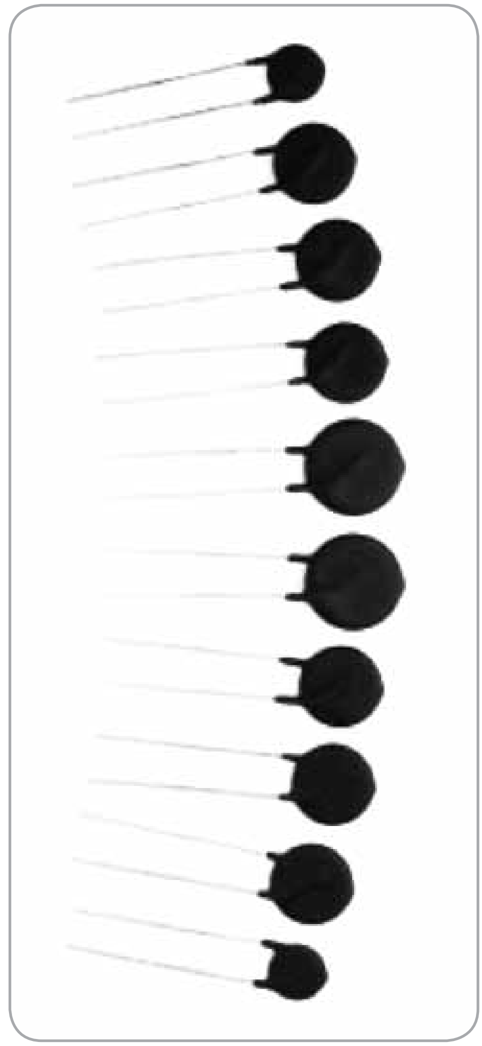
THERMOMETRICS
A COMMITMENT TO EXCELLENCE

NTC Inrush Current Limiter

Thermometrics Thermistors



Features

- UL Approval (UL 1434 File# E82830)
- Small physical size offers design-in benefits over larger passive components
- Low cost, solid state device for inrush current suppression
- Best-in-class capacitance ratings
- Low steady resistance and accompanying power loss
- Excellent mechanical strength
- Wide operating temperature range: -58°F to 347°F (-50°C to 175°C)
- Suitable for PCB mounting
- Available with kinked or straight leads and tape and reel to EIS RS-468A for automatic insertion

Applications

Control of the inrush current in switching power supplies, fluorescent lamp, inverters, motors, etc.

Amphenol
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Inrush Current Limiters In Switching Power Supplies

The problem of current surges in switch-mode power supplies is caused by the large filter capacitors used to smooth the ripple in the rectified 60 Hz current prior to being chopped at a high frequency. The diagram above illustrates a circuit commonly used in switching power supplies.

In the circuit above the maximum current at turn-on is the peak line voltage divided by the value of R; for 120 V, it is approximately $120 \times \sqrt{2}/R_I$. Ideally, during turn-on R_I should be very large, and after the supply is operating, should be reduced to zero. The NTC thermistor is ideally suited for this application. It limits surge current by functioning as a power resistor which drops from a high cold resistance to a low hot resistance when heated by the current flowing through it. Some of the factors to consider when designing NTC thermistor as an inrush current limiter are:

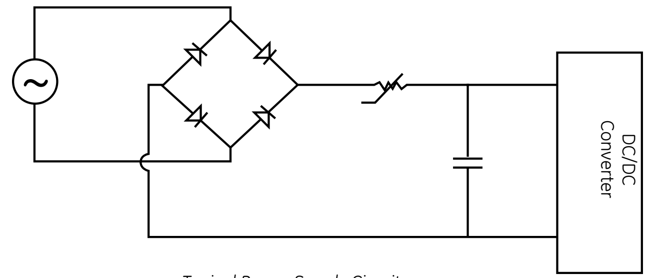
- Maximum permissible surge current at turn-on
- Matching the thermistor to the size of the filter capacitors
- Maximum value of steady state current
- Maximum ambient temperature
- Expected life of the power supply

Maximum Surge Current

The main purpose of limiting inrush current is to prevent components in series with the input to the DC/DC convertor from being damaged. Typically, inrush protection prevents nuisance blowing of fuses or breakers as well as welding of switch contacts. Since most thermistor materials are very nearly ohmic at any given temperature, the minimum no-load resistance of the thermistor is calculated by dividing the peak input voltage by the maximum permissible surge current in the power supply ($V_{peak/Imax\ surge}$).

Energy Surge at Turn-On

At the moment the circuit is energized, the filter caps in a switcher appear like a short circuit which, in a relatively short period of time, will store an amount of energy equal to $1/2CV^2$. All of the charge that the filter capacitors store must flow through the thermistor. The net effect of this large current surge is to increase the temperature of the thermistor very rapidly during the period the capacitors are charging. The amount of energy generated in the thermistor during this capacitor-charging period is dependent on the voltage waveform of the source charging the capacitors. However, a good approximation for the energy generated by the thermistor during this period is $1/2CV^2$ (energy stored in the filter capacitor). The ability of the NTC thermistor to handle this energy surge is largely a function of the mass of the device. This logic can be seen in the energy balance equation for a thermistor being self-heated:



Typical Power Supply Circuit

Input Energy = Energy Stored + Energy Dissipated
or in differential form:

$$Pdt = HdT + (T - T_A)dt$$

where:
P = Power generated in the NTC
t = Time
H = Heat capacity of the thermistor
T = Temperature of the thermistor body
 = Dissipation constant
T_A = Ambient temperature

During the short time that the capacitors are charging (usually less than 0.1 second), very little energy is dissipated. Most of the input energy is stored as heat in the thermistor body. In the table of standard inrush limiters there is listed a recommended value of maximum capacitance at 120 V and 240 V. This rating is not intended to define the absolute capabilities of the thermistors; instead, it is an experimentally determined value beyond which there may be some reduction in the life of the inrush current limiter.

Maximum Steady-State Current

The maximum steady-state current rating of a thermistor is mainly determined by the acceptable life of the final products for which the thermistor becomes a component. In the steady-state condition, the energy balance in the differential equation already given reduces to the following heat balance formula:

$$\text{Power} = I^2R = (T - T_A)$$

As more current flows through the device, its steady-state operating temperature will increase and its resistance will decrease. The maximum current rating correlates to a maximum allowable temperature.
In the table of standard inrush current limiters is a list of values for resistance under load for each unit, as well as a recommended maximum steady-state current. These ratings are based upon standard PC board heat sinking, with no air flow, at an ambient temperature of 77° (25°C). However, most power supplies have some air flow, which further enhances the safety margin that is already built into the maximum current rating. To derate the maximum steady state current for operation at elevated ambient temperatures, use the following equation:

$$I_{derated} = \sqrt{(1.1425 - 0.0057 \times T_A)} \times I_{max} \text{ @ } 77°F\ (25°C)$$

Type CL Specifications

NTC discs for inrush current limiting

Description

Disc thermistor with uninsulated lead-wires.

Options

- For kinked leads, add suffix “A”
- For tape and reel, add suffix “B”
- Other tolerances in the range 0.7 Ω to 120 Ω
- Other tolerances, tolerances at other temperatures
- Alternative lead lengths, lead materials, insulations

Data

*maximum rating at 77°F (25°C) or $I_{derated} = \sqrt{(1.1425–0.0057 \times T_A)} \times I_{max}$ @ 77°F (25°C) for ambient temperatures other than 77°F (25°C).

**maximum ratings

***$R_0=XI^Y$ where X and Y are found in the table below

					C_xMax ** (μ Farads)			Equation Constants for resistance under load ***			Approximate Resistance Load at % Maximum Rated						
Type	Resistance @ 25°C (Ω) ±25%	*Max. Steady State Current (Amps RMS)	Max. Disc Dia. in (mm)	Max. Disc Thick. in (mm)	@120 (VAC Rms)	@240 (VAC Rms)	Max. Energy (Joules)	X	Y	Current Range Min I Max I	25%	50%	75%	100%	Dissip. Constant (mW/°C)	Time Constant (sec.)	Max. Current Flow @ 25°C and 240 V Rms (Amps)
CL-11	0.7	12	0.77 (19.56)	0.22 (5.59)	2700	675	19.44	0.5	-1.18	4≤I≤12	0.14	0.06	0.04	0.03	25	100	457
CL-21	1.3	8	0.55 (13.97	0.21 (5.33)	800	200	5.76	0.6	-1.25	3≤I≤8	0.25	0.11	0.06	0.04	15	60	246
CL-30	2.5	8	0.77 (19.56)	0.22 (5.59)	6000	1500	43.20	0.81	-1.25	2.5≤I≤8	0.34	0.14	0.09	0.06	25	100	128
CL-40	5	6	0.77 (19.56)	0.22 (5.59)	5200	1300	37.44	1.09	-1.27	1.5≤I≤6	0.65	0.27	0.16	0.11	25	100	64
CL-50	7	5	0.77 (19.56)	0.26 (6.60)	5000	1250	36.00	1.28	-1.27	1.5≤I≤5	0.96	0.40	0.24	0.17	25	120	46
CL-60	10	5	0.77 (19.56)	0.22 (5.59)	5000	1250	36.00	1.45	-1.3	1.2≤I≤5	1.08	0.44	0.26	0.18	25	100	32
CL-70	16	4	0.77 (19.56)	0.22 (5.59)	5000	1250	36.00	1.55	-1.26	1≤I≤4	1.55	0.65	0.39	0.27	25	100	20
CL-80	47	3	0.77 (19.56)	0.22 (5.59)	5000	1250	36.00	2.03	-1.29	0.5≤I≤3	2.94	1.20	0.71	0.49	25	100	7
CL-90	120	2	0.93 (23.62)	0.22 (5.59)	5000	1250	36.00	3.04	-1.36	0.5≤I≤2	7.80	3.04	1.75	1.18	30	120	3
CL-101	0.5	16	0.93 (23.62)	0.22 (5.59)	4000	1000	28.80	0.44	-1.12	4≤I≤16	0.09	0.04	0.03	0.02	30	120	640
CL-110	10	3.2	0.40 (10.16)	0.17 (4.32)	600	150	4.32	0.83	-1.29	0.7≤I≤3.2	1.11	0.45	0.27	0.19	8	30	32
CL-120	10	1.7	0.40 (10.16)	0.17 (4.32)	600	150	4.32	0.61	-1.09	0.4≤I≤1.7	1.55	0.73	0.47	0.34	4	90	32
CL-130	50	1.6	0.45 (11.43)	0.17 (4.32)	600	150	4.32	1.45	-1.38	0.4≤I≤1.6	5.13	1.97	1.13	0.76	8	30	6
CL-140	50	1.1	0.45 (11.43)	0.17 (4.32)	600	150	4.32	1.01	-1.28	0.2≤I≤1.1	5.27	2.17	1.29	0.89	4	90	6
CL-150	5	4.7	0.55 (13.97)	0.18 (4.57)	1600	400	11.52	0.81	-1.26	1≤I≤4.7	0.66	0.28	0.17	0.12	15	110	64
CL-160	5	2.8	0.55 (13.97)	0.18 (4.57)	1600	400	11.52	0.6	-1.05	0.8≤I≤2.8	0.87	0.42	0.28	0.20	9	130	64
CL-170	16	2.7	0.55 (13.97)	0.18 (4.57)	1600	400	11.52	1.18	-1.28	0.5≤I≤2.7	1.95	0.80	0.48	0.33	15	110	20
CL-180	16	1.7	0.55 (13.97)	0.18 (4.57)	1600	400	11.52	0.92	-1.18	0.4≤I≤1.7	2.53	1.11	0.69	0.49	9	130	20
CL-190	25	2.4	0.55 (13.97)	0.18 (4.57)	800	200	5.76	1.33	-1.34	0.5≤I≤2.4	2.64	1.04	0.61	0.41	15	110	13
CL-200	25	1.7	0.55 (13.97)	0.18 (4.57)	800	200	5.76	0.95	-1.24	0.4≤I≤1.7	2.74	1.16	0.70	0.49	9	130	13
CL-210	30	1.5	0.40 (10.16)	0.2 (5.08)	600	150	4.32	1.02	-1.35	0.3≤I≤1.5	3.83	1.50	0.87	0.59	8	30	11

Selection Criteria for Thermometrics CL-Products

1. I_{max} - Thermometrics CLs are rated for maximum steady state current. The maximum steady current is mainly determined by the acceptable life of the final products for which the thermistor becomes a component. The differential equation Pdt = HdT + $(T - T_A)$dt reduces to Power = I^2R = $(T - T_A)$. An example in the case of a 100 watt power supply with an efficiency rating of 80%, 100% load is calculated to be 125 watts. The maximum input current is calculated from the minimum supply voltage. For a standard 120V supply, this could be rated as low at 110V. Therefore, input current would be calculated by 125 watts/110 V = 1.14 Amps. Selection of the CL should have an I max rating of at least 1.14 Amps.

2. The second step of selection of the CL is to understand the desired maximum inrush current allowable. This is generally specificed by the components in line of the CL, such as the diode bridge. In the case of the diode bridge rated at 200 Amps, one would should select a CL that would limit max surge current to 50% of the rating, therefore limit surge to a maximum of 100 Amps. The listed maximum current flow is rated at 25°C, so derating is required if the ambient temperture is greater than 25°C.

3. The next selection of criteria for the CL is to understand the bulk Capacitance of the device to be protected. On power, the bulk capacitance of the device appears as a short to the system. The designer needs to understand the bulk capacitance at the RMS voltage rating of the system. Assuming the input capacitance is approximately 500 µFds, the selection of the CL needs to be able to absorb input energy.

Using the above criteria, the selection of the CL provides multiple solutions. One would opt for the smallest size CL to achieve the required protection. The selection criteria is as follows:

1. I_{max} >1.14 Amps
2. Max allowable Inrush current 100 Amps
3. Bulk Capacitance listed as 500 µfd
4. Choose smallest physical size that will allow protection for the device.

Criteria indicates that either the CL-150 or CL-160 would be suitable for the application. In the case of the CL-150 less heat is dissipated allowing the operating resistance to drop but at a higher temperature. This increases efficiency of the system but may lead to shorter component life.

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