BE1M13VES

Manufacturing of Electrical Components

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Overview

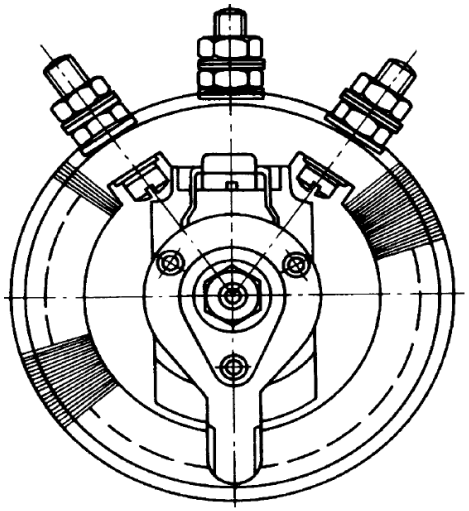
TOPIC

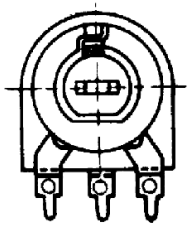
Variable resistors

Types:

- potentiometers (for controls - a lot of cycles),
- trimmers (for settings - a few of cycles).

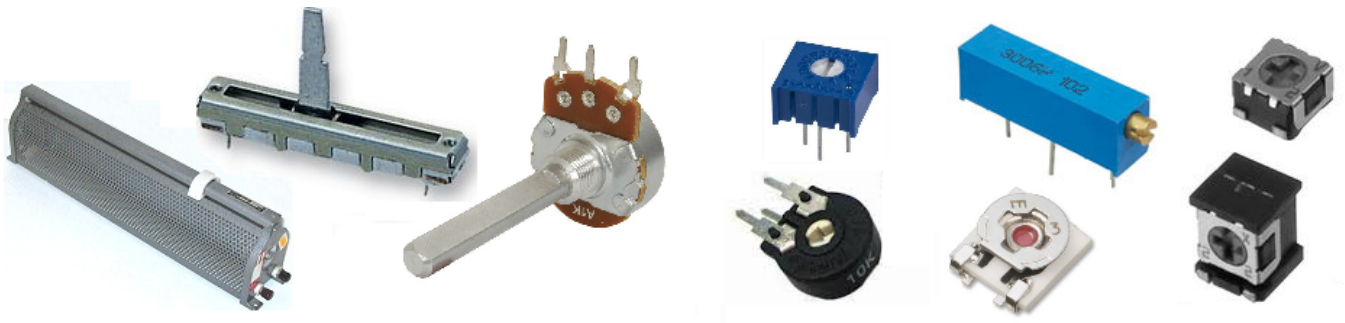
- Design of variable resistors is based on slider (wiper) moving or rotating above a resistive track.



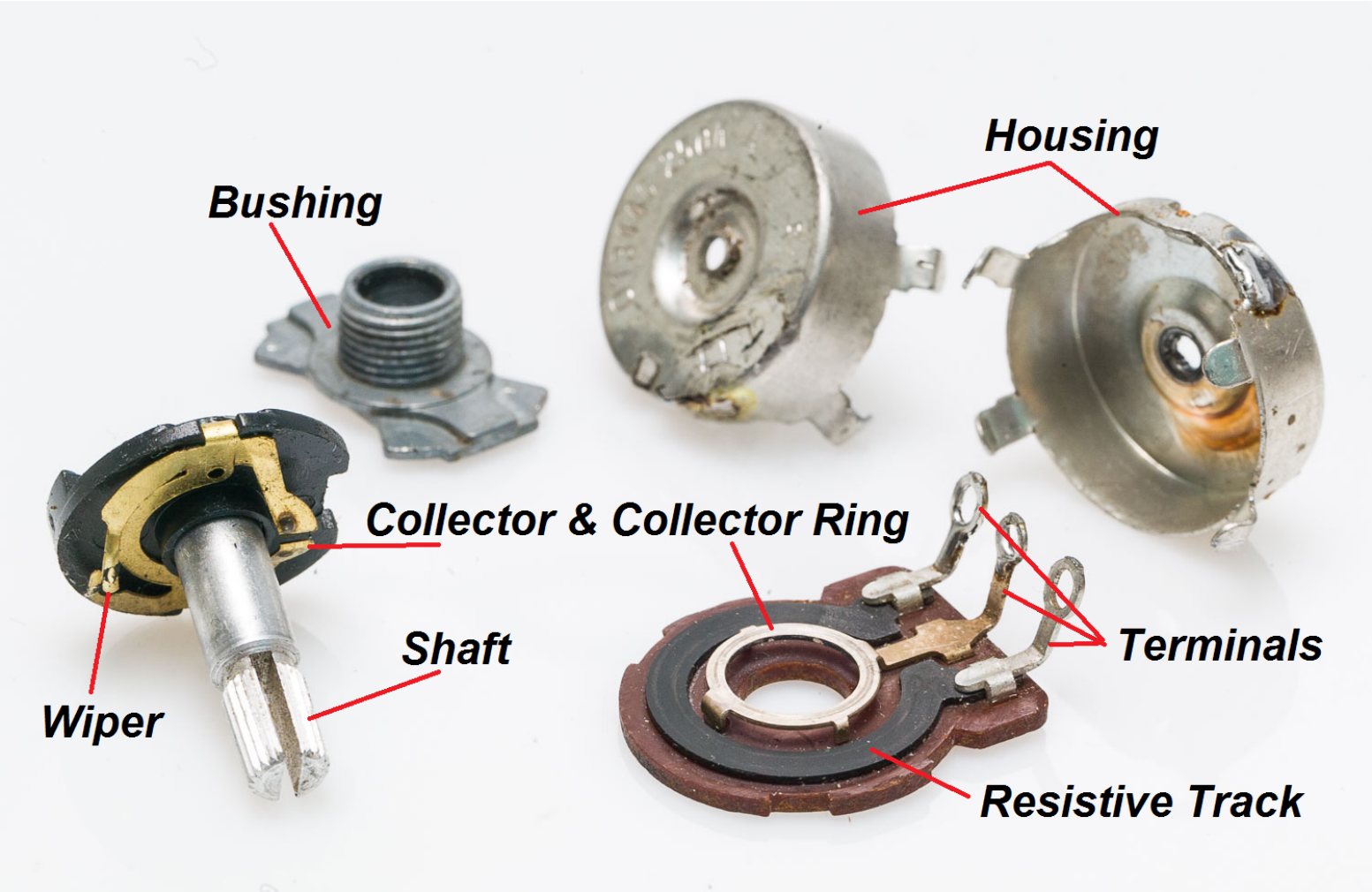


Parameters

- Similar parameters to normal resistors
- Values from sets E6 or E12
- Resistivity of layer tracks can be between 100 Ω and 5 MΩ
- Resistivity of wired tracks can be between 1 Ω and 100 kΩ
- Common tolerance (accuracy) is 20 %, in case of special usage 0.3 %,
- Several constructions:



Disassembly

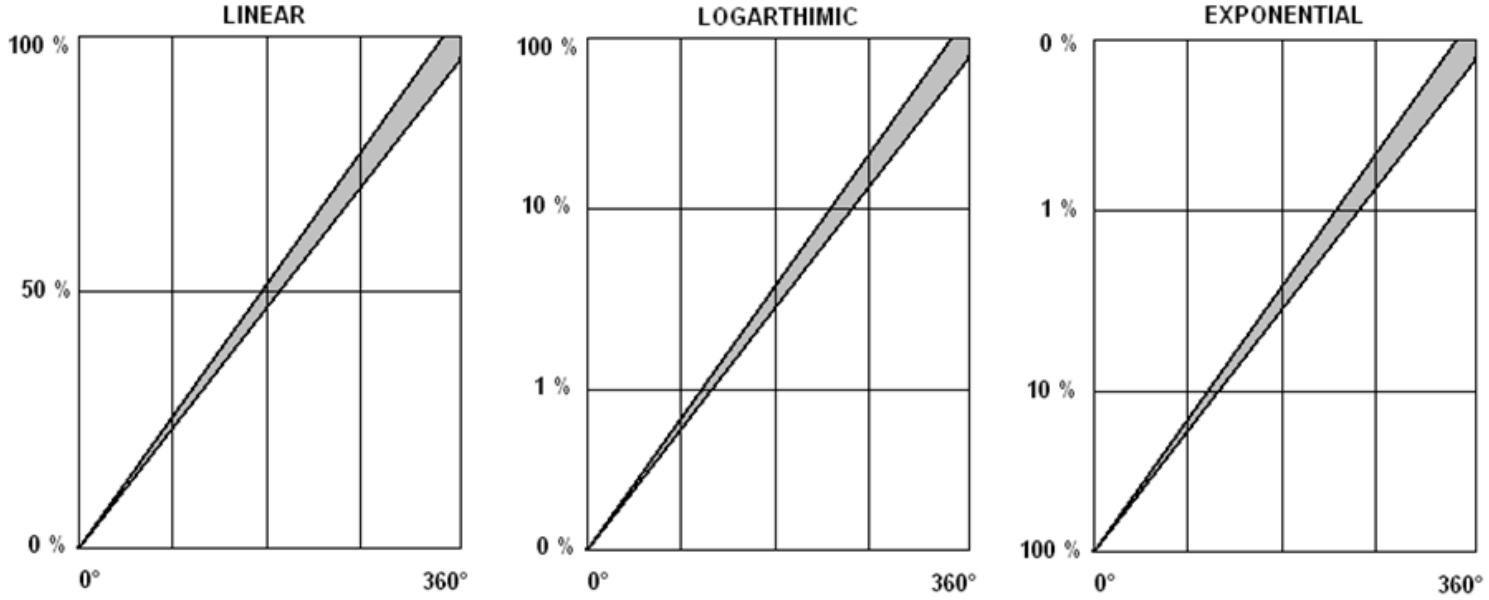


Technology

Track: wire, varnished ceramic, conductive plastic (carbon), cermets (ceramics + metal)

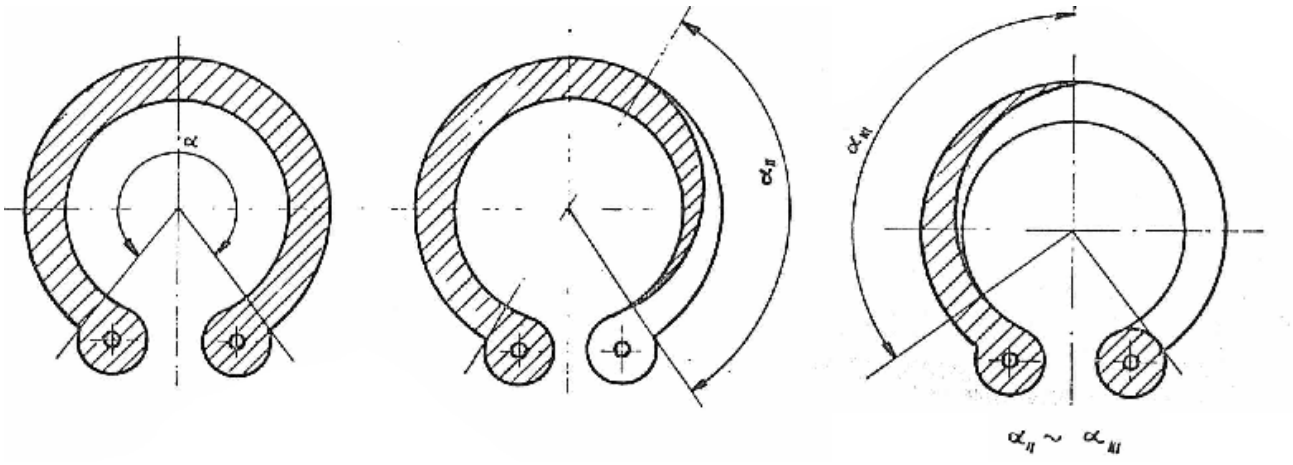
Wiper: metal or with carbon layer, small transient resistivity is required

Track Profile: linear, logarithmic, exponencial



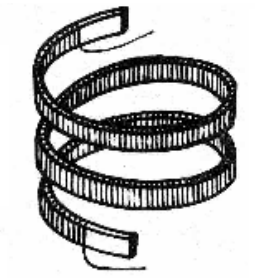
Design of Resistive Track

Nonlinear resistive track is made from several layers.

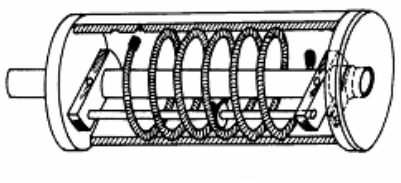


- The first layer is applied on an insulating pad, other layers are made on the previous one.
- Bottom layer has the highest resistivity, the top layer has the lowest resistivity.

Multiturn Potentiometers - ARIPOT and similars



carrier with winding of square cross-section



helixial design of variable resistor

- Collector moves along helix winding or resistive track.
- The track can be long in comparison to common flat design.
- Collector must be able of axial movement - very precise construction, wiper in form of a roller.

Layers Overview

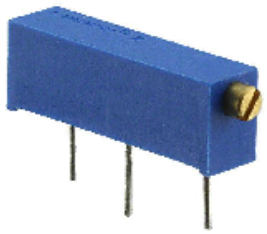
Varnished Track: layer is sprayed or print via screen from a mixture of varnish and carbon filler.

Cermets Track: resistive layer is made from burned paste on a ceramic basis. Layers are made by screen-printing technology (silk-screen printing). Only linear profile can be made.

Tracks from conductive plastics: tracks have a large cross-section area, they are abrasion-proof, also tracks with non-linear profile can be made.

Trimmers

- Basic principle is the same for potentiometers as for trimmers.
- Trimmers usually don't have shaft and knob, setting in done manually by some tool (e.g. screwdriver).
- Design is simplified - without cover, trimmers used to be fixed by outlets (missing armature/chassis).
- Long-life operation is not expected, trimmers are used just for settings.



Comparison of different types of variable resistors

	carbon	**cermets**	**wired**	**multiturn**	**plastic**	**cermets**
accuracy of track	10%	1%	1%	0.1%	10%	1%
whisper signals	1 μV/V	10 μV/V	none	none	100 μV/V	100 μV/V
max. power	1 W	1 W	1 kW	1 W	1 W	2-3 W
life-time (cycles)	$10^4 - 10^5$	$10^4 - 10^5$	$10^4 - 10^5$	10^7	10^8	100
stability	10%	1%	1%	0.1%	0.5%	1%

TOPIC

Nonlinear Resistors

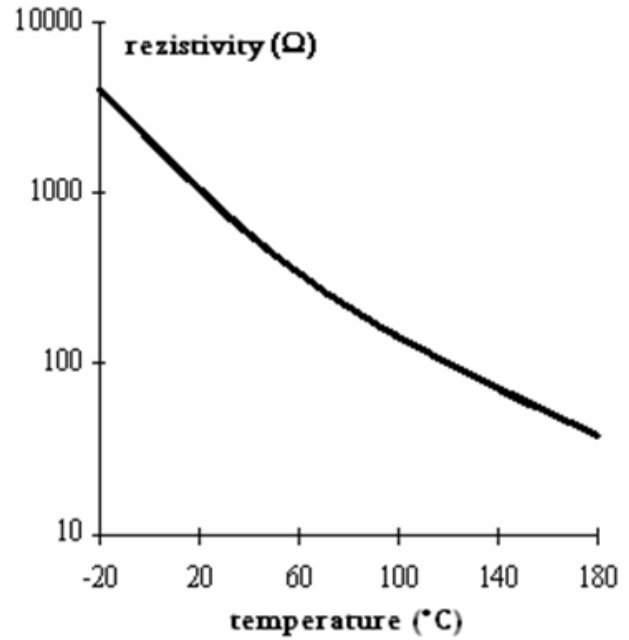
- thermistors (NTC, PTC).
- voltage depended resistors (VDR) - varistors.
- photoresistors.

NTC Thermistor

NTC = negative temperature coefficient

$$R = A \cdot e^{\frac{B}{T}}$$

- A... Resistivity for infinity temperature
- B... Material parameter
- T... Thermodynamic temperature



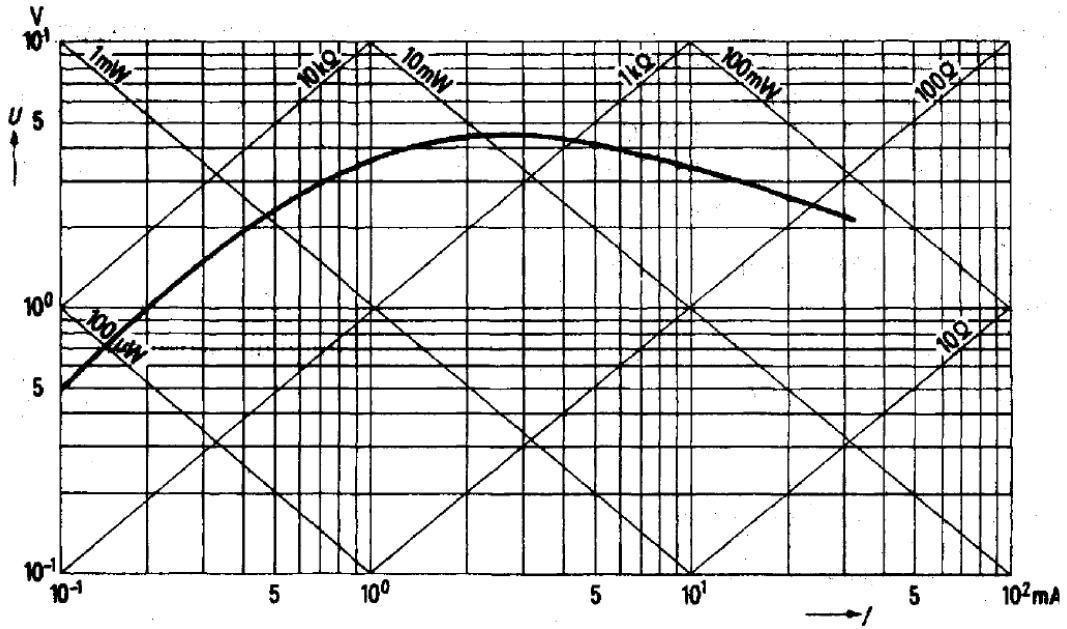
NTC Thermistor

Parameters A, B

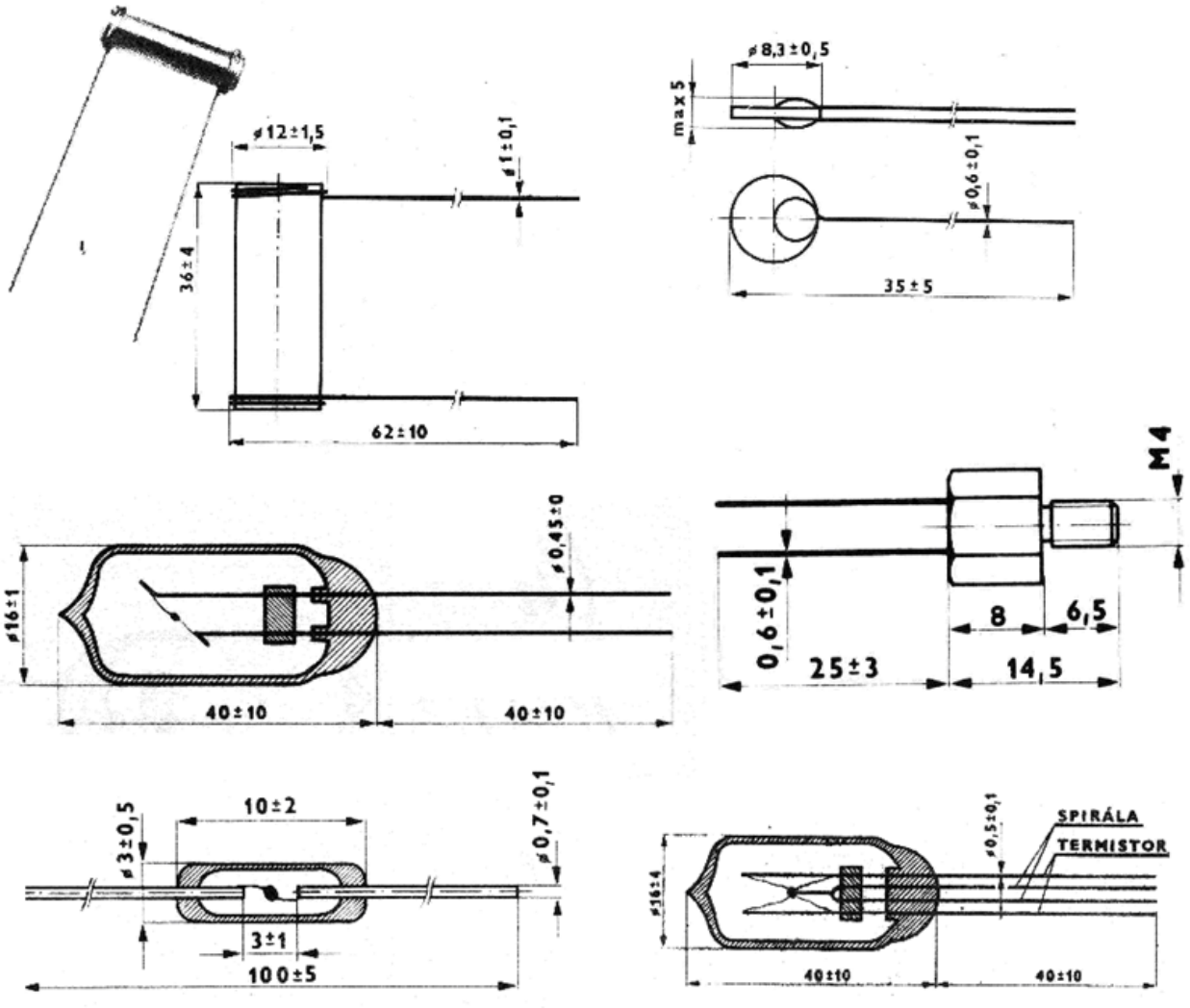
$$ln(R) = ln(A) + \frac{B}{T}$$

This is a linear function of $ln(R)$ in dependency to $\frac{1}{T}$

VA - characteristic: affected by self heating.



Packages Examples



Design of NTC Thermistors

- shapes similar to: pales, tablets, small pearls,
- materials: polycrystalline semiconductors plus oxides of *Mn*, *Ni*, *Cu*, *Co*, *Cr*, *Ti*, *W*, (in the past often used UO_2, TiO_2, CuO). Minced mixture of oxides must be homogenous and well mixed.

Pales and tablets:

- pressed under big stress (600 kg/cm^2) into required shapes,
- burning at temperature 1000 °C (up to 1400 °C) in oxidation atmosphere,
- soldering of *Cu* outlets by *Ag* paste.

Design of NTC Thermistors

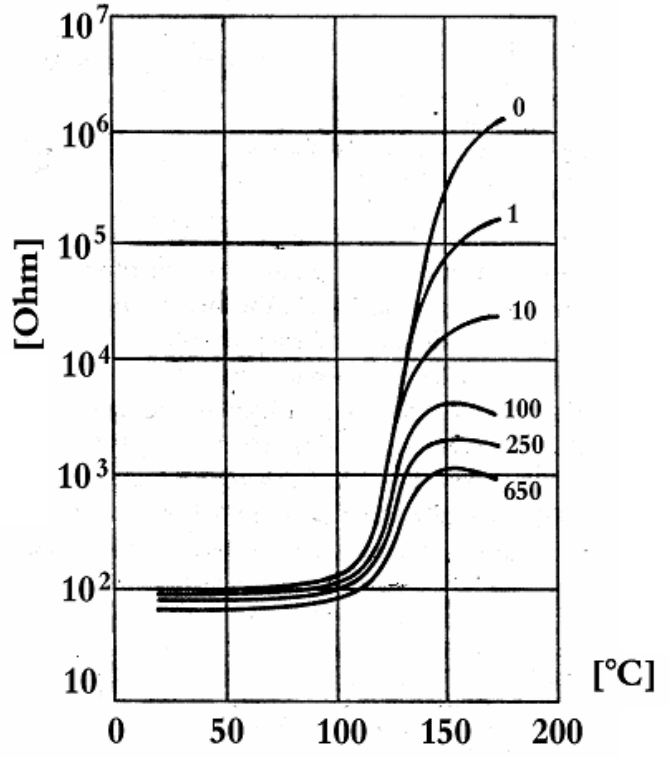
Small pearls:

- between two wires of Pt-alloy (with diameter $25 - 100$ μm) is putted a drop of minced mixture,
- burning at temperature 1000 °C (up to 1400 °C),
- encapsulation into glass (thermometers) or vacuum capsule,
- important is artificial aging to stabilizing electric features.

PTC Thermistors

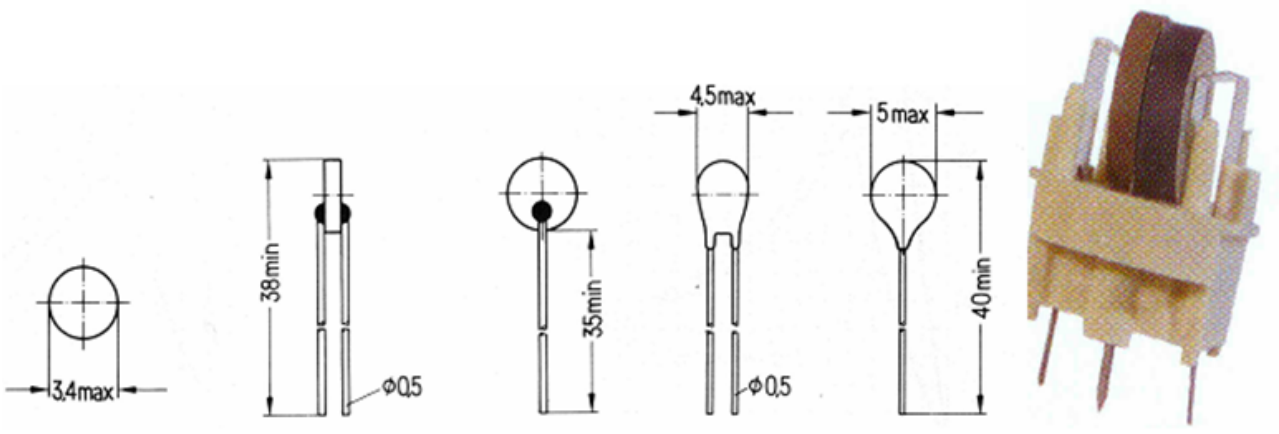
PTC = positive temperature coefficient, at cold-state low impedance, at hot-state high impedance. This effect is caused by ferroelectric material and changes of its permittivity.

- **low temperature** = ferroelectric domains exhibit high electrical strength - conductive low impedance state,
- **high temperature** = ferroelectric domains exhibit lower permittivity and lower electric strength - high impedance state.
- **PTC** are both voltage and frequency dependent devices.



Design of PTC Thermistors

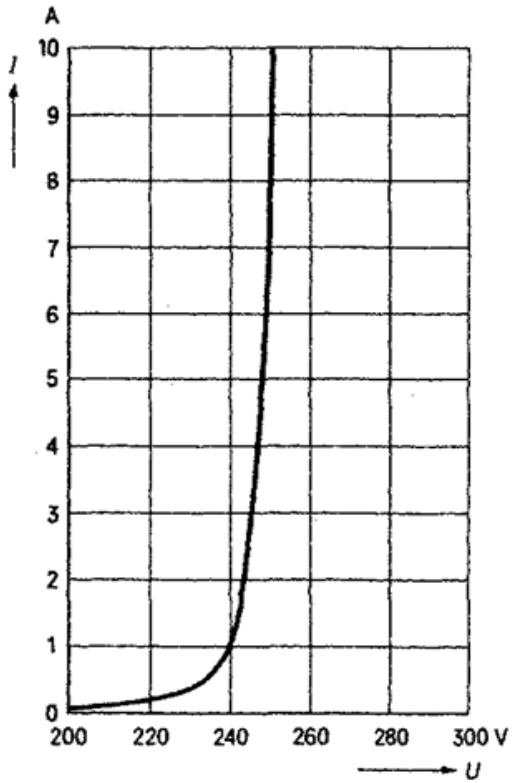
- used shapes: pales and tables again,
- materials: burned mixture of $BaCO_3$, $SrCO_3$, La_2O_3, TiO_2, SiO_2,
- processing: minced mixture is formed under a big stress; burning at the temperature 1100 °C starts calcinations process; than second mincing and final burning/annealing at 1400 °C for 2 hours; soldering of *Cu* outlets (wires).



Varistors

- B... Material parameter
- resistor made from polycrystalline semiconductor,
- fast increase of flowing current after achieving of breakdown voltage,
- decrease of impedance is caused by increase of electrical strength between domains of semiconductor,
- fast response in the order of 50 ns,
- at higher frequencies VDR behaves as capacitor with big power loss.

$$I = B \cdot V^{\alpha}$$



Design of Varistor

- shape: typically tablets, pressed from a mixture of polycrystalline semiconductor,
- material: *SiC* (old), now *ZnO* with *MnO*, Sb_2O, *MgO*, Bi_2O_3 and fixed with a glass fibers,
- outlets: burned *AgPd* pads and soldered *Cu* wires outlets,
- covering: synthetic or epoxy resin.