# 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

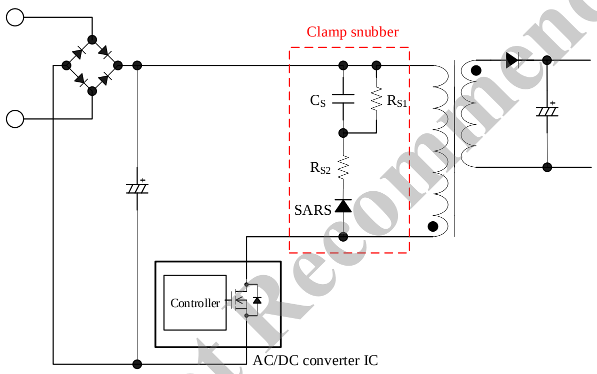
- Improves Cross Regulation
- Reduces Noise
- Improves Efficiency

## Applications

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

- White Goods
- Adaptor
- Industrial Equipment

## Typical Application

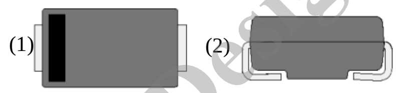


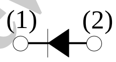

## Package

SARS01 (Axial φ 2.7 / φ 0.60)


SARS02 (Axial φ 4 / φ 0.78)

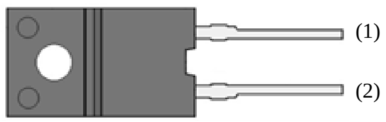

SARS05 (SJP 4.5 mm × 2.6 mm)

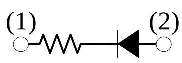



(1) Cathode
(2) Anode

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

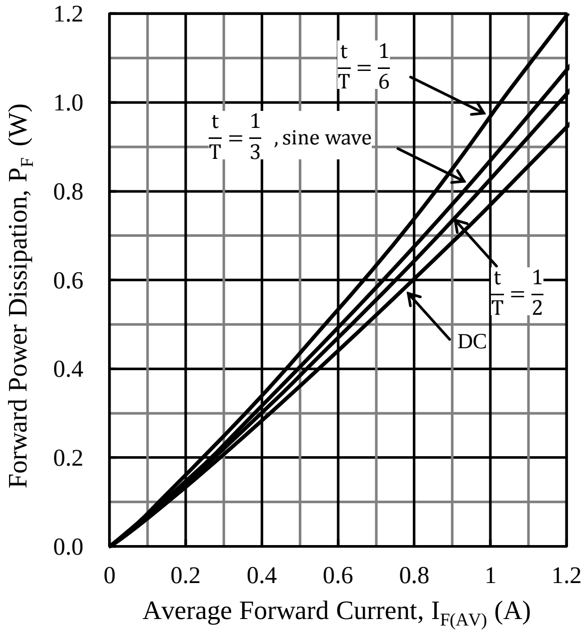



Figure 1. $I_{F(AV)}$ vs. $P_F$ Power Dissipation Curves ($T_J$ = 150 °C)

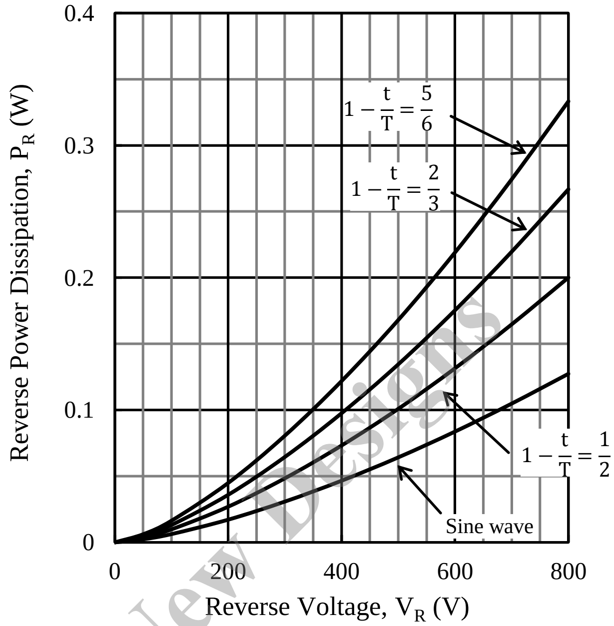



Figure 2. $V_R$ vs. $P_R$ Power Dissipation Curves ($T_J$ = 150 °C)

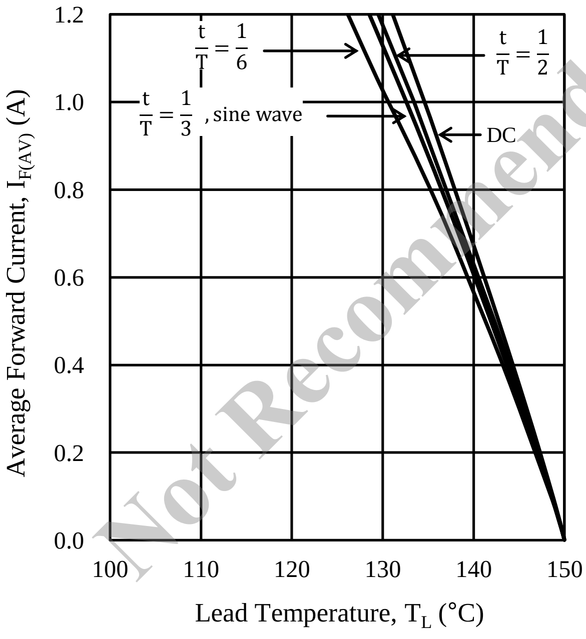



Figure 3. $T_L$ vs. $I_{F(AV)}$ Derating Curves ($V_R$ = 0 V, $T_J$ = 150 °C)

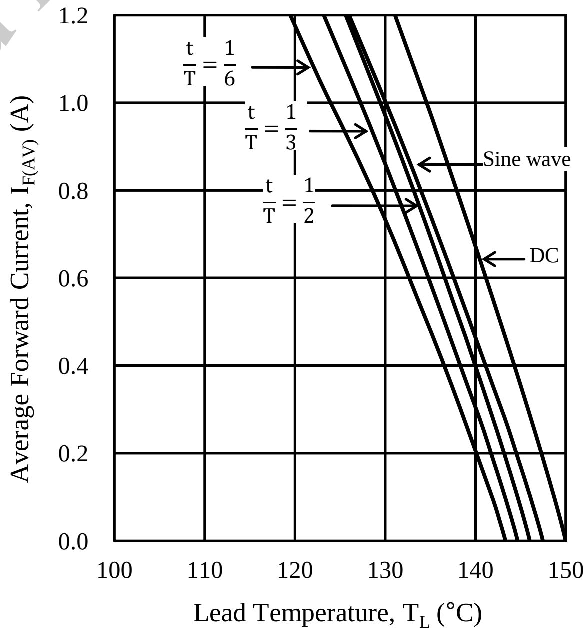



Figure 4. $T_L$ vs. $I_{F(AV)}$ Derating Curves ($V_R$ = 800 V, $T_J$ = 150 °C)

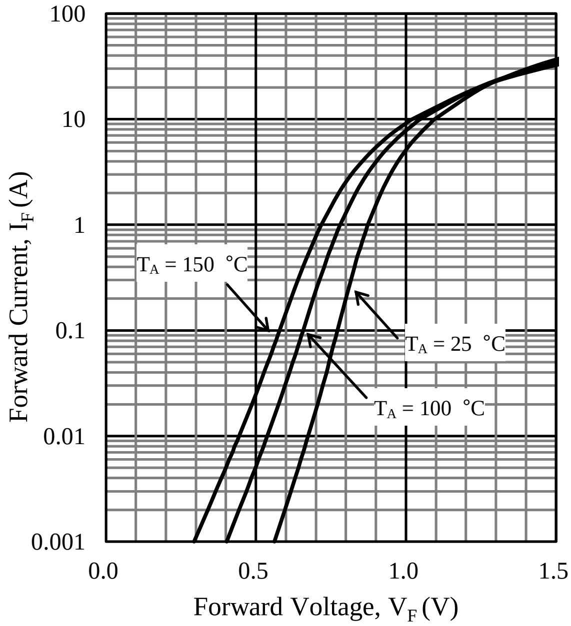



Figure 5. $V_F$ vs. $I_F$ Typical Characteristics

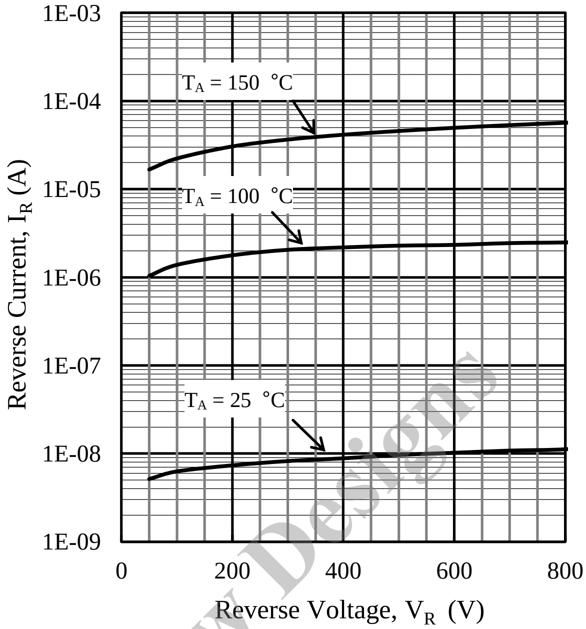



Figure 6. $V_R$ vs. $I_R$ Typical Characteristics



## SARS02 Rating and Characteristic Curves

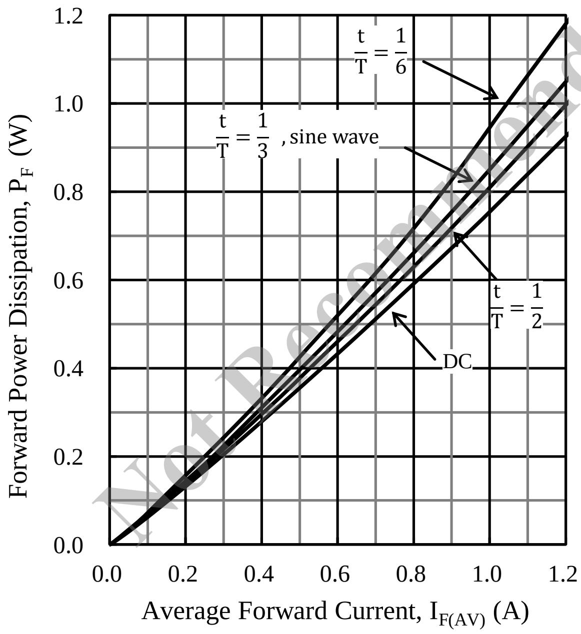



Figure 7. $I_{F(AV)}$ vs. $P_F$ Power Dissipation Curves ($T_J$ = 150 °C)

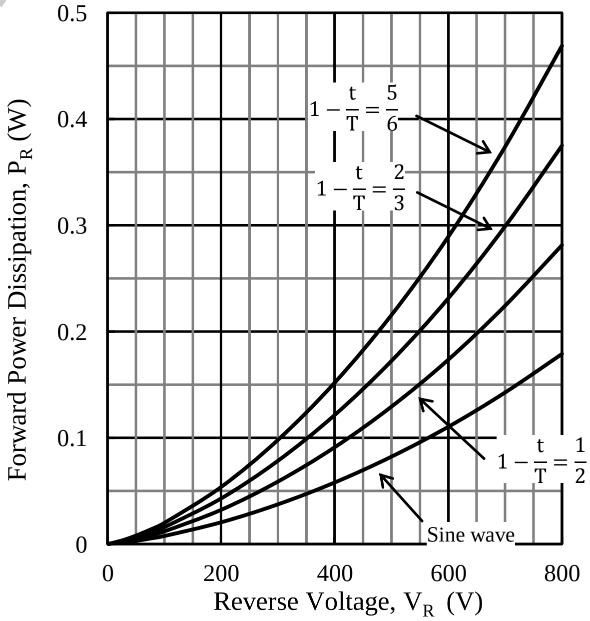



Figure 8. $V_R$ vs. $P_R$ Power Dissipation Curves ($T_J$ = 150 °C)

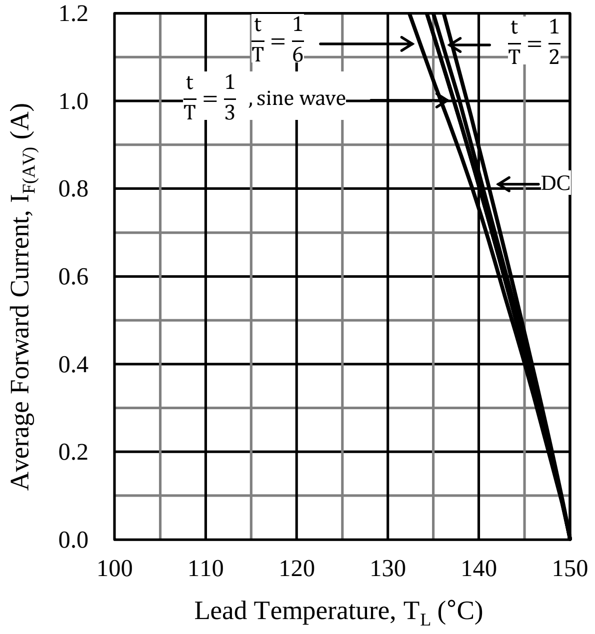



Figure 9. $T_L$ vs. $I_{F(AV)}$ Derating Curves
($V_R$ = 0 V, $T_J$ = 150 °C)

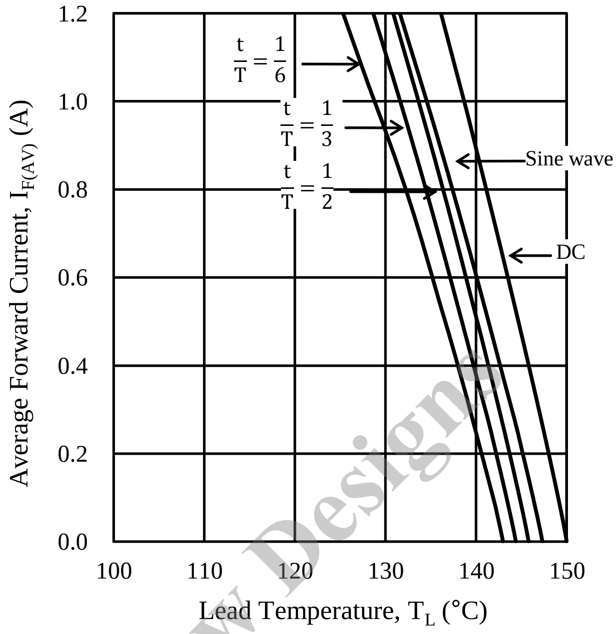



Figure 10. $T_L$ vs. $I_{F(AV)}$ Derating Curves
($V_R$ = 800 V, $T_J$ = 150 °C)

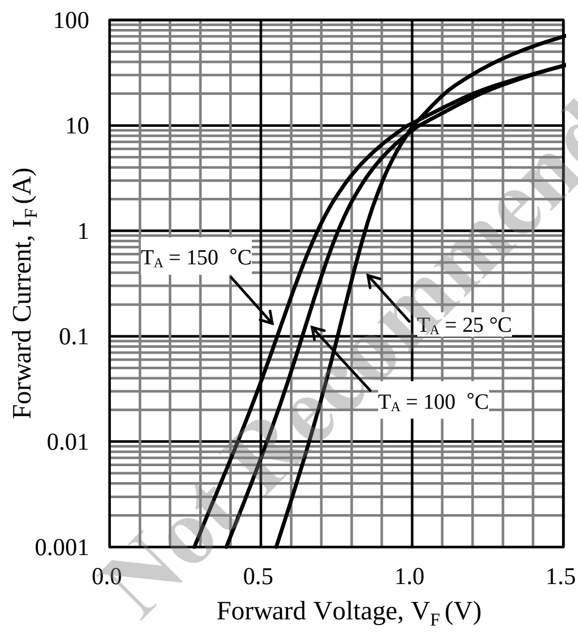



Figure 11. $V_F$ vs. $I_F$ Typical Characteristics

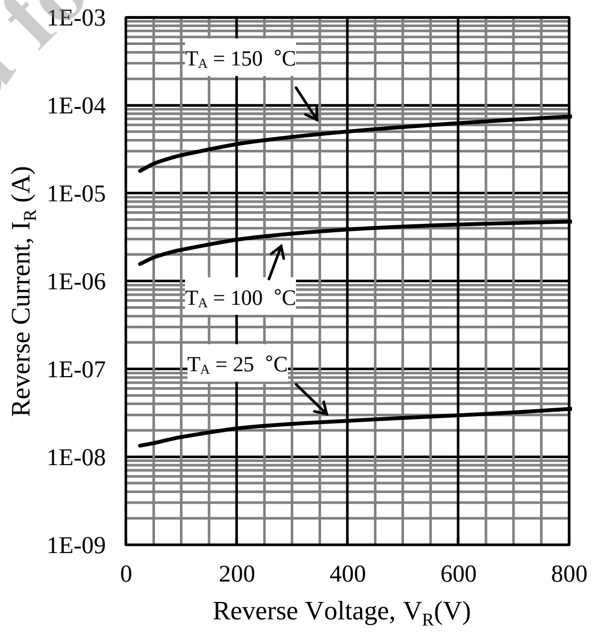



Figure 12. $V_R$ vs. $I_R$ Typical Characteristics

## SARS05 Rating and Characteristic Curves

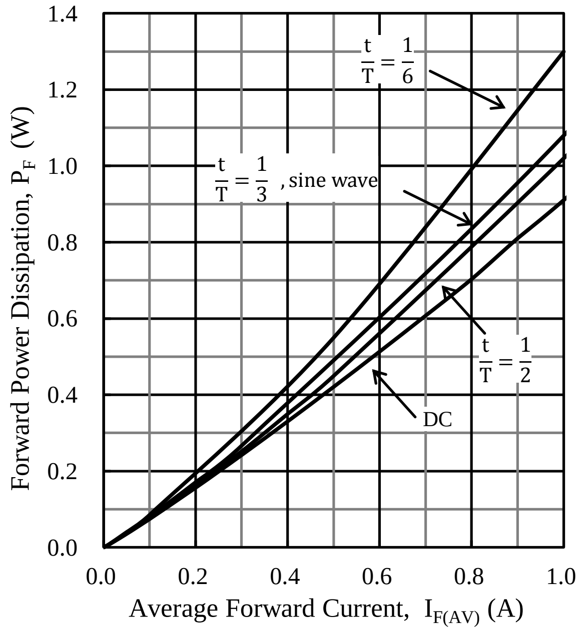



Figure 13. $I_{F(AV)}$ vs. $P_F$ Power Dissipation Curves ($T_J$ = 150 °C)

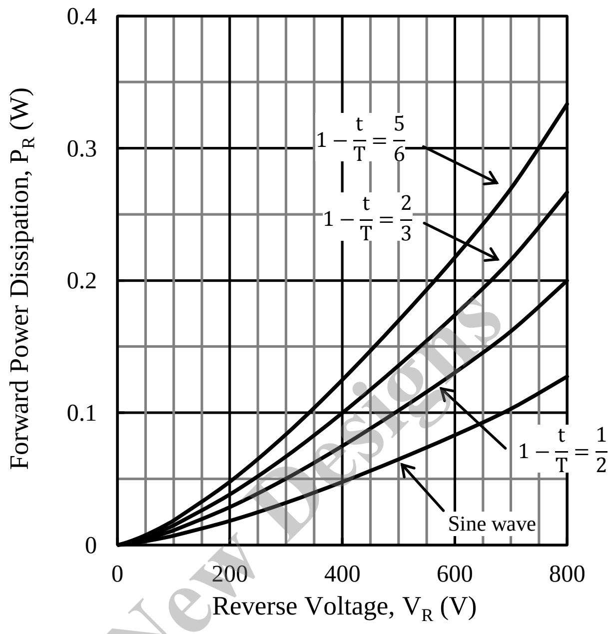



Figure 14. $V_R$ vs. $P_R$ Power Dissipation Curves ($T_J$ = 150 °C)

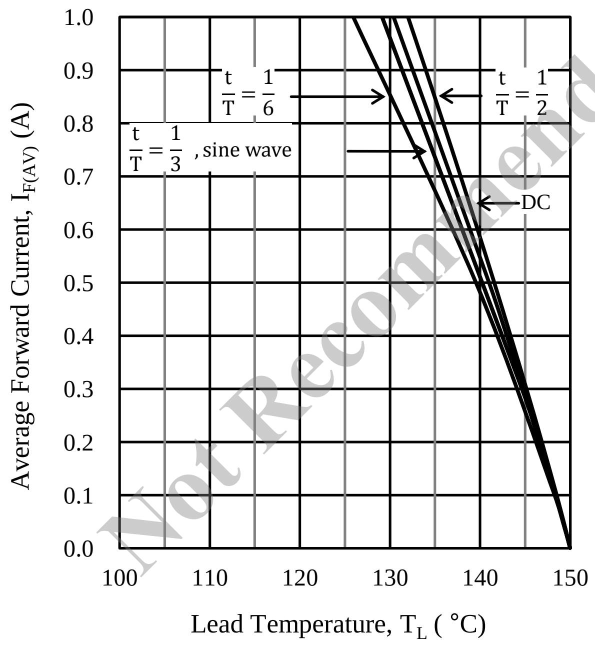



Figure 15. $T_L$ vs. $I_{F(AV)}$ Derating Curves ($V_R$ = 0 V, $T_J$ = 150 °C)

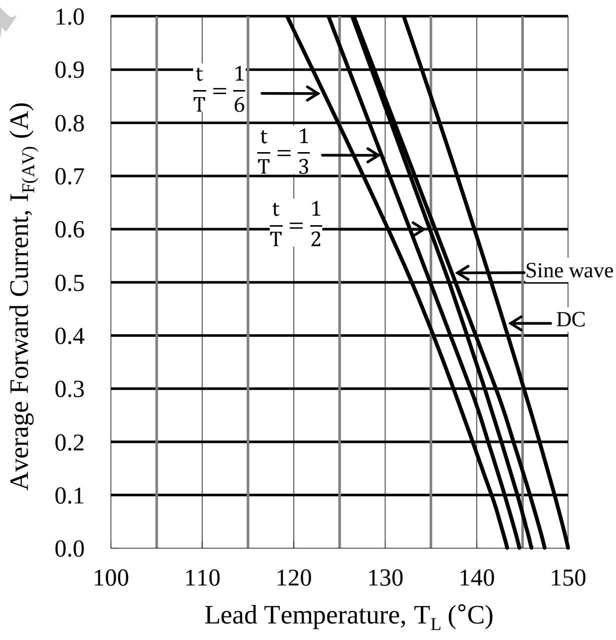



Figure 16. $T_L$ vs. $I_{F(AV)}$ Derating Curves ($V_R$ = 800 V, $T_J$ = 150 °C)

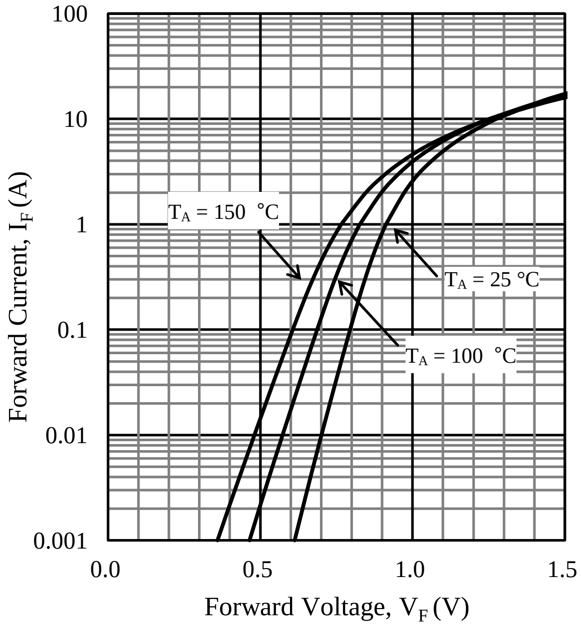



Figure 17. $V_F$ vs. $I_F$ Typical Characteristics

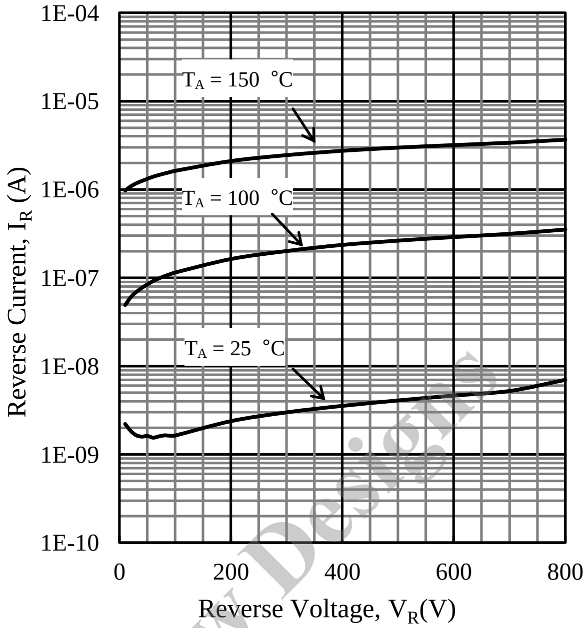



Figure 18. $V_R$ vs. $I_R$ Typical Characteristics



## SARS10 Rating and Characteristic Curves

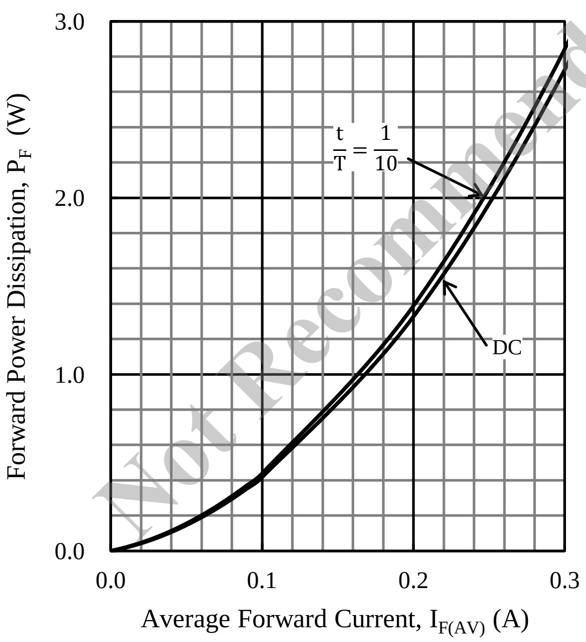



Figure 19. $I_{F(AV)}$ vs. $P_F$ Power Dissipation Curves
($T_J$ = 125 °C)

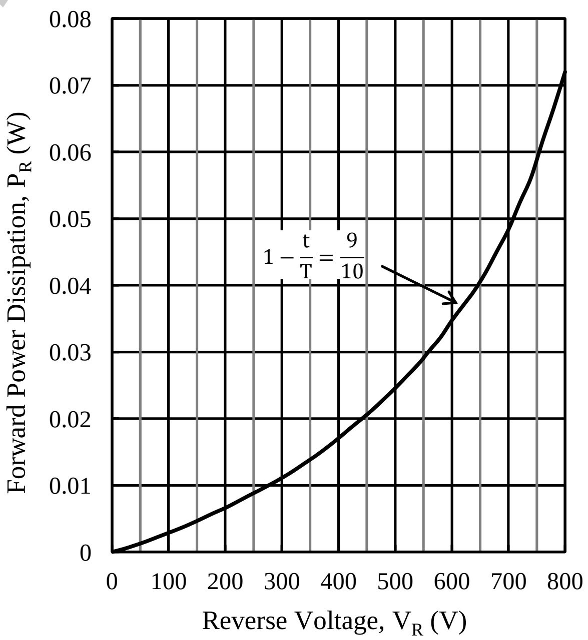



Figure 20. $V_R$ vs. $P_R$ Power Dissipation Curve
($T_J$ = 125 °C)

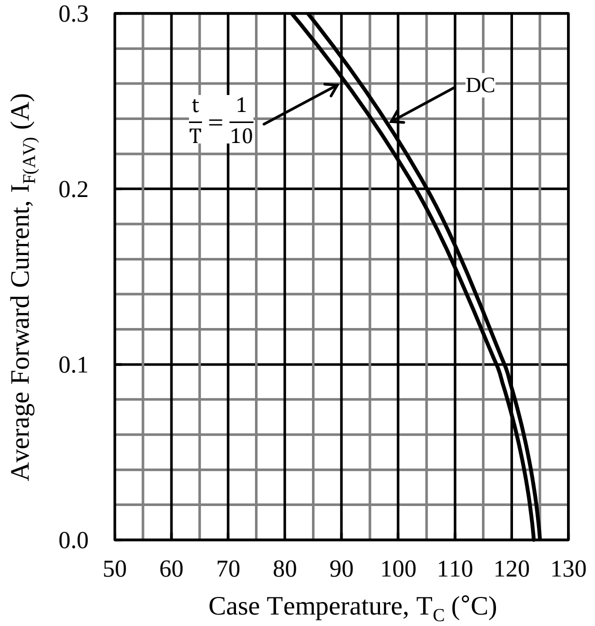



Figure 21. $T_C$ vs. $I_{F(AV)}$ Derating Curves
($V_R$ = 800 V, $T_J$ = 125 °C)

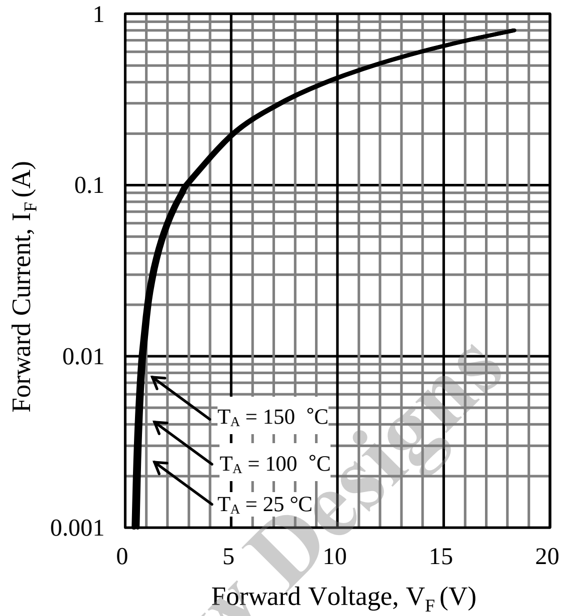



Figure 22. $V_F$ vs. $I_F$ Typical Characteristics

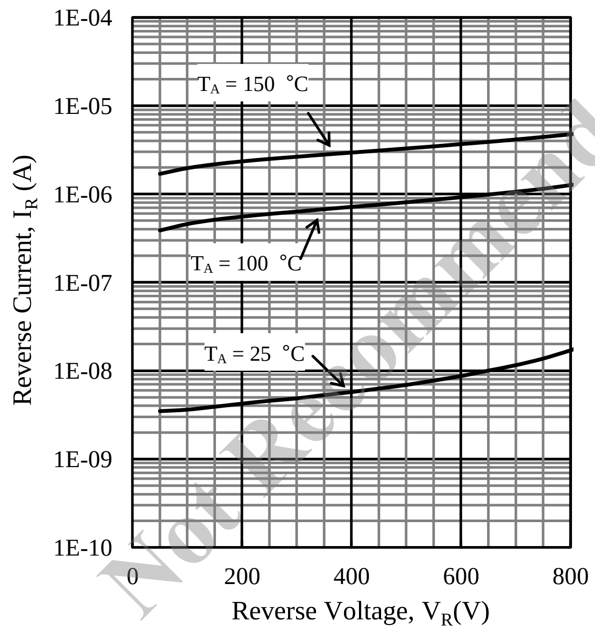
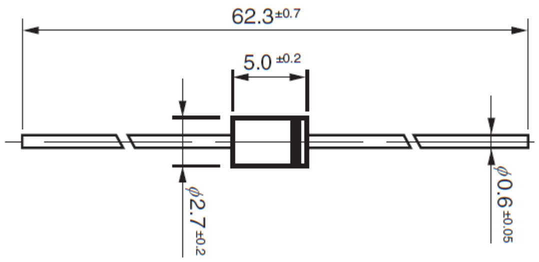
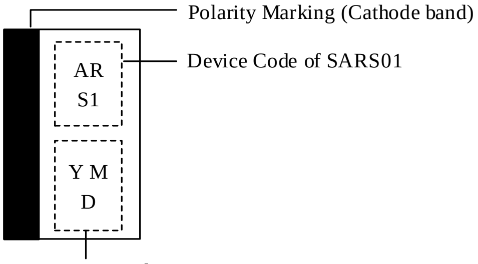



Figure 23. $V_R$ vs. $I_R$ Typical Characteristics

## Physical Dimensions and Marking Diagrams

- **SARS01**
  Axial (φ 2.7 / φ 0.6)

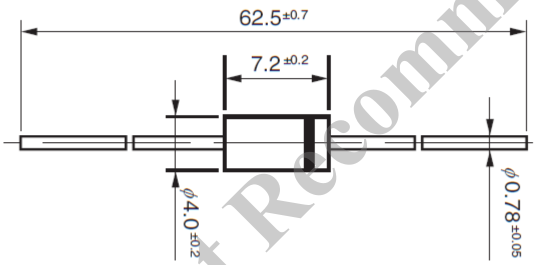


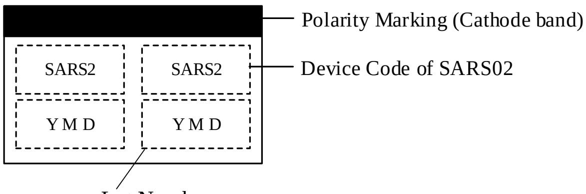




Lot Number:
Y is the last digit of the year of manufacture (0 to 9)
M is the month of the year (1 to 9, O, N, or D)
D is a period of days:
"•" is the first 10 days of the month (1st to 10th)
"••" is the second 10 days of the month (11th to 20th)
"•••" is the last 10–11 days of the month (21st to 31st)

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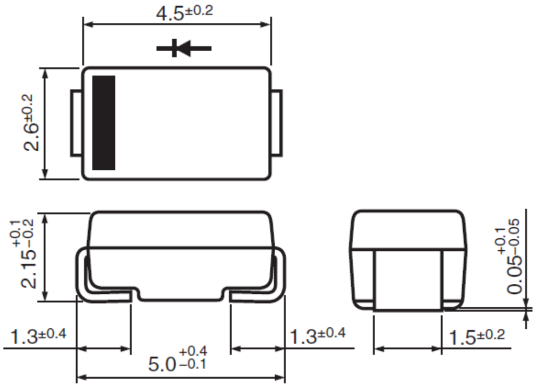
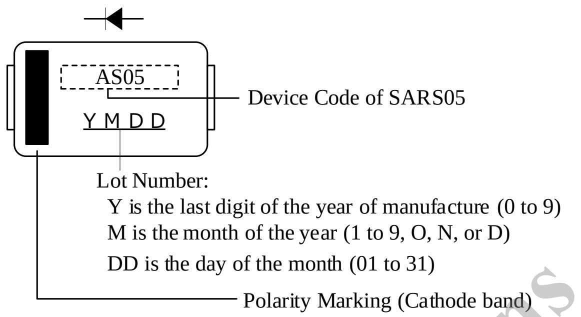
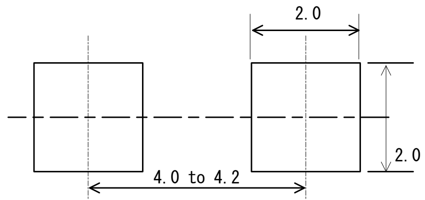
**NOTES:**
- Dimensions in millimeters
- Bare lead: Pb-free (RoHS compliant)
- When soldering the products, be sure to minimize the working time within the following limits:
  Flow: 260 ± 5 °C / 10 ± 1 s, 2 times
  Soldering iron: 380 ± 10 °C / 3.5 ± 0.5 s, 1 time (Soldering should be at a distance of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

- **SARS05**
  SJP 4.5 mm × 2.6 mm



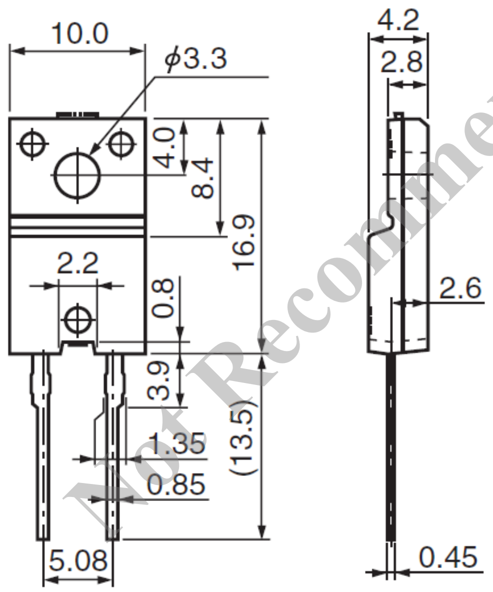



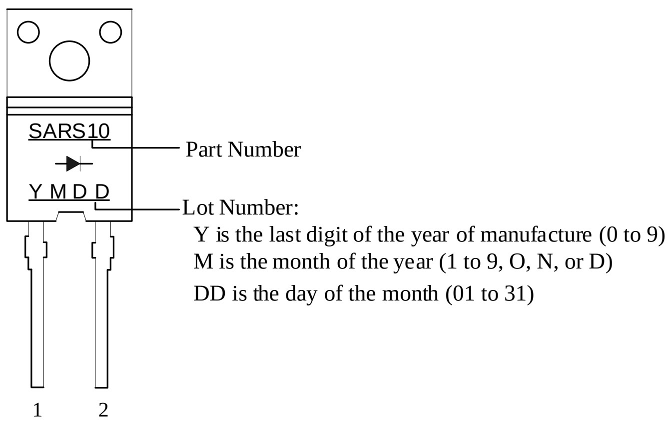

SJP Land Pattern Example




**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.

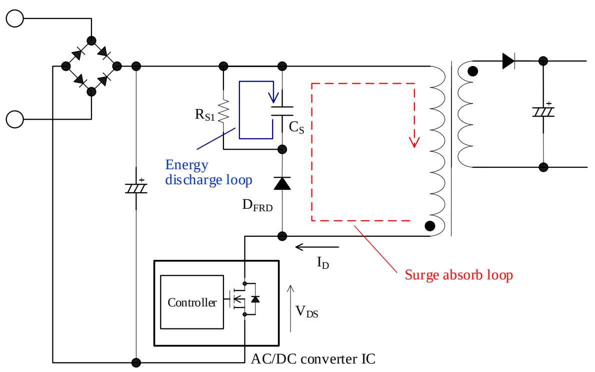



Figure 24. General Clamp Snubber Circuit

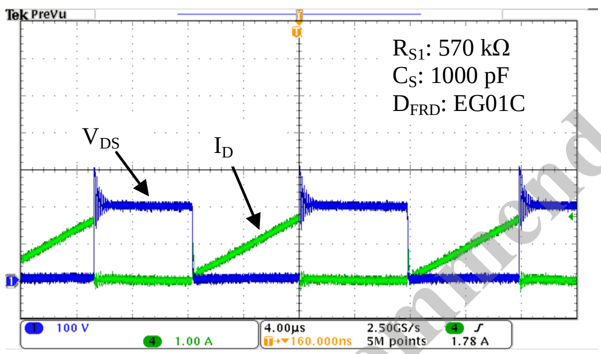



Figure 25. Waveforms of General Clamp Snubber Circuit

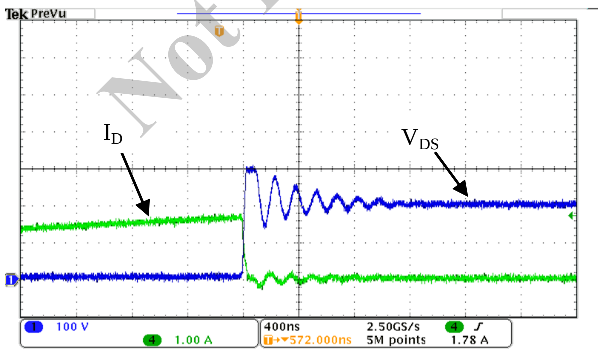



Figure 26. Enlarged View of Figure 25

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.

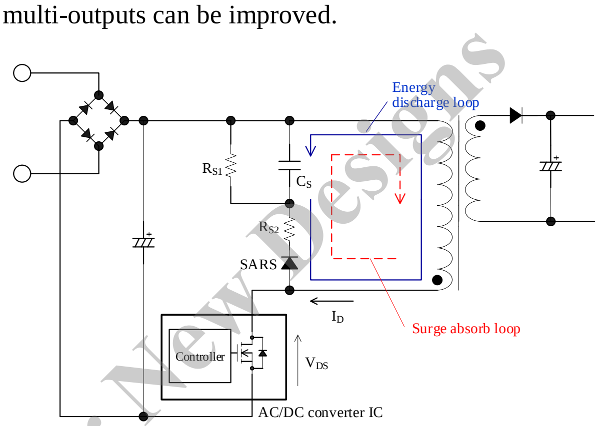



Figure 27. Clamp Snubber Circuit using SARS

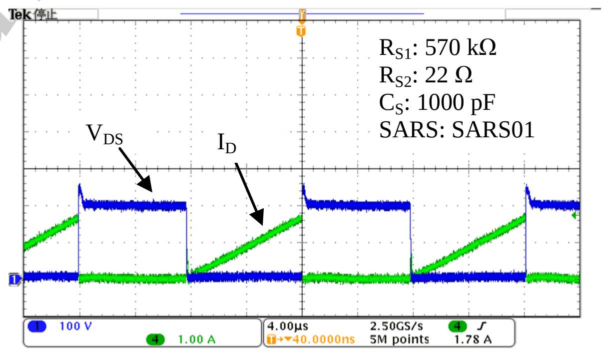



Figure 28. Waveforms of Clamp Snubber Circuit using SARS

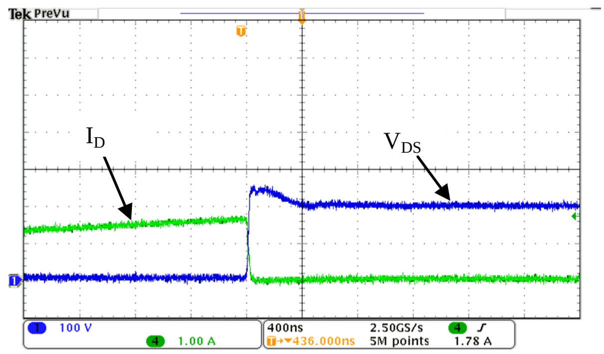



Figure 29. Enlarged View of Figure 28

## 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):

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

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.

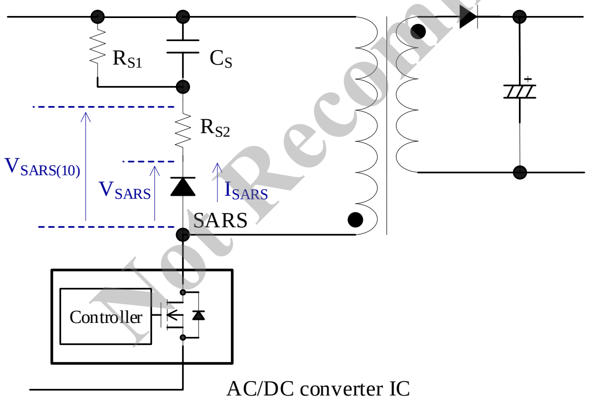



Figure 30. Typical Application

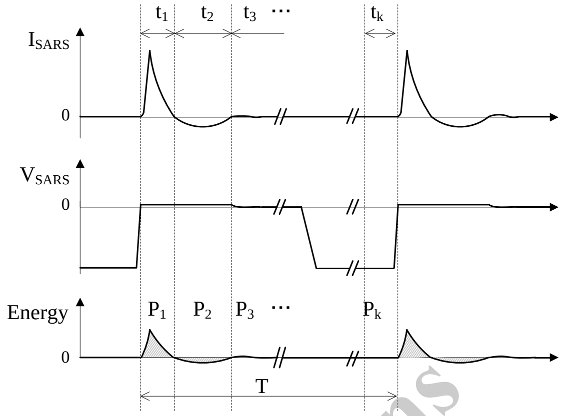



Figure 31. SARS Current

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**

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

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

- **SARS10**

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

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

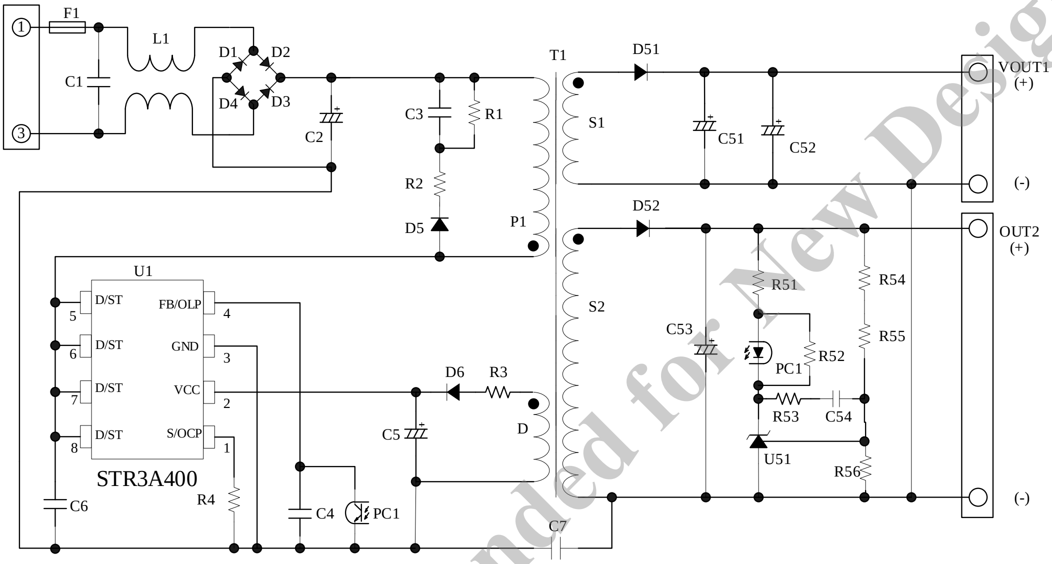
## Reference Design of Power Supply

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 |



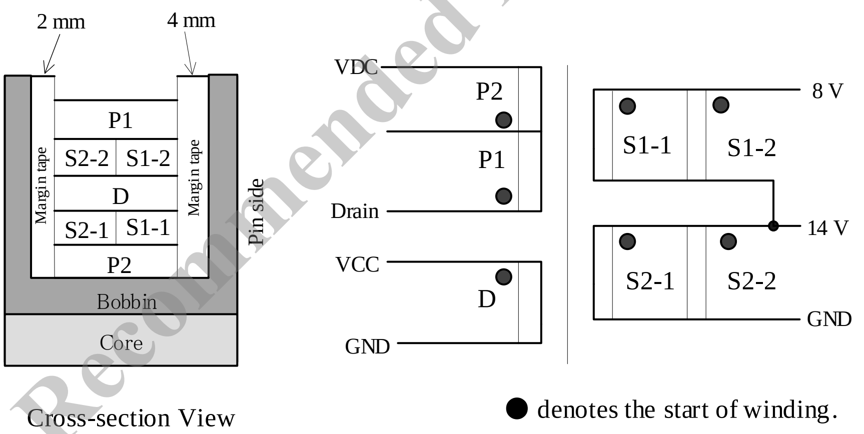



Figure 32. Winding Structure

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