# Aluminum Electrolytic Capacitors SMD (Chip), High Temperature, Low Impedance, High Vibration Capability



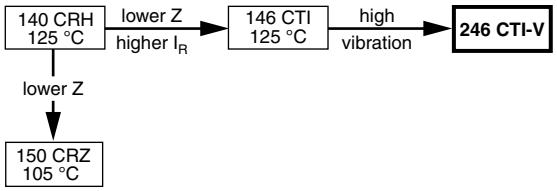



Fig. 1

## FEATURES

- Extended useful life: up to 6000 h at 125 °C
- 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
- Advanced temperature reflow soldering according to JEDEC® J-STD-020
- Vibration proof, 6-pin version up to 30 *g*
- AEC-Q200 qualified
- High reliability
- Low ESR
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

## APPLICATIONS

- SMD technology, for high temperature reflow soldering
- Industrial and professional applications
- Automotive, general industrial, telecom
- Smoothing, filtering, buffering

## MARKING

- Rated capacitance (in µF)
- Rated voltage (in V)
- Date code, in accordance with IEC 60062
- Black mark or "-" sign indicating the cathode (the anode is identified by beveled edges)
- Code indicating group number (T)

## PACKAGING

Supplied in blister tape on reel

| QUICK REFERENCE DATA | |
|---|---|
| **DESCRIPTION** | **VALUE** |
| Nominal case sizes (L x W x H in mm) | 16 x 16 x 16 to 18 x 18 x 21 |
| Rated capacitance range, $C_R$ | 150 µF to 4700 µF |
| Tolerance on $C_R$ | ± 20 % |
| Rated voltage range, $U_R$ | 16 V to 100 V |
| Category temperature range | -55 °C to +125 °C |
| Endurance test at 125 °C | 2000 h to 5000 h |
| Useful life at 125 °C | 2500 h to 6000 h |
| Useful life at 40 °C 1.8 x $I_R$ applied | 350 000 h to 400 000 h |
| Shelf life at 0 V, 125 °C | 1000 h |
| Based on sectional specification | IEC 60384-18 / CECC 32300 |
| Climatic category IEC 60068 | 55 / 125 / 56 |



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| 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 | 63 | 80 | 100 |
| 150 | → | → | → | → | → | → | 16 x 16 x 16 |
| 220 | → | → | → | → | → | 16 x 16 x 16 | 16 x 16 x 21 |
| | | | | | | | 18 x 18 x 16 |
| 330 | → | → | → | → | 16 x 16 x 16 | 16 x 16 x 21 | 18 x 18 x 21 |
| | | | | | | 18 x 18 x 16 | |
| 470 | → | → | → | 16 x 16 x 16 | 16 x 16 x 16 | 18 x 18 x 21 | - |
| 680 | → | → | 16 x 16 x 16 | 16 x 16 x 16 | 18 x 18 x 16 | - | - |
| 820 | → | → | → | → | 16 x 16 x 21 | - | - |
| 1000 | → | 16 x 16 x 16 | 16 x 16 x 16 | 16 x 16 x 21 | 18 x 18 x 21 | - | - |
| | | | | 18 x 18 x 16 | | | |
| 1200 | → | → | 18 x 18 x 16 | 18 x 18 x 21 | - | - | - |
| 1500 | 16 x 16 x 16 | 16 x 16 x 16 | 16 x 16 x 21 | - | - | - | - |
| 1800 | → | → | 18 x 18 x 21 | - | - | - | - |
| 2200 | 16 x 16 x 16 | 16 x 16 x 21 | - | - | - | - | - |
| | | 18 x 18 x 16 | | | | | |
| 2700 | → | 18 x 18 x 21 | - | - | - | - | - |
| 3300 | 16 x 16 x 21 | - | - | - | - | - | - |
| | 18 x 18 x 16 | | | | | | |
| 3900 | 18 x 18 x 21 | - | - | - | - | - | - |
| 4700 | 18 x 18 x 21 | - | - | - | - | - | - |

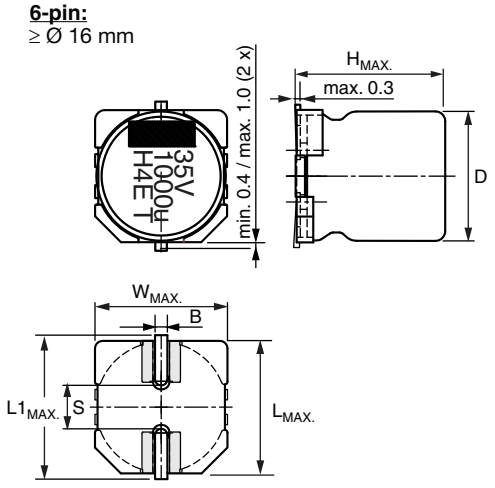



Fig. 2 - Dimensional outline

**Table 1**

| DIMENSIONS in millimeters AND MASS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| NOMINAL CASE SIZE L x W x H | CASE CODE | $L_{MAX.}$ | $W_{MAX.}$ | $H_{MAX.}$ | Ø D | $B_{MAX.}$ | S | $L1_{MAX.}$ | MASS (g) |
| 16 x 16 x 16 | 1616 | 16.6 | 16.6 | 17.5 | 16.0 | 1.3 | 6.5 | 18.6 | ≈ 5.5 |
| 16 x 16 x 21 | 1621 | 16.6 | 16.6 | 22.0 | 16.0 | 1.3 | 6.5 | 18.6 | ≈ 6.0 |
| 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 | ≈ 8.3 |


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**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** |
| 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.

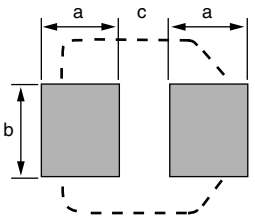
## SOLDERING

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.




Case size Ø D ≥ 16 mm

Fig. 3 - Recommended soldering pad dimensions

**Table 3**

| **RECOMMENDED SOLDERING PAD DIMENSIONS** in millimeters | | | |
|---|---|---|---|
| **CASE CODE** | **a** | **b** | **c** |
| 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 |



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

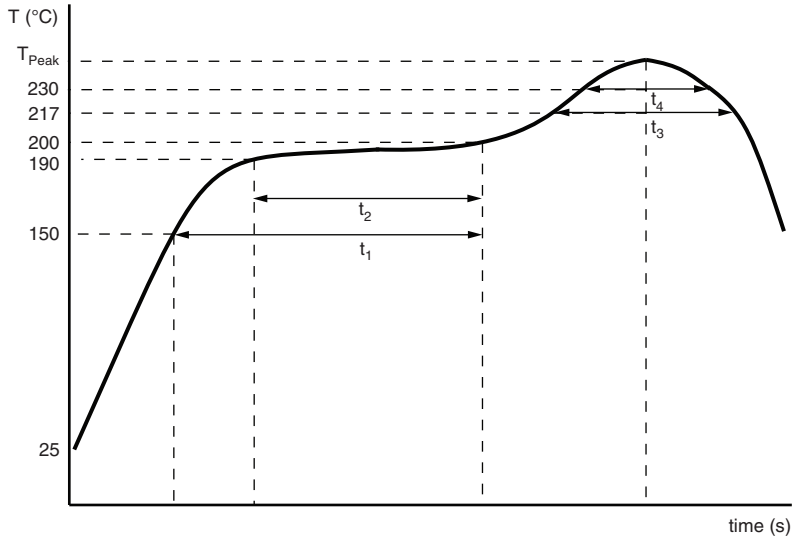



Fig. 4 - Maximum temperature load during reflow soldering

**Table 4**

| **REFLOW SOLDERING CONDITIONS** for MAL224699xxxE3 | |
|---|---|
| **PROFILE FEATURES** | **CASE CODE 1616 TO 1821** |
| Maximum time from 25 °C to $T_{Peak}$ | 300 s |
| Maximum ramp-up rate to 150 °C | 3 K/s |
| Maximum time from 150 °C to 200 °C ($t_1$) | 150 s |
| Maximum time from 190 °C to 200 °C ($t_2$) | 110 s |
| Ramp up rate from 200 °C to $T_{Peak}$ | 0.5 K/s to 3 K/s |
| Maximum time above $T_{Liquidus}$ (217 °C) ($t_3$) | 90 s |
| Maximum time above 230 °C ($t_4$) | 60 s |
| Peak temperature $T_{Peak}$ | 245 °C |
| Maximum time above $T_{Peak}$ minus 5 °C | 30 s |
| Ramp-down rate from $T_{Liquidus}$ | 3 K/s to 6 K/s |

**Notes**

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


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| ELECTRICAL DATA | |
|---|---|
| SYMBOL | DESCRIPTION |
| $C_R$ | Rated capacitance at 100 Hz, tolerance ± 20 % |
| $I_R$ | Rated RMS ripple current at 100 kHz, 125 °C |
| $I_{L2}$ | Maximum leakage current after 2 min at $U_R$ |
| tan δ | Maximum dissipation factor at 100 Hz |
| Z | Maximum impedance at 100 kHz |

**Note**

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

## ORDERING EXAMPLE

Electrolytic capacitor 246 CTI-V series

220 µF / 80 V; ± 20 %

Nominal case size: 16 mm x 16 mm x 16 mm; taped on reel

Ordering code: MAL224699708E3

**Table 5**

| ELECTRICAL DATA AND ORDERING INFORMATION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $U_R$ (V) | $C_R$ (µF) | NOMINAL CASE SIZE L x W x H (mm) | $I_R$ 125 °C 100 kHz (mA) | $I_{L2}$ 2 min (µA) | tan δ 100 Hz | Z 100 kHz 20 °C (Ω) | Z 100 kHz -40 °C (Ω) | LIFE CODE [1] | ORDERING CODE MAL2246... |
| 16 | 1500 | 16 x 16 x 16 | 1400 | 240 | 0.16 | 0.050 | 0.45 | L2 | 99505E3 |
| | 2200 | 16 x 16 x 16 | 1400 | 352 | 0.18 | 0.050 | 0.45 | L2 | 99506E3 |
| | 3300 | 16 x 16 x 21 | 1660 | 528 | 0.20 | 0.035 | 0.32 | L3 | 99507E3 |
| | 3300 | 18 x 18 x 16 | 1500 | 528 | 0.20 | 0.050 | 0.45 | L2 | 99508E3 |
| | 3900 | 18 x 18 x 21 | 1750 | 624 | 0.20 | 0.035 | 0.32 | L3 | 99509E3 |
| | 4700 | 18 x 18 x 21 | 1750 | 752 | 0.22 | 0.035 | 0.32 | L3 | 99511E3 |
| 25 | 1000 | 16 x 16 x 16 | 1400 | 250 | 0.14 | 0.050 | 0.45 | L2 | 99605E3 |
| | 1500 | 16 x 16 x 16 | 1400 | 375 | 0.14 | 0.050 | 0.45 | L2 | 99606E3 |
| | 2200 | 16 x 16 x 21 | 1660 | 550 | 0.16 | 0.035 | 0.32 | L3 | 99607E3 |
| | 2200 | 18 x 18 x 16 | 1500 | 550 | 0.16 | 0.050 | 0.45 | L2 | 99608E3 |
| | 2700 | 18 x 18 x 21 | 1750 | 675 | 0.16 | 0.035 | 0.32 | L3 | 99609E3 |
| 35 | 680 | 16 x 16 x 16 | 1400 | 238 | 0.12 | 0.050 | 0.45 | L2 | 99007E3 |
| | 1000 | 16 x 16 x 16 | 1400 | 350 | 0.12 | 0.050 | 0.45 | L2 | 99008E3 |
| | 1200 | 18 x 18 x 16 | 1500 | 420 | 0.12 | 0.050 | 0.45 | L2 | 99009E3 |
| | 1500 | 16 x 16 x 21 | 1660 | 525 | 0.12 | 0.035 | 0.32 | L3 | 99011E3 |
| | 1800 | 18 x 18 x 21 | 1750 | 630 | 0.12 | 0.035 | 0.32 | L3 | 99012E3 |
| 50 | 470 | 16 x 16 x 16 | 1300 | 235 | 0.10 | 0.072 | 0.65 | L2 | 99108E3 |
| | 680 | 16 x 16 x 16 | 1300 | 340 | 0.10 | 0.072 | 0.65 | L2 | 99109E3 |
| | 1000 | 16 x 16 x 21 | 1500 | 500 | 0.10 | 0.052 | 0.47 | L3 | 99111E3 |
| | 1000 | 18 x 18 x 16 | 1300 | 500 | 0.10 | 0.070 | 0.63 | L2 | 99112E3 |
| | 1200 | 18 x 18 x 21 | 1600 | 600 | 0.10 | 0.049 | 0.44 | L3 | 99113E3 |
| 63 | 330 | 16 x 16 x 16 | 1050 | 208 | 0.10 | 0.100 | 0.90 | L2 | 99809E3 |
| | 470 | 16 x 16 x 16 | 1050 | 296 | 0.10 | 0.100 | 0.90 | L2 | 99811E3 |
| | 680 | 18 x 18 x 16 | 1150 | 428 | 0.10 | 0.095 | 0.86 | L2 | 99812E3 |
| | 820 | 16 x 16 x 21 | 1300 | 517 | 0.10 | 0.075 | 0.68 | L3 | 99813E3 |
| | 1000 | 18 x 18 x 21 | 1400 | 630 | 0.10 | 0.072 | 0.65 | L3 | 99814E3 |
| 80 | 220 | 16 x 16 x 16 | 900 | 176 | 0.12 | 0.180 | 1.44 | L1 | 99708E3 |
| | 330 | 16 x 16 x 21 | 1100 | 264 | 0.12 | 0.120 | 0.96 | L1 | 99709E3 |
| | 330 | 18 x 18 x 16 | 900 | 264 | 0.12 | 0.160 | 1.28 | L1 | 99711E3 |
| | 470 | 18 x 18 x 21 | 1100 | 376 | 0.12 | 0.110 | 0.88 | L1 | 99712E3 |
| 100 | 150 | 16 x 16 x 16 | 650 | 150 | 0.12 | 0.300 | 2.40 | L1 | 99907E3 |
| | 220 | 16 x 16 x 21 | 810 | 220 | 0.12 | 0.230 | 1.80 | L1 | 99908E3 |
| | 220 | 18 x 18 x 16 | 650 | 220 | 0.12 | 0.300 | 2.40 | L1 | 99909E3 |
| | 330 | 18 x 18 x 21 | 810 | 330 | 0.12 | 0.230 | 1.80 | L1 | 99911E3 |

**Note**

[1] Determines the applicable row in the table “Endurance Test Duration and Useful Life”


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**Table 6**

| EXTENDED VIBRATION SPECIFICATIONS | | |
|---|---|---|
| **PARAMETER** | **PROCEDURE** | **REQUIREMENTS** |
| Vibration improvement | From 10 *g* to 30 *g* | No visible damage; no leakage of electrolyte; marking legible<br>ΔC/C: ± 5 % with respect to initial measurements |
| Vibration frequency range | 10 Hz to 2 kHz | |
| Vibration profile | • Constant sinus sweep (1 oct./min.)<br>• 3 directions<br>• 8 h per direction | |

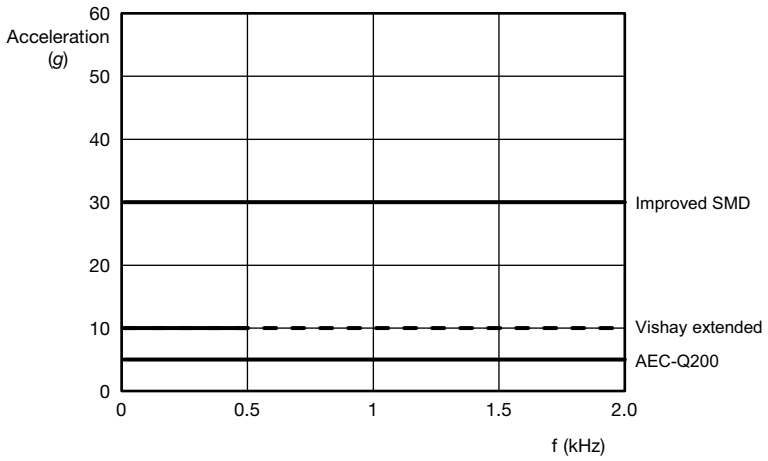



Fig. 5 - Vibration profile

**Table 7**

| 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; $T_A \leq 105$ °C | $U_{rev} \leq 1$ 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) | Ø D ≥ 16 mm | Typ. 11 nH |
| **Resistance** | | |
| Equivalent series resistance (ESR) at 100 Hz | Calculated from tan $\delta_{max.}$ and $C_R$ (see Table 5) | ESR = tan $\delta/2\pi f C_R$ |

## CAPACITANCE (C)

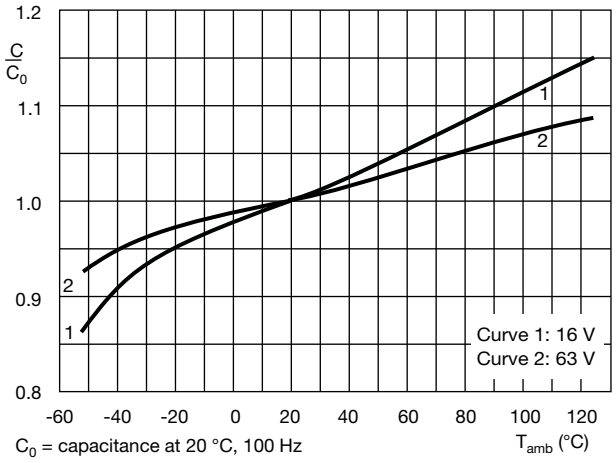



Fig. 6 - Typical multiplier of capacitance as a function of ambient temperature

## DISSIPATION FACTOR (tan δ)

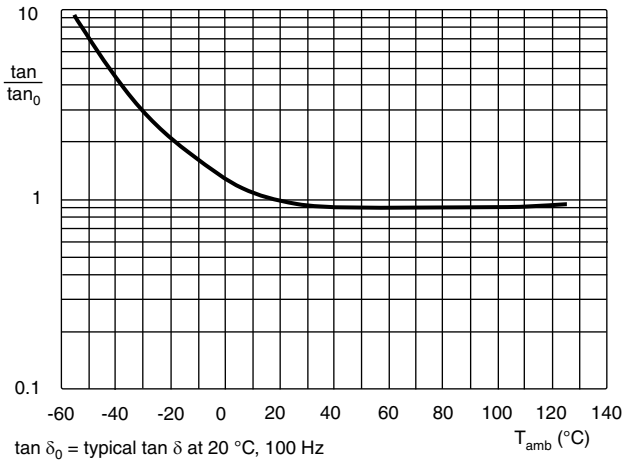



Fig. 7 - Typical multiplier of dissipation factor (tan δ) as a function of ambient temperature


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## EQUIVALENT SERIES RESISTANCE (ESR)

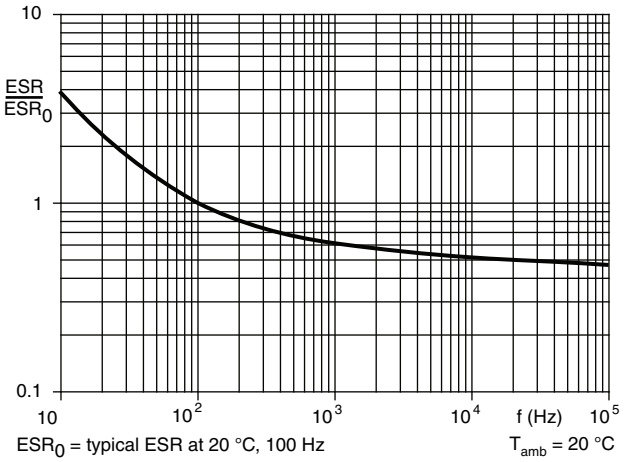



Fig. 8 - Typical multiplier of ESR as a function of frequency

## IMPEDANCE (Z)

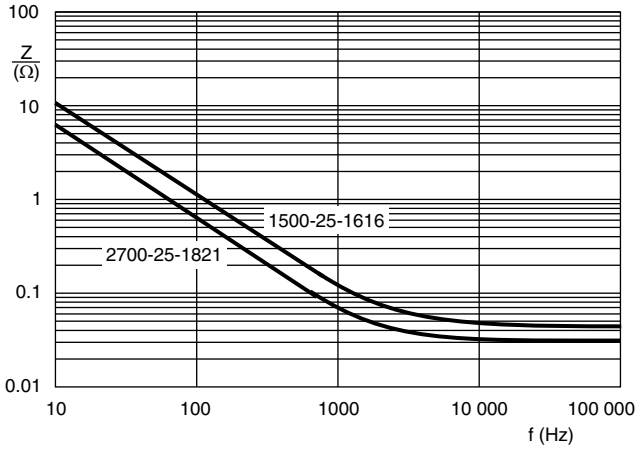



Fig. 9 - Typical impedance as a function of frequency

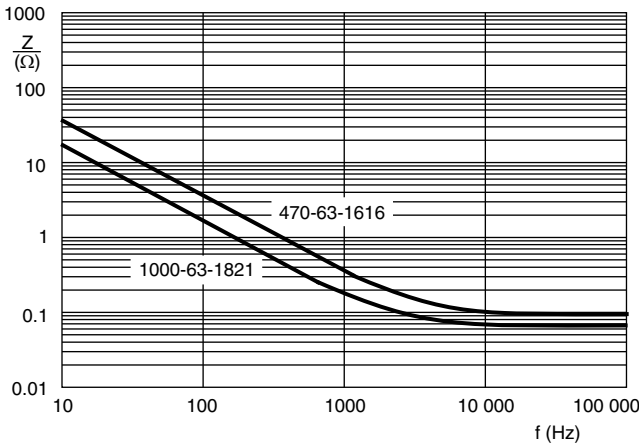



Fig. 10 - Typical impedance as a function of frequency

## IMPEDANCE (Z)

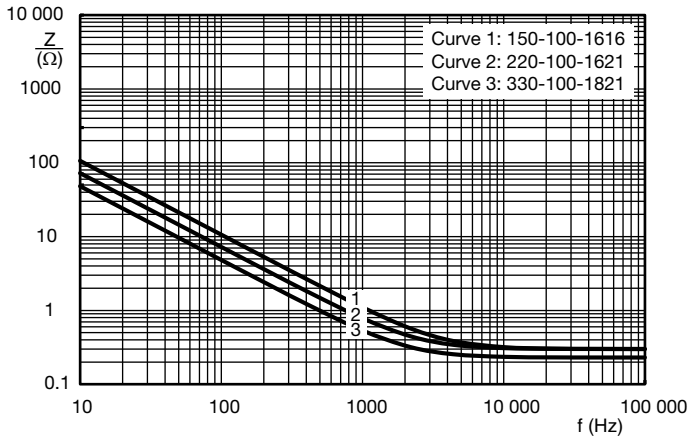



Fig. 11 - Typical impedance as a function of frequency


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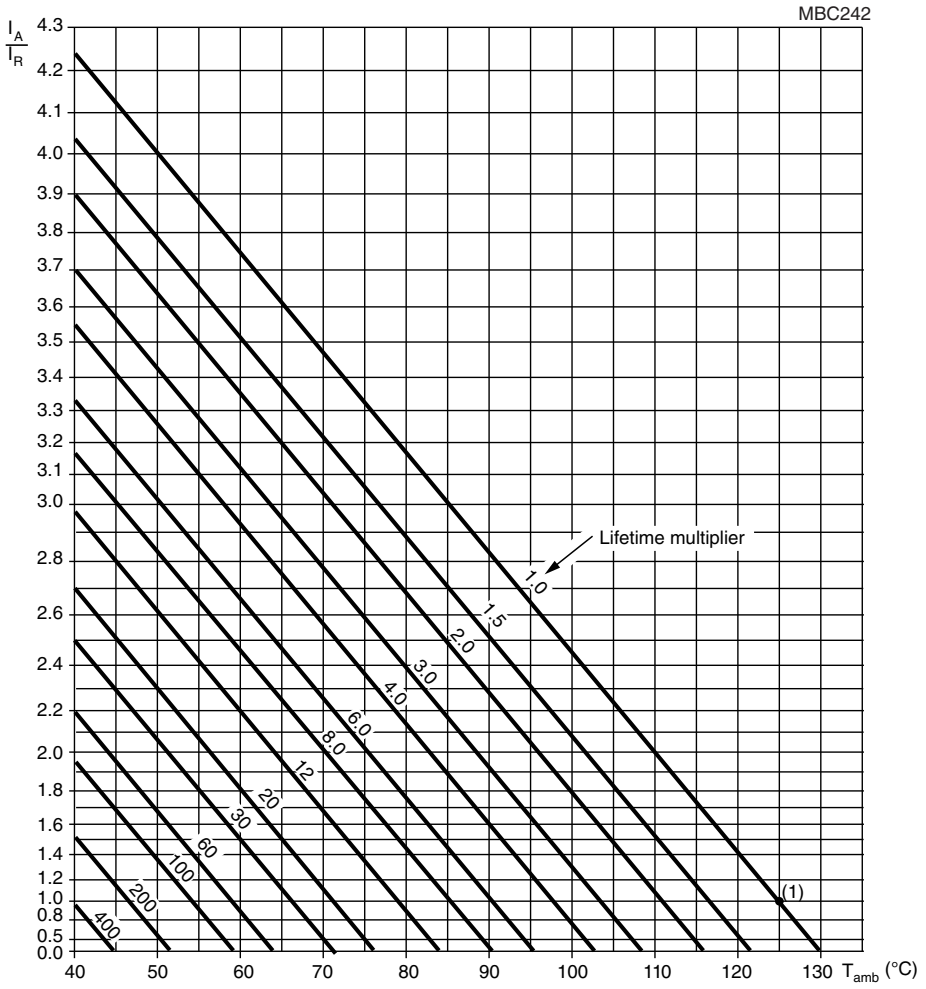
## RIPPLE CURRENT AND USEFUL LIFE

**Table 8**

| ENDURANCE TEST DURATION AND USEFUL LIFE | | | |
|---|---|---|---|
| LIFE CODE | ENDURANCE AT 125 °C (h) | USEFUL LIFE AT 125 °C (h) | USEFUL LIFE AT 40 °C 1.8 x $I_R$ APPLIED (h) |
| L1 | 2000 | 2500 | 250 000 |
| L2 | 4000 | 5000 | 350 000 |
| L3 | 5000 | 6000 | 400 000 |

**Note**

- Multiplier of useful life code: MBC242




$I_A$ = Actual ripple current at 100 kHz
$I_R$ = Rated ripple current at 100 kHz, 125 °C
(1) Useful life at 125 °C and $I_R$ applied; see Table 7

Fig. 12 - Multiplier of useful life as a function of ambient temperature and ripple current load


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**Table 9**

| MULTIPLIER OF RIPPLE CURRENT ($I_R$) AS A FUNCTION OF FREQUENCY | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $U_R$ (V) | FREQUENCY (Hz) | | | | | | | |
| | 50 | 100 | 300 | 1000 | 3000 | 10 000 | 30 000 | 100 000 |
| 16 | 0.60 | 0.70 | 0.80 | 0.85 | 0.90 | 0.95 | 0.97 | 1.00 |
| 25 | 0.60 | 0.70 | 0.80 | 0.85 | 0.90 | 0.95 | 0.97 | 1.00 |
| 35 | 0.45 | 0.65 | 0.80 | 0.85 | 0.90 | 0.95 | 0.97 | 1.00 |
| 50 | 0.40 | 0.60 | 0.75 | 0.82 | 0.90 | 0.95 | 0.97 | 1.00 |
| 63 | 0.40 | 0.60 | 0.75 | 0.82 | 0.90 | 0.95 | 0.97 | 1.00 |
| 80 | 0.40 | 0.60 | 0.75 | 0.82 | 0.90 | 0.95 | 0.97 | 1.00 |
| 100 | 0.40 | 0.60 | 0.75 | 0.82 | 0.90 | 0.95 | 0.97 | 1.00 |

**Table 10**

| 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” | ΔC/C: ± 5 %<br>tan δ ≤ spec. limit<br>$I_{L2}$ ≤ spec. limit |
| Endurance | IEC 60384-18 / CECC 32300, subclause 4.15 | $T_{amb}$ = 125 °C; $U_R$ applied; for test duration see Table 7 | $U_R$ ≥ 16 V; ΔC/C: ± 20 %<br>tan δ ≤ 2 x spec. limit<br>$I_{L2}$ ≤ spec. limit |
| Useful life | CECC 30301, subclause 1.8.1 | $T_{amb}$ = 125 °C; $U_R$ and $I_R$ applied; for test duration see Table 7 | ΔC/C: ± 30 %<br>tan δ ≤ 3 x spec. limit<br>$I_{L2}$ ≤ spec. limit<br>no short or open circuit<br>total failure percentage: ≤ 1 % |
| Shelf life (storage at high temperature) | IEC 60384-18 / CECC 32300, subclause 4.17 | $T_{amb}$ = 125 °C; no voltage applied; 1000 h<br>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 | $T_{amb}$ = 125 °C:<br>125 h at U = -0.5 V,<br>followed by 125 h at $U_R$ | ΔC/C: ± 15 %<br>tan δ ≤ 1.5 x spec. limit<br>$I_{L2}$ ≤ spec. limit |

*Statements about product lifetime are based on calculations and internal testing. They should only be interpreted as estimations. Also due to external factors, the lifetime in the field application may deviate from the calculated lifetime. In general, nothing stated herein shall be construed as a guarantee of durability.*


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