SARS01/02/05/10

Description

SARS is the auxiliary switch diode for snubber circuit, used in the primary side clamp snubber circuit of switched-mode power supplies with fly back topology.

Since the ringing voltage at turning off the power MOSFET is more reduced by the clamp snubber circuit using SARS, the cross regulation of multi-outputs is improved. Since some energy of the ringing is transferred to the secondary side, the power supply efficiency can be improved.

Features

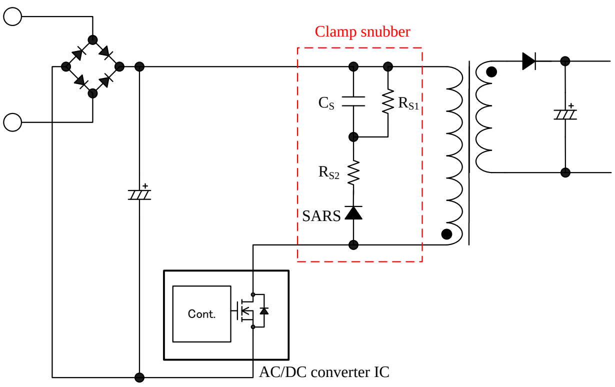
- Improving cross regulation
- Reducing noise
- Improving efficiency

Application

Switched-mode power supply (SMPS) with flyback topology such as for the followings:

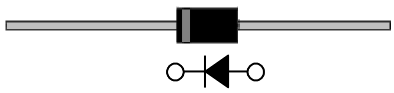
- White goods
- Adaptor
- Industrial equipment

Typical Application

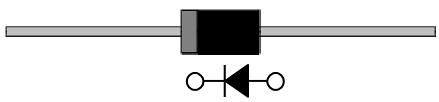


Package

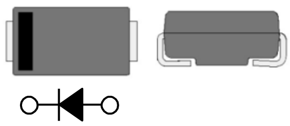
SARS01 (Axial φ 2.7 / φ 0.60)



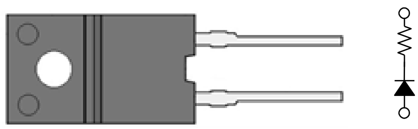
SARS02 (Axial φ 4 / φ 0.78)



SARS05 (SMA 4.5×2.6)



SARS10 (TO220F-2L)



Not to Scale

Lineup

- V_{RM}=800V

R_{S2}	Products	$I_{F(AVG)}$	V_F (max.)	Power supply output power, P_O*
External component	SARS01	1.2 A	0.92 V	~50W
	SARS02	1.5 A	0.92 V	~100W
	SARS05	1 A	1.05 V	~50W
Built-in 22Ω	SARS10	0.3 A	13 V	~300W

* P_O is the reference value at selection. The temperature of SARS should be measured based on actual operation in the application.

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1. Absolute Maximum Ratings

Unless specifically noted T_A = 25 °C. SARS10 incorporates a resistance (22Ω).

Parameter	Symbol	Conditions	Rating	Unit	Note
Transient Peak Reverse Voltage	V_{RSM}		800	V	
Peak Repetitive Reverse Voltage	V_{RM}		800	V	
Average Forward Current*	$I_{F(AV)}$		1.2	A	SARS01
			1.2		SARS02
			1.0		SARS05
			0.3		SARS10
Surge Forward Current	I_{FSM}	10 ms, half sine wave, one shot	110	A	SARS01
			100		SARS02
			30		SARS05
		1 ms, square pulse, one 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

* Refer to Section 3 Derating Curves

2. Electrical Characteristics

Unless specifically noted, T_A = 25 °C. SARS10 incorporates a resistance (22Ω).

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	Note
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	$R_{th(j-L)}$	(1)	–	–	20	°C/W	SARS01
			–	–	15		SARS02
			–	–	20		SARS05
	$R_{th(j-C)}$	(2)	–	–	15	°C/W	SARS10

(1) $R_{th(j-L)}$ is thermal resistance between junction and lead.
(2) $R_{th(j-c)}$ is thermal resistance between junction and case.

3. Performance Curves

T is pulse cycle, t is pulse width.

3.1 SARS01

3.1.1 Typical Characteristics

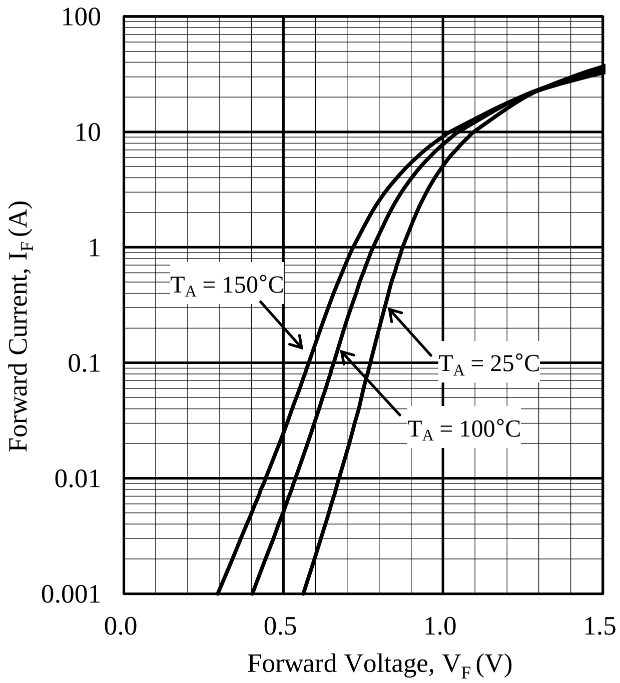


Figure 3-1 V_F − I_F typical characteristics

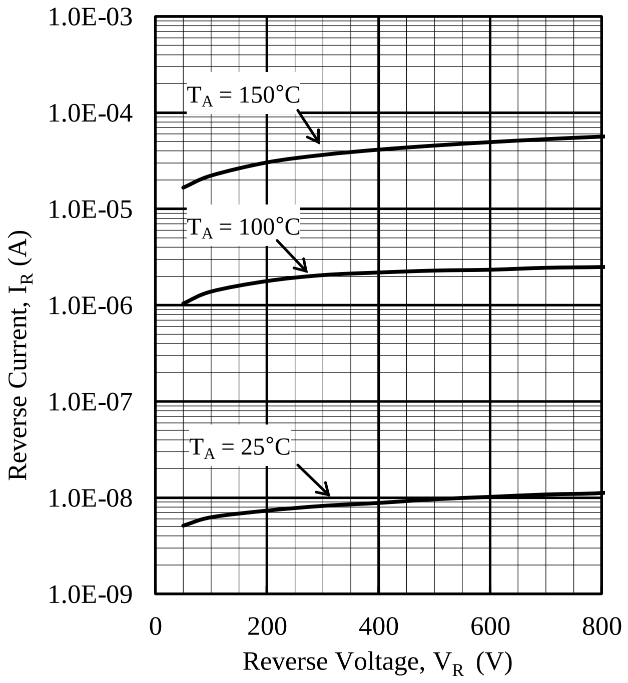


Figure 3-2 V_R − I_R typical characteristics

3.1.2 Power Dissipation Curves (T_j = 150°C)

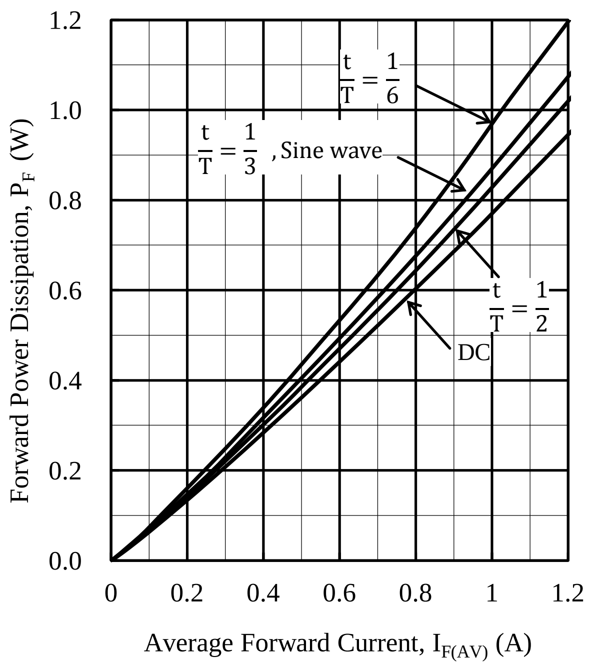


Figure 3-3 $I_{F(AV)}$ − P_F

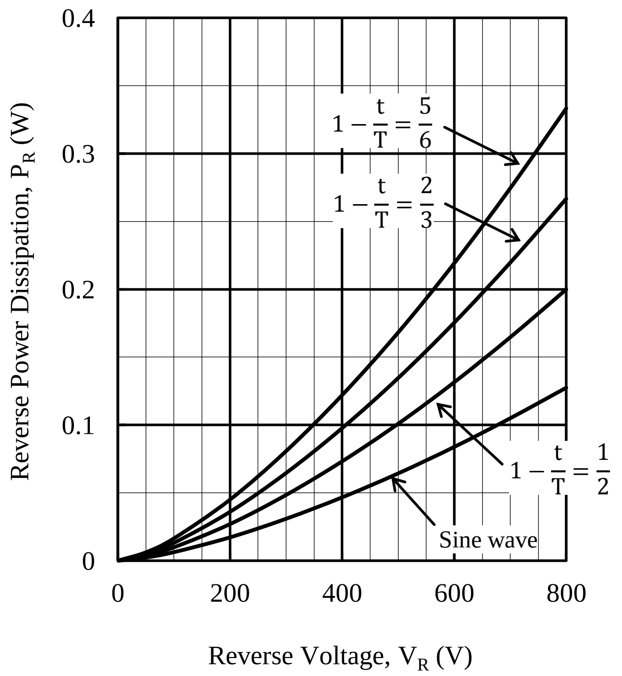


Figure 3-4 V_R − P_R

3.1.3 Derating Curves (T_j = 150°C)

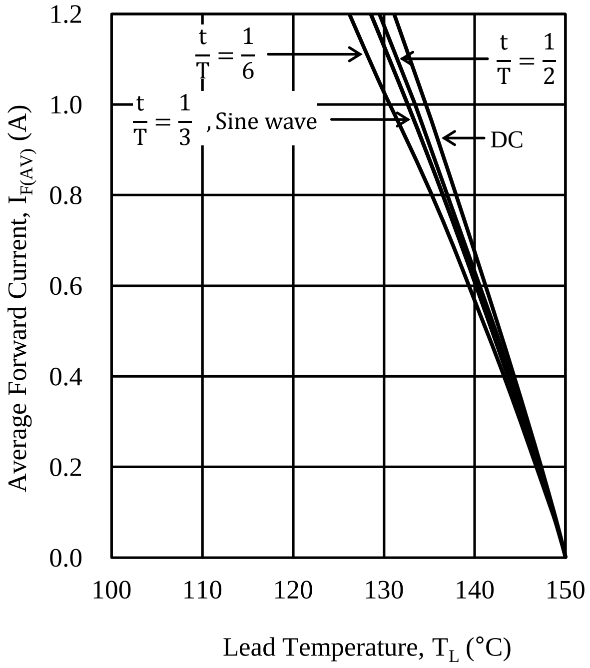


Figure 3-5 T_L — $I_{F(AV)}$ (V_R = 0 V)

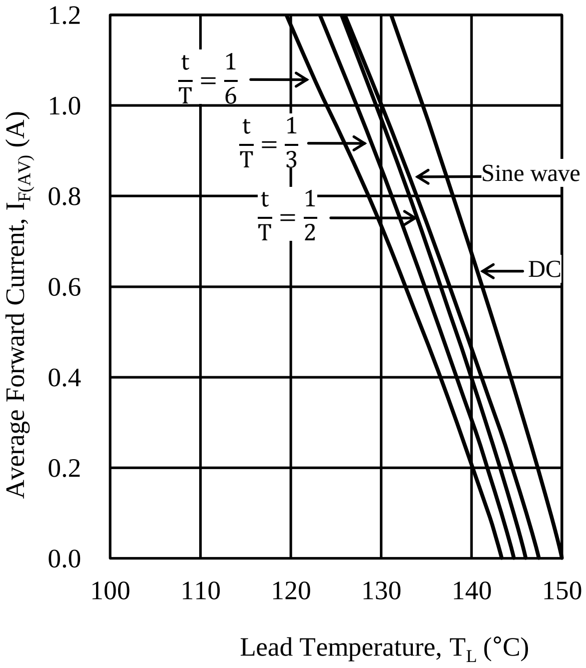


Figure 3-6 T_L — $I_{F(AV)}$ (V_R = 800 V)

3.2 SARS02

3.2.1 Typical Characteristics

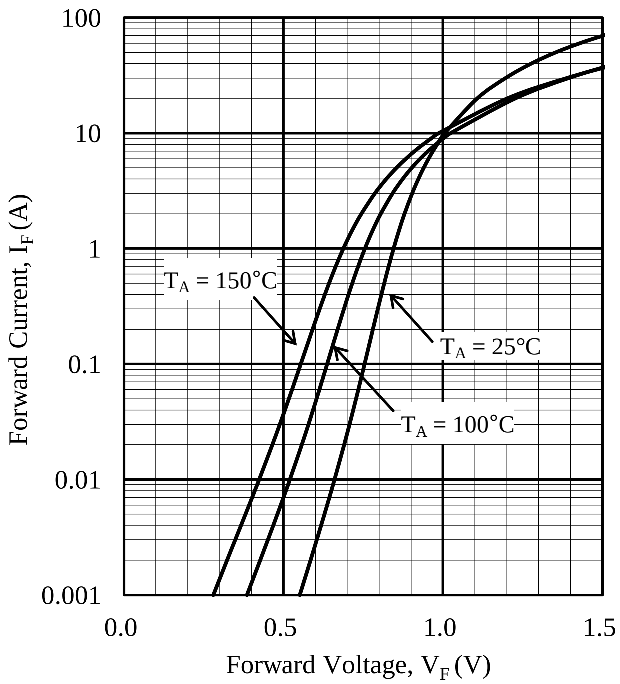


Figure 3-7 V_F — I_F typical characteristics

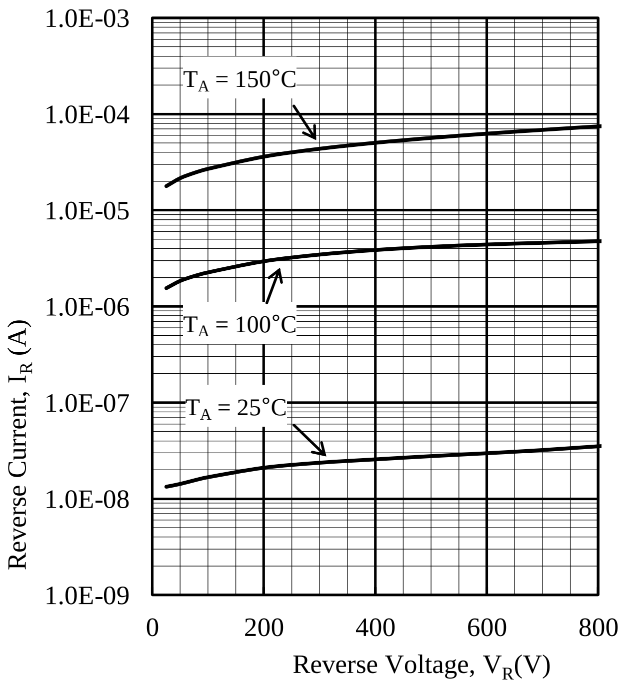


Figure 3-8 V_R — I_R typical characteristics

3.2.2 Power Dissipation Curves (T_j = 150°C)

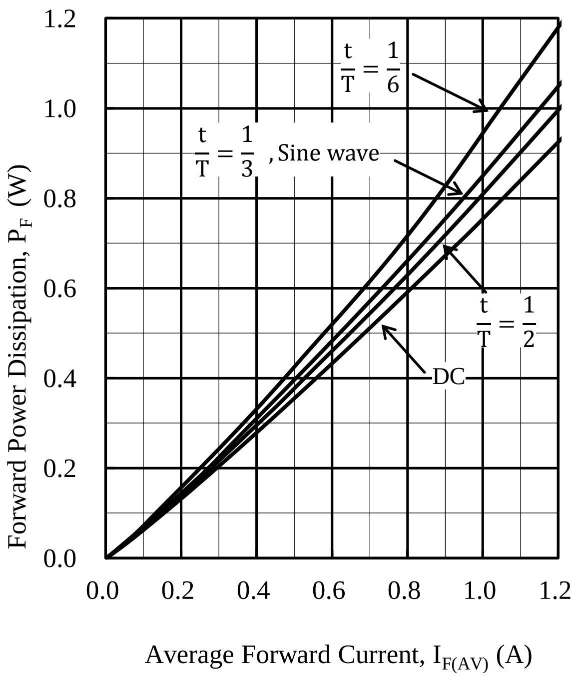


Figure 3-9 $I_{F(AV)}$ — P_F

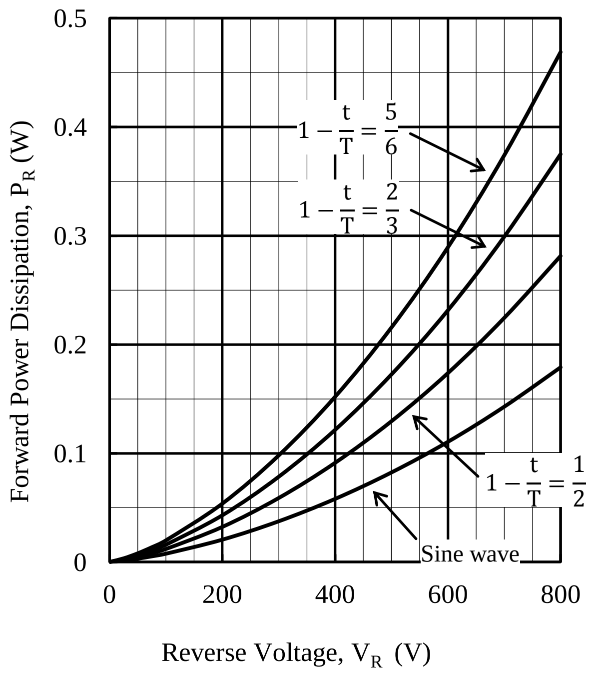


Figure 3-10 V_R — P_R

3.2.3 Derating Curves (T_j = 150°C)

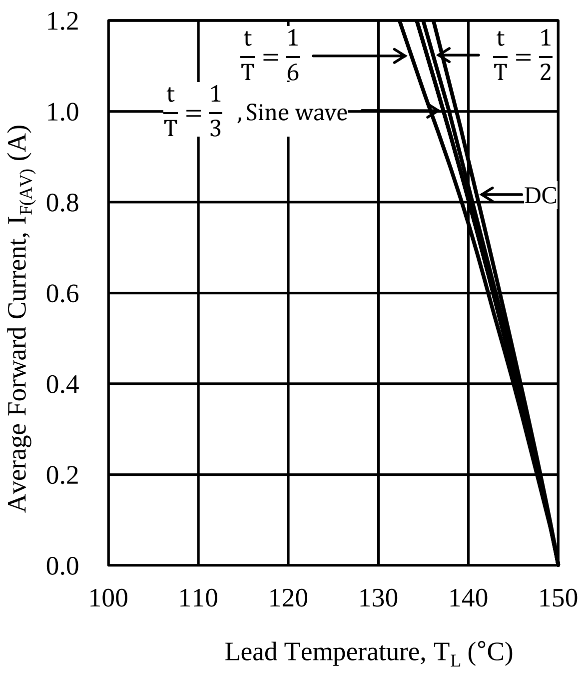


Figure 3-11 T_L — $I_{F(AV)}$ (V_R = 0 V)

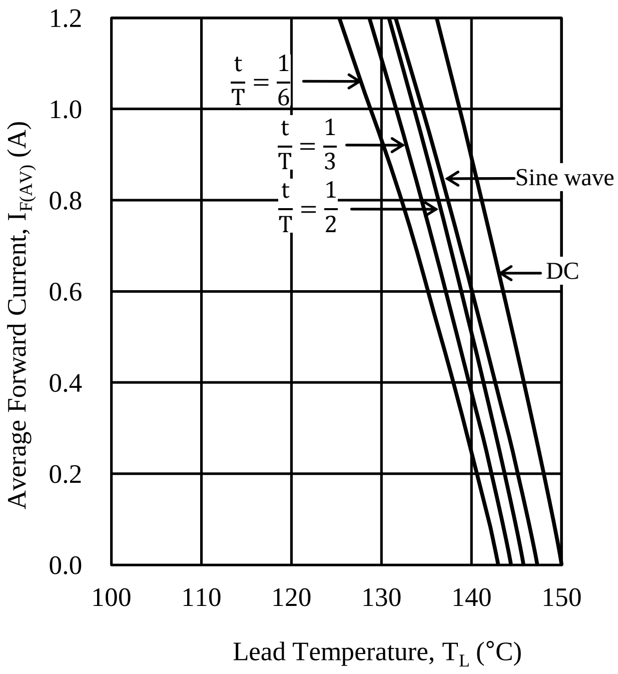


Figure 3-12 T_L — $I_{F(AV)}$ (V_R = 800 V)

3.3 SARS05

3.3.1 Typical Characteristics

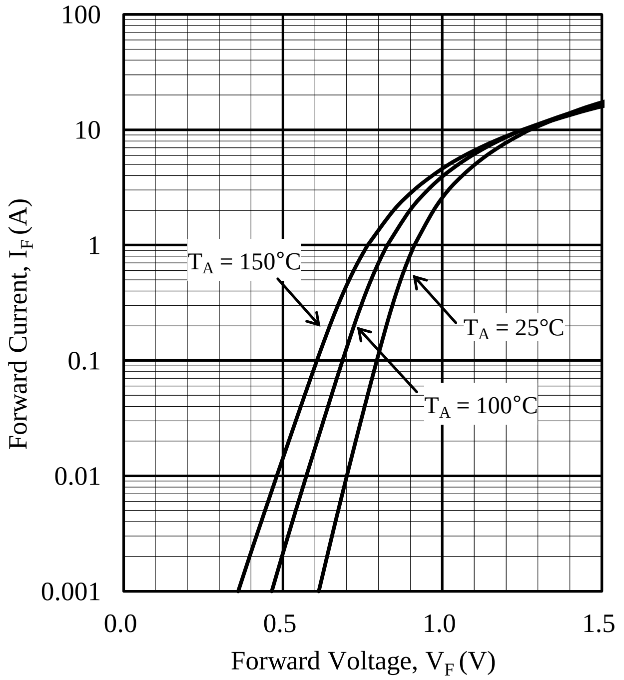


Figure 3-13 V_F − I_F typical characteristics

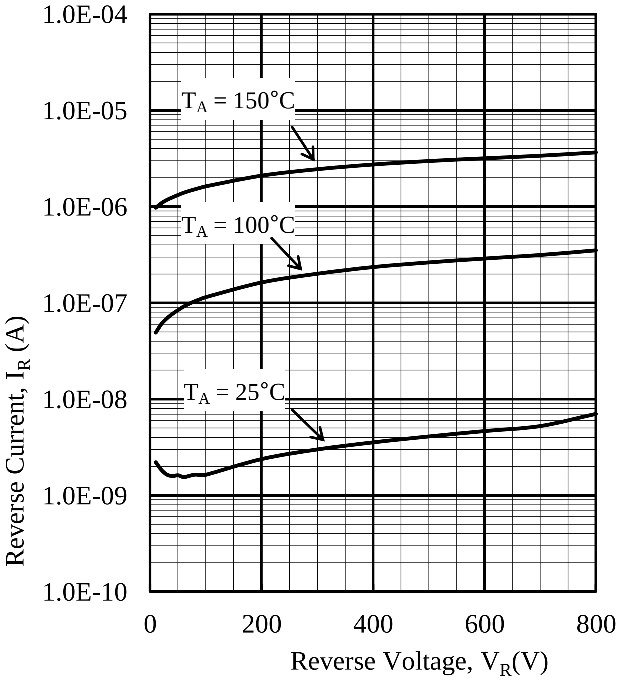


Figure 3-14 V_R − I_R typical characteristics

3.3.2 Power Dissipation Curves (T_j = 150°C)

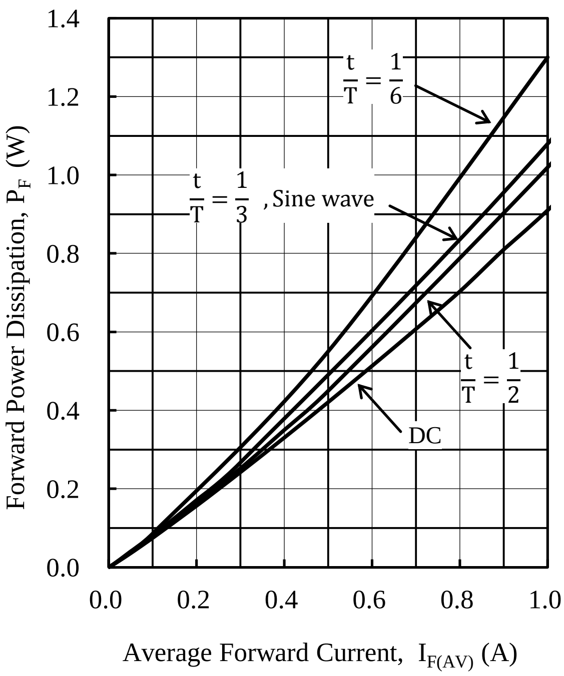


Figure 3-15 $I_{F(AV)}$ − P_F

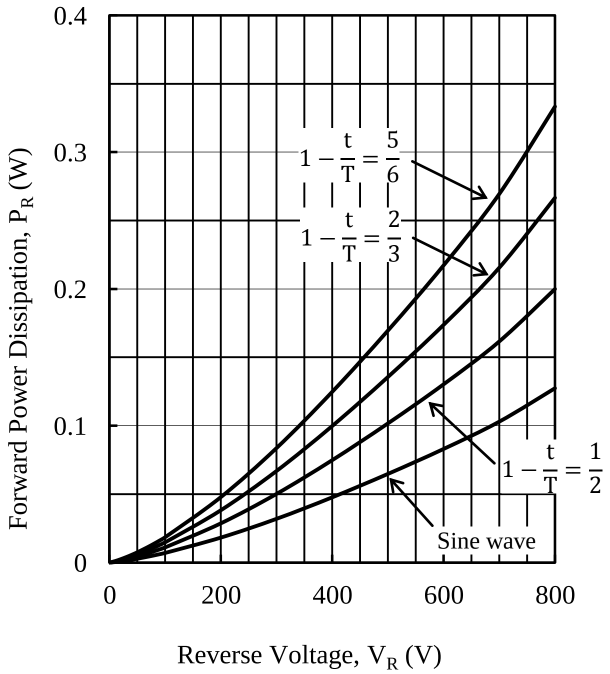


Figure 3-16 V_R − P_R

3.3.3 Derating Curves (T_j = 150°C)

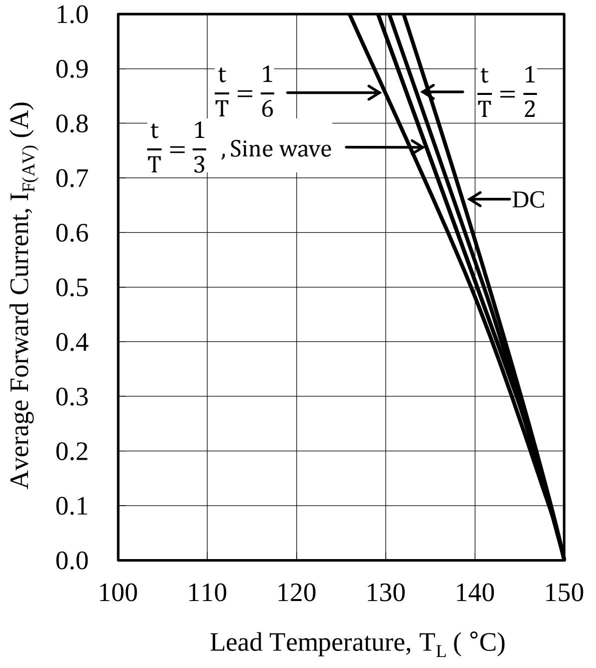


Figure 3-17 T_L − $I_{F(AV)}$ (V_R = 0 V)

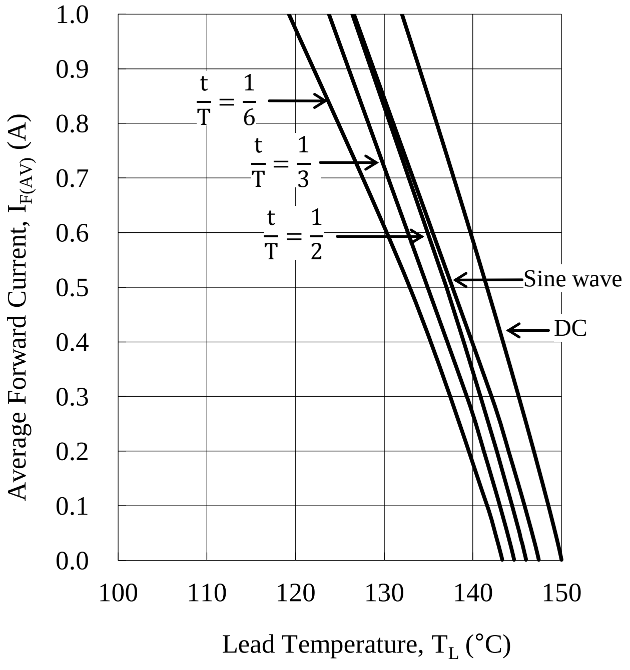


Figure 3-18 T_L − $I_{F(AV)}$ (V_R = 800 V)

3.4 SARS10

3.4.1 Typical Characteristics

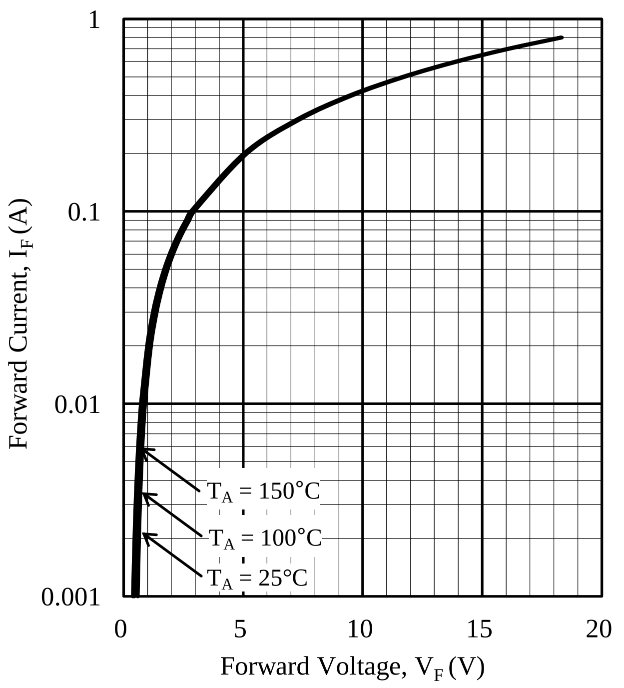


Figure 3-19 V_F − I_F typical characteristics

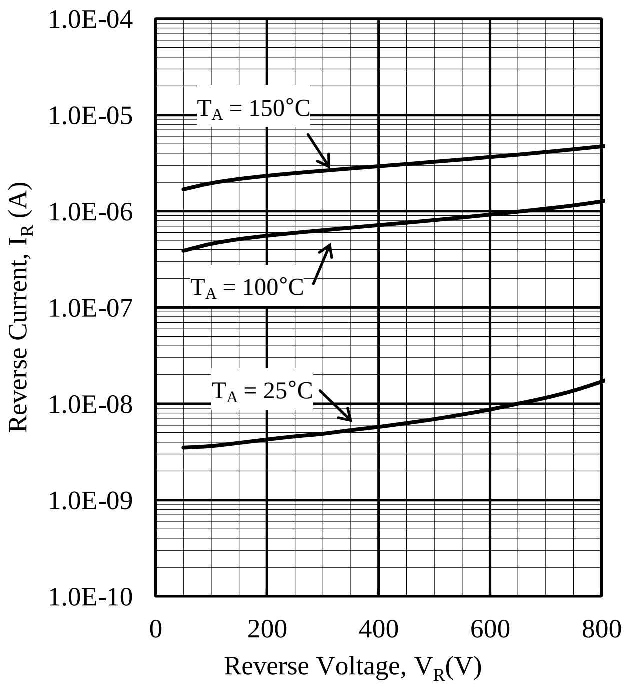


Figure 3-20 V_R − I_R typical characteristics

3.4.2 Power Dissipation Curves (T_j = 125°C)

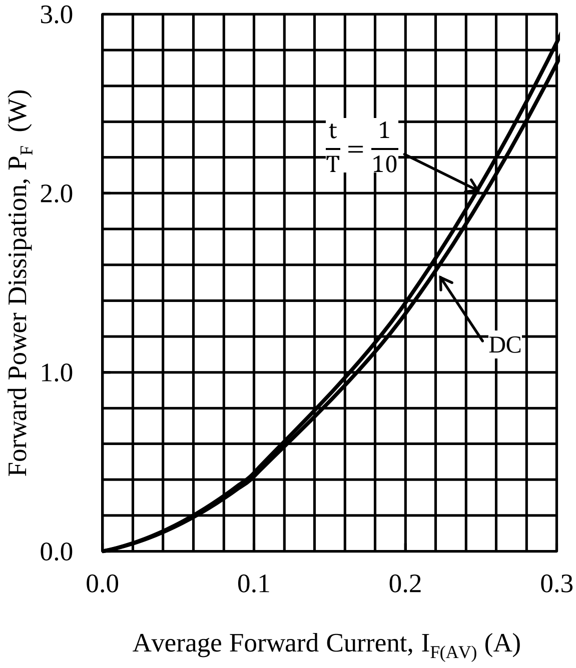


Figure 3-21 $I_{F(AV)}$ — P_F

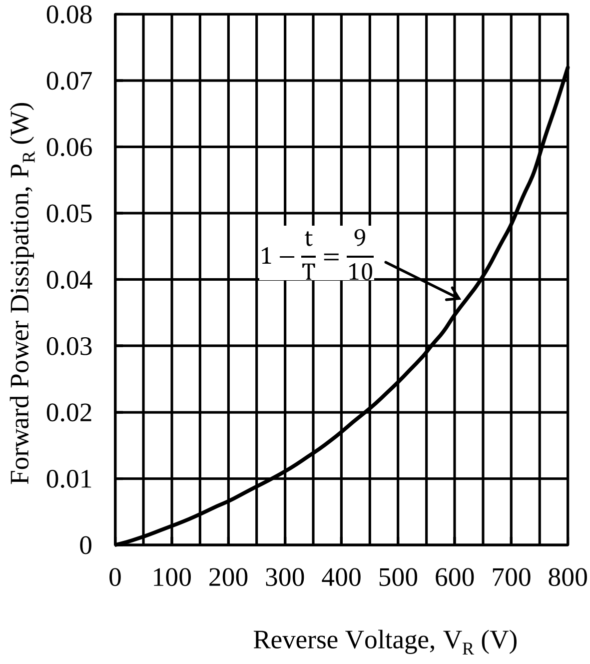


Figure 3-22 V_R — P_R

3.4.3 Derating Curves (T_j = 125°C)

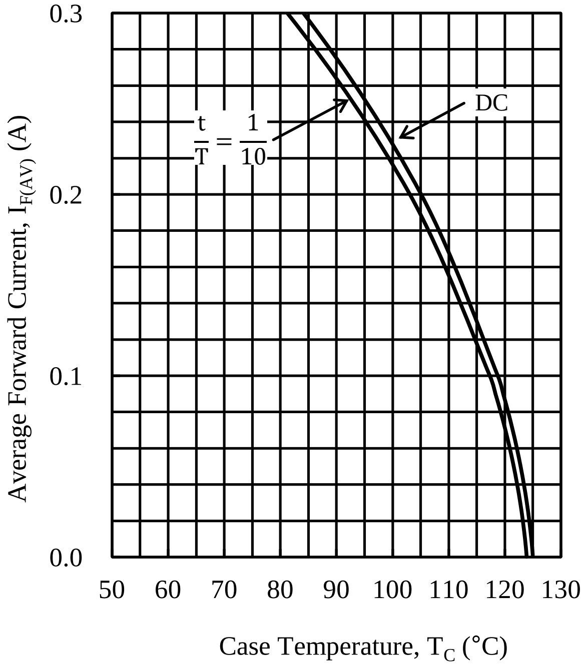
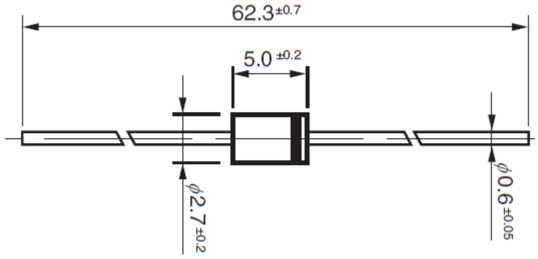


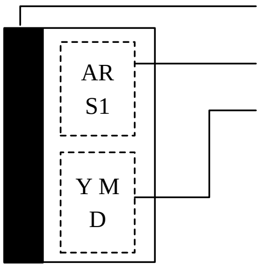
Figure 3-23 T_C — $I_{F(AV)}$ (V_R = 800 V)

4. External Dimensions and Marking Diagram

4.1 SARS01

Axial φ 2.7 / φ 0.60





Polarity marking (Cathode band)

Part Number

Lot Number

Y is the last digit of year (0 to 9)

M is the month (1 to 9, O, N or D)

D is a period of days

• : 1st to 10th

•• : 11th to 20th

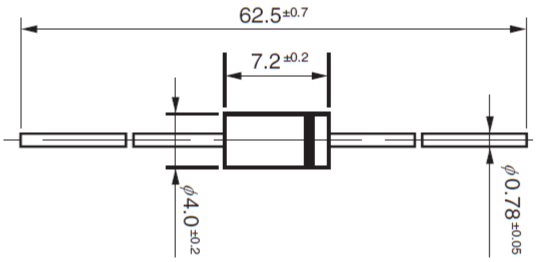
••• : 21st to 31st

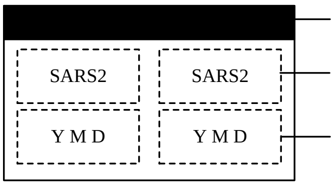
NOTES:

- Dimension is in millimeters.
- Pb-free. Device composition compliant with the RoHS directive.

4.2 SARS02

Axial φ 4 / φ 0.78





Polarity marking (Cathode band)

Part Number

Lot Number

Y is the last digit of year (0 to 9)

M is the month (1 to 9, O, N or D)

D is a period of days

• : 1st to 10th

•• : 11th to 20th

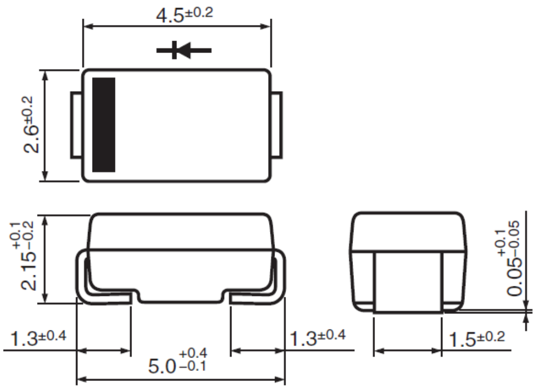
••• : 21st to 31st

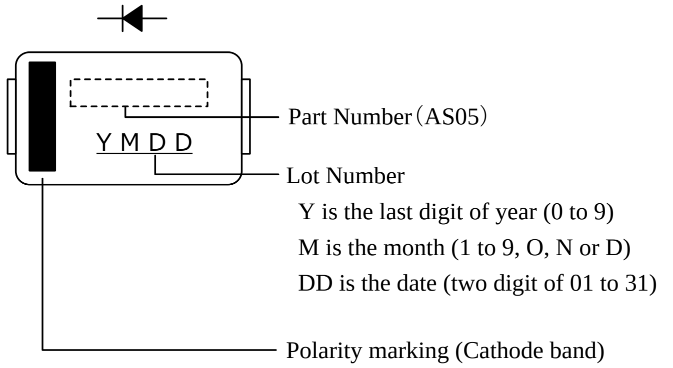
NOTES:

- Dimension is in millimeters.
- Pb-free. Device composition compliant with the RoHS directive.

4.3 SARS05

SMA 4.5×2.6



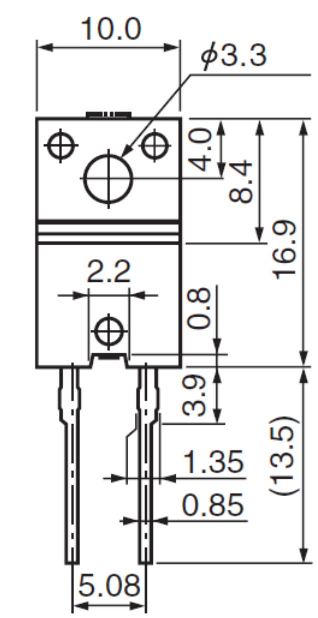


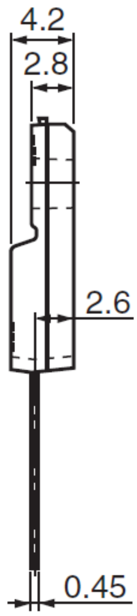
NOTES:

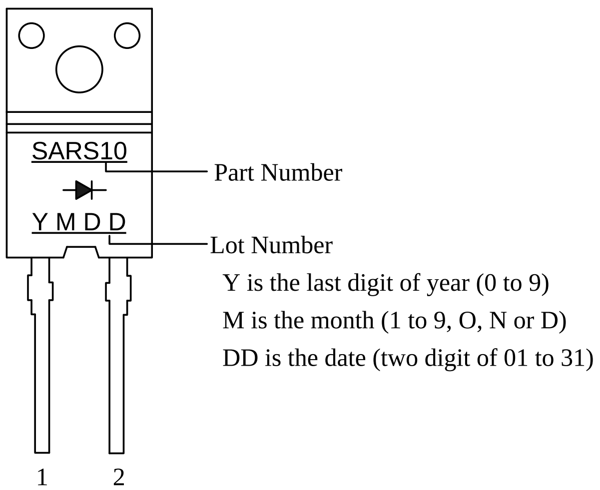
- Dimension is in millimeters.
- Pb-free. Device composition compliant with the RoHS directive.

4.4 SARS10

TO220F-2L







NOTES:

- Dimension is in millimeters.
- Pb-free. Device composition compliant with the RoHS directive.

5. Operating Comparison of Clamp Snubber Circuit

Figure 5-1 shows the general clamp snubber circuit. In the circuit, the surge voltage at tuning off a power MOSFET is charged to C_S through "Surge absorb loop", and is consumed by R_{S1} through "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.

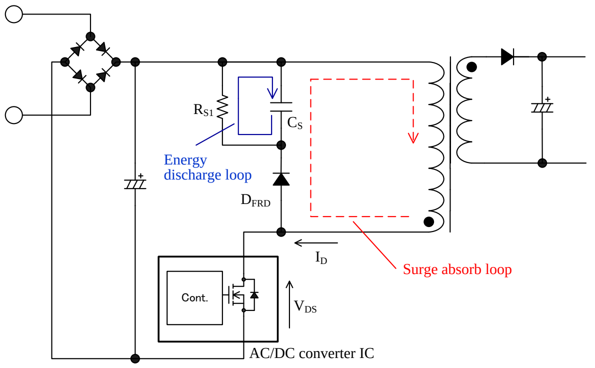


Figure 5-1 General clamp snubber circuit

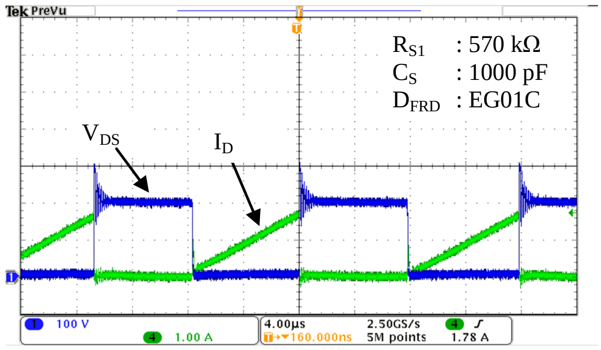


Figure 5-2 Waveforms in general clamp snubber circuit

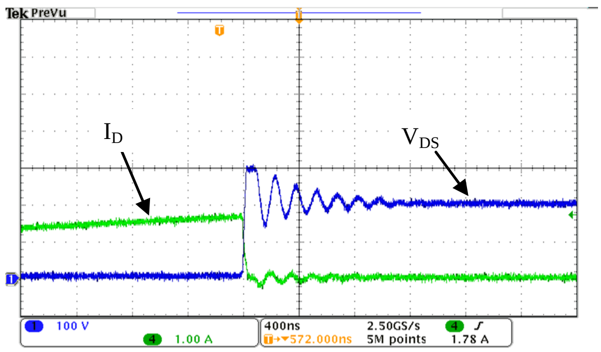


Figure 5-3 Enlarged view of Figure 5-2

Figure 5-4 shows the clamp snubber circuit using SARS. The surge voltage at tuning off a power MOSFET is charged to C_S through "Surge absorb loop". Since the reverse recovery time, trr, of SARS is a relatively long period, the energy charged to C_S is discharged to the reverse direction of "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 SARS reduces the ringing voltage. Thus, the cross regulation of multi-outputs can be improved.

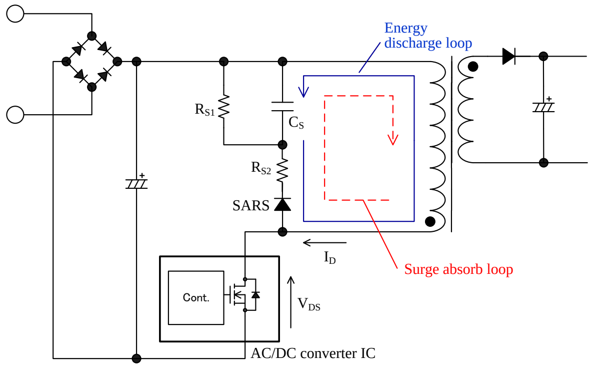


Figure 5-4 Clamp snubber circuit using SARS

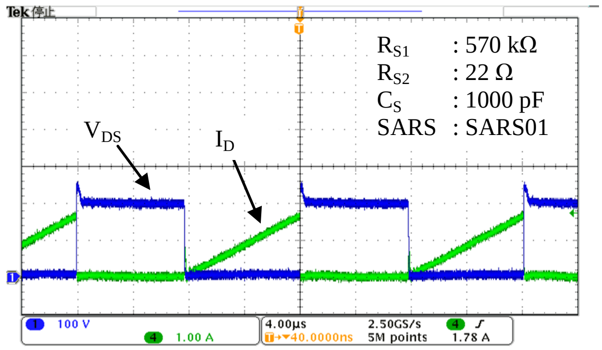


Figure 5-5 Waveforms in clamp snubber circuit using SARS

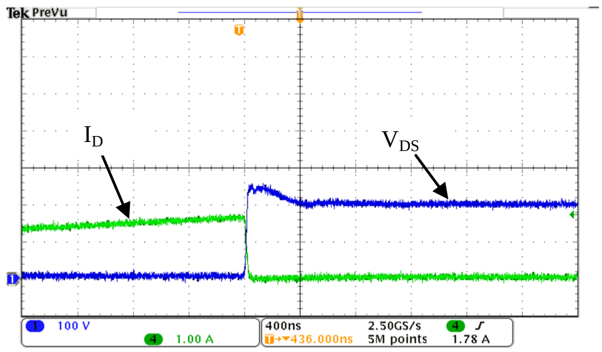


Figure 5-6 Enlarged view of Figure 5-5

6. Power Dissipation and Junction Temperature Calculation

Figure 6-1 shows typical application using SARS. Figure 6-2 shows the operating waveforms of SARS.

The power dissipation of SARS is calculated as follows:

1) The waveforms of SARS Voltage, V_{SARS}, and SARS current, I_{SARS}, is measured in actual application operation. $V_{SARS} \times I_{SARS}$ is calculated by the math function of oscilloscope.
   (Since SARS10 incorporates a resistance, $V_{SARS(10)}$ 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 6-1 by the automatic measurement function of the oscilloscope.
3) The power dissipation of 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}: Power dissipation of SARS
T: Switching cycle of power MOSFET (s)
P_k: Average energy of period t_k (W)

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

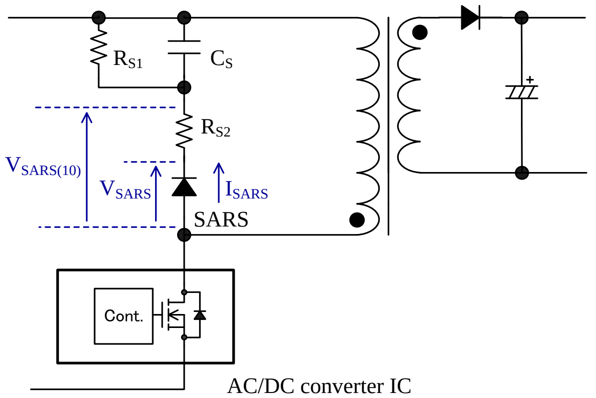


Figure 6-1 Typical application

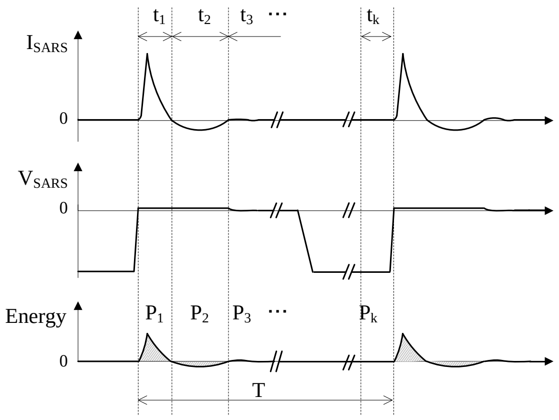


Figure 6-2 SARS current

In addition, by using the temperature of SARS in actual application operation, the estimated junction temperature of 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
$T_{j(SARS)}$: Junction temperature of SARS
T_L: Lead temperature of SARS
$\theta_{j\text{-}L}$: Thermal resistance between junction to lead

- SARS10

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

where
$T_{j(SARS)}$: Junction temperature of SARS
T_C: Case temperature of SARS
$\theta_{j\text{-}C}$: Thermal resistance between junction to case

7. Parameter Setting of Snubber circuit using SARS

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

The reference values of snubber circuit using 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 SARS, and is 100 kΩ to 1 MΩ.
  Since R_{S1} is applied a high voltage and is a high resistance, the following should be considered according to the requirement of the application:
  Select a resistor designed against electromigration, or
  Use a combination of resistors in series to reduce applied voltage to each of them.
  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 SARS in series (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.

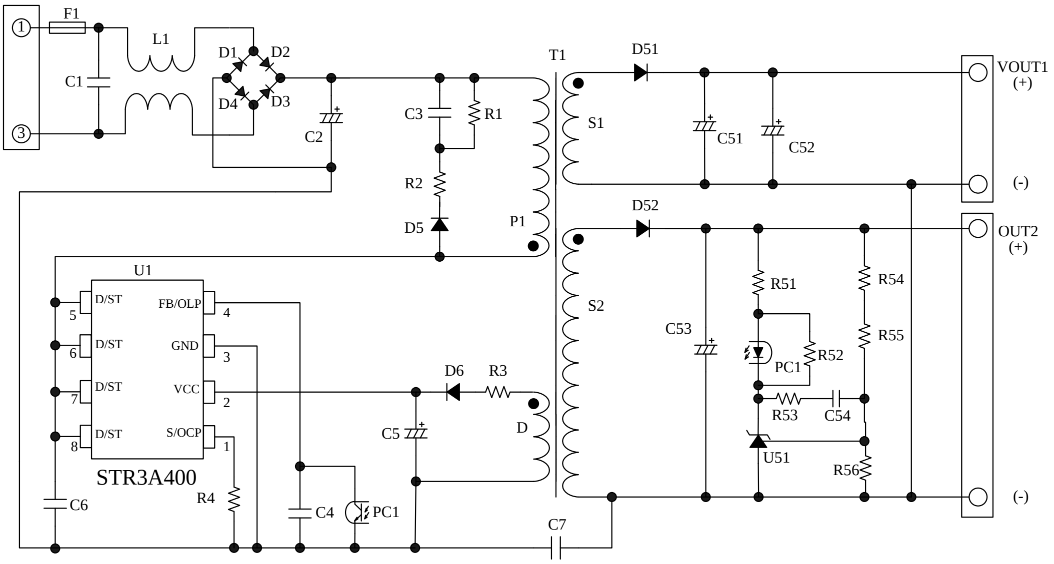
8. Reference Design of Power Supply

As an example, the following show the power supply specification, the circuit schematic, the bill of materials, and the transformer specification.

- Power supply specification

IC	STR3A453D
Input voltage	AC85V to AC265V
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



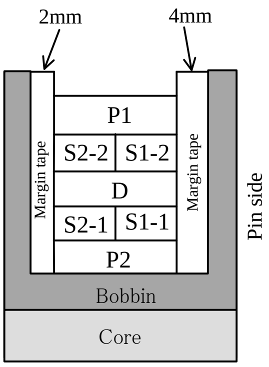
- Bill of materials

Symbol	Ratings[1]	Recommended Sanken Parts	Symbol	Ratings[1]	Recommended Sanken Parts
C1 [2]	Film, 0.1 µF, 275 V		D52	Schottky, 100V, 10A	FMEN-210A
C2 [2]	Electrolytic, 150 µF, 400 V		F1	Fuse, AC 250 V, 3 A	
C3	Ceramic, 1000 pF, 1 kV		L1 [2]	CM inductor, 3.3 mH	
C4	Ceramic, 0.01 µF		PC1	Photo-coupler, 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 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			

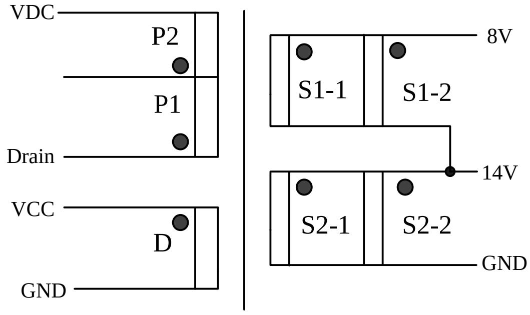
[1] Unless otherwise specified, the voltage rating of capacitor is 50 V or less and the power rating of resistor is 1/8 W or less.
[2] It is necessary to be adjusted based on actual operation in the application.
[3] Resistors applied high DC voltage and of high resistance are recommended to select resistors designed against electromigration or use combinations of resistors in series to reduce applied voltage to each of them, according to the requirement of the application.

- Transformer specification
  Primary inductance, L_P : 518 μH
  Core size : EER-28
  Al-value : 245 nH/N^2 (Center gap of about 0.56 mm)
  Winding specification

Winding	Symbol	Number of turns (turns)	Wire diameter (mm)	Construction
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



●: Start at this pin

OPERATING PRECAUTIONS

In the case that you use Sanken products or design your products by using Sanken products, the reliability largely depends on the degree of derating to be made to the rated values. Derating may be interpreted as a case that an operation range is set by derating the load from each rated value or surge voltage or noise is considered for derating in order to assure or improve the reliability. In general, derating factors include electric stresses such as electric voltage, electric current, electric power etc., environmental stresses such as ambient temperature, humidity etc. and thermal stress caused due to self-heating of semiconductor products. For these stresses, instantaneous values, maximum values and minimum values must be taken into consideration. In addition, it should be noted that since power devices or IC's including power devices have large self-heating value, the degree of derating of junction temperature affects the reliability significantly.

Because reliability can be affected adversely by improper storage environments and handling methods, please observe the following cautions.

Cautions for Storage

- Ensure that storage conditions comply with the standard temperature (5 to 35°C) and the standard relative humidity (around 40 to 75%); avoid storage locations that experience extreme changes in temperature or humidity.
- Avoid locations where dust or harmful gases are present and avoid direct sunlight.
- Reinspect for rust on leads and solderability of the products that have been stored for a long time.

Cautions for Testing and Handling

When tests are carried out during inspection testing and other standard test periods, protect the products from power surges from the testing device, shorts between the product pins, and wrong connections. Ensure all test parameters are within the ratings specified by Sanken for the products.

Remarks About Using Thermal Silicone Grease

- When thermal silicone grease is used, it shall be applied evenly and thinly. If more silicone grease than required is applied, it may produce excess stress.
- The thermal silicone grease that has been stored for a long period of time may cause cracks of the greases, and it cause low radiation performance. In addition, the old grease may cause cracks in the resin mold when screwing the products to a heatsink.
- Fully consider preventing foreign materials from entering into the thermal silicone grease. When foreign material is immixed, radiation performance may be degraded or an insulation failure may occur due to a damaged insulating plate.
- The thermal silicone greases that are recommended for the resin molded semiconductor should be used.
  Our recommended thermal silicone grease is the following, and equivalent of these.

Type	Suppliers
G746	Shin-Etsu Chemical Co., Ltd.
YG6260	Momentive Performance Materials Japan LLC
SC102	Dow Corning Toray Co., Ltd.

Cautions for Mounting to a Heatsink

- When the flatness around the screw hole is insufficient, such as when mounting the products to a heatsink that has an extruded (burred) screw hole, the products can be damaged, even with a lower than recommended screw torque. For mounting the products, the mounting surface flatness should be 0.05mm or less.
- Please select suitable screws for the product shape. Do not use a flat-head machine screw because of the stress to the products. Self-tapping screws are not recommended. When using self-tapping screws, the screw may enter the hole diagonally, not vertically, depending on the conditions of hole before threading or the work situation. That may stress the products and may cause failures.
- Recommended screw torque:

Package	Recommended Screw Torque
TO-220, TO-220F	0.490 to 0.686 N・m (5 to 7 kgf・cm)
TO-3P, TO-3PF, TO-247	0.686 to 0.882 N・m (7 to 9 kgf・cm)
SLA	0.588 to 0.784 N・m (6 to 8 kgf・cm)

- For tightening screws, if a tightening tool (such as a driver) hits the products, the package may crack, and internal stress fractures may occur, which shorten the lifetime of the electrical elements and can cause catastrophic failure. Tightening with an air driver makes a substantial impact. In addition, a screw torque higher than the set torque can be applied and the package may be damaged. Therefore, an electric driver is recommended.
  When the package is tightened at two or more places, first pre-tighten with a lower torque at all places, then tighten with the specified torque. When using a power driver, torque control is mandatory.
- Please pay special attention about the slack of the press mold. In case that the hole diameter of the heatsink is less than 4 mm, it may cause the resin crack at tightening.

Soldering

- When soldering the products, please be sure to minimize the working time, within the following limits:
  260 ± 5 °C 10 ± 1 s (Flow, 2 times)
  380 ± 10 °C 3.5 ± 0.5 s (Soldering iron, 1 time)
- Soldering should be at a distance of at least 1.5 mm from the body of the products.

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