**NTC THERMISTORS: TYPE CL**

**DESCRIPTION:**
Disc thermistor with uninsulated lead-wires.

**FEATURES:**
- Low cost solid state device for inrush current suppression
- Excellent mechanical strength
- Wide operating temperature range: -50°C to 175°C
- Suitable for PCB mounting
- Available as a standard with kinked leads and on tape and reel to EIA RS-468A for automatic insertion

<table>
<thead>
<tr>
<th>Type Fig.</th>
<th>Res @ 25°C (±25%) ohms</th>
<th>Max* Steady Current (RMS)</th>
<th>Disc Dia. (Max)</th>
<th>Disc Thick. (Max)</th>
<th>Current Range Min. Max.</th>
<th>Approx. Res. Under Load at % Max. Rated Current</th>
<th>Diss. Const. (mW/°C)</th>
<th>Time Const. (sec.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL-11</td>
<td>0.7</td>
<td>12</td>
<td>0.77</td>
<td>0.22</td>
<td>0.328</td>
<td>2700, 600, 0.50, -1.18, 4.05, 1.2, 14, 0.06, 0.04, 0.02</td>
<td>25</td>
<td>100</td>
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<tr>
<td>CL-21</td>
<td>1.3</td>
<td>8</td>
<td>0.55</td>
<td>0.21</td>
<td>0.328</td>
<td>6000, 1500, 0.81, -1.25, 2.5, 1.6, 1.5, 0.65, 0.27, 0.16</td>
<td>15</td>
<td>60</td>
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<td>CL-30</td>
<td>2.5</td>
<td>8</td>
<td>0.77</td>
<td>0.22</td>
<td>0.328</td>
<td>5200, 1300, 1.09, -1.27, 1.5, 1.5, 0.5, 0.27, 0.16, 0.11</td>
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<td>100</td>
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<tr>
<td>CL-40</td>
<td>5</td>
<td>6</td>
<td>0.77</td>
<td>0.22</td>
<td>0.328</td>
<td>5000, 1250, 1.28, -1.27, 1.5, 1.5, 0.96, 0.40, 0.24, 0.16</td>
<td>25</td>
<td>120</td>
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<td>CL-50</td>
<td>7</td>
<td>5</td>
<td>0.77</td>
<td>0.26</td>
<td>0.328</td>
<td>5000, 1250, 1.45, -1.30, 1.2, 1.5, 1.09, 0.44, 0.26, 0.18</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>CL-60</td>
<td>10</td>
<td>5</td>
<td>0.77</td>
<td>0.22</td>
<td>0.328</td>
<td>5000, 1250, 1.55, -1.26, 1.0, 1.5, 1.55, 0.65, 0.39, 0.27</td>
<td>25</td>
<td>100</td>
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<td>CL-70</td>
<td>16</td>
<td>4</td>
<td>0.77</td>
<td>0.22</td>
<td>0.328</td>
<td>5000, 1250, 2.03, -1.29, 0.5, 1.5, 2.92, 1.2, 0.71, 0.49</td>
<td>25</td>
<td>100</td>
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<tr>
<td>CL-80</td>
<td>47</td>
<td>3</td>
<td>0.77</td>
<td>0.22</td>
<td>0.328</td>
<td>5000, 1250, 3.04, -1.36, 0.5, 2.0, 3.78, 3.0, 1.75, 1.18</td>
<td>30</td>
<td>120</td>
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<tr>
<td>CL-90</td>
<td>120</td>
<td>2</td>
<td>0.93</td>
<td>0.22</td>
<td>0.328</td>
<td>4000, 1000, 0.44, -1.12, 4.0, 1.6, 0.09, 0.04, 0.03, 0.02</td>
<td>30</td>
<td>120</td>
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<tr>
<td>CL-110</td>
<td>0.5</td>
<td>16</td>
<td>0.22</td>
<td>0.328</td>
<td>0.328</td>
<td>600, 150, 0.83, -1.29, 0.7, 3.2, 1.1, 0.45, 0.27, 0.18</td>
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<tr>
<td>CL-120</td>
<td>10</td>
<td>3.2</td>
<td>0.40</td>
<td>0.17</td>
<td>0.250</td>
<td>600, 150, 0.61, -1.09, 0.4, 1.7, 1.55, 0.73, 0.46, 0.34</td>
<td>4</td>
<td>90</td>
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<tr>
<td>CL-130</td>
<td>10</td>
<td>1.7</td>
<td>0.40</td>
<td>0.17</td>
<td>0.250</td>
<td>600, 150, 1.45, -1.38, 0.4, 1.6, 5.13, 1.97, 1.13, 0.75</td>
<td>8</td>
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<tr>
<td>CL-140</td>
<td>50</td>
<td>1.6</td>
<td>0.45</td>
<td>0.17</td>
<td>0.250</td>
<td>600, 150, 1.01, -1.28, 0.2, 1.1, 5.27, 2.17, 1.28, 0.89</td>
<td>4</td>
<td>90</td>
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<tr>
<td>CL-150</td>
<td>50</td>
<td>1.1</td>
<td>0.45</td>
<td>0.17</td>
<td>0.250</td>
<td>600, 150, 1.01, -1.28, 0.2, 1.1, 5.27, 2.17, 1.28, 0.89</td>
<td>4</td>
<td>90</td>
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<tr>
<td>CL-160</td>
<td>5</td>
<td>4.7</td>
<td>0.55</td>
<td>0.18</td>
<td>0.328</td>
<td>1600, 400, 0.81, -1.26, 1.0, 4.7, 0.66, 0.27, 0.16, 0.11</td>
<td>15</td>
<td>110</td>
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<tr>
<td>CL-170</td>
<td>16</td>
<td>2.7</td>
<td>0.55</td>
<td>0.18</td>
<td>0.328</td>
<td>1600, 400, 0.60, -1.05, 0.8, 2.8, 0.87, 0.42, 0.27, 0.20</td>
<td>10</td>
<td>130</td>
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<tr>
<td>CL-180</td>
<td>16</td>
<td>2.7</td>
<td>0.55</td>
<td>0.18</td>
<td>0.328</td>
<td>1600, 400, 0.92, -1.18, 0.4, 1.7, 2.52, 1.1, 0.69, 0.49</td>
<td>9</td>
<td>130</td>
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<tr>
<td>CL-190</td>
<td>25</td>
<td>2.4</td>
<td>0.55</td>
<td>0.18</td>
<td>0.328</td>
<td>800, 200, 1.33, -1.34, 0.5, 2.4, 2.63, 1.04, 0.60, 0.41</td>
<td>15</td>
<td>110</td>
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<tr>
<td>CL-200</td>
<td>25</td>
<td>1.7</td>
<td>0.55</td>
<td>0.18</td>
<td>0.328</td>
<td>800, 200, 0.95, -1.24, 0.4, 1.7, 2.74, 1.18, 0.70, 0.49</td>
<td>9</td>
<td>130</td>
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<tr>
<td>CL-210</td>
<td>30</td>
<td>1.5</td>
<td>0.40</td>
<td>0.20</td>
<td>0.250</td>
<td>600, 150, 1.02, -1.35, 0.3, 1.5, 3.83, 1.50, 0.87, 0.60</td>
<td>8</td>
<td>30</td>
</tr>
</tbody>
</table>

**OPTIONS:**
- For kinked leads, add suffix “A”
- For tape and reel, add suffix “B”
- For tape and reel, add suffix “AB”
- Other tolerances in the range 0.7Ω to 12Ω
- Other tolerances, tolerances at other temperatures
- Alternative lead lengths, lead materials, insulations

**DATA:**
*maximum rating at 25°C or
\[ I_{\text{derated}} = \sqrt{(1.1425 - 0.0057 \times T_0)} \times I_{\text{max}} @ 25°C \]
for ambient temperatures other than 25°C.
**maximum ratings
***R_0=X1Y where X and Y are found in the table above

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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 60Hz 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 $R_1$; for 120V, it is approximately $120 \times \sqrt{2}/R_1$. Ideally, during turn-on $R_1$ 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 converter 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 ($V_{peak}/I_{max \, surge}$).
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 $\frac{1}{2}CV^2$. 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 $\frac{1}{2}CV^2$ (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:

Input Energy = Energy Stored + Energy Dissipated

or in differential form:

$$P \, dt = H \, dT + \delta(T - T_A) \, dt$$

where:

- $P$ = Power generated in the NTC
- $t$ = Time
- $H$ = Heat capacity of the thermistor
- $T$ = Temperature of the thermistor body
- $\delta$ = 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 volts and 240 volts. 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:

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

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 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:

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

Inrush Current Limiters