

Trends in Energy Varistors

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Product range

Piezo and Protection Devices Business Group

- Leaded and Energy varistors
- Strap and block varistors
- Inrush Current Limiters (ICL)
- PTC thermistors (overload, telecom & motor start)

Aluminum & Film

Capacitors Business Group

- DC film capacitors
- PFC and PEC capacitors

Sensors Business Group

- Sensor systems for automotive elect.
- Cable sensors for home appliances

Certification

ISO 9001, ISO/TS 16949,
ISO 14001



49,000 m², founded in 1998



Energy Varistor Standard Range



- Diameter: 28 to 115 mm
- Rated voltage: 1kV to 6kV
- Height: 7mm ~ 44mm
- Surge currents: 65kA to 100 kA (4/10 μ s)
- Energy absorption: 150A to 3,200A (2 ms)

Energy Varistor Production Flow (1)

1. Powder production



2. Pressing



3. De-carbonization



4. Sintering



5. Glass-coating



6. Tempering



Energy Varistor Production Flow (2)

7. Grinding



8. Ultrasonic cleaning



9. Schooping



10. Electric test



11. Packing



12. Outgoing inspection



Trends in energy varistors

- DC application
- High gradient
- Size reduction
- High-impulse energy handling capability (4/10 μ s, 2 ms)
- Low power loss at high temperatures (for example $\sim 150^{\circ}$ C or $\sim 200^{\circ}$ C)

EPCOS new DC energy varistors

Solutions for new DC energy varistor:

- 1.Optimizing the recipe
- 2.Optimizing powder production process
- 3.Optimizing heat treatment process

●EPCOS new DC energy varistors can meet IEC60099-9 requirement on both polarity reversal DC ageing test and unipolar DC ageing test.

●EPCOS has started mass production of the new DC energy varistors since 2014.

Polarity reversal DC ageing test of E99NR702D

Test procedure a) and criterion for polarity reversal DC ageing test according to IEC60099-9 as below:

- P_0 be measured at 30~60min, positive polarity
- P_1 be measured at 24h, positive polarity, change to negative polarity after reading
- P_2 be measured at 24.5h, negative polarity
- ...
- P_7 be measured at 360h, negative polarity, change to positive polarity after reading
- P_8 be measured at 360.5h, positive polarity
- P_9 be measured at 1000h~1100h, positive polarity
- $P_1 \dots P_9 \leq 1.1 * P_0$

P/P_0	Typical value
P_1/P_0	0.79
P_2/P_0	0.86
P_3/P_0	0.72
P_4/P_0	0.76
P_5/P_0	0.69
P_6/P_0	0.75
P_7/P_0	0.68
P_8/P_0	0.82
P_9/P_0	0.68

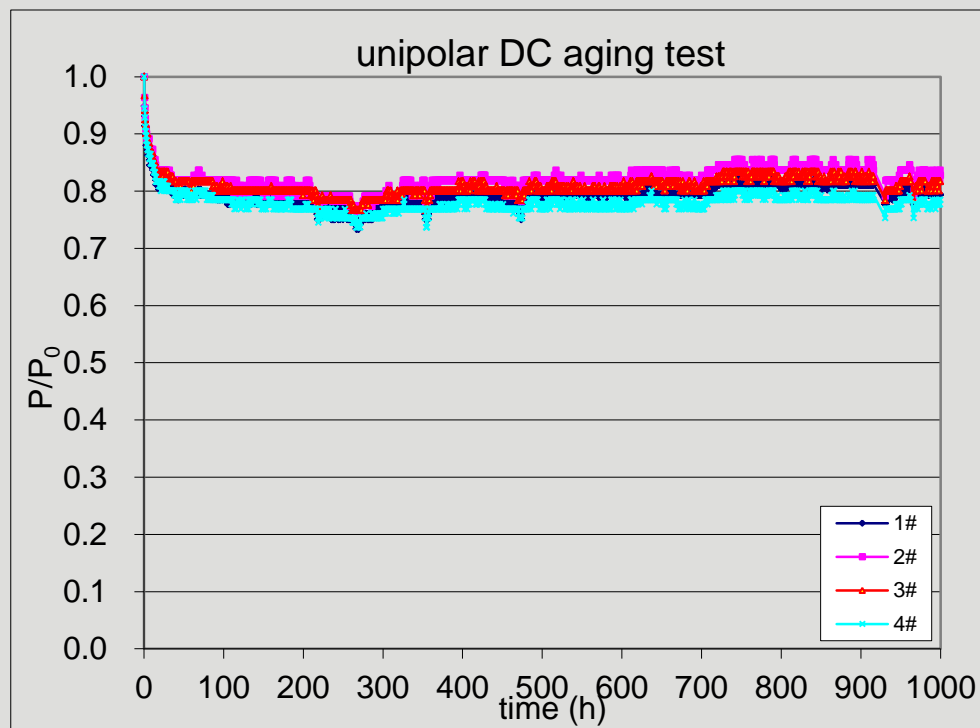
Unipolar DC ageing test of E99NR702D

Criterion for unipolar DC ageing test according to IEC60099-9 as below:

- P_0 be measured at 30~60min
- P_1 be measured at 100h
- ...
- P_{10} be measured at 1000h~1100h
- $P_1 \dots P_{10} \leq 1.1 * P_0$
- $P_{10} \leq 1.3 * \min\{P_1 \dots P_9\}$

Typical unipolar DC ageing test results of E99NR702D as below:

- $P_{10} / P_0: \sim 0.81$
- $P_{10} / \min\{P_1 \dots P_9\}: \sim 1.04$

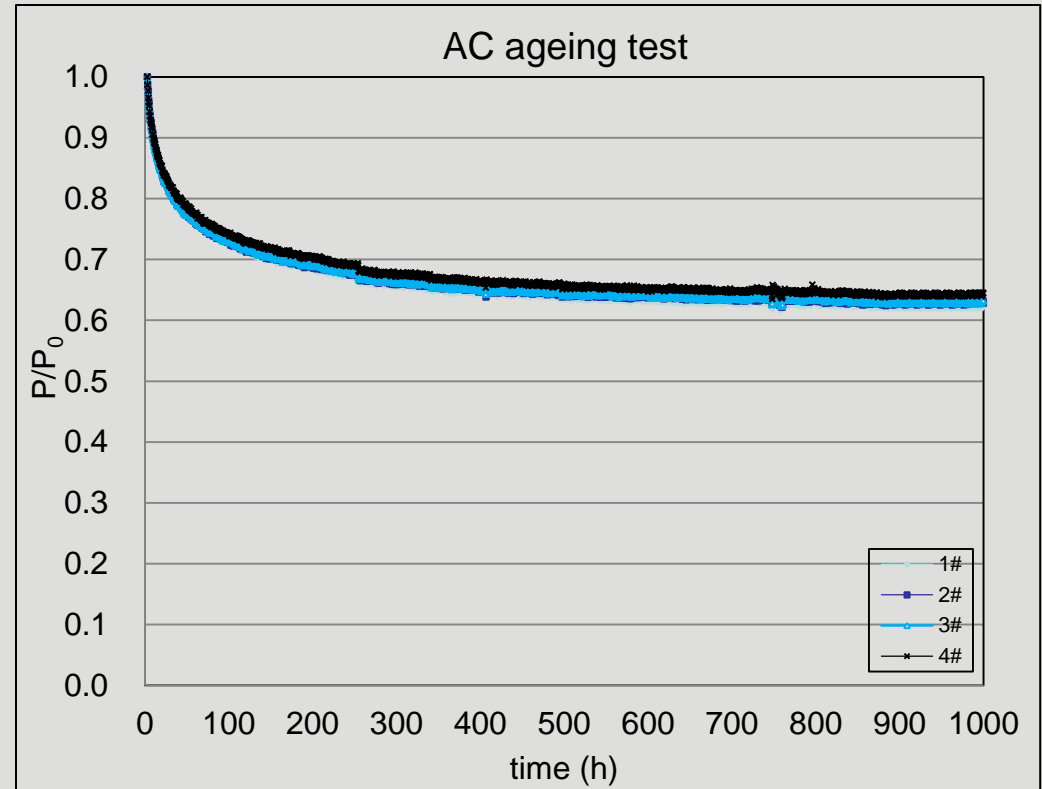


AC ageing test of E99NR702D

Criterion for AC ageing test according to IEC60099-4 as below:

- P_{start} be measured at $3\text{h} \pm 15\text{min}$
- P_{end} be measured at $1000\text{h} \sim 1100\text{h}$
- P_{min} is the lowest power loss during test period
- All $P \leq 1.1 * P_{\text{start}}$
- All P after $P_{\text{min}} \leq 1.3 * P_{\text{min}}$

Power loss show permanent decreasing trend in 1000h AC ageing test for E99NR702D.



EPCOS high gradient energy varistor

Solutions for high gradient energy varistor:

1. Adding some rare earth elements which inhibit grain growth
2. Increasing the amount of additives which can inhibit grain growth
3. Reducing the amount of additives which can promote grain growth
4. Optimizing the powder production process to get finer particles
5. Using lower maximum sintering temperatures

EPCOS has started mass production of high gradient energy varistor since 2009 and ultra-high gradient energy varistor is under development.

Series	$U_{1mA,DC}/\text{height}$ (V/mm)
Standard	~ 200
High gradient	~ 400
Ultra-high gradient	~ 600

EPCOS solution for improving 4/10 μ s performance

Typical 4/10 μ s test failure



Solutions for improving 4/10 μ s performance:

- 1.Reducing the stress caused by temperature distribution – more homogeneous microstructure and higher thermal conductivity
- 2.Improving the ceramic mechanical strength – optimizing the recipe and process, reducing the loss of elements during sintering
- 3.Using a glaze coating or other coating with high insulating properties

4/10 μ s performance of EPCOS parts

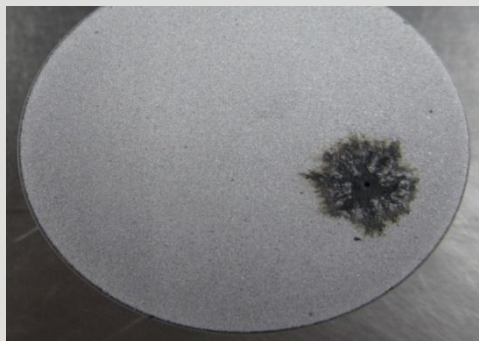
Typical 4/10 μ s performance of EPCOS parts with standard gradient:

- E28 --- 70kA, 2 impulses
- E32 --- 90kA, 2 impulses
- E36 --- 105kA, 2 impulses
- E41 --- 140kA (up to 4kV), 2 impulses

EPCOS has started mass production of above types since 2012.

EPCOS solutions for improving 2 ms performance

Typical 2ms test failure

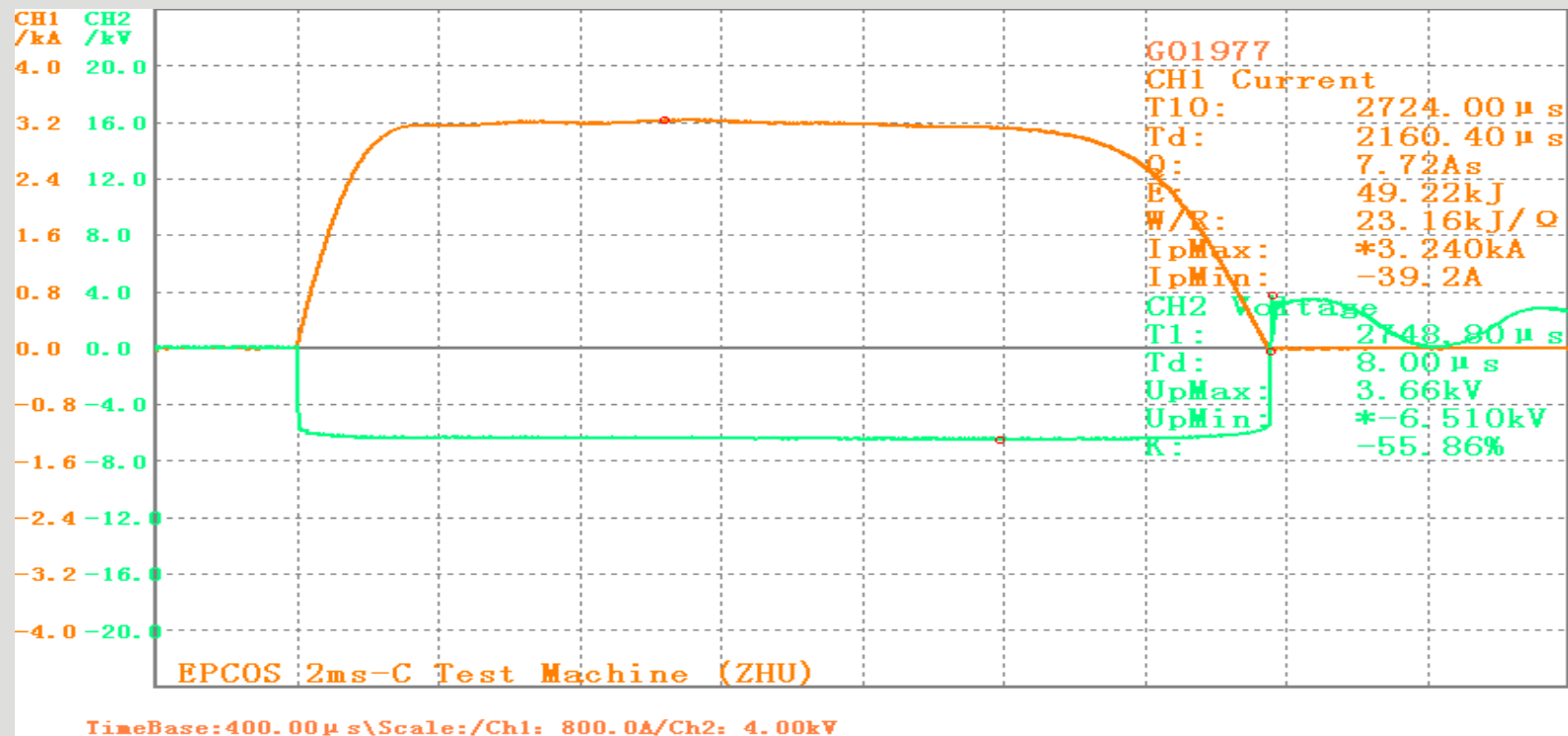


Solutions for improving 2ms performance:

- 1.Improving powder production
- 2.Optimizing heat treatment process
- 3.Precise geometry of Al metallization
- 4.Reducing defects at edge
- 5.Reducing ceramic diameter deviation

2 ms performance of E99NR702

E99NR702 (standard gradient) can pass 18 impulses 2ms at 3200A, or 20 impulses 7.0As charge test. EPCOS has started mass production since 2010.



EPCOS solution for low power loss at high temperature

Low power loss at high temperature ($\sim 200^{\circ}\text{C}$) is a precondition for reducing size and improving 4/10 μs & 2 ms specifications.

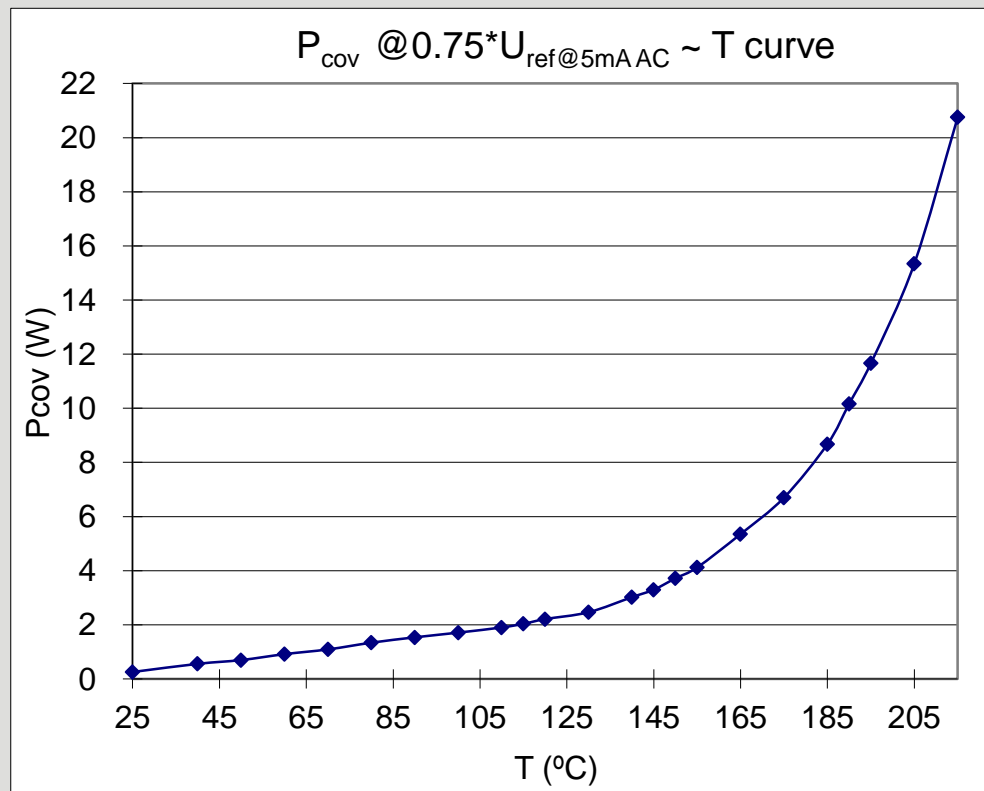
EPCOS solutions for low power loss:

1. Optimizing the recipe
2. Optimizing the sintering profile
3. Optimizing the heat-treatment process

EPCOS has started mass production of low power loss types since 2010.

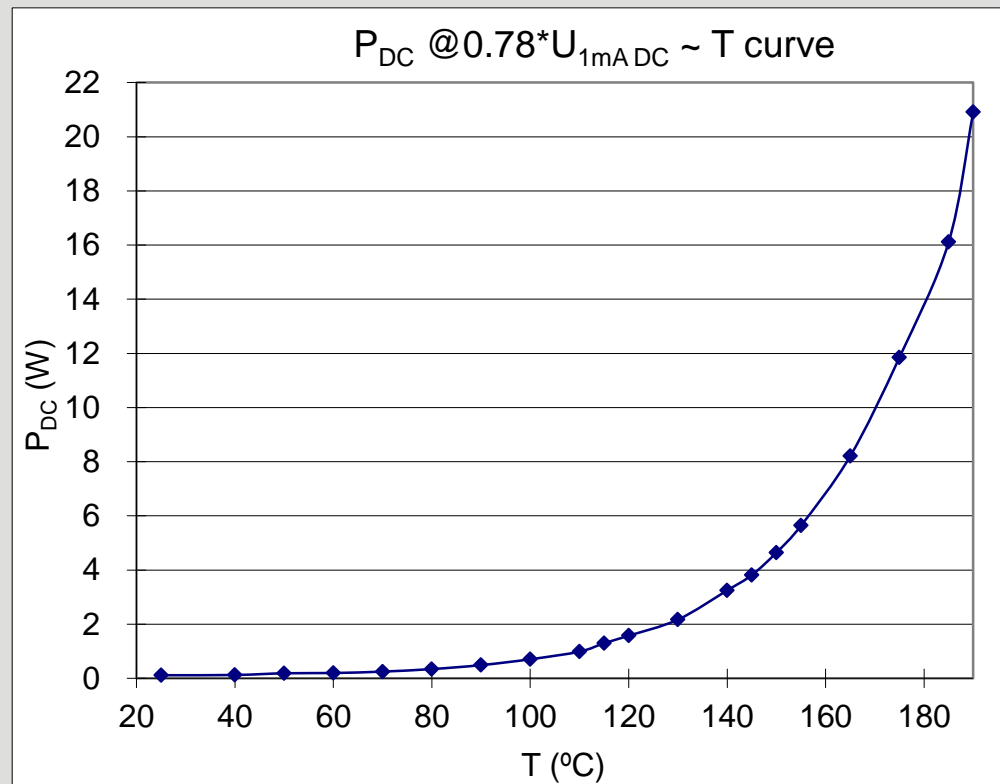
Resistive power loss (AC) vs temperature of E78NR123

- After impulses for operating duty test, parts temperature will be above 100°C normally or even up to 200°C, it depends on arrester design and specified current value.
- Power loss at high temperature is decisive for operating duty test.
- Different material system have different $P_{cov} \sim T$ curve.
- U_{cov} of E78NR123 specified as around $0.75 \cdot U_{ref} @ 5mA$.



DC power loss vs temperature of E78NR123

- After impulses for operating duty test, parts temperature will be above 100°C normally or even up to 200°C, it depends on arrester design and specified current value.
- Power loss at high temperature is decisive for operating duty test.
- Different material system have different $P_{DC} \sim T$ curve.
- U_{DC} of E78NR123 specified as around $0.78 \cdot U_{1mA,DC}$.



Summary

1. **EPCOS offers a wide range of products and has high production capacity for energy varistors.**
2. **In recent years, the company has developed new DC energy varistors and high gradient energy varistors.**
3. **EPCOS has also greatly improved energy varistors in 4/10 μ s energy handling capability, 2 ms energy handling capability and power loss at high temperature.**

