PTC thermistors

SMD inrush current limiter

Series/Type:	**J404**
Ordering code:	**B59404J0170A062**
Date:	2023-02-20
Version:	1

Applications

- Inrush current limiter (charging, discharging resistor) for smoothing and DC link capacitors
- To replace high-power fixed resistors for capacitor charging, discharging
- Discharge resistor for DC link capacitors

Features

- Self-protecting in case of malfunction of short-circuit relay or internal short circuit of capacitor
- Encased PTC thermistor with clamp contacts for high reliability
- For high pulse currents and a high number of operating cycles
- Inrush current limiters are not damaged when directly connected to V_{max} even without additional current limitation
- Reflow solderable according to JEDEC J-STD-020D
- Flame-retardant plastic case, case material UL-listed
- Sn-plated lead-free solder pads
- Manufacturer's logo, type designation and laser printed date code YYWW
- RoHS-compatible

Delivery mode

- Blister tape 380-mm reel with 24-mm tape, taping to IEC 60286-3
- Packing unit: 300 pcs. per reel

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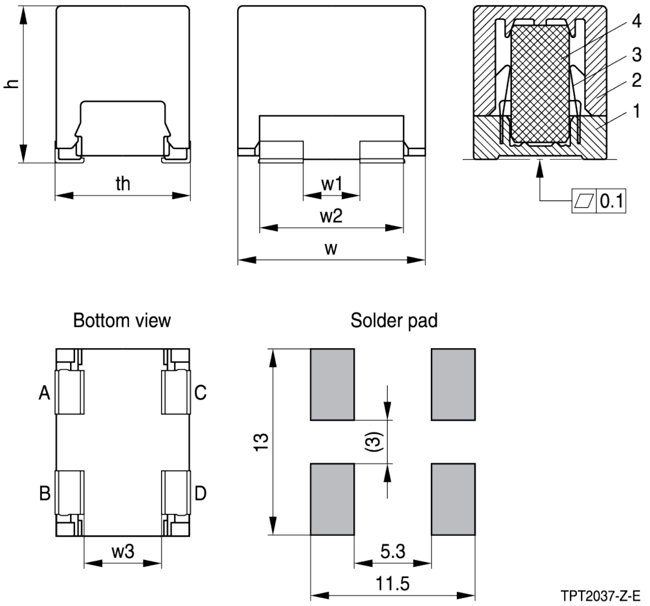
Dimensional drawings

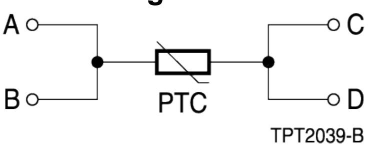


Material

1	Base:	High temperature resistant plastics
2	Cap:	High temperature resistant plastics
3	Spring terminal:	Stainless steel tinned
4	PTC thermistor:	Bariumtitanate

Symbol	Min.	Nom.	Max.	Unit
w			13.5	mm
th			10.0	mm
h			11.0	mm
$\mathbf{w_1}$	3.7	4.0	4.3	mm
$\mathbf{w_2}$	9.7	10.0	10.3	mm
$\mathbf{w_3}$	5.2	5.5	5.8	mm

Circuit diagram



General technical data

Operating cycles at $V_{link, max}$ (charging, discharging of capacitor) [1]	N_c	100 000	cycles
Switching cycles at V_{max} (failure mode) [1]	N_r	100	cycles
Operating temperature range (V = 0)	T_{op}	-40 / +125	°C
Operating temperature range (V = $V_{link, max}$)	T_{op}	-40 / +105	°C

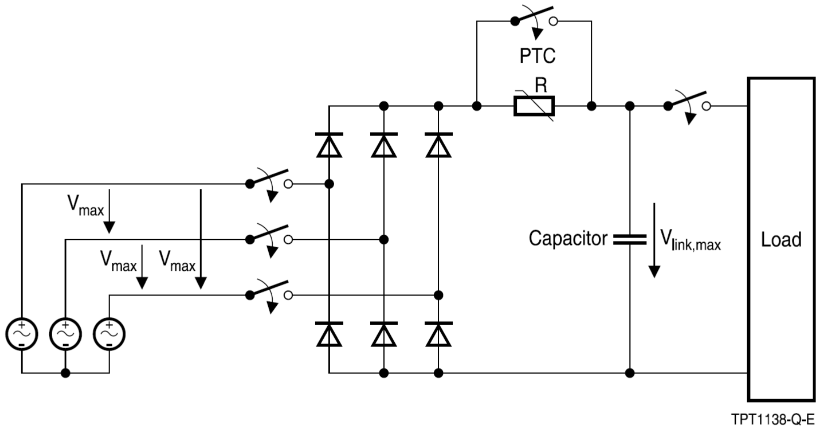
Electrical specifications

Maximum DC link voltage [2]	$V_{link, max}$	500	V_{DC}
Maximum operating voltage [3]	V_{max}	350	V_{AC}
Rated resistance at 25 °C (V_{meas} < 1 V) [1]	R_{25}	500	Ω
Resistance tolerance [1]	ΔR_{25}	±30	%
Minimum PTC resistance at $V_{link, max}$ (typical)	R_{min}	150	Ω
Reference temperature (typical)	T_{ref}	170	°C
Heat capacity (typical) [1]	C_{th}	1	J/K
Thermal time constant (typical) [1]	τ_{th}	100	s

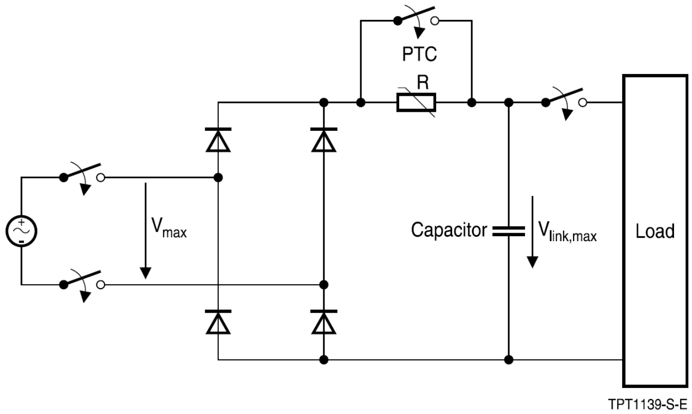
[1] Specification for T_A = 25 °C
[2] $V_{link, max}$ or V_{max} can be applied directly to the PTC – no additional current limitation necessary.
[3] AC voltage source shall be a commercial voltage supply at f = 50/60 Hz. In case of high frequency PTC resistance and break down voltage are reduced.

Circuit diagrams

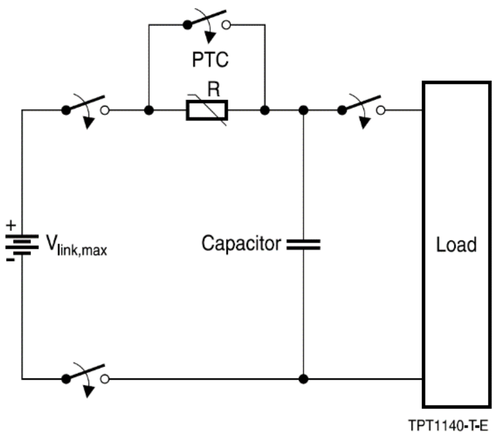
1) Three phases circuit



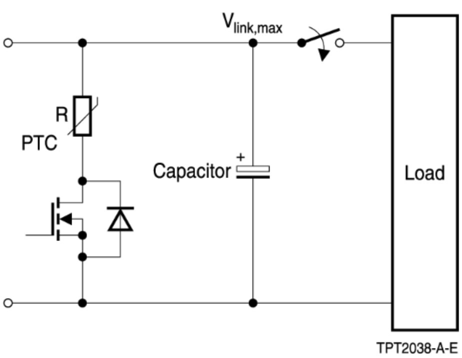
2) Single phase circuit



3) DC circuit



4) Discharging circuit



Calculation of the number of required PTC elements

Number of required PTC elements (connected in parallel) as function of capacitance and charging voltage of smoothing or DC link capacitor.

$$N \geq \frac{K \cdot C \cdot V^2}{2 \cdot C_{th} \cdot \left(T_{ref} - T_{A,max}\right)}$$

K	K factor K = 1 for DC source K = 0.96 for 3-phase bridge rectifier K = 0.76 for single phase bridge rectifier
N	Number of required PTC thermistors connected in parallel
C	Capacitance of smoothing or DC link capacitor in F
V	Charging voltage of capacitor in V
C_{th}	Heat capacity in J/K
T_{ref}	Reference temperature of PTC in °C
$T_{A,max}$	Expected maximum ambient temperature in °C

In case of large N values the resulting resistance of the parallel PTC network might be too low for effective limitation of the charging current. In this case a combination of series and parallel connected PTC thermistors can be used.

In case of discharging application the below equation is to be applied.

$$N \geq \frac{C \cdot \left({V_{link,max}}^2 - {V_{safety}}^2\right)}{2 \cdot C_{th} \cdot \left(T_{ref} - T_{A,max}\right)}$$

$V_{link, max}$	Maximum DC link voltage
V_{safety}	Safety voltage in V

Calculation of the number of applicable charging/ discharging cycles in short time

In case repeated charging/ discharging cycles are applied in short time, the number of cycles N_C shall be limited to avoid unwanted tripping to high-resistance state.

$$N_C \leq \frac{T_{ref} - T_{A,max}}{\Delta T_{PTC}}$$

where

$$\Delta T_{PTC} = \frac{K \cdot C \cdot V^2}{2 \cdot C_{th} \cdot N} \quad \text{(charging) or} \quad \Delta T_{PTC} = \frac{C \cdot \left({V_{link,max}}^2 - {V_{safety}}^2\right)}{2 \cdot C_{th} \cdot N} \quad \text{(discharging)}$$

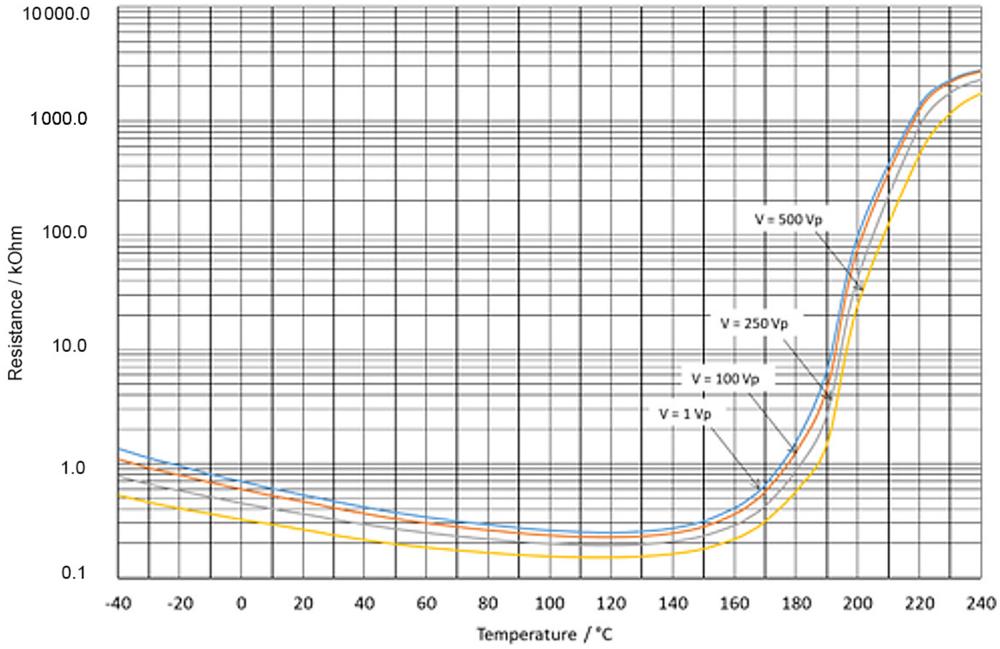
In case of time interval for cooling between cycles, there might be a possibility to reduce number of PTC elements N or increase number of applicable cycles Nc. PTC temperature at the beginning of charging / discharging cycle can be estimated using the below equation, which describes cooling behaviour of PTC elements over time.

$$T_{PTC} = T_A + (T_i - T_A) \cdot \exp\left(-\frac{t}{\tau_{th}}\right)$$

T_{PTC}	PTC temperature in °C
T_i	Initially elevated PTC temperature through charging / discharging cycle in °C
t	Elapsed time in s
τ_{th}	Thermal time constant in s

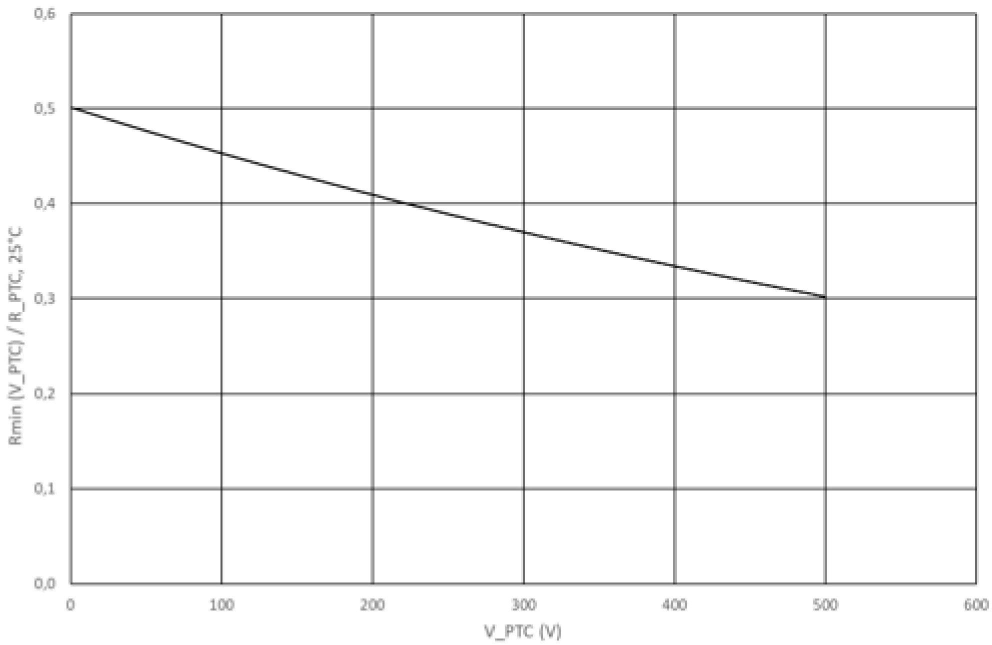
Characteristics (typical)

PTC resistance R_{PTC} versus PTC temperature T_{PTC}

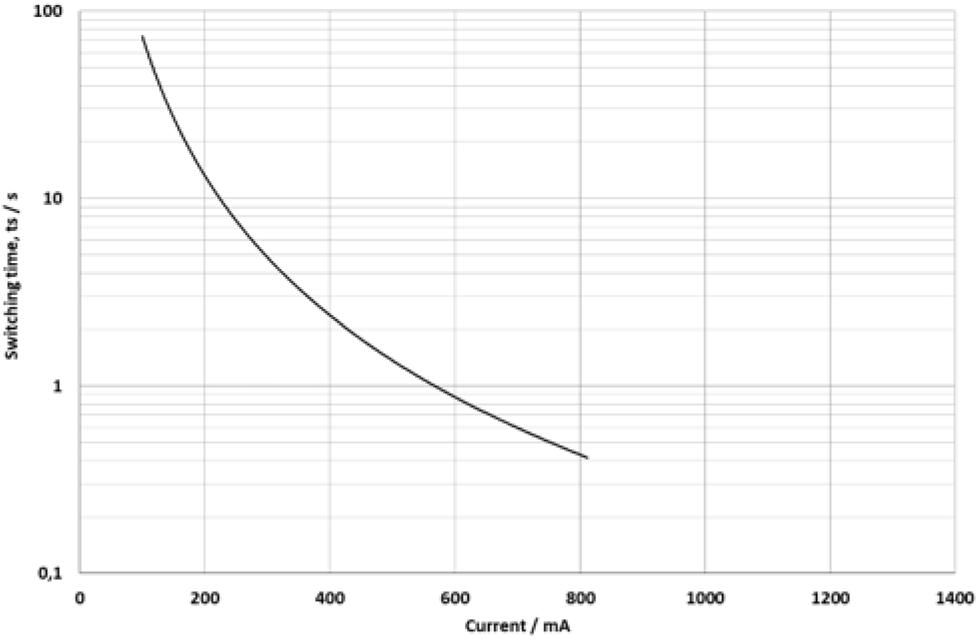


Vp: pulsed voltage

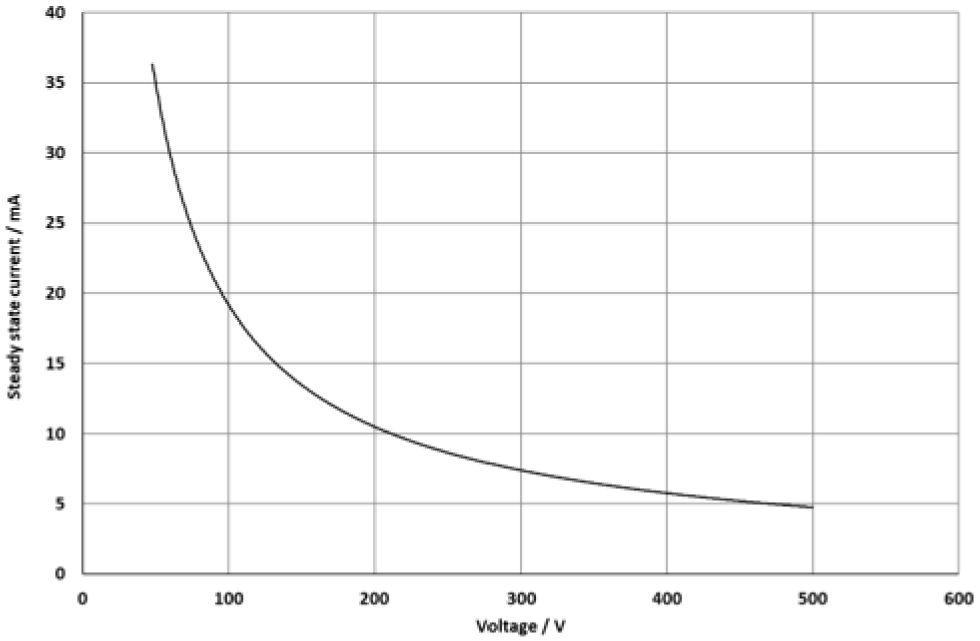
Minimum resistance of PTC versus applied voltage (pulsed)



Switching time t_s versus switching current Is at



Residual current in high-ohmic state I_{res} as function of applied voltage V_{PTC} at 25 °C in still air.

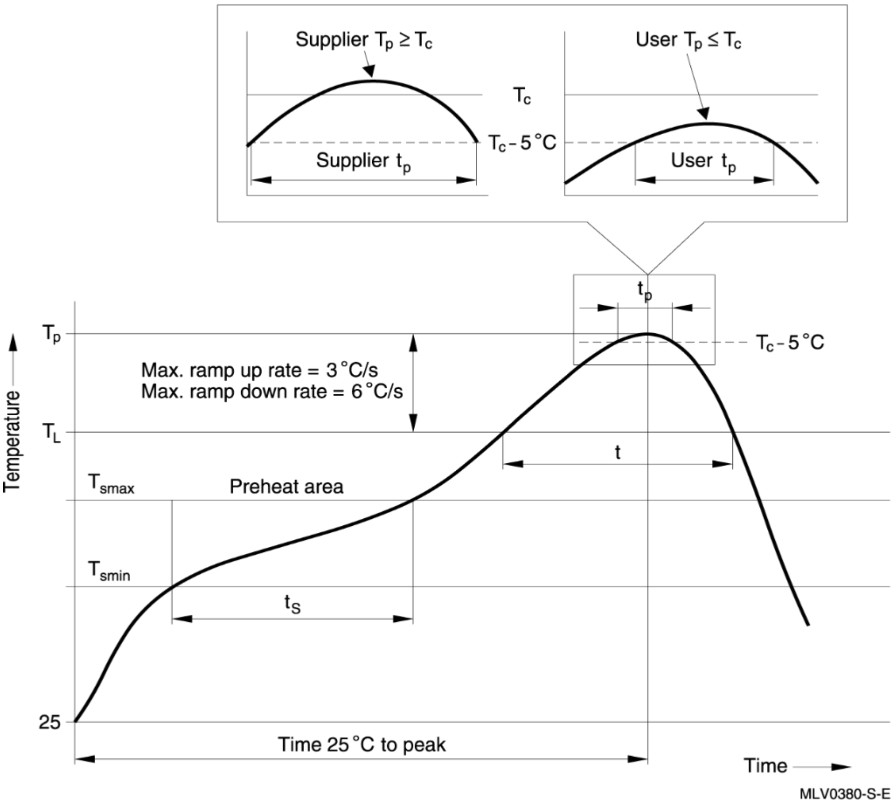


Reliability data

Test	Standard	Test conditions	$\lvert\Delta R_{25}/R_{25}\rvert$
Electrical endurance cycling	IEC 60738-1	Room temperature, $V = V_{link, max}$, applied energy < $C_{th}\cdot(T_{ref} - T_A)$ Number of cycles: 100 000	≤ 25%
Electrical endurance cycling (failure mode)		Room temperature, $V = V_{max}$, $R_S = 0\ \Omega$, $t_{on} = 2$ s, $t_{off} = 600$ s Number of cycles: 100	≤ 25%
Voltage impulse cycling		Room temperature, V = 1000 V_{peak}, t_{rise} = 10 µs, pulse width = 1000 µs, $t_{interval}$ = 60 s, number of cycles: 100	≤ 25%
High temperature exposure	MIL-STD-202 Method 108	1000 h at max. operating temperature +125 °C (V = 0) Measurement at 24 ± 2 h after test	≤ 20%
Temperature cycling	JESD22 Method JA-104	1000 cycles, -55 °C to +125 °C, dwell time = 15 min at each temperature extreme, 1 min. max. transition time Measurement at 24 ± 2 h after test	≤ 25%
Biased humidity	MIL-STD-202 Method 103	1000 h, 85 °C/85% RH, V = 0.05 x V_{max} (10% rated power), measurement at 24 ± 2 h after test conclusion	≤ 20%
Operational life	MIL-STD-202 Method 108	1000 h at max. operating temperature +105 °C, $V = V_{link, max}$, measurement at 24 ± 2 h after test conclusion	≤ 25%
Mechanical shock	MIL-STD-202 – 213 Condition F	a = 15000 m/s², d = 0.5 ms, 3 pulses per axis (6 directions)	≤ 5%
Vibration	MIL-STD-202 Method 204	f = 10 – 2000 – 10 Hz, h = 0.75 mm respective a = 50 m/s² (peak value), duration: 3 x 4 h (3 directions, 4 h/direction)	≤ 5%
Resistance to soldering heat		Reflow soldering, T = 260 -0/+5 °C, t_{peak} = 20 … 40 s, Pb-free EPC 260 N2, soldering 3 times	≤ 20%
ESD	AEC-Q200-002 ISO/DIS 10605	150 pF / 300 Ω, 8 kV contact discharge, polarity +/-, 10 pulses in each polarity	≤ 5%
Solderability	IEC 60068-2-58	Reflow soldering, T = 235 -5/+0 °C, t_{peak} = 30 … 40 s, Pb-free EPC 235 N2, soldering 1 time	≤ 20%
Board flex	AEC-Q200-005	Parameters: d = 2 mm, t = 60 s Remark: measuring of the R-value every 0.1 mm	≤ 5% No mechanical damage
Terminal strength	AEC-Q200-006	F = 17.7 N, apply perpendicular to the longitudinal axis of component, t = 60 + 1 s	≤ 5% No mechanical damage

Recommended soldering profile

Recommended temperature characteristic for reflow soldering following JEDEC J-STD-020D.



Profile feature		Pb-free assembly
Preheat and soak - Temperature min - Temperature max - Time	 T_{smin} T_{smax} T_{smin} to t_{smax}	 +150 °C +200 °C 60 ... 180 s
Average ramp-up rate	T_{smax} to T_p	3 °C/ s max.
Liquidous temperature Time at liquidous	T_L t_L	+217 °C 60 ... 150 s
Peak package body temperature	T_p[1)]	+245 °C ... +260 °C[2)]
Time (tp)[3] within 5°C of specified classification temperature (T_c)	t_p	30 s[3)]
Average ramp-down rate	T_p to T_{smax}	6 °C/ s max.
Time +25 °C to peak temperature		max. 8 minutes

[1)] Tolerance for peak profile temperature (T_P) is defined as a supplier minimum and a user maximum.

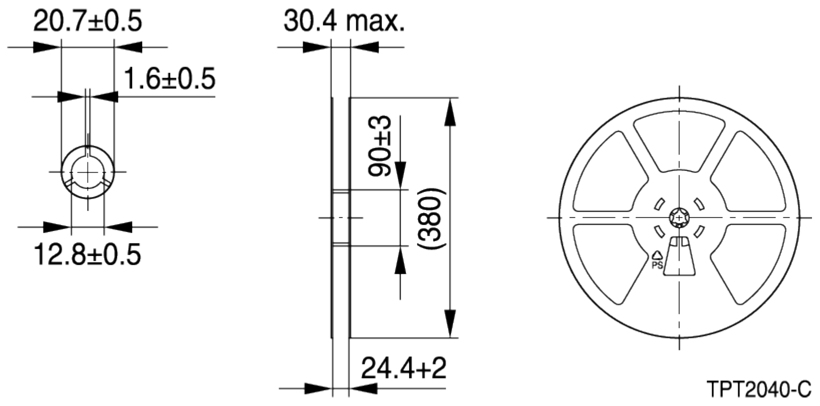
[2)] Depending on package thickness. For details please refer to JEDEC J-STD-020D.

[3)] Tolerance for time at peak profile temperature (t_P) is defined as a supplier minimum and a user maximum.

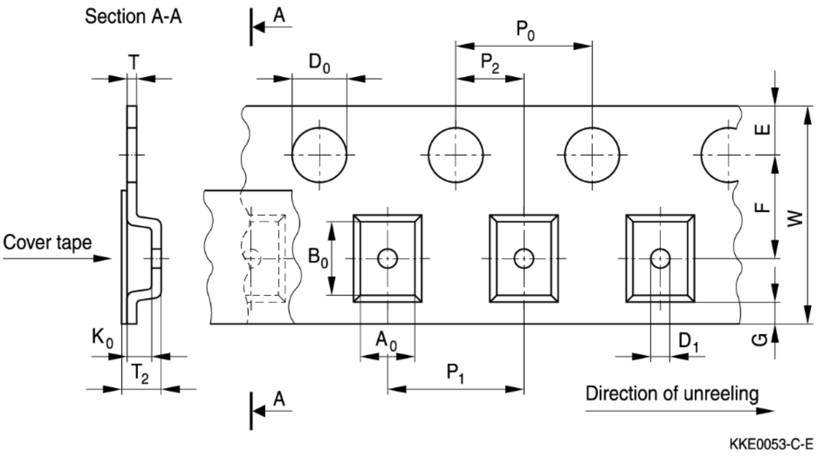
Note: All temperatures refer to topside of the package, measured on the package body surface.

Number of reflow cycles: 3. soldering on PCB must be performed with lead free solder.
Material with content of lead is not allowed to be used.

Packaging: Blister tape, 380 mm reel, 24 mm tape, 300 pcs. per reel



Blister / Carrier



Description	Symbol	Measure mm	Tolerance mm
Tape width	W	24.0	±0.3
Carrier tape thickness	T	0.5	
Overall thickness	T2		max.
Pitch of the sprocket holes	P_{0^*}	4.0	±0.1
Pitch of component compartment	P_1	20	±0.1
Dimension (centre to centre)	P_2	2.0	±0.1
Diameter of sprocket holes	D_0	1.5	+0.1
Distance upper edge of tape - centre sprocket hole	E	1.75	±0.1
Distance between centre of sprocket hole - centre of cavity	F	11.5	±0.1
Distance cavity - end of tape	G	0.75	min.
Component compartment	A_0	11.3	±0.2
	B_0	14.4	±0.2
	K_0	11.4	±0.2

Material: Polystyrene, antistatic, black for blister tape
Polystyrene for reel

Cautions and warnings

General

- TDK Electronics thermistors are designed for specific applications and should not be used for purposes not identified in our specifications, application notes and data books unless otherwise agreed with TDK Electronics during the design-in-phase.
- Ensure suitability of thermistor through reliability testing during the design-in phase. The thermistors should be evaluated taking into consideration worst-case conditions.

Storage

- Store thermistors only in original packaging. Do not open the package prior to processing.
- Storage conditions in original packaging: storage temperature -25°C ... +45°C, relative humidity ≤75% annual mean, maximum 95%, dew precipitation is inadmissible.
- Avoid contamination of thermistors surface during storage, handling and processing.
- Avoid storage of thermistor in harmful environment with effect on function on long-term operation (examples given under operation precautions).
- Use thermistor within the following period after delivery:
  - Through-hole devices (housed and leaded PTCs): 24 months
  - Motor protection sensors, glass-encapsulated sensors and probe assemblies: 24 months
  - Telecom pair and quattro protectors (TPP, TQP): 24 months
  - Leadless PTC thermistors for pressure contacting: 12 months
  - Leadless PTC thermistors for soldering: 6 months
  - SMDs in EIA sizes 3225 and 4032, and for PTCs with metal tags: 24 months
  - SMDs in EIA sizes 1210 and smaller: 12 months

Handling

- PTCs must not be dropped. Chip-offs must not be caused during handling of PTCs.
- The ceramic and metallization of the components must not be touched with bare hands. Gloves are recommended.
- Avoid contamination of thermistor surface during handling.

Soldering (where applicable)

- Use rosin-type flux or non-activated flux.
- Insufficient preheating may cause ceramic cracks.
- Rapid cooling by dipping in solvent is not recommended.
- Complete removal of flux is recommended.
- Standard PTC heaters are not suitable for soldering.

Mounting

- Electrode must not be scratched before/during/after the mounting process.
- Contacts and housing used for assembly with thermistor have to be clean before mounting. Especially grease or oil must be removed.
- When PTC thermistors are encapsulated with sealing material, the precautions given in chapter "Mounting instructions", "Sealing and potting" must be observed.
- When the thermistor is mounted, there must not be any foreign body between the electrode of the thermistor and the clamping contact.
- The minimum force and pressure of the clamping contacts pressing against the PTC must be 10 N and 50 kPa, respectively. In case the assembly is exposed to mechanical shock and/ or vibration this force should be higher in order to avoid movement of the PTC during operation.
- During operation, the thermistor’s surface temperature can be very high. Ensure that adjacent components are placed at a sufficient distance from the thermistor to allow for proper cooling at the thermistors.
- Ensure that adjacent materials are designed for operation at temperatures comparable to the surface temperature of thermistor. Be sure that surrounding parts and materials can withstand this temperature.
- Avoid contamination of thermistor surface during processing.

Operation

- Use thermistors only within the specified temperature operating range.
- Use thermistors only within the specified voltage and current ranges.
- Environmental conditions must not harm the thermistors. Use thermistors only in normal atmospheric conditions. Avoid use in deoxidizing gases (chlorine gas, hydrogen sulfide gas, ammonia gas, sulfuric acid gas etc), corrosive agents, humid or salty conditions. Contact with any liquids and solvents should be prevented.
- Be sure to provide an appropriate fail-safe function to prevent secondary product damage caused by abnormal function (e.g. use VDR for limitation of overvoltage condition).

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