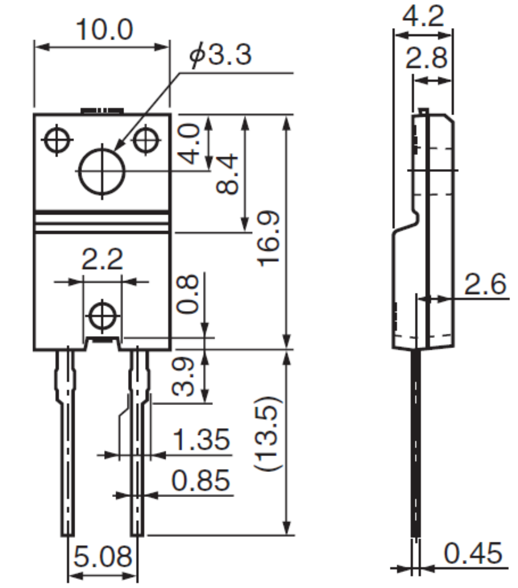


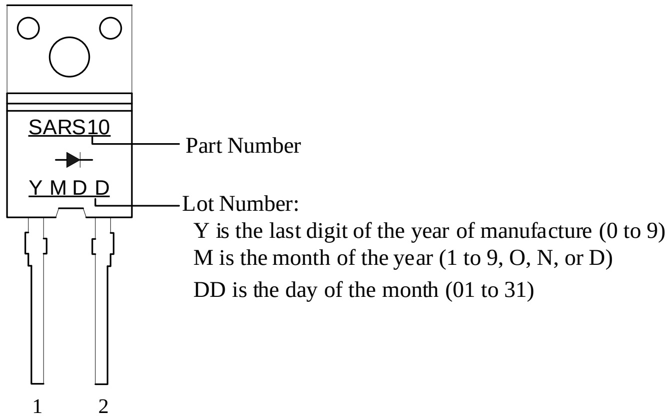
SJP Land Pattern Example



NOTES:
- Dimensions in millimeters
- Bare lead frame: Pb-free (RoHS compliant)
- When soldering the products, be sure to minimize the working time, within the following limits:
  Reflow (MSL 1):
  Preheat: 180 °C, 90 ± 30 s
  Solder heating: 250 °C, 10 ± 1s, 2 times (260 °C peak)
  Soldering iron: 380 ± 10 °C, 3.5 ± 0.5s, 1 time

- **SARS10**
  TO220F-2L





NOTES:
- Dimensions in millimeters
- Bare lead frame: Pb-free (RoHS compliant)
- When soldering the products,be sure to minimize the working time, within the following limits:
  Flow: 260 ± 5 °C / 10 ± 1 s, 2 times
  Soldering Iron: 380 ± 10 °C / 3.5 ± 0.5 s, 1 time (Soldering should be at a distance of at least 1.5 mm from the body of the products.)
- The recommended screw torque for TO220F: 0.490 N·m to 0.686 N·m (5 kgf·cm to 7 kgf·cm)

Operational Comparison of Clamp Snubber Circuits

Figure 24 shows a general clamp snubber circuit. In the circuit, the surge voltage at tuning off a power MOSFET is charged to C_S through the surge absorb loop, and is consumed by R_{S1} through the energy discharge loop. All the consumed energy becomes loss in R_{S1}. In addition, the ringing of surge voltage results in poor cross regulation of multi-outputs.

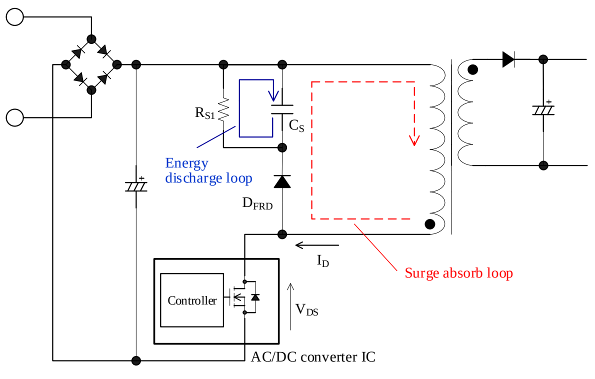


Figure 24. General Clamp Snubber Circuit

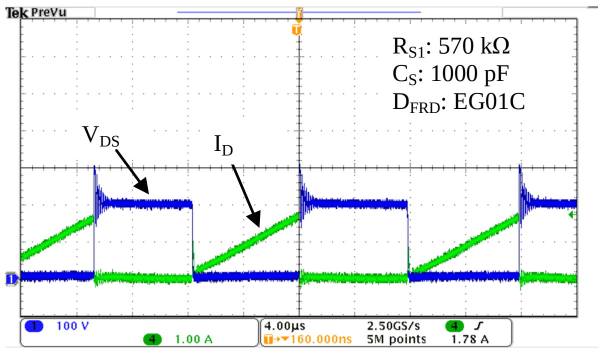


Figure 25. Waveforms of General Clamp Snubber Circuit

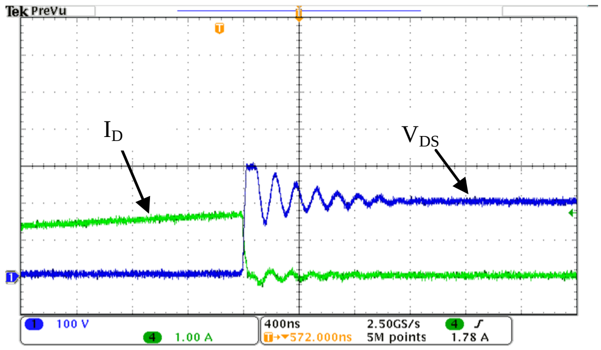


Figure 26. Enlarged View of Figure 25

Figure 27 shows the clamp snubber circuit using the SARS. The surge voltage at tuning off a power MOSFET is charged to C_S through the surge absorb loop. Since the reverse recovery time, trr, of the SARS is a relatively long period, the energy charged to C_S is discharged to the reverse direction of the surge absorb loop until C_S voltage is equal to the flyback voltage. Some discharged energy is transferred to secondary side. Thus, the power supply efficiency improves.

In addition, the power supply using the SARS reduces the ringing voltage. Thus, the cross regulation of multi-outputs can be improved.

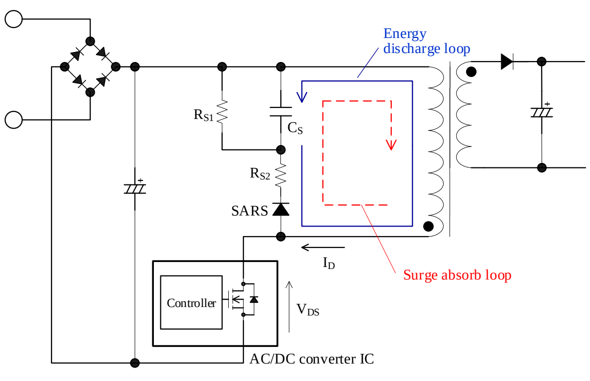


Figure 27. Clamp Snubber Circuit using SARS

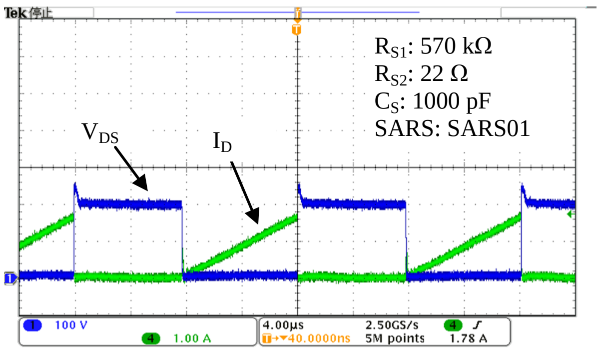


Figure 28. Waveforms of Clamp Snubber Circuit using SARS

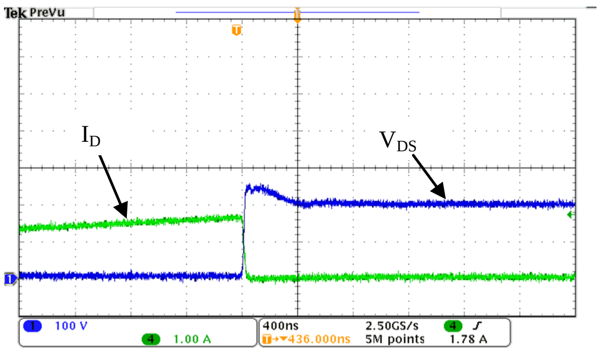


Figure 29. Enlarged View of Figure 28

Power Dissipation and Junction Temperature Calculation

Figure 30 shows a typical application using the SARS. Figure 31 shows the operating waveforms of the SARS.

The power dissipation of the SARS is calculated as follows:

1) The waveforms of the SARS voltage, V_{SARS}, and the SARS current, I_{SARS}, are measured in actual application operation. $V_{SARS} \times I_{SARS}$ is calculated by the math function of oscilloscope. (Since the SARS10 incorporates a resistor, $V_{SARS(10)}$ is measured.)
2) The each average energy (P_1, $P_2 \cdots P_k$) is measured at period of each polarity of $V_{SARS} \times I_{SARS}$ (t_1, $t_2, \cdots t_k$) as shown in Figure 30 by the automatic measurement function of the oscilloscope.
3) The power dissipation of the SARS, P_{SARS}, is calucultaed by Equation (1):

$$P_{SARS} = \frac{1}{T}(|P_1 \times t_1| + |P_2 \times t_2| + \cdots |P_k \times t_k|) \qquad (1)$$

where:
P_{SARS} is power dissipation of the SARS,
T is switching cycle of power MOSFET (s), and
P_k is average energy of period t_k (W).

A differential probe is recommended to use for the measurement of V_{SARS}. Please conform to the oscilloscope manual about power dissipation measurement including the delay compensation of probe.

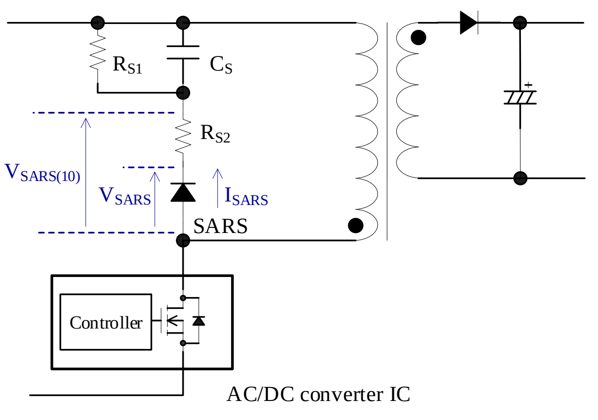


Figure 30. Typical Application

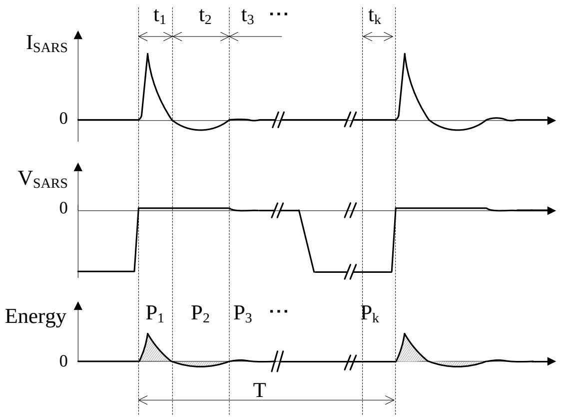


Figure 31. SARS Current

In addition, by using the temperature of the SARS in actual application operation, the estimated junction temperature of the SARS is calculated by Equation (2) and Equation (3). It should be enough lower than T_J of the absolute maximum rating.

- **SARS01/02/05**

$$T_{J(SARS)} = T_L + \theta_{J-L} \times P_{SARS}\ (°C) \qquad (2)$$

where:
$T_{J(SARS)}$ is junction temperature of the SARS,
T_L is lead temperature of the SARS, and
$\theta_{J\text{-}L}$ is thermal resistance between junction to lead.

- **SARS10**

$$T_{J(SARS)} = T_C + \theta_{J-C} \times P_{SARS}\ (°C) \qquad (3)$$

Where:
$T_{J(SARS)}$ is junction temperature of the SARS,
T_C is case temperature of the SARS, and
$\theta_{J\text{-}C}$ is thermal resistance between junction to case.

Parameter Setting of Snubber Circuit using SARS

The temperature of the SARS and peripheral components should be measured in actual application operation.

The reference values of snubber circuit using the SARS are as follows:

- **C_S**

680 pF to 0.01 μF.

The voltage rating is selected according to the voltage subtraced the input voltage from the peak of V_{DS}.

- **R_{S1}**

R_{S1} is the bias resistance to turn off the SARS, and is 100 kΩ to 1 MΩ.

Since a high voltage is applied to R_{S1} that has high resistance, the following should be considered according to the requirement of the application:

- Select a resistor designed for electromigration, or
- Connect more resistors in series so that the applied voltages of individual resistors can be reduced.

The power rating of resistor should be selected from the measurement of the effective current of R_{S1} based on actual operation in the application.

- **R_{S2}**

R_{S2} is the limited resistance in the energy discharging. The value of 22 Ω to 220 Ω is connected to the SARS in series (the SARS10 incorporates R_{S2}).

The power rating of resistor should be selected from the measurement of the effective current of R_{S2} based on actual operation in the application.

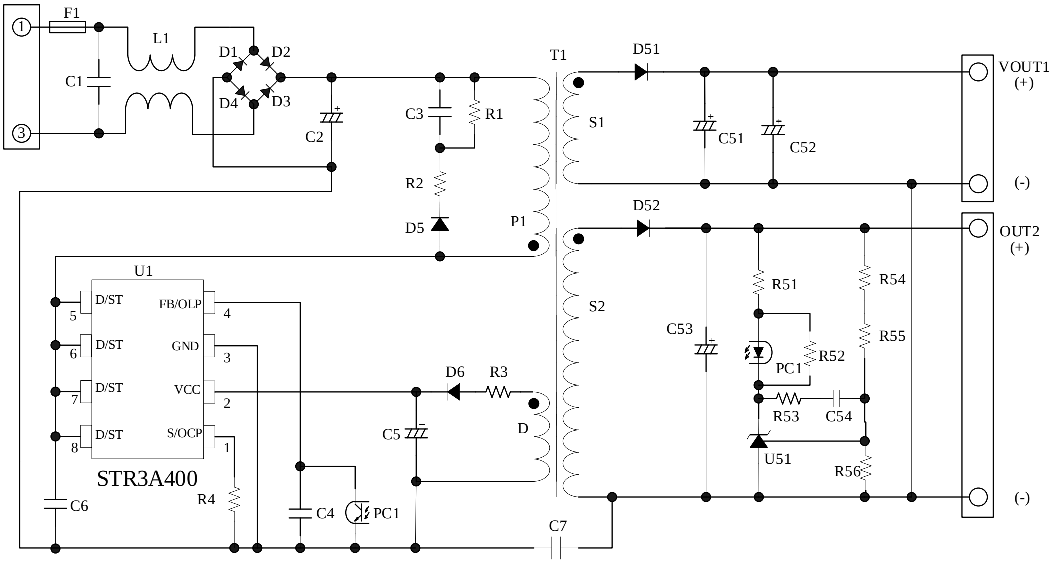
Reference Design of Power Supply

This section provides the information on a reference design, including power supply specifications, a circuit diagram, the bill of materials, and transformer specifications.

- **Power Supply Specifications**

Item	Specification
Input Voltage	85 VAC to 265 VAC
Output Power	34.8 W (40.4 W peak)
Output 1	8 V / 0.5 A
Output 2	14 V / 2.2 A (2.6 A peak)

- **Circuit Schematic**



- **Bill of Materials**

Symbol	Ratings[1]	Recommended Part No.	Symbol	Ratings[1]	Recommended Part No.
C1[2]	Film, 0.1 µF, 275 V		D52	Schottky, 100 V, 10 A	FMEN-210A
C2[2]	Electrolytic, 150 µF, 400 V		F1	Fuse, 250 V AC, 3 A	
C3	Ceramic, 1000 pF, 1 kV		L1[2]	CM inductor, 3.3 mH	
C4	Ceramic, 0.01 µF		PC1	Optocoupler, PC123 or equiv.	
C5	Electrolytic, 22 µF, 50 V		R1[3]	Metal oxide, 330 kΩ, 1 W	
C6[2]	Ceramic, 15 pF / 2 kV		R2	47 Ω, 1 W	
C7[2]	Ceramic, 2200 pF, 250 V		R3	10 Ω	
C51[2]	Electrolytic, 680 µF, 25 V		R4[2]	0.47 Ω, 1/2 W	
C52	Electrolytic, 680 µF, 25 V		R51	1 kΩ	
C53	Electrolytic, 470 µF, 16 V		R52	1.5 kΩ	
C54[2]	Ceramic, 0.1 µF, 50 V		R53[2]	100 kΩ	
D1	600 V, 1 A	EM01A	R54[2]	6.8 kΩ	
D2	600 V, 1 A	EM01A	R55	± 1%, 39 kΩ	
D3	600 V, 1 A	EM01A	R56	± 1%, 10 kΩ	
D4	600 V, 1 A	EM01A	T1	See the Transformer Specification	
D5	800 V, 1.2 A	SARS01	U1	IC,	STR3A453D
D6	Fast recovery, 200 V, 1 A	AL01Z	U51	Shunt regulator, V_{REF} = 2.5 V	(TL431 or equiv.)
D51	Schottky, 60 V, 1.5 A	EK16			

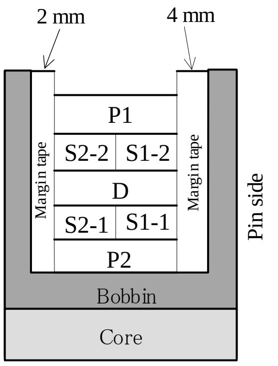
(1) Unless otherwise specified, the voltage rating of capacitor is 50 V or less and the power rating of resistor is 1/8 W or less.
(2) Refers to a part that requires adjustment based on operation performance in an actual application.
(3) High voltage is applied to this resistor that has high resistance. To meet your application requirements, it is required to select resistors designed for electromigration, or to connect more resistors in series so that the applied voltages of individual resistors can be reduced.

● **Transformer Specifications**

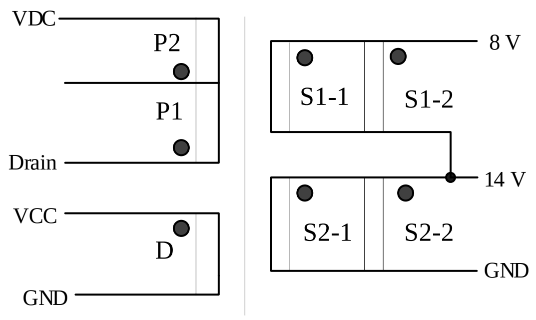
Item	Specification
Primary Inductance, L_P	518 µH
Core Size	EER-28
AL Value	245 nH/N^2 (with a center gap of about 0.56 mm)
Winding Specification	See Table 1
Winding Structure	See Figure 32

Table 1. Winding Specification

Winding	Symbol	Number of Turns (turns)	Wire Diameter (mm)	Structure
Primary Winding	P1	18	φ 0.23 × 2	Single-layer, solenoid winding
Primary Winding	P2	28	φ 0.30	Single-layer, solenoid winding
Auxiliary Winding	D	12	φ 0.30 × 2	Solenoid winding
Output 1 Winding	S1-1	6	φ 0.4 × 2	Solenoid winding
Output 1 Winding	S1-2	6	φ 0.4 × 2	Solenoid winding
Output 2 Winding	S2-1	4	φ 0.4 × 2	Solenoid winding
Output 2 Winding	S2-2	4	φ 0.4 × 2	Solenoid winding



Cross-section View



● denotes the start of winding.

Figure 32. Winding Structure

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