

Aluminum Capacitors

SMD (Chip), High Temperature, Low Impedance

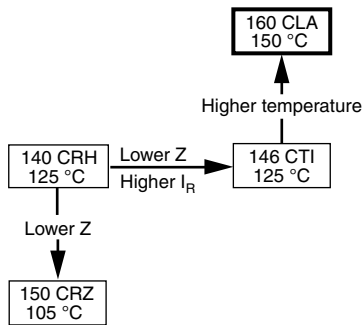


Fig. 1

| QUICK REFERENCE DATA | |
|---|----------------------------------|
| DESCRIPTION | VALUE |
| Nominal case sizes (L x W x H in mm) | 12.5 x 12.5 x 13 to 18 x 18 x 21 |
| Rated capacitance range, C_R | 100 μ F to 3300 μ F |
| Tolerance on C_R | $\pm 20 \%$ |
| Rated voltage range, U_R | 16 V to 50 V |
| Category temperature range | - 55 °C to + 150 °C |
| Endurance test at 150 °C | 1000 h to 1500 h |
| Useful life at 150 °C | 1250 h to 2000 h |
| Useful life at 40 °C 1.8 x I_R applied | 300 000 h to 400 000 h |
| Shelf life at 0 V, 150 °C | 1000 h |
| Based on sectional specification | IEC 60384-18/CECC 32300 |
| Climatic category IEC 60068 | 55/150/56 |

FEATURES

- Polarized aluminum electrolytic capacitors, non-solid electrolyte, self healing
- SMD-version with base plate, lead (Pb)-free reflow solderable
- Charge and discharge proof, no peak current limitation
- High temperature reflow soldering according to JEDEC J-STD-020
- High temperature proof
- Vibration proof, 4-pin version and 6-pin version
- AEC-Q200 qualified
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

 AUTOMOTIVE
GRADE

RoHS
COMPLIANT

APPLICATIONS

- SMD technology, for high temperature reflow soldering
- High temperature environment, high peak load
- Automotive, industrial
- Smoothing, filtering, buffering

MARKING

- Rated capacitance (in μ F)
- Rated voltage (in V)
- Date code, in accordance with IEC 60062
- Black mark or “-” sign indicating the cathode (the anode is identified by bevelled edges)
- Code indicating group number (A)

PACKAGING

Supplied in blister tape on reel

| SELECTION CHART FOR C_R, U_R, AND RELEVANT NOMINAL CASE SIZES (L x W x H in mm) | | | | |
|--|------------------|------------------|------------------|------------------|
| C_R (μF) | U_R (V) | | | |
| | 16 | 25 | 35 | 50 |
| 100 | → | → | → | 12.5 x 12.5 x 13 |
| 150 | → | → | → | 12.5 x 12.5 x 13 |
| 220 | → | → | 12.5 x 12.5 x 13 | 12.5 x 12.5 x 16 |
| 330 | → | 12.5 x 12.5 x 13 | 12.5 x 12.5 x 13 | 16 x 16 x 16 |
| 470 | 12.5 x 12.5 x 13 | 12.5 x 12.5 x 13 | 16 x 16 x 16 | 18 x 18 x 16 |
| 680 | 12.5 x 12.5 x 13 | 16 x 16 x 16 | 18 x 18 x 16 | 16 x 16 x 21 |
| 1000 | 16 x 16 x 16 | 18 x 18 x 16 | 16 x 16 x 21 | 18 x 18 x 21 |
| 1500 | 18 x 18 x 16 | 16 x 16 x 21 | 18 x 18 x 21 | - |
| 2200 | 16 x 16 x 21 | 18 x 18 x 21 | - | - |
| 2700 | 18 x 18 x 21 | - | - | - |
| 3300 | 18 x 18 x 21 | - | - | - |

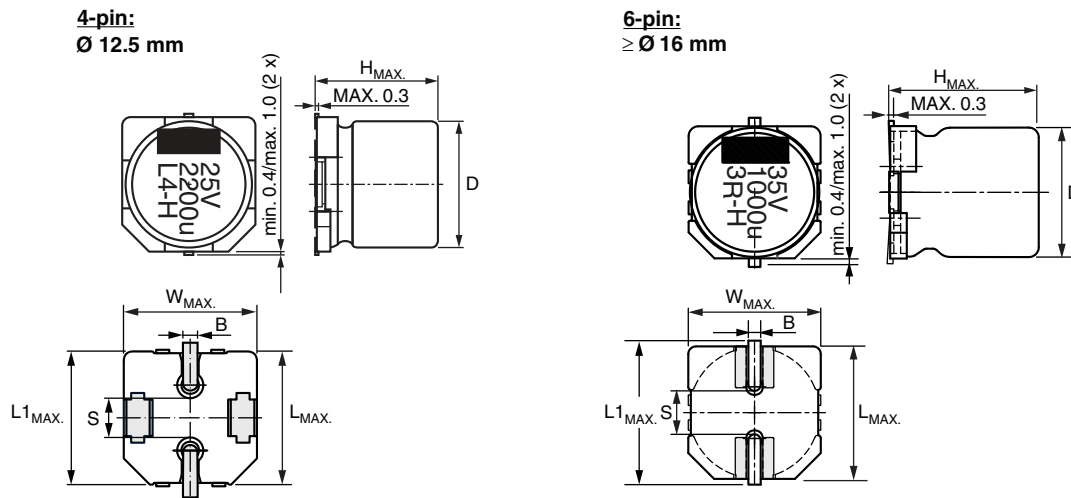


Fig. 2 - Dimensional outline

Table 1

| DIMENSIONS in millimeters AND MASS | | | | | | | | | |
|---|-----------|------------|------------|------------|-----------------|------------|-----|-------------|----------|
| NOMINAL CASE SIZE L x W x H | CASE CODE | $L_{MAX.}$ | $W_{MAX.}$ | $H_{MAX.}$ | $\varnothing D$ | $B_{MAX.}$ | S | $L1_{MAX.}$ | MASS (g) |
| 12.5 x 12.5 x 13 | 1213 | 12.9 | 12.9 | 14.0 | 12.5 | 1.3 | 3.6 | 14.9 | ≈ 2.9 |
| 12.5 x 12.5 x 16 | 1216 | 12.9 | 12.9 | 16.5 | 12.5 | 1.3 | 3.6 | 14.9 | ≈ 3.2 |
| 16 x 16 x 16 | 1616 | 16.6 | 16.6 | 17.5 | 16.0 | 1.3 | 6.5 | 18.6 | ≈ 5.8 |
| 16 x 16 x 21 | 1621 | 16.6 | 16.6 | 22.0 | 16.0 | 1.3 | 6.5 | 18.6 | ≈ 7.1 |
| 18 x 18 x 16 | 1816 | 19.0 | 19.0 | 17.5 | 18.0 | 1.3 | 6.5 | 21.0 | ≈ 8.0 |
| 18 x 18 x 21 | 1821 | 19.0 | 19.0 | 22.0 | 18.0 | 1.3 | 6.5 | 21.0 | ≈ 9.3 |

Table 2

| TAPE AND REEL DIMENSIONS in millimeters, PACKAGING QUANTITIES | | | | | | |
|---|------------------|--------------------------------|------------------------|---|----------------------|------------------------------------|
| NOMINAL CASE SIZE L x W x H | CASE CODE | PITCH P ₁ | TAPE WIDTH W | TAPE THICKNESS T ₂ | REEL DIAMETER | PACKAGING QUANTITY PER REEL |
| 12.5 x 12.5 x 13 | 1213 | 20 | 24 | 16.2 | 380 | 250 |
| 12.5 x 12.5 x 16 | 1216 | 24 | 32 | 18.5 | 380 | 200 |
| 16 x 16 x 16 | 1616 | 28 | 44 | 18.9 | 380 | 150 |
| 16 x 16 x 21 | 1621 | 28 | 44 | 23.4 | 380 | 100 |
| 18 x 18 x 16 | 1816 | 32 | 44 | 18.9 | 380 | 125 |
| 18 x 18 x 21 | 1821 | 32 | 44 | 23.4 | 380 | 100 |

Note

- Detailed tape dimensions see section "PACKAGING"

MOUNTING

The capacitors are designed for automatic placement on to printed-circuit boards.

Optimum dimensions of soldering pads depend amongst others on soldering method, mounting accuracy, print layout and/or adjacent components.

For recommended soldering pad dimensions, refer to Fig. 3 and Table 3.

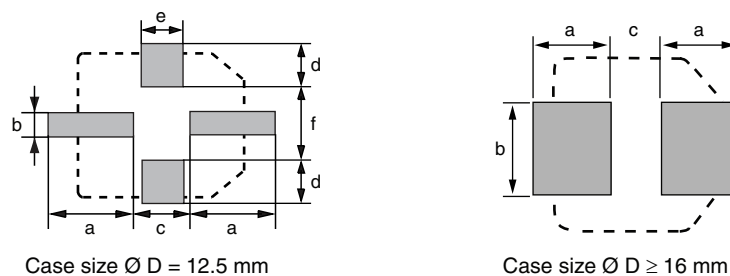
SOLDERING

Soldering conditions are defined by the curve, temperature versus time, where the temperature is that measured on the component during processing.

For maximum conditions refer to Fig. 4.

Any temperature versus time curve which does not exceed the specified maximum curves may be applied.

As a general principle, temperature and duration shall be the **minimum** necessary required to ensure good soldering connections. However, the specified maximum curves should never be exceeded.


Fig. 3 - Recommended soldering pad dimensions
Table 3

| RECOMMENDED SOLDERING PAD DIMENSIONS in millimeters | | | | | | |
|--|----------|----------|----------|----------|----------|----------|
| CASE CODE | a | b | c | d | e | f |
| 1213 | 6.3 | 2.5 | 4.0 | 4.2 | 5.0 | 5.6 |
| 1216 | 6.3 | 2.5 | 4.0 | 4.2 | 5.0 | 5.6 |
| 1616 | 7.8 | 9.6 | 4.7 | - | - | - |
| 1621 | 7.8 | 9.6 | 4.7 | - | - | - |
| 1816 | 8.8 | 9.6 | 4.7 | - | - | - |
| 1821 | 8.8 | 9.6 | 4.7 | - | - | - |

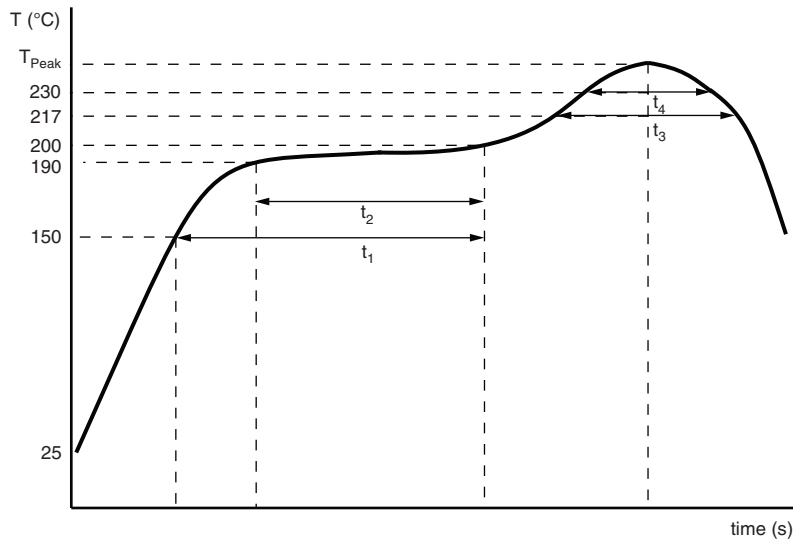
**ADVANCED SOLDERING PROFILE FOR LEAD (Pb)-FREE REFLOW PROCESS
ACCORDING TO JEDEC J-STD-020**


Fig. 4 - Maximum temperature load during reflow soldering

Table 4

| REFLOW SOLDERING CONDITIONS for MAL216099xxxE3 | | |
|---|---------------------------|---------------------------|
| PROFILE FEATURES | CASE CODE 1213 TO 1216 | CASE CODE 1616 TO 1821 |
| Max. time from 25 °C to T_{Peak} | 300 s | 300 s |
| Min. ramp-up rate to 150 °C | 3 K/s | 3 K/s |
| Max. time from 150 °C to 200 °C (t_1) | 150 s | 150 s |
| Max. time from 190 °C to 200 °C (t_2) | 110 s | 110 s |
| Ramp up rate from 200 °C to T_{Peak} | 0.5 K/s to 3 K/s | 0.5 K/s to 3 K/s |
| Max. time above $T_{Liquidus}$ (217 °C) (t_3) | 90 s | 90 s |
| Max. time above 230 °C (t_4) | 65 s | 60 s |
| Peak temperature T_{Peak} | 250 °C | 245 °C |
| Max. time above T_{Peak} minus 5 °C | 30 s | 30 s |
| Ramp-down rate from $T_{Liquidus}$ | 3 K/s to 6 K/s | 3 K/s to 6 K/s |

Notes

- Temperature measuring point on top of the case and on terminals.
- Max. 2 runs with pause of min. 30 min in between.



| ELECTRICAL DATA | |
|-----------------|---|
| SYMBOL | DESCRIPTION |
| C_R | Rated capacitance at 100 Hz, tolerance $\pm 20\%$ |
| I_R | Rated RMS ripple current at 100 kHz, 150 °C |
| I_{L2} | Max. leakage current after 2 min at U_R |
| $\tan \delta$ | Max. dissipation factor at 100 Hz |
| Z | Max. impedance at 100 kHz |

ORDERING EXAMPLE

Electrolytic capacitor 160 CLA series
 220 $\mu\text{F}/50\text{ V}$; $\pm 20\%$
 Nominal case size: 12.5 mm x 12.5 mm x 16 mm;
 taped on reel
 Ordering code: MAL216099103E3

Note

- Unless otherwise specified, all electrical values in Table 5 apply at $T_{\text{amb}} = 20\text{ °C}$, $P = 86\text{ kPa}$ to 106 kPa , $\text{RH} = 45\%$ to 75%

Table 5

| ELECTRICAL DATA AND ORDERING INFORMATION | | | | | | | | |
|--|----------------------------|--|------------------------------------|--|-------------------------|---------------------------------------|---|-----------------------------|
| U_R (V) | C_R (μF) | NOMINAL CASE SIZE L x W x H (mm) | I_R 150 °C 100 kHz (mA) | I_{L2} 2 min (μA) | $\tan \delta$ 100 Hz | Z 100 kHz 20 °C (Ω) | Z 100 kHz - 40 °C (Ω) | ORDERING CODE MAL2160... |
| 16 | 470 | 12.5 x 12.5 x 13 | 750 | 75 | 0.16 | 0.080 | 0.70 | 99501E3 |
| | 680 | 12.5 x 12.5 x 13 | 800 | 109 | 0.16 | 0.080 | 0.70 | 99502E3 |
| | 1000 | 16 x 16 x 16 | 850 | 160 | 0.16 | 0.050 | 0.45 | 99503E3 |
| | 1500 | 18 x 18 x 16 | 900 | 240 | 0.16 | 0.050 | 0.45 | 99504E3 |
| | 2200 | 16 x 16 x 21 | 1100 | 352 | 0.18 | 0.035 | 0.32 | 99505E3 |
| | 2700 | 18 x 18 x 21 | 1350 | 432 | 0.18 | 0.035 | 0.32 | 99506E3 |
| | 3300 | 18 x 18 x 21 | 1400 | 528 | 0.20 | 0.035 | 0.32 | 99507E3 |
| 25 | 330 | 12.5 x 12.5 x 13 | 650 | 83 | 0.14 | 0.080 | 0.70 | 99601E3 |
| | 470 | 12.5 x 12.5 x 13 | 700 | 118 | 0.14 | 0.080 | 0.70 | 99602E3 |
| | 680 | 16 x 16 x 16 | 800 | 170 | 0.14 | 0.050 | 0.45 | 99603E3 |
| | 1000 | 18 x 18 x 16 | 830 | 250 | 0.14 | 0.050 | 0.45 | 99604E3 |
| | 1500 | 16 x 16 x 21 | 1050 | 375 | 0.14 | 0.035 | 0.32 | 99605E3 |
| | 2200 | 18 x 18 x 21 | 1350 | 550 | 0.16 | 0.035 | 0.32 | 99606E3 |
| 35 | 220 | 12.5 x 12.5 x 13 | 550 | 77 | 0.12 | 0.080 | 0.70 | 99001E3 |
| | 330 | 12.5 x 12.5 x 13 | 650 | 116 | 0.12 | 0.080 | 0.70 | 99002E3 |
| | 470 | 16 x 16 x 16 | 800 | 165 | 0.12 | 0.050 | 0.45 | 99003E3 |
| | 680 | 18 x 18 x 16 | 830 | 238 | 0.12 | 0.050 | 0.45 | 99004E3 |
| | 1000 | 16 x 16 x 21 | 1000 | 350 | 0.12 | 0.035 | 0.32 | 99005E3 |
| | 1500 | 18 x 18 x 21 | 1350 | 525 | 0.12 | 0.035 | 0.32 | 99006E3 |
| 50 | 100 | 12.5 x 12.5 x 13 | 420 | 50 | 0.10 | 0.130 | 1.20 | 99101E3 |
| | 150 | 12.5 x 12.5 x 13 | 450 | 75 | 0.10 | 0.120 | 1.10 | 99102E3 |
| | 220 | 12.5 x 12.5 x 16 | 550 | 110 | 0.10 | 0.085 | 0.76 | 99103E3 |
| | 330 | 16 x 16 x 16 | 700 | 165 | 0.10 | 0.072 | 0.65 | 99104E3 |
| | 470 | 18 x 18 x 16 | 720 | 235 | 0.10 | 0.070 | 0.63 | 99105E3 |
| | 680 | 16 x 16 x 21 | 800 | 340 | 0.10 | 0.052 | 0.47 | 99106E3 |
| | 1000 | 18 x 18 x 21 | 1100 | 500 | 0.10 | 0.049 | 0.44 | 99107E3 |

Table 6

| ADDITIONAL ELECTRICAL DATA | | |
|--|--|--|
| PARAMETER | CONDITIONS | VALUE |
| Voltage | | |
| Surge voltage for short periods | IEC 60384-18, subclause 4.14 | $U_S \leq 1.15 \times U_R$ |
| Reverse voltage for short periods | IEC 60384-18, subclause 4.16; $T_A \leq 150^\circ\text{C}$ | $U_{\text{rev}} \leq 1\text{ V}$ |
| Current | | |
| Leakage current | After 2 min at U_R | $I_{L2} \leq 0.01 \times C_R \times U_R$ |
| Inductance | | |
| Equivalent series inductance (ESL) | $\varnothing D \geq 12.5\text{ mm}$ | Typ. 11 nH |
| Resistance | | |
| Equivalent series resistance (ESR) at 100 Hz | Calculated from $\tan \delta_{\text{max}}$ and C_R (see Table 5) | $\text{ESR} = \tan \delta / 2\pi f C_R$ |

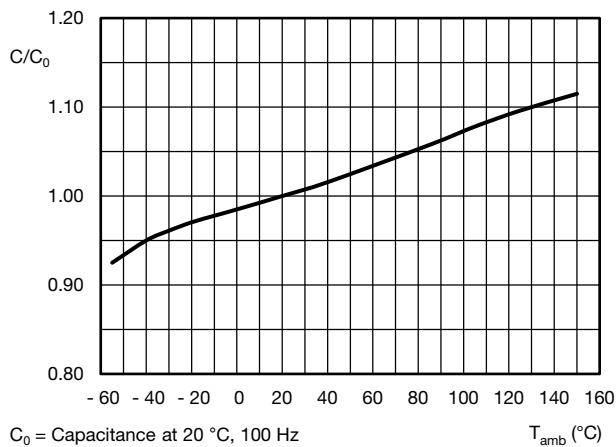
CAPACITANCE (C)


Fig. 5 - Typical multiplier of capacitance as a function of ambient temperature

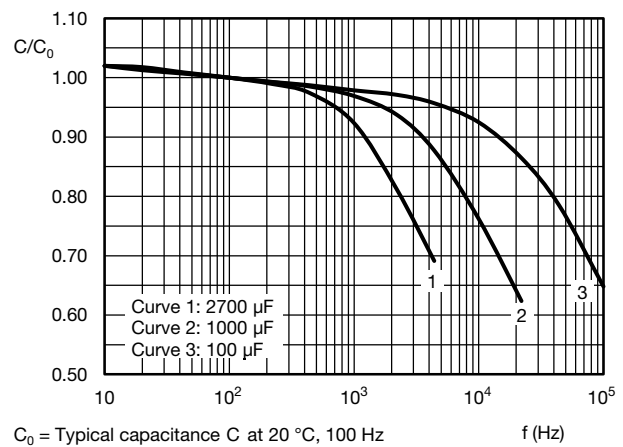
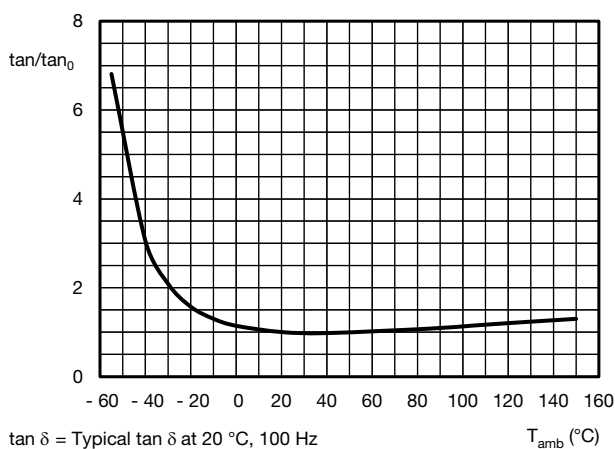
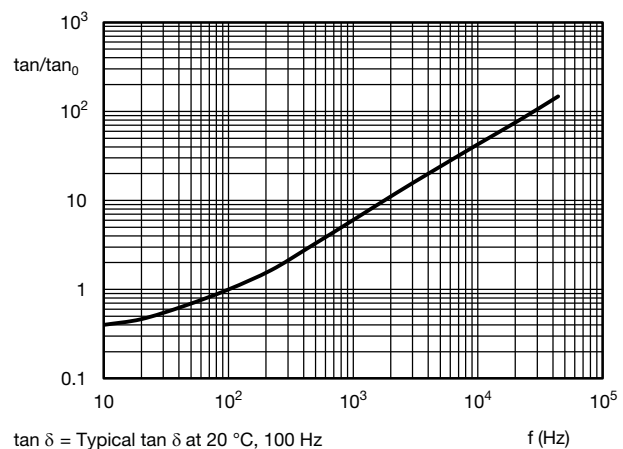


Fig. 6 - Typical multiplier of capacitance as a function of frequency

DISSIPATION FACTOR ($\tan \delta$)

 Fig. 7 - Typical multiplier of dissipation factor ($\tan \delta$) as a function of ambient temperature

 Fig. 8 - Typical multiplier of dissipation factor ($\tan \delta$) as a function of frequency

EQUIVALENT SERIES RESISTANCE (ESR)

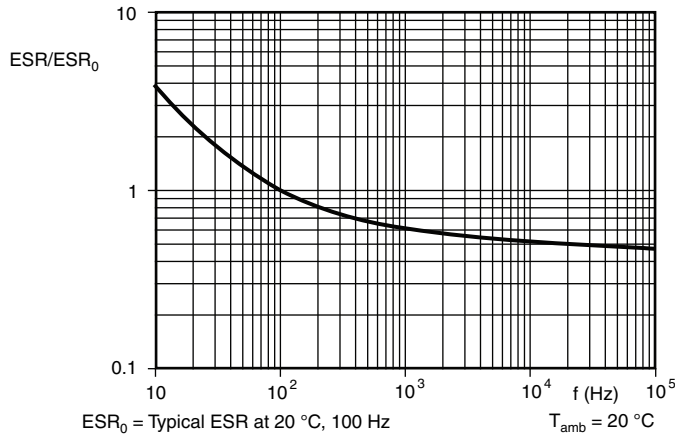


Fig. 9 - Typical multiplier of ESR as a function of frequency

IMPEDANCE (Z)

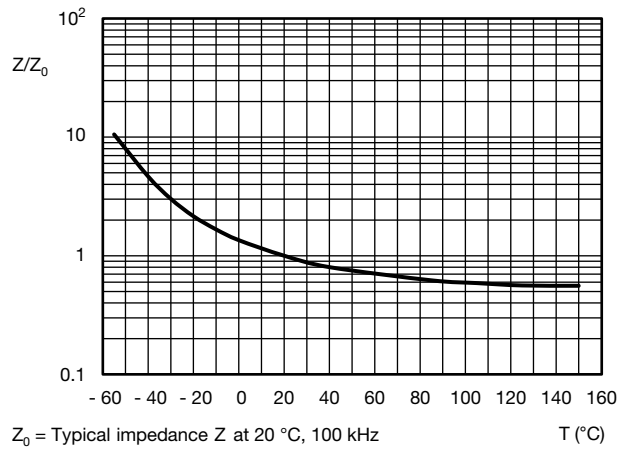


Fig. 10 - Typical multiplier of impedance as a function of temperature

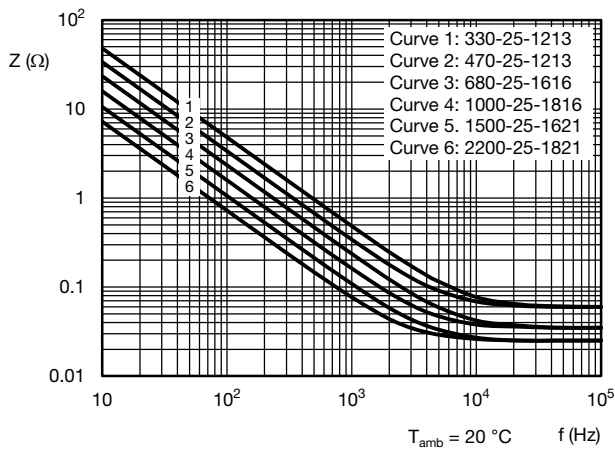


Fig. 11 - Typical impedance as a function of frequency

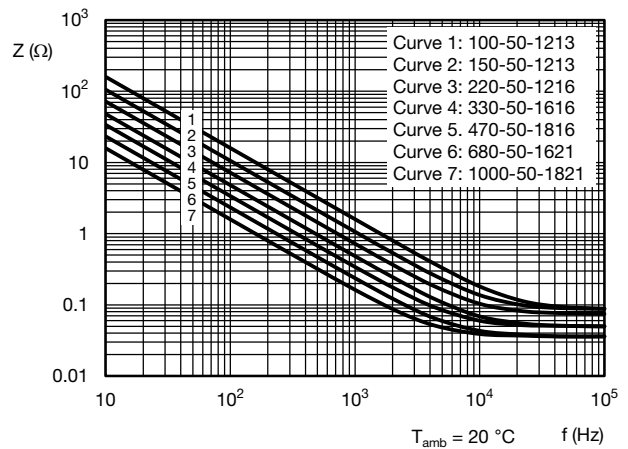


Fig. 12 - Typical impedance as a function of frequency

RIPPLE CURRENT AND USEFUL LIFE

Table 7

| ENDURANCE TEST DURATION AND USEFUL LIFE AS A FUNCTION OF CASE SIZE | | | | |
|--|-----------|-------------------------------|---------------------------------|---|
| NOMINAL CASE SIZE Ø D x L (mm) | CASE CODE | ENDURANCE AT 150 °C (h) | USEFUL LIFE AT 150 °C (h) | USEFUL LIFE AT 40 °C 1.8 x I _R APPLIED (h) |
| 12.5 x 12.5 x 13 | 1213 | 1000 | 1250 | 300 000 |
| 12.5 x 12.5 x 16 | 1216 | 1000 | 1250 | 325 000 |
| 16 x 16 x 16 | 1616 | 1000 | 1500 | 350 000 |
| 16 x 16 x 21 | 1621 | 1500 | 2000 | 400 000 |
| 18 x 18 x 16 | 1816 | 1000 | 1500 | 350 000 |
| 18 x 18 x 21 | 1821 | 1500 | 2000 | 400 000 |

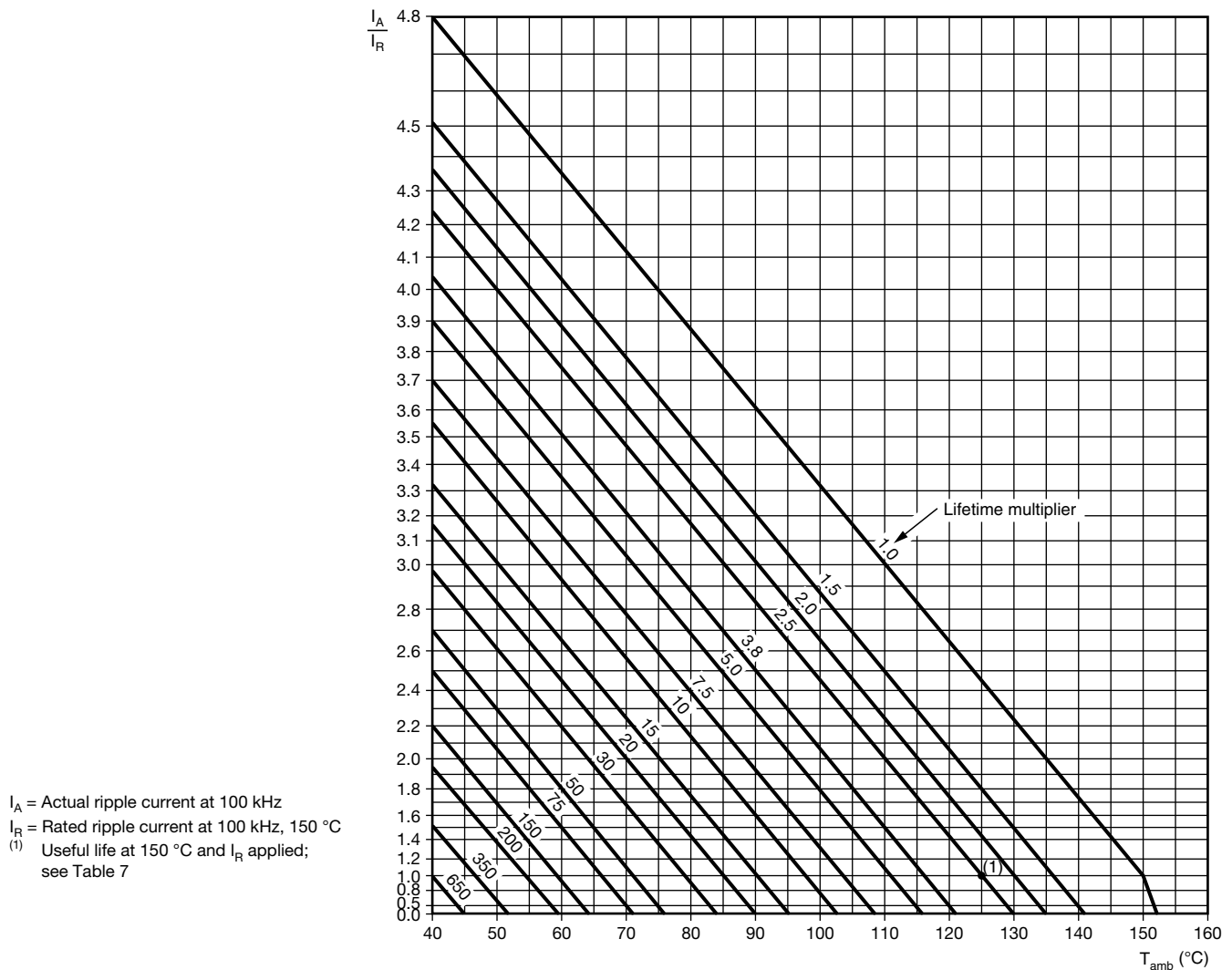
RIPPLE CURRENT AND USEFUL LIFE


Fig. 13 - Multiplier of useful life as a function of ambient temperature and ripple current load

Table 8

| MULTIPLIER OF RIPPLE CURRENT (I_R) AS A FUNCTION OF FREQUENCY | |
|---|--|
| FREQUENCY (Hz) | I_R MULTIPLIER |
| | $U_R = 16\text{ V TO }50\text{ V}$ |
| 50 | 0.40 |
| 100 | 0.60 |
| 300 | 0.75 |
| 1000 | 0.80 |
| 3000 | 0.90 |
| 10 000 | 0.95 |
| 30 000 | 0.97 |
| 100 000 | 1.00 |

Table 9

| TEST PROCEDURES AND REQUIREMENTS | | | |
|--|--|--|--|
| TEST | | PROCEDURE (quick reference) | REQUIREMENTS |
| NAME OF TEST | REFERENCE | | |
| Mounting | IEC 60384-18, subclause 4.3 | Shall be performed prior to tests mentioned below; reflow soldering; for maximum temperature load refer to chapter "Mounting" | $\Delta C/C: \pm 5\%$ $\tan \delta \leq \text{spec. limit}$ $I_{L2} \leq \text{spec. limit}$ |
| Endurance | IEC 60384-18/ CECC 32300, subclause 4.15 | $T_{\text{amb}} = 150\text{ }^\circ\text{C}$; U_R applied; for test duration see Table 7 | $\Delta C/C: \pm 20\%$ $\tan \delta \leq 2 \times \text{spec. limit}$ $I_{L2} \leq \text{spec. limit}$ |
| Useful life | CECC 30301, subclause 1.8.1 | $T_{\text{amb}} = 150\text{ }^\circ\text{C}$; U_R and I_R applied; for test duration see Table 7 | $\Delta C/C: \pm 30\%$ $\tan \delta \leq 3 \times \text{spec. limit}$ $I_{L2} \leq \text{spec. limit}$ no short or open circuit total failure percentage: $\leq 1\%$ |
| Shelf life (storage at high temperature) | IEC 60384-18/ CECC 32300, subclause 4.17 | $T_{\text{amb}} = 150\text{ }^\circ\text{C}$; no voltage applied; 1000 h After test: U_R to be applied for 30 min, 24 h to 48 h before measurement | For requirements see "Endurance test" above |
| Reverse voltage | IEC 60384-18/ CECC 32300, subclause 4.16 | $T_{\text{amb}} = 150\text{ }^\circ\text{C}$: 125 h at $U = -0.5\text{ V}$, followed by 125 h at U_R | $\Delta C/C: \pm 15\%$ $\tan \delta \leq 1.5 \times \text{spec. limit}$ $I_{L2} \leq \text{spec. limit}$ |

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