THERMAL PARAMETERS

Heat generated by SR Series Resistors is dissipated mainly by radiation and convection from the exposed surface areas. Within restricted domains, mathematical models may be employed to permit heat transfer estimations.

Symbols

ΔT = Temperature Rise (°C)
W_a = Watts / Unit Exposed Surface Area ($W.cm^{-2}$)
v = Volume of Active Material (cm^3)
c_m = Specific Heat Capacity of Active Material = $2J.\ cm^{-3}.°C^{-1}$
Do = Overall Diameter (mm)
τ = Resistor Thermal Time Constant (s)

Radiation and Convection $W_a = 0.00026(\Delta T)^{1.4}$
(ΔT = 50°C to 175°C, Do = 10 mm to 151 mm, Ambient 25°C)

Thermal Conductivity 0.04 W / cm^2.°C / cm

Maximum Insertion Energy Ratings
For a Resistor initially at 25°C : 350 Joules / cm^3 (Infrequently)
For a Resistor initially at 25°C : 250 Joules / cm^3 (Continuously)

Recommended Operating Temperatures
200 °C (Infrequent Operation)
150 °C (Continuous Operation)

Temperature Rise from Energy Injection ΔT (°C) = Joules (per Resistor) / (v x c_m) (Free Air)

Thermal Time Constant τ (s) = Max Joules @ 25°C / Max Watts @ 25°C
Full Cooling $\geq 4\tau$

De-rating for other ambient Temperatures (Ta°C) Multiply Max Joules @ 25°C & Max Watts @ 25°C by the ratio (150 - Ta) / 125

Repetitive Thermal Impulsing:
Assuming that the Heat Transfer Coefficient α (W / cm^2.°C / cm) is constant over the operating temperature range, then the Peak Temperature Rise (ΔTp) associated with repetitive impulsing can be estimated by way of reference to a classical geometric progression ...

$$\Delta Tp\ (°C) = \Delta T \times (1 - (e^{-(t/\tau)})^n) \div (1 - e^{-(t/\tau)}) \quad ....1$$

where:
ΔT is the Temperature Rise associated with each electrical impulse (°C)
τ is the Resistor Thermal Time Constant (s)
t is the Repetition Rate (s)
n is the number of impulses

If the number of impulses (n) → ∞ (ie continuous duty), then equation 1 can be simplified thus ...

$$\Delta Tp\ (°C) = \Delta T \div (1 - e^{-(t/\tau)}) \quad .... 2$$

Custom Variants Although the SR Series is intended to provide design engineers with a wide range of standard Surge Resistor types and values, custom variants are available. Specific length versions, specific Resistance Value versions of standard types and +/- 5% Resistance Tolerance are available at additional cost.

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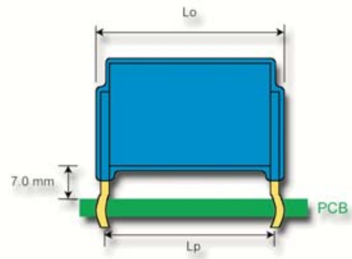
SR Series : Surge Resistors for PCB Mounting

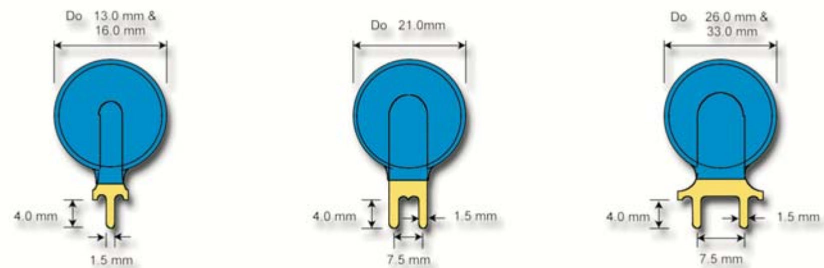
- High Surge Energy Rating
- 100% Active Material
- Compact Size
- Designed for PCB Assembly
- High Voltage Withstand
- Essentially Non-Inductive
- Wide Resistivity Range
- Coating Approved to UL94 V-0
- Free Design Service

The SR Series of Surge Resistors for PCB mounting are manufactured from a carefully selected mixture of clays, alumina and carbon. After blending, the material is pressed to the required shape and then fired, in a controlled atmosphere, at high temperature.

This sintering process produces a Ceramic Carbon Resistor which is 100% active material and therefore of minimum size. The SR Series feature Gold Plated Brass spring pin terminations for ease of assembly into Printed Circuit Boards (PCB's). Dielectric withstand and mechanical robustness are enhanced by the UL94 V-0 approved epoxy resin coating.



Compact in size and with high surge energy rating, the modular SR Series is designed to provide the optimum solution to many Power Electronics applications ; notably soft starting the DC link capacitors in Switch Mode Power Supplies. Inherently non–inductive and capable of withstanding transient high voltage impulses, the SR Series is similarly effective with respect to overvoltage protection and crowbar discharge applications.



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Technical Specifications

RESISTOR TYPE	ACTIVE MATERIAL DIMENSION CODE	OVERALL DIMENSIONS Do MAXIMUM	Lo MAXIMUM	Lp PITCH	VOLUME OF ACTIVE MATERIAL (v)	MAXIMUM JOULES @ 25°C	MAXIMUM WATTS @ 25°C	THERMAL TIME CONSTANT (τ)	WEIGHT	A / L	RESISTANCE RANGE MINIMUM	MAXIMUM
Units		(mm)	(mm)	(mm)	(cm^3)	(J)	(W)	(Seconds)	(g)	(cm)	(Ohms)	(Ohms)
SR 0250	1111	13	15	11 - 12	1.0	250	1.50	165	3.5	0.9	12R0	5K6
SR 0325	1114	13	18	14 - 15	1.3	325	1.75	185	4.0	0.7	15R0	6K8
SR 0400	1117	13	21	17 - 18	1.6	400	2.00	200	5.0	0.6	18R0	8K2
SR 0550	1414	16	18	14 - 15	2.2	550	2.25	245	6.5	1.1	10R0	4K7
SR 0650	1417	16	21	17 - 18	2.6	650	2.50	260	7.0	0.9	12R0	5K6
SR 0775	1911	21	15	11 - 12	3.1	775	3.00	260	9.0	2.6	3R9	1K8
SR 1000	1914	21	18	14 - 15	4.0	1000	3.50	285	10.5	2.0	5R6	2K7
SR 1200	1917	21	21	17 - 18	4.8	1200	3.75	320	13.0	1.7	6R8	3K3
SR 1425	1920	21	24	20 - 21	5.7	1425	4.25	335	15.0	1.4	8R2	3K9
SR 1775	1925	21	29	25 - 26	7.1	1775	5.00	355	18.0	1.1	10R0	4K7
SR 2250	2420	26	24	20 - 21	9.0	2250	5.75	390	22.5	2.3	4R7	2K2
SR 2825	2425	26	29	25 - 26	11.3	2825	6.50	435	28.0	1.8	5R6	2K7
SR 3500	2431	26	35	31 - 32	14.0	3500	7.50	465	34.0	1.5	6R8	3K3
SR 4175	2437	26	41	37 - 38	16.7	4175	8.50	490	40.0	1.2	10R0	4K7
SR 5200	2446	26	50	46 - 47	20.8	5200	10.00	520	50.0	1.0	10R0	4K7
SR 6975	3137	33	41	37 - 38	27.9	6975	11.50	605	66.0	2.0	5R6	2K7
SR 8675	3146	33	50	46 - 47	34.7	8675	13.25	655	81.5	1.6	6R8	3K3
SR 10375	3155	33	59	55 - 56	41.5	10375	15.25	680	97.0	1.4	8R2	3K9

RESISTOR TYPE	MAXIMUM WORKING VOLTAGE ($V_{Working}$) (50 Hz rms)	MAXIMUM WORKING VOLTAGE ($V_{Working}$) (1.2/50 μs IMPULSE)	MAXIMUM WORKING VOLTAGE ($V_{Working}$) (10/1000 μs IMPULSE)	MAXIMUM WORKING VOLTAGE ($V_{Working}$) (500/5000 μs IMPULSE)
Units	(kV)	(kV)	(kV)	(kV)
SR 0250	$1.0 \times (0.9 R/t)^{0.3}$	$0.26R \times (-1 + \sqrt{(1 + 69/R)})$	$0.0131R \times (-1 + \sqrt{(1 + 1377/R)})$	$0.0026R \times (-1 + \sqrt{(1 + 6887/R)})$
SR 0325	$1.3 \times (0.7 R/t)^{0.3}$	$0.26R \times (-1 + \sqrt{(1 + 88/R)})$	$0.0131R \times (-1 + \sqrt{(1 + 1753/R)})$	$0.0026R \times (-1 + \sqrt{(1 + 8765/R)})$
SR 0400	$1.6 \times (0.6 R/t)^{0.3}$	$0.26R \times (-1 + \sqrt{(1 + 106/R)})$	$0.0131R \times (-1 + \sqrt{(1 + 2128/R)})$	$0.0026R \times (-1 + \sqrt{(1 + 10644/R)})$
SR 0550	$1.3 \times (1.1 R/t)^{0.3}$	$0.43R \times (-1 + \sqrt{(1 + 54/R)})$	$0.0214R \times (-1 + \sqrt{(1 + 1082/R)})$	$0.0043R \times (-1 + \sqrt{(1 + 5411/R)})$
SR 0650	$1.6 \times (0.9 R/t)^{0.3}$	$0.43R \times (-1 + \sqrt{(1 + 66/R)})$	$0.0214R \times (-1 + \sqrt{(1 + 1314/R)})$	$0.0043R \times (-1 + \sqrt{(1 + 6571/R)})$
SR 0775	$1.0 \times (2.6 R/t)^{0.3}$	$0.79R \times (-1 + \sqrt{(1 + 23/R)})$	$0.0393R \times (-1 + \sqrt{(1 + 462/R)})$	$0.0079R \times (-1 + \sqrt{(1 + 2308/R)})$
SR 1000	$1.3 \times (2.0 R/t)^{0.3}$	$0.79R \times (-1 + \sqrt{(1 + 29/R)})$	$0.0393R \times (-1 + \sqrt{(1 + 588/R)})$	$0.0079R \times (-1 + \sqrt{(1 + 2938/R)})$
SR 1200	$1.6 \times (1.7 R/t)^{0.3}$	$0.79R \times (-1 + \sqrt{(1 + 36/R)})$	$0.0393R \times (-1 + \sqrt{(1 + 714/R)})$	$0.0079R \times (-1 + \sqrt{(1 + 3568/R)})$
SR 1425	$1.9 \times (1.4 R/t)^{0.3}$	$0.79R \times (-1 + \sqrt{(1 + 42/R)})$	$0.0393R \times (-1 + \sqrt{(1 + 839/R)})$	$0.0079R \times (-1 + \sqrt{(1 + 4197/R)})$
SR 1775	$2.4 \times (1.1 R/t)^{0.3}$	$0.79R \times (-1 + \sqrt{(1 + 52/R)})$	$0.0393R \times (-1 + \sqrt{(1 + 1049/R)})$	$0.0079R \times (-1 + \sqrt{(1 + 5246/R)})$
SR 2250	$1.9 \times (2.3 R/t)^{0.3}$	$1.26R \times (-1 + \sqrt{(1 + 26/R)})$	$0.0627R \times (-1 + \sqrt{(1 + 526/R)})$	$0.0126R \times (-1 + \sqrt{(1 + 2630/R)})$
SR 2825	$2.4 \times (1.8 R/t)^{0.3}$	$1.26R \times (-1 + \sqrt{(1 + 33/R)})$	$0.0627R \times (-1 + \sqrt{(1 + 658/R)})$	$0.0126R \times (-1 + \sqrt{(1 + 3288/R)})$
SR 3500	$2.9 \times (1.5 R/t)^{0.3}$	$1.18R \times (-1 + \sqrt{(1 + 41/R)})$	$0.0589R \times (-1 + \sqrt{(1 + 815/R)})$	$0.0118R \times (-1 + \sqrt{(1 + 4077/R)})$
SR 4175	$3.5 \times (1.2 R/t)^{0.3}$	$1.11R \times (-1 + \sqrt{(1 + 49/R)})$	$0.0552R \times (-1 + \sqrt{(1 + 973/R)})$	$0.0110R \times (-1 + \sqrt{(1 + 4866/R)})$
SR 5200	$4.4 \times (1.0 R/t)^{0.3}$	$1.00R \times (-1 + \sqrt{(1 + 61/R)})$	$0.0495R \times (-1 + \sqrt{(1 + 1210/R)})$	$0.0100R \times (-1 + \sqrt{(1 + 6050/R)})$
SR 6975	$3.5 \times (2.0 R/t)^{0.3}$	$1.84R \times (-1 + \sqrt{(1 + 29/R)})$	$0.0920R \times (-1 + \sqrt{(1 + 583/R)})$	$0.0184R \times (-1 + \sqrt{(1 + 2917/R)})$
SR 8675	$4.4 \times (1.6 R/t)^{0.3}$	$1.65R \times (-1 + \sqrt{(1 + 36/R)})$	$0.0826R \times (-1 + \sqrt{(1 + 725/R)})$	$0.0165R \times (-1 + \sqrt{(1 + 3626/R)})$
SR 10375	$5.2 \times (1.4 R/t)^{0.3}$	$1.46R \times (-1 + \sqrt{(1 + 43/R)})$	$0.0732R \times (-1 + \sqrt{(1 + 867/R)})$	$0.0146R \times (-1 + \sqrt{(1 + 4336/R)})$

PHYSICAL / MECHANICAL PARAMETERS

Explanation of Dimension Code — Each Resistor type is assigned a 4 digit code, the first 2 digits give the nominal Active Diameter (D) in mm and the last 2 digits give the nominal Active Length (L) of the Resistor in mm. From this information the Volume of Active Material (v) may be determined.

Construction — The Gold Plated Brass terminations are attached to the Copper metallised contact on the Resistor body opposing flat surfaces, with high melting point solder. This permits reliable short time operation at temperatures up to 200°C.

Coating — The UL94 V-0 approved epoxy resin coating is applied by fluidised bed technique. The coating finish is hard, smooth and has good appearance to harmonise with other electronic components.

If this range of Resistors experience surface temperatures regularly in excess of 150°C, the coating will tend to degrade slightly, becoming darker. Though unsightly, performance is not compromised.

Whilst the coating can reduce the rate of moisture ingress, it is not impervious to liquids.

Terminations / Soldering — The Gold Plated Brass termination pins are 1.5mm wide by 0.4mm thick with the spring pin format designed to ensure stability during PCB assembly. HVR recommend, as a minimum, PCB mounting holes of 2.0mm Diameter.

Soldering is permissible with mildly activated fluxed solders with liquidous properties less than 230°C.

Coefficient of Linear Expansion — In the range $+4 \times 10^{-6}$ to $+10 \times 10^{-6}$ per °C depending on material Resistivity.

ELECTRICAL PARAMETERS

Resistance Values — E6 and E12 values are available as standard.

Resistance Tolerance — +/- 20% and +/- 10% available as standard.

Resistivity Range - ρ — 10 Ohm cm to 5000 Ohm cm $\rho = R \times A/L$ where R = Resistance Value

Temperature Coefficient - TCR — -0.05% to -0.15% per °C Temperature Rise depending on Resistivity Value.
$TCR = 0.16 \times e^{-(\log\rho/1.4)} - 0.135$ (%/°C Temperature Rise)

Voltage Coefficient - VCR — -0.5% to -7.5% / kV / cm
$VCR = -0.62 \times \rho^{0.22}$ (%/kV/cm) For ρ domain 10 to 5000 Ohm cm

Inductance — This is negligible (nH) and the Resistors may be described as non-inductive. In practice the inductance of connecting leads will be greater than that of the Resistors.

Maximum Working Voltages — The Maximum Working Voltage levels ($V_{working}$) can be derived from the appropriate formulae illustrated in the table above. Waveforms are defined in the usual manner: 1.2/50μs indicates a rise time to peak value in 1.2μs and an exponential decay to half amplitude in a total time of 50μs.

Worked example (50Hz rms) : Consider an SR 2825 Resistor with a Resistance Value of 100R0. What is the maximum 50 Hz rms Working Voltage (kV) sustainable for an insertion time of 100 ms?

$V_{working} = 2.4 \times (1.8R/t)^{0.3} = 2.86$ kV

(Note: R = Resistance Value in Ohms and t = 50Hz Insertion time in ms)

Worked example (1.2/50μs) : Consider an SR 2825 Resistor with a Resistance Value of 100R0. What is the maximum Working Voltage (kV) for a 1.2/50μs waveform?

$V_{working} = 1.26R \times (-1 + \sqrt{(1+33/R)}) = 19.3$ kV