Auxiliary Switch Diodes for Snubber

# SARS01, SARS05

Data Sheet

## Description

The SARS01/05 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 SARS01/05-incorporated snubber circuits allow better cross regulation of multiple outputs.

The SARS01/05 can also improve power supply efficiency by partially transferring such ringing voltage into the secondary side of a power supply unit.

## Features

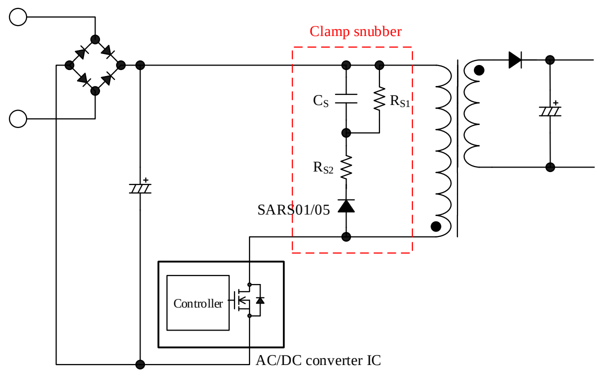
- Improves Cross Regulation
- Reduces Noise
- Improves Efficiency

## Applications

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

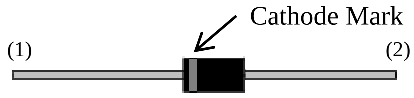
- White Goods
- Adaptor
- Industrial Equipment

## Typical Application

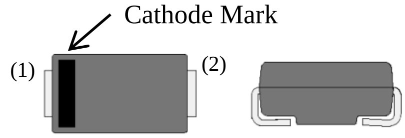


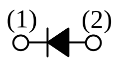

## Package

- SARS01
  Axial (φ2.7 × 5.0L / φ0.6)




- SARS05
  SJP (4.5 mm × 2.6 mm)




(1) Cathode
(2) Anode

Not to scale

## Selection Guide

| Part Number | $I_{F(AV)}$ | $V_F$ (max.) | Package |
|---|---|---|---|
| SARS01 | 1.2 A | 0.92 V | Axial |
| SARS05 | 1.0 A | 1.05 V | SJP |

## Contents

## Absolute Maximum Ratings

Unless otherwise specified, $T_A$ = 25 °C.

| Parameter | Symbol | Conditions | Rating | Unit | Remarks |
|---|---|---|---|---|---|
| Nonrepetitive Peak Reverse Voltage | $V_{RSM}$ | | 800 | V | |
| Repetitive Peak Reverse Voltage | $V_{RM}$ | | 800 | V | |
| Average Forward Current(1) | $I_{F(AV)}$ | | 1.2 | A | SARS01 |
| | | | 1.0 | | SARS05 |
| Surge Forward Current | $I_{FSM}$ | Half cycle sine wave, positive side, 10 ms, 1 shot | 110 | A | SARS01 |
| | | | 30 | | SARS05 |
| $I^2t$ Limiting Value | $I^2t$ | 1 ms ≤ t ≤ 10 ms | 60.5 | $A^2s$ | SARS01 |
| | | | 4.5 | | SARS05 |
| Junction Temperature | $T_J$ | | −40 to 150 | °C | |
| Storage Temperature | $T_{STG}$ | | −40 to 150 | °C | |

## Electrical Characteristics

Unless otherwise specified, $T_A$ = 25 °C.

| 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 | — | 0.91 | 1.05 | | SARS05 |
| Reverse Leakage Current | $I_R$ | $V_R = V_{RM}$ | — | — | 10 | µA | SARS01 |
| | | | — | — | 5 | | SARS05 |
| Reverse Leakage Current under High Temperature | $H \cdot I_R$ | $V_R = V_{RM}$, $T_J$ = 100 °C | — | — | 50 | µA | |
| Reverse Recovery Time | $t_{rr}$ | $I_F = I_{RP}$ = 10 mA, $T_J$ = 25 °C, 90% recovery point | 2 | — | 18 | µs | SARS01 |
| | | $I_F = I_{RP}$ = 100 mA, $T_J$ = 25 °C, 90% recovery point | 2 | — | 19 | | SARS05 |
| Thermal Resistance(2) | $R_{th(J-L)}$ | | — | — | 20 | °C/W | SARS01 |
| | | | — | — | 20 | | SARS05 |

## Mechanical Characteristics

| Parameter | Conditions | Min. | Typ. | Max. | Unit | Remarks |
|---|---|---|---|---|---|---|
| Package Weight | | — | 0.2 | — | g | SARS01 |
| | | — | 0.072 | — | g | SARS05 |

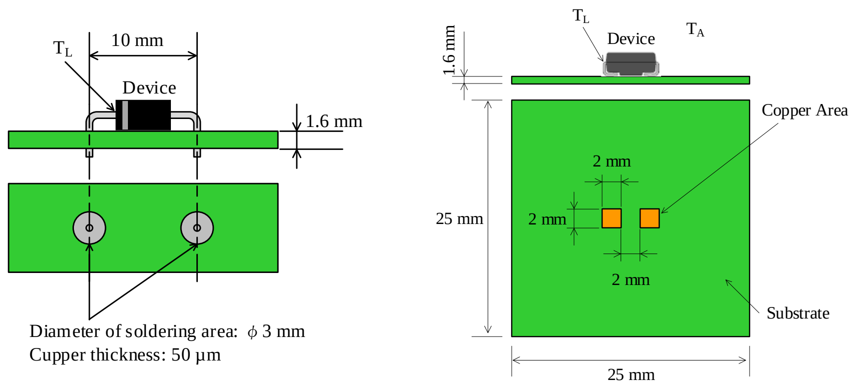



Figure 1. Lead Temperature Measurement Conditions

(1) See the derating curves of each product.
(2) $R_{th(J-L)}$ is thermal resistance between junction and lead. Lead temperature ($T_L$) is measured near the root of pin (see Figure 1).

## SARS01 Derating Curves

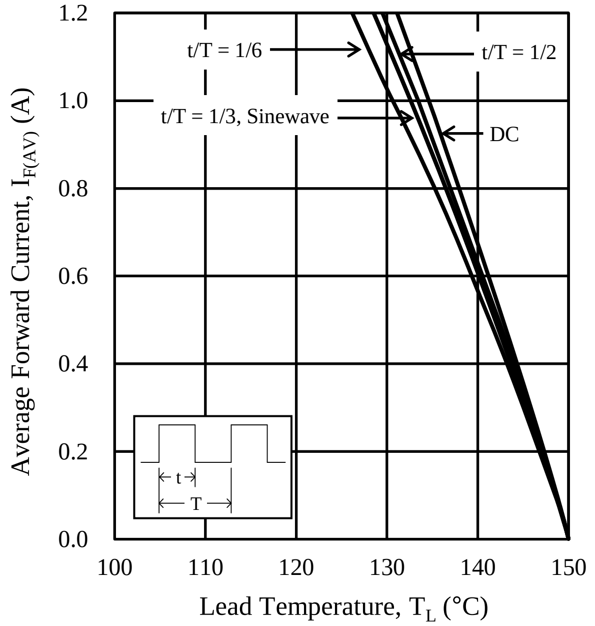



Figure 2. SARS01 $I_{F(AV)}$ vs. $T_L$ ($T_J$ = 150 °C, $V_R$ = 0 V)

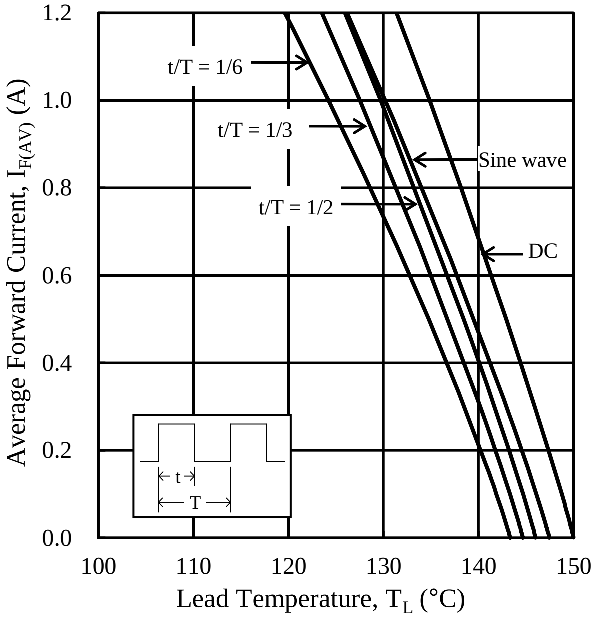



Figure 3. SARS01 $I_{F(AV)}$ vs. $T_L$ ($T_J$ = 150 °C, $V_R$ = 800 V)

## SARS01 Characteristic Curves

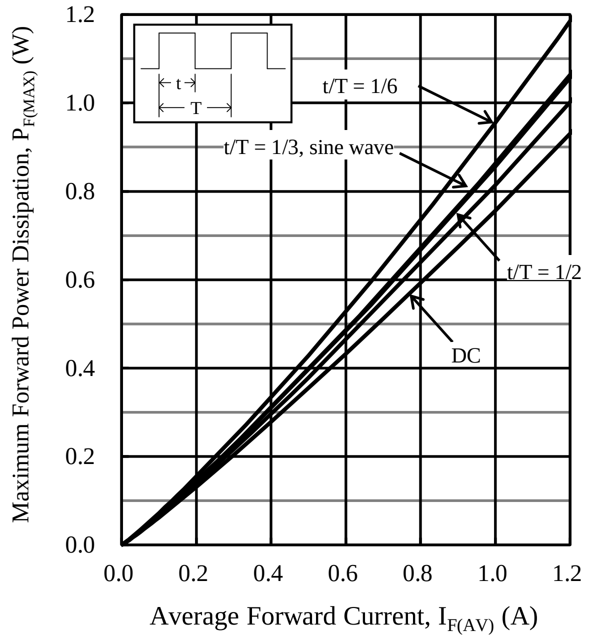



Figure 4. SARS01 $P_{F(MAX)}$ vs. $I_{F(AV)}$ ($T_J$ = 150 °C)

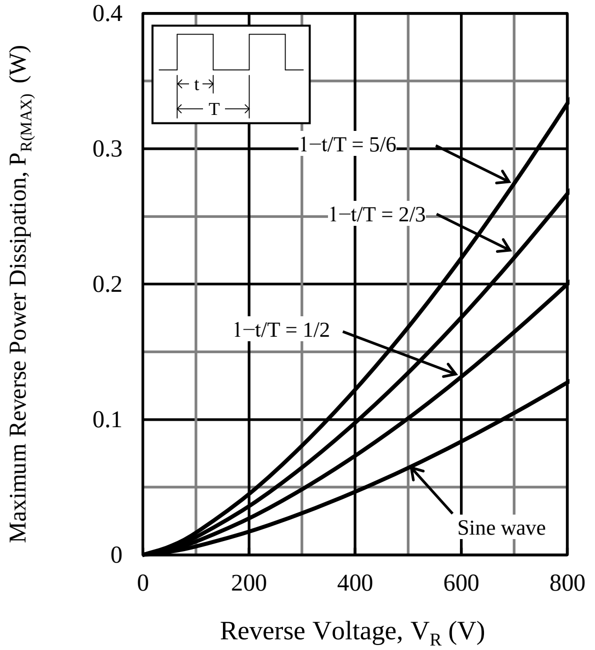



Figure 5. SARS01 $P_{R(MAX)}$ vs. $V_R$ ($T_J$ = 150 °C)

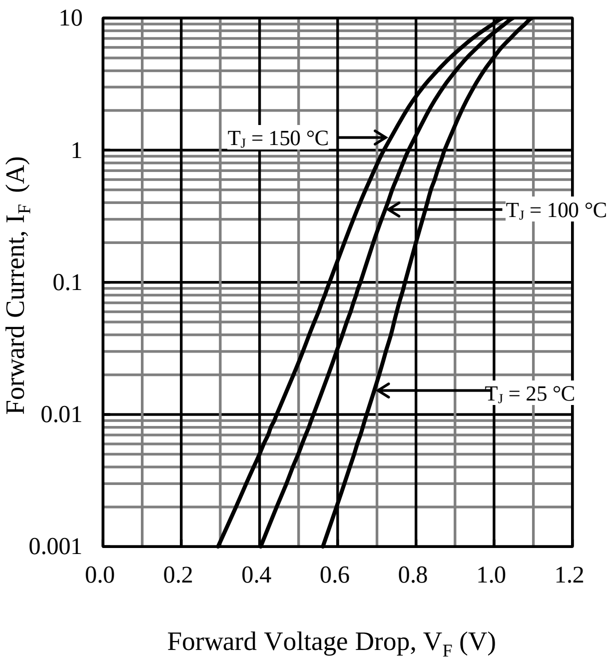



Figure 6. SARS01 Typical Characteristics: $I_F$ vs. $V_F$

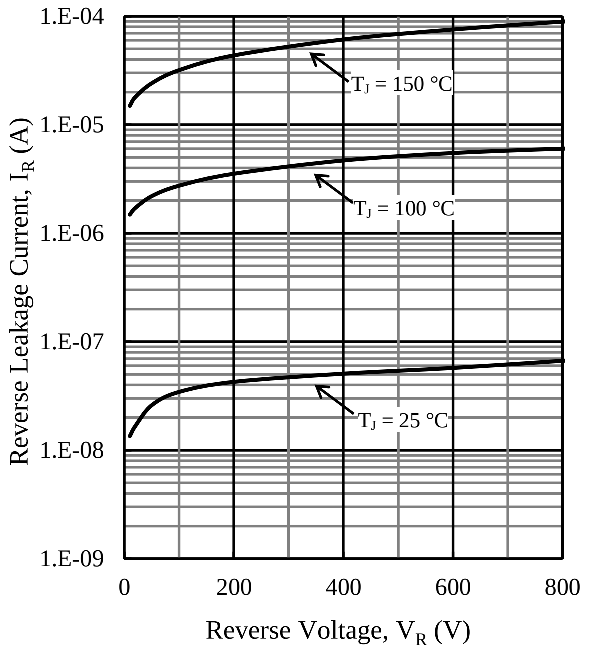



Figure 7. SARS01 Typical Characteristics: $I_R$ vs. $V_R$

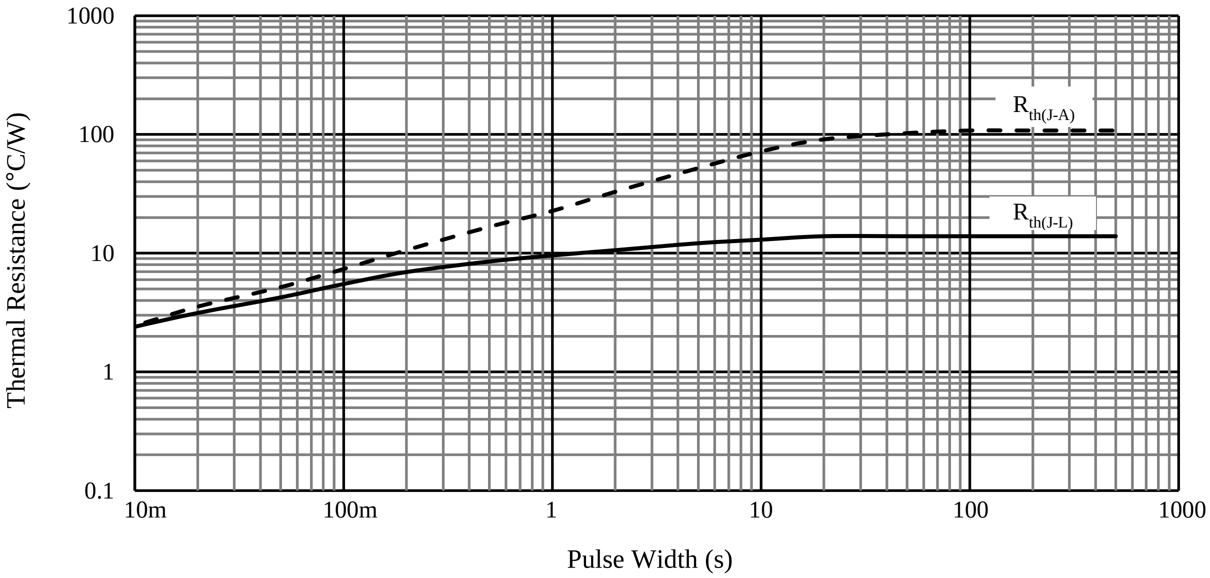



Figure 8. SARS01 Typical Transient Thermal Resistance Characteristics

## SARS05 Derating Curves

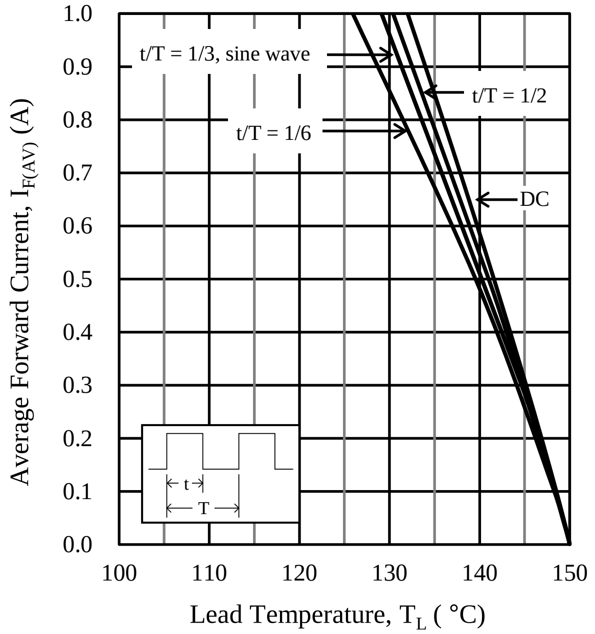



Figure 9. SARS05 $I_{F(AV)}$ vs. $T_L$
($T_J$ = 150 °C, $V_R$ = 0 V)

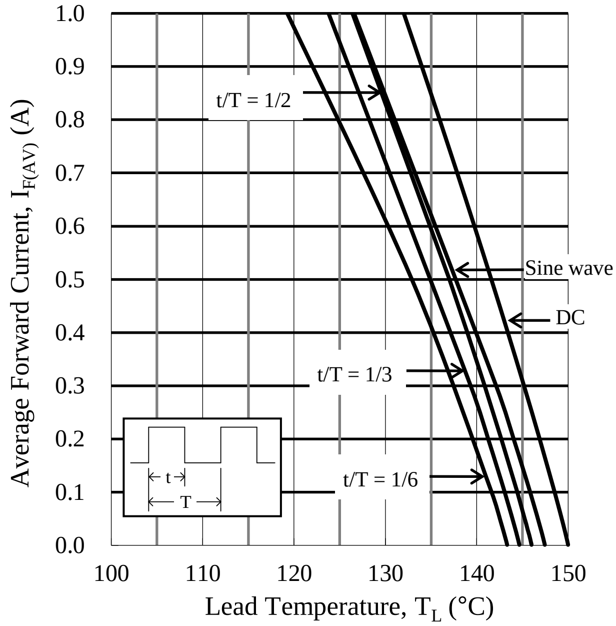



Figure 10. SARS05 $I_{F(AV)}$ vs. $T_L$
($T_J$ = 150 °C, $V_R$ = 800 V)

## SARS05 Characteristic Curves

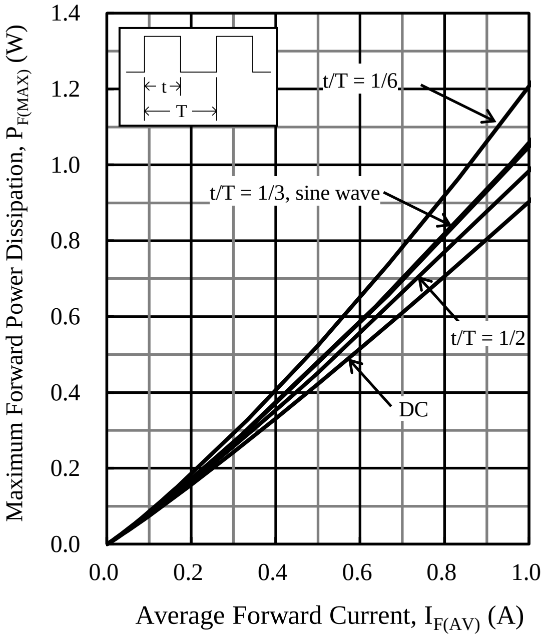



Figure 11. SARS05 $P_{F(MAX)}$ vs. $I_{F(AV)}$ ($T_J$ = 150 °C)

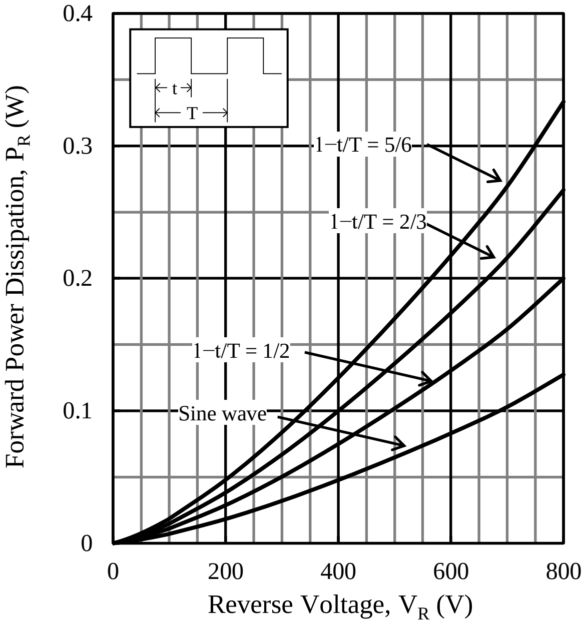



Figure 12. SARS05 $P_{R(MAX)}$ vs. $V_R$ ($T_J$ = 150 °C)

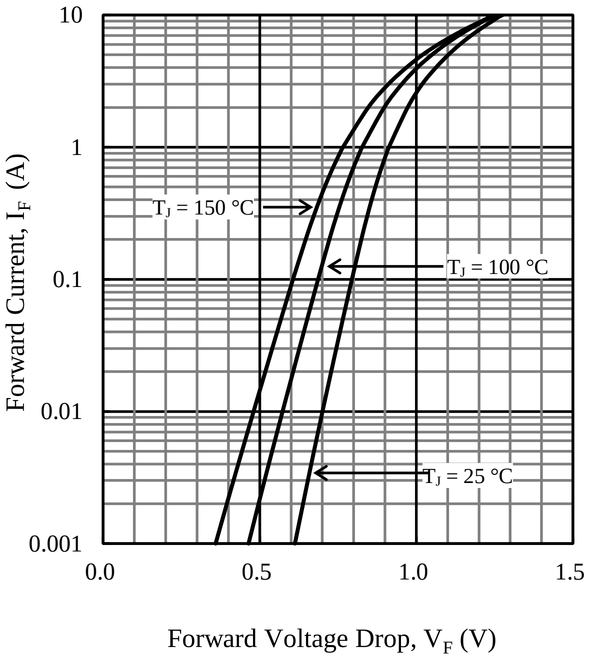



Figure 13. SARS05 Typical Characteristics: $I_F$ vs. $V_F$

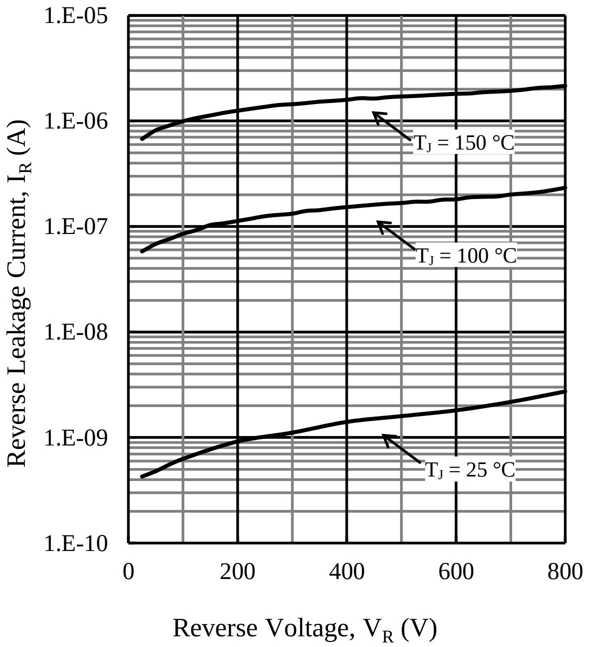



Figure 14. SARS05 Typical Characteristics: $I_R$ vs. $V_R$

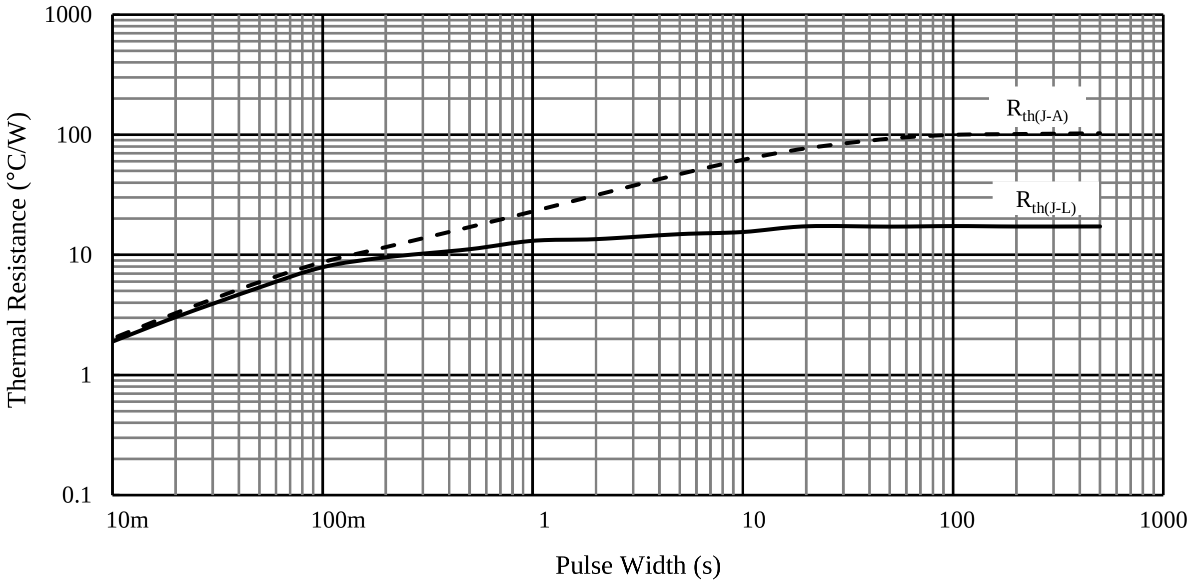
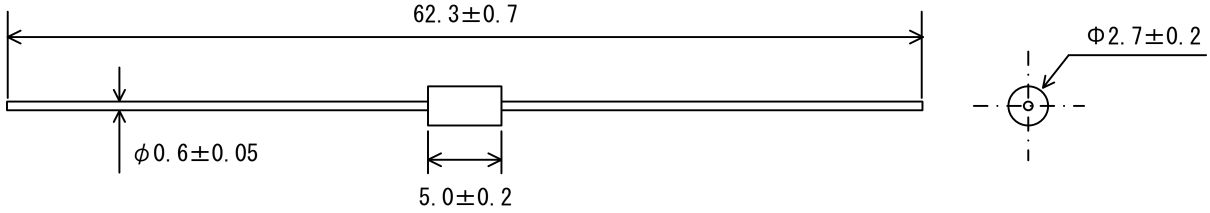



Figure 15. SARS05 Typical Transient Thermal Resistance Characteristics

## SARS01 Physical Dimensions and Marking Diagram

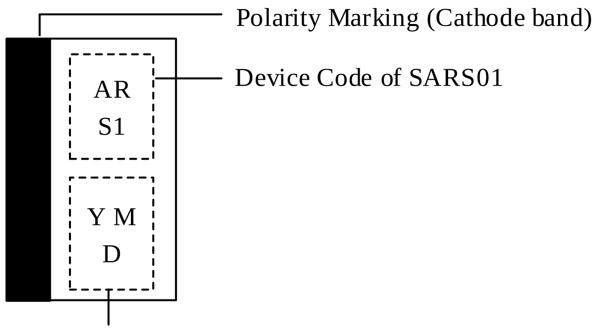
- **SARS01 Physical Dimensions**
  Axial (φ2.7 × 5.0L / φ0.6)




**NOTES:**

- Dimensions in millimeters
- Bare leads: Pb-free (RoHS compliant)
- The allowance position of Body against the center of whole lead wire is 0.5 mm (max.).
- The centric allowance of lead wire against center of physical body is 0.2 mm (max.).
- The burr may exit up to 2 mm from the body of lead.
- When soldering the products, it is required to minimize the working time, within the following limits:
  Flow: 260 °C, 10 s, 1 time
  Soldering Iron: 350 °C, 3.5 s, 1 time (Soldering should be at a distance of at least 1.5 mm from the body of the product.)

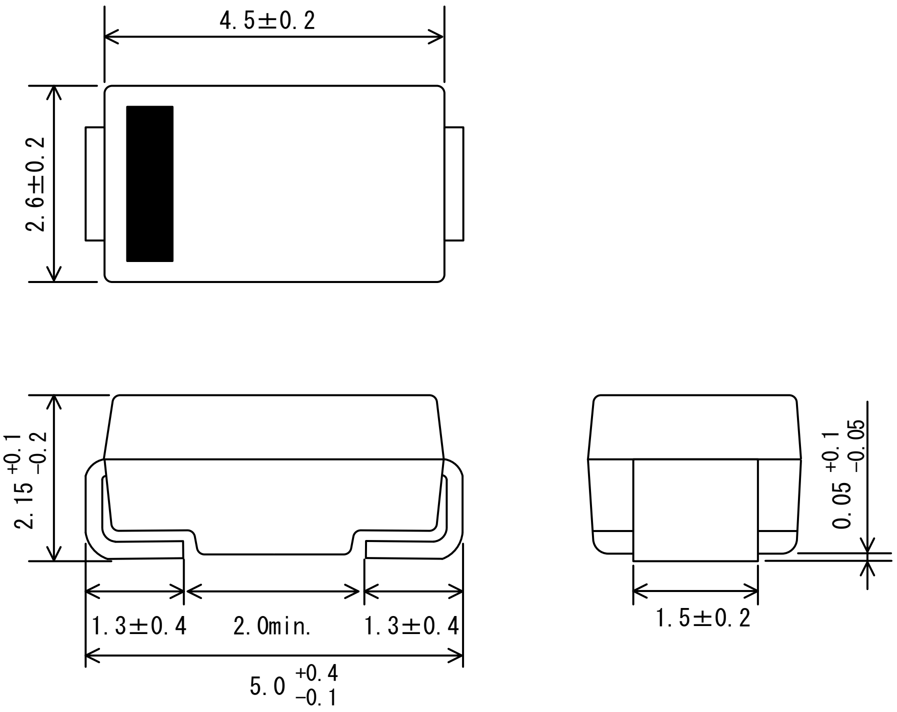
- **SARS01 Marking Diagram**




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)

## SARS05 Physical Dimensions and Marking Diagram

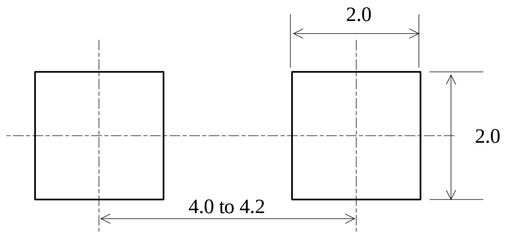
- **SARS05 Physical Dimensions**




**NOTES:**

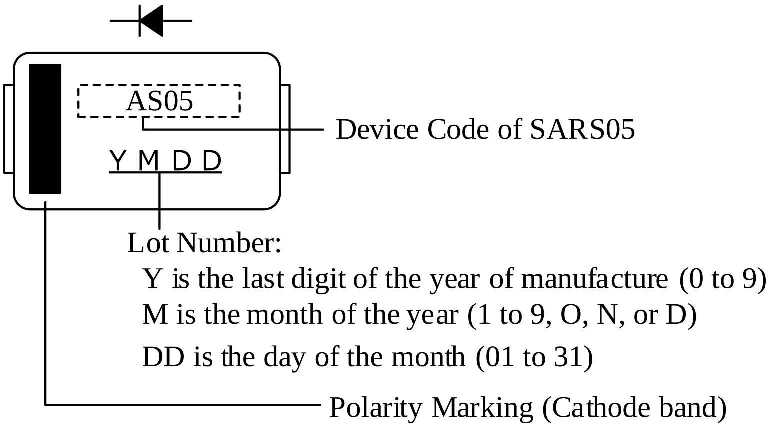
- Dimensions in millimeters
- Bare lead frame: Pb-free (RoHS compliant)
- Moisture Sensitivity Level 1 (MSL 1)
- When soldering the products, it is required to minimize the working time within the following limits:
  Flow: 260 °C / 10 s, 1 time
  Reflow:
    Preheat: 150 °C to 200 °C / 60 s to 120 s
    Solder heating: 255 °C / 30 s, 3 times (260 °C peak)
  Soldering iron: 350 °C / 3.5 s, 1 time

- **SARS05 Land Pattern Example**




**NOTE:**
Dimensions in millimeters

- **SARS05Marking Diagram**



## Operational Comparison of Clamp Snubber Circuits

Figure 16 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.

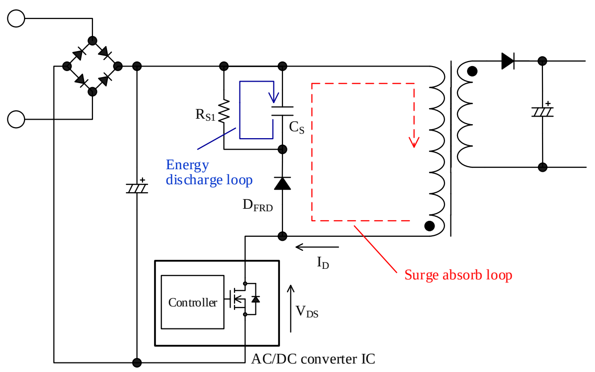



Figure 16. General Clamp Snubber Circuit

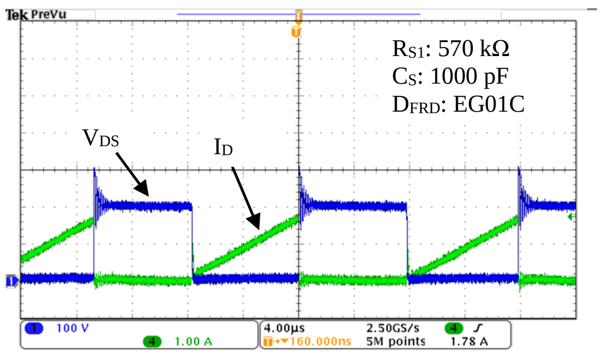



Figure 17. Waveforms of General Clamp Snubber Circuit

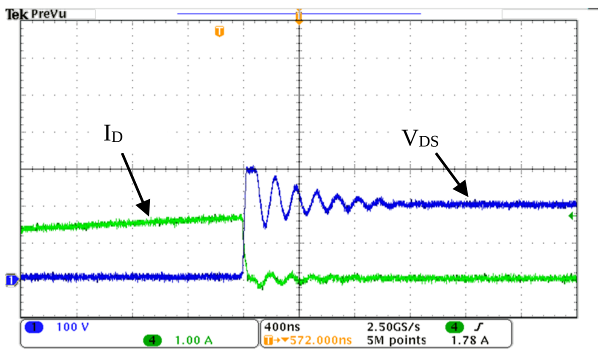



Figure 18. Enlarged View of Figure 17

Figure 19 shows the clamp snubber circuit using the SARS01/05. 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 SARS01/05 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 SARS01/05 reduces the ringing voltage. Thus, the cross regulation of multi-outputs can be improved.

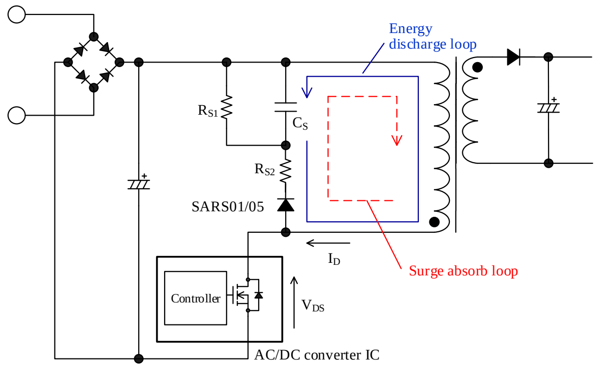



Figure 19. Clamp Snubber Circuit using SARS01/05

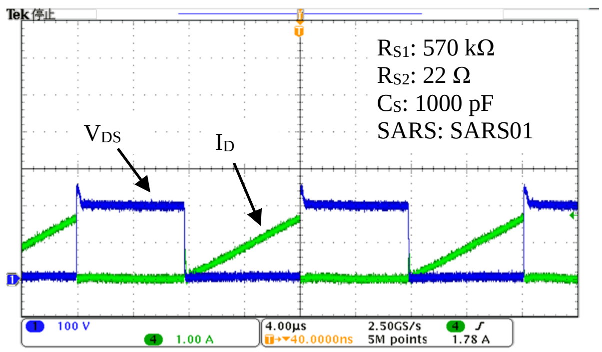



Figure 20. Waveforms of Clamp Snubber Circuit using SARS01

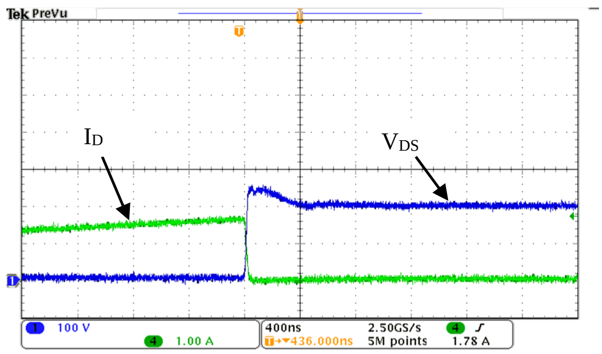



Figure 21. Enlarged View of Figure 20

## Power Dissipation and Junction Temperature Calculation

Figure 22 shows a typical application using the SARS01/05. Figure 23 shows the operating waveforms of the SARS01/05. The power dissipation of the SARS01/05 is calculated as follows:

1) The waveforms of the SARS01/05 voltage, $V_{SARS}$, and the SARS01/05 current, $I_{SARS}$, are measured in actual application operation. $V_{SARS} \times I_{SARS}$ is calculated by the math function of oscilloscope.
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 22 by the automatic measurement function of the oscilloscope.
3) The power dissipation of the SARS01/05, $P_{SARS}$, 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 SARS01/05,
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. In addition, by using the temperature of the SARS01/05 in actual application operation, the estimated junction temperature of the SARS01/05 is calculated by Equation (2). It should be enough lower than $T_J$ of the absolute maximum rating.

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

where:
$T_{J(SARS)}$ is junction temperature of the SARS01/05,
$T_L$ is lead temperature of the SARS01/05, and
$\theta_{J-L}$ is thermal resistance between junction to lead.

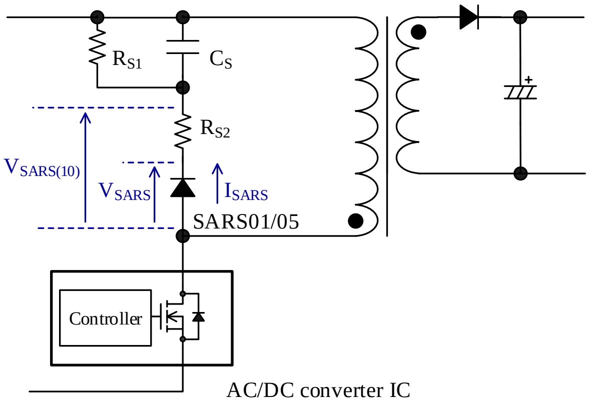



Figure 22. Typical Application

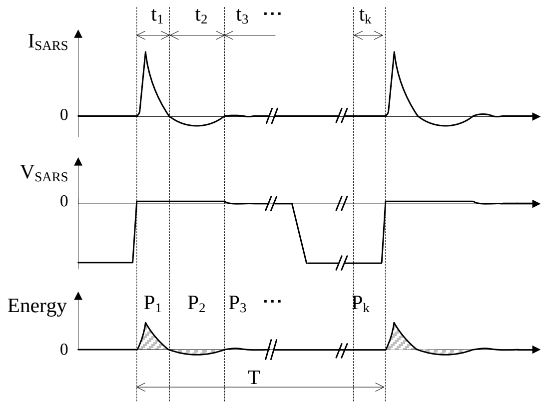



Figure 23. SARS01/05 Current

## Parameter Setting of Snubber Circuit using SARS01/05

The temperature of the SARS01/05 and peripheral components should be measured in actual application operation.

The reference values of snubber circuit using the SARS01/05 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 SARS01/05, 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 SARS01/05 in series.

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.

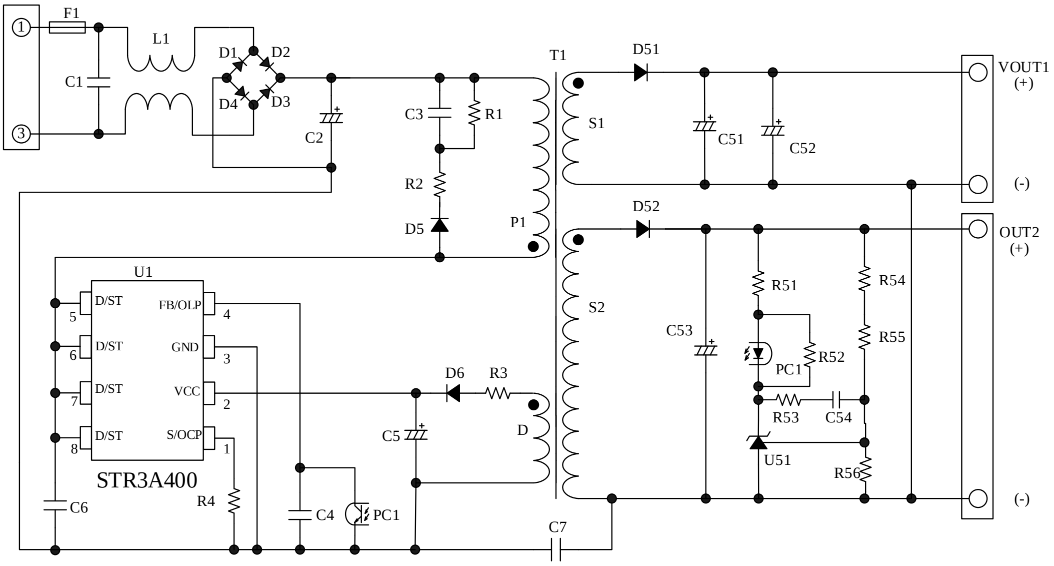
## Reference Design of Power Supply

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, 20 A | FMEN-220A |
| 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, 1.0 A | SARS05 | U1 | IC | STR3A453D |
| D6 | Fast recovery, 200 V, 1.5A | SJPX-F2 | U51 | Shunt regulator, $V_{REF}$ = 2.5 V | (TL431 or equiv.) |
| D51 | Schottky, 60 V, 1.5 A | SJPB-H6 | | | |

(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 24 |

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 |

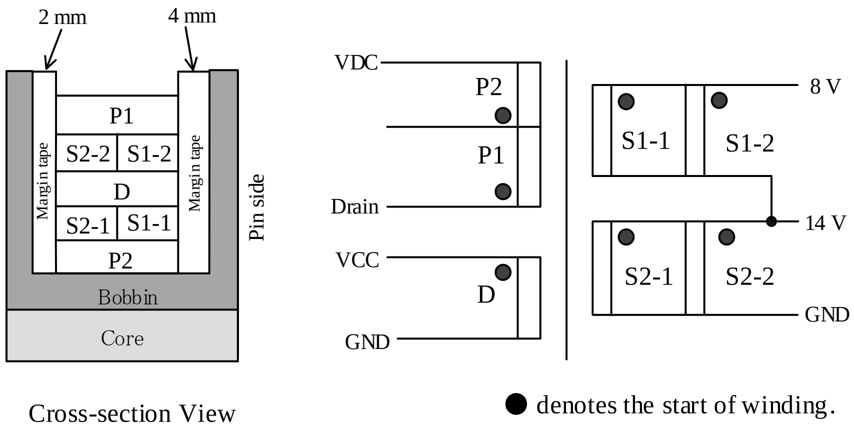



Figure 24. Winding Structure

## Important Notes

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