

## Aluminum Electrolytic Capacitors Radial Low Leakage Current

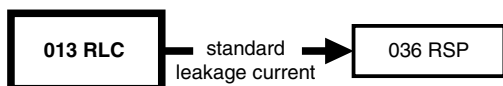


Fig. 1

### QUICK REFERENCE DATA

| DESCRIPTION                                           | VALUE                                                          |
|-------------------------------------------------------|----------------------------------------------------------------|
| Nominal case sizes<br>( $\varnothing$ D x L in mm)    | 5 x 11 and 8.2 x 11                                            |
| Rated capacitance range, $C_R$                        | 2.2 $\mu$ F to 470 $\mu$ F                                     |
| Tolerance on $C_R$                                    | $\pm 20$ %; $\pm 10$ % on request                              |
| Rated voltage range, $U_R$                            | 6.3 V to 50 V                                                  |
| Category temperature range                            | -40 °C to +85 °C                                               |
| Leakage current after 2 min:<br>$U_R = 6.3$ V to 25 V | 0.002 $C_R \times U_R$ or 0.7 $\mu$ A,<br>whichever is greater |
| $U_R = 35$ V and 50 V                                 | 0.002 $C_R \times U_R + 1$ $\mu$ A                             |
| Endurance test at 85 °C                               | 2000 h                                                         |
| Useful life at 105 °C                                 | 750 h                                                          |
| Useful life at 85 °C                                  | 3000 h                                                         |
| Useful life at 40 °C, 1.4 x $I_R$ applied             | 80 000 h                                                       |
| Shelf life at 0 V, 85 °C                              | 500 h                                                          |
| Based on sectional specification                      | IEC 60384-4 / EN 130300                                        |
| Climatic category IEC 60068                           | 40 / 085 / 56                                                  |

### FEATURES

- Useful life at +85 °C: 3000 h
- Low leakage current, low energy consumption
- Miniaturized, high CV-product per unit volume
- Natural pitch 2.5 mm and 5 mm
- Polarized aluminum electrolytic capacitors, non-solid electrolyte
- Radial leads, cylindrical aluminum case, all-insulated (light blue)
- Charge and discharge proof
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)


**RoHS**  
COMPLIANT

### APPLICATIONS

- Telecommunication, automotive, audio-video, EDP and industrial
- Coupling, decoupling, buffering, timing, energy storage
- Portable and mobile equipment
- Low surface demand on printed-circuit board

### MARKING

The capacitors are marked (where possible) with the following information:

- Rated capacitance (in  $\mu$ F)
- Tolerance on rated capacitance, code letter in accordance with IEC 60062 (M for  $\pm 20$  %)
- Rated voltage (in V)
- Date code in accordance with IEC 60062
- Code indicating factory of origin
- Name of manufacturer
- “-”-sign on top to identify the negative terminal
- Series number (013)

### SELECTION CHART FOR $C_R$ , $U_R$ , AND RELEVANT NOMINAL CASE SIZES ( $\varnothing$ D x L in mm)

| $C_R$<br>( $\mu$ F) | $U_R$ (V) |          |        |          |          |          |
|---------------------|-----------|----------|--------|----------|----------|----------|
|                     | 6.3       | 10       | 16     | 25       | 35       | 50       |
| 2.2                 | -         | -        | -      | 5 x 11   | -        | 5 x 11   |
| 3.3                 | -         | -        | -      | 5 x 11   | -        | 5 x 11   |
| 4.7                 | -         | -        | -      | 5 x 11   | -        | 5 x 11   |
| 10                  | -         | -        | -      | 5 x 11   | -        | 5 x 11   |
| 22                  | -         | -        | -      | 5 x 11   | -        | 5 x 11   |
| 33                  | -         | -        | 5 x 11 | -        | 5 x 11   | 8.2 x 11 |
| 47                  | -         | 5 x 11   | 5 x 11 | 8.2 x 11 | -        | 8.2 x 11 |
| 68                  | -         | 5 x 11   | -      | -        | -        | 8.2 x 11 |
| 100                 | -         | 5 x 11   | -      | -        | 8.2 x 11 | -        |
| 220                 | -         | 8.2 x 11 | -      | -        | -        | -        |
| 330                 | 8.2 x 11  | -        | -      | -        | -        | -        |
| 470                 | 8.2 x 11  | -        | -      | -        | -        | -        |

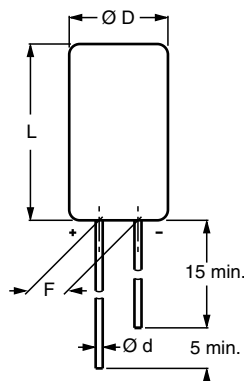
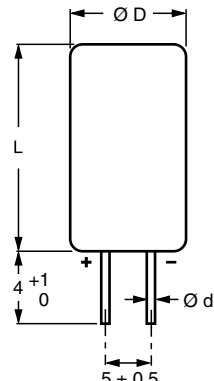
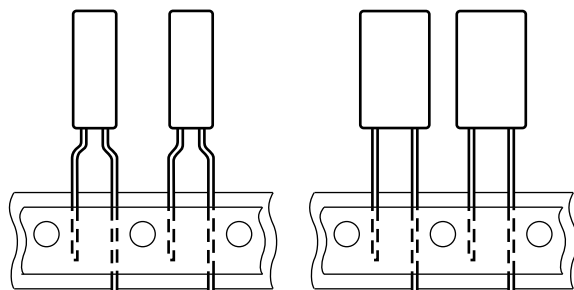
**DIMENSIONS** in millimeters **AND AVAILABLE FORMS**

Fig. 2 - **Form CA:** Long leads

Fig. 3 - **Form CB:** Cut leads

Case  $\varnothing D \times L = 5 \text{ mm} \times 11 \text{ mm}$  and  $8.2 \text{ mm} \times 11 \text{ mm}$   
Pitch  $F = 5 \text{ mm}$ 

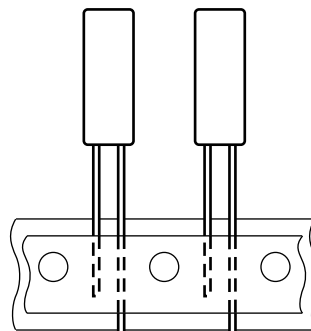
Fig. 4 - **Form TFA:** Taped in box (ammopack)

Case  $\varnothing D \times L = 5 \text{ mm} \times 11 \text{ mm}$  only  
Pitch  $F = 2.5 \text{ mm}$ 

Fig. 5 - **Form TNA:** Taped in box (ammopack)

| <b>DIMENSIONS</b> in millimeters, <b>MASS AND PACKAGING QUANTITIES</b> |              |                 |                               |                   |               |               |                      |                  |
|------------------------------------------------------------------------|--------------|-----------------|-------------------------------|-------------------|---------------|---------------|----------------------|------------------|
| NOMINAL<br>CASE SIZE<br>$\varnothing D \times L$                       | CASE<br>CODE | $\varnothing d$ | $\varnothing D_{\text{max.}}$ | $L_{\text{max.}}$ | F             | MASS<br>(g)   | PACKAGING QUANTITIES |                  |
|                                                                        |              |                 |                               |                   |               |               | FORM<br>CA, CB       | FORM<br>TFA, TNA |
| 5 x 11                                                                 | 11           | 0.5             | 5.5                           | 12                | $2.5 \pm 0.5$ | $\approx 0.4$ | 1000                 | 2000             |
| 8.2 x 11                                                               | 13           | 0.6             | 8.7                           | 12                | $5.0 \pm 0.5$ | $\approx 1.1$ | 1000                 | 1000             |

**Note**

- For detailed tape dimensions, please see [www.vishay.com/doc?28360](http://www.vishay.com/doc?28360).



| ELECTRICAL DATA |                                                   |
|-----------------|---------------------------------------------------|
| SYMBOL          | DESCRIPTION                                       |
| $C_R$           | Rated capacitance at 100 Hz, tolerance $\pm 20\%$ |
| $I_R$           | Rated RMS ripple current at 100 Hz, 85 °C         |
| $I_{L2}$        | Max. leakage current after 2 min at $U_R$         |
| $\tan \delta$   | Max. dissipation factor at 100 Hz                 |
| $Z$             | Max. impedance at 10 kHz and + 20 °C              |

**Note**

- Unless otherwise specified, all electrical values in Table 1 apply at  $T_{amb} = 20\text{ °C}$ ,  $P = 86\text{ kPa}$  to  $106\text{ kPa}$ ,  $RH = 45\%$  to  $75\%$ .

Table 1

| ELECTRICAL DATA AND ORDERING INFORMATION |                                  |                                            |                                           |                                  |                 |                    |                            |           |            |           |                |           |             |           |
|------------------------------------------|----------------------------------|--------------------------------------------|-------------------------------------------|----------------------------------|-----------------|--------------------|----------------------------|-----------|------------|-----------|----------------|-----------|-------------|-----------|
| U <sub>R</sub><br>(V)                    | C <sub>R</sub><br>100 Hz<br>(μF) | NOMINAL<br>CASE<br>SIZE<br>Ø D x L<br>(mm) | I <sub>R</sub><br>100 Hz<br>85 °C<br>(mA) | I <sub>L2</sub><br>2 min<br>(μA) | tan δ<br>100 Hz | Z<br>10 kHz<br>(Ω) | ORDERING CODE MAL2013..... |           |            |           |                |           |             |           |
|                                          |                                  |                                            |                                           |                                  |                 |                    | BULK PACKAGING             |           |            |           | TAPED AMMOPACK |           |             |           |
|                                          |                                  |                                            |                                           |                                  |                 |                    | LONG LEADS                 |           | CUT LEADS  |           |                |           |             |           |
|                                          |                                  |                                            |                                           |                                  |                 |                    | FORM<br>CA                 | F<br>(mm) | FORM<br>CB | F<br>(mm) | FORM<br>TFA    | F<br>(mm) | FORM<br>TNA | F<br>(mm) |
| 6.3                                      | 330                              | 8.2 x 11                                   | 210                                       | 4.2                              | 0.2             | 0.9                | 53331E3                    | 5.0       | 63331E3    | 5.0       | 33331E3        | 5.0       | -           | -         |
|                                          | 470                              | 8.2 x 11                                   | 250                                       | 5.9                              | 0.2             | 0.64               | 53471E3                    | 5.0       | 63471E3    | 5.0       | 33471E3        | 5.0       | -           | -         |
| 10                                       | 47                               | 5 x 11                                     | 75                                        | 1.0                              | 0.16            | 2.8                | 54479E3                    | 2.5       | -          | -         | 34479E3        | 5.0       | 74479E3     | 2.5       |
|                                          | 68                               | 5 x 11                                     | 90                                        | 1.4                              | 0.16            | 2.5                | 54689E3                    | 2.5       | -          | -         | 34689E3        | 5.0       | 74689E3     | 2.5       |
|                                          | 100                              | 5 x 11                                     | 110                                       | 2.0                              | 0.16            | 1.7                | 54101E3                    | 2.5       | -          | -         | 34101E3        | 5.0       | 74101E3     | 2.5       |
|                                          | 220                              | 8.2 x 11                                   | 190                                       | 4.4                              | 0.16            | 0.9                | 54221E3                    | 5.0       | 64221E3    | 5.0       | 34221E3        | 5.0       | -           | -         |
| 16                                       | 33                               | 5 x 11                                     | 70                                        | 1.1                              | 0.13            | 2.8                | 55339E3                    | 2.5       | -          | -         | 35339E3        | 5.0       | 75339E3     | 2.5       |
|                                          | 47                               | 5 x 11                                     | 85                                        | 1.5                              | 0.13            | 2.1                | 55479E3                    | 2.5       | -          | -         | 35479E3        | 5.0       | 75479E3     | 2.5       |
|                                          | 100                              | 8.2 x 11                                   | 150                                       | 3.2                              | 0.13            | 1.0                | 55101E3                    | 5.0       | 65101E3    | 5.0       | 35101E3        | 5.0       | -           | -         |
| 25                                       | 2.2                              | 5 x 11                                     | 10                                        | 0.7                              | 0.06            | 18                 | 56228E3                    | 2.5       | -          | -         | 36228E3        | 5.0       | 76228E3     | 2.5       |
|                                          | 3.3                              | 5 x 11                                     | 18                                        | 0.7                              | 0.06            | 12                 | 56338E3                    | 2.5       | -          | -         | 36338E3        | 5.0       | 76338E3     | 2.5       |
|                                          | 4.7                              | 5 x 11                                     | 25                                        | 0.7                              | 0.06            | 8.5                | 56478E3                    | 2.5       | -          | -         | 36478E3        | 5.0       | 76478E3     | 2.5       |
|                                          | 10                               | 5 x 11                                     | 50                                        | 0.7                              | 0.06            | 4.0                | 56109E3                    | 2.5       | -          | -         | 36109E3        | 5.0       | 76109E3     | 2.5       |
|                                          | 22                               | 5 x 11                                     | 75                                        | 1.1                              | 0.08            | 2.7                | 56229E3                    | 2.5       | -          | -         | 36229E3        | 5.0       | 76229E3     | 2.5       |
|                                          | 47                               | 8.2 x 11                                   | 130                                       | 2.4                              | 0.08            | 1.3                | 56479E3                    | 5.0       | 66479E3    | 5.0       | 36479E3        | 5.0       | -           | -         |
| 35                                       | 33                               | 5 x 11                                     | 70                                        | 3.3                              | 0.13            | 2.8                | 50339E3                    | 2.5       | -          | -         | 30339E3        | 5.0       | 70339E3     | 2.5       |
|                                          | 100                              | 8.2 x 11                                   | 150                                       | 8.0                              | 0.13            | 1.0                | 50101E3                    | 5.0       | 60101E3    | 5.0       | 30101E3        | 5.0       | -           | -         |
| 50                                       | 2.2                              | 5 x 11                                     | 20                                        | 1.2                              | 0.06            | 18                 | 51228E3                    | 2.5       | -          | -         | 31228E3        | 5.0       | 71228E3     | 2.5       |
|                                          | 3.3                              | 5 x 11                                     | 32                                        | 1.3                              | 0.06            | 12                 | 51338E3                    | 2.5       | -          | -         | 31338E3        | 5.0       | 71338E3     | 2.5       |
|                                          | 4.7                              | 5 x 11                                     | 38                                        | 1.5                              | 0.06            | 8.5                | 51478E3                    | 2.5       | -          | -         | 31478E3        | 5.0       | 71478E3     | 2.5       |
|                                          | 10                               | 5 x 11                                     | 55                                        | 2.0                              | 0.06            | 4.0                | 51109E3                    | 2.5       | -          | -         | 31109E3        | 5.0       | 71109E3     | 2.5       |
|                                          | 22                               | 5 x 11                                     | 75                                        | 3.2                              | 0.08            | 2.7                | 51229E3                    | 2.5       | -          | -         | 31229E3        | 5.0       | 71229E3     | 2.5       |
|                                          | 33                               | 8.2 x 11                                   | 110                                       | 4.3                              | 0.06            | 1.4                | 51339E3                    | 5.0       | 61339E3    | 5.0       | 31339E3        | 5.0       | -           | -         |
|                                          | 47                               | 8.2 x 11                                   | 130                                       | 5.7                              | 0.08            | 1.3                | 51479E3                    | 5.0       | 61479E3    | 5.0       | 31479E3        | 5.0       | -           | -         |
|                                          | 68                               | 8.2 x 11                                   | 150                                       | 7.8                              | 0.08            | 1.2                | 51689E3                    | 5.0       | 61689E3    | 5.0       | 31689E3        | 5.0       | -           | -         |

**ORDERING EXAMPLE**

Electrolytic capacitor 013 series

100  $\mu\text{F}$  / 16 V;  $\pm 20\%$ Nominal case size:  $\varnothing 8.2\text{ mm} \times 11\text{ mm}$ ; Form TFA

Ordering Code: MAL201335101E3

Former 12NC: 2222 013 35101

| ADDITIONAL ELECTRICAL DATA         |                                                                                                            |                                                                                                                                      |
|------------------------------------|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| PARAMETER                          | CONDITIONS                                                                                                 | VALUE                                                                                                                                |
| <b>Voltage</b>                     |                                                                                                            |                                                                                                                                      |
| Surge voltage                      |                                                                                                            | $U_s \leq 1.3 \times U_R$                                                                                                            |
| Reverse voltage                    |                                                                                                            | $U_{rev} \leq 1 \text{ V}$                                                                                                           |
| <b>Current</b>                     |                                                                                                            |                                                                                                                                      |
| Leakage current                    | After 2 min at $U_R$ :<br>$U_R = 6.3 \text{ V to } 25 \text{ V}$<br>$U_R = 35 \text{ V and } 50 \text{ V}$ | $I_{L2} \leq 0.002 C_R \times U_R$ or $0.7 \mu\text{A}$ , whichever is greater<br>$I_{L2} \leq 0.002 C_R \times U_R + 1 \mu\text{A}$ |
| <b>Inductance</b>                  |                                                                                                            |                                                                                                                                      |
| Equivalent series inductance (ESL) | Case $\varnothing D \times L = 5 \text{ mm} \times 11 \text{ mm}$                                          | Typ. 13 nH                                                                                                                           |
|                                    | Case $\varnothing D \times L = 8.2 \text{ mm} \times 11 \text{ mm}$                                        | Typ. 16 nH                                                                                                                           |
| <b>Resistance</b>                  |                                                                                                            |                                                                                                                                      |
| Equivalent series resistance (ESR) | Calculated from $\tan \delta_{max}$ and $C_R$ (see Table 1)                                                | $ESR = \tan \delta / 2 \pi f C_R$                                                                                                    |

## CAPACITANCE (C)

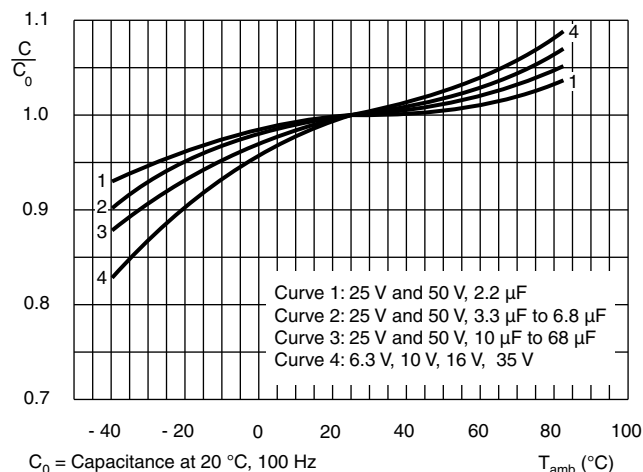


Fig. 6 - Typical multiplier of capacitance as a function of ambient temperature

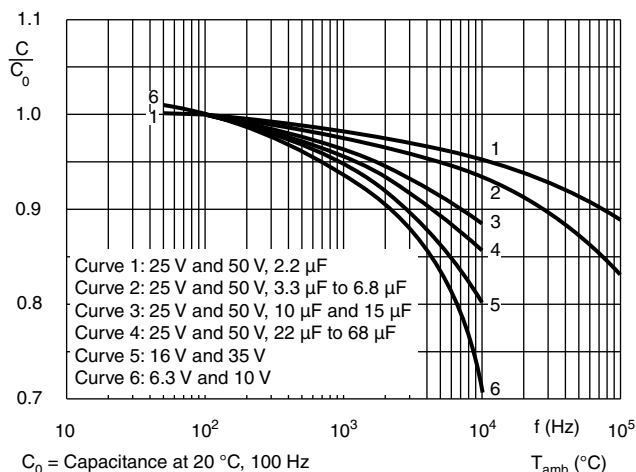


Fig. 7 - Typical multiplier of capacitance as a function of frequency

## LEAKAGE CURRENT

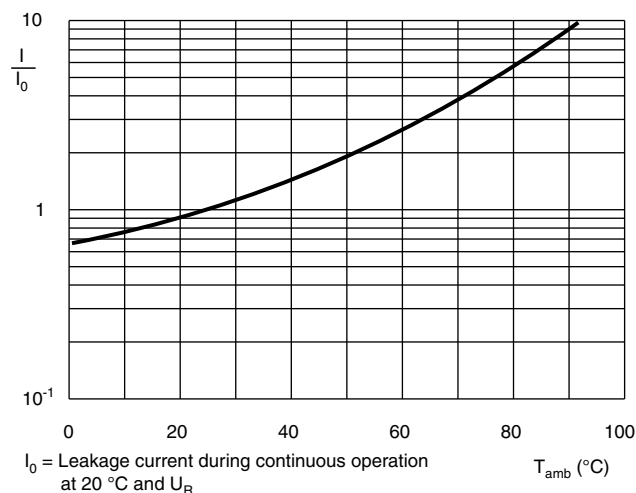


Fig. 8 - Typical multiplier of leakage current as a function of ambient temperature

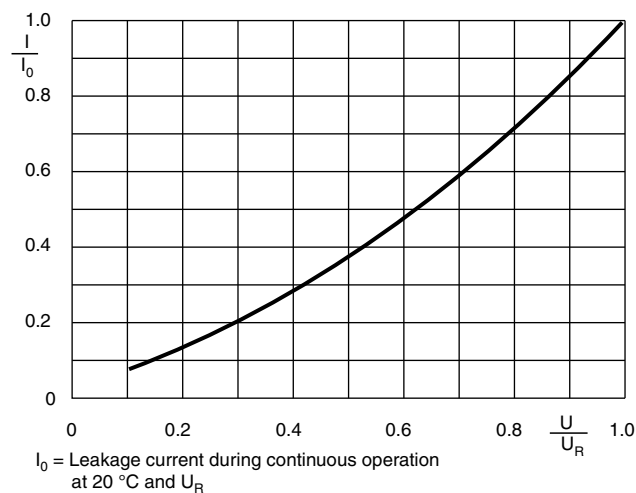


Fig. 9 - Typical multiplier of leakage current as a function of time

## LEAKAGE CURRENT

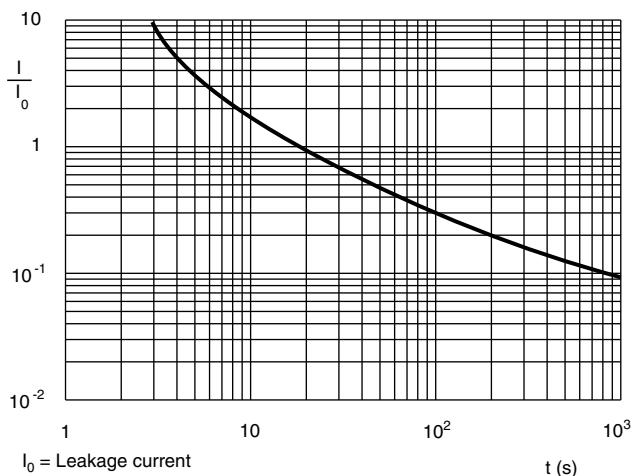


Fig. 10 - Typical multiplier of leakage current as a function of time

## RIPPLE CURRENT AND USEFUL LIFE

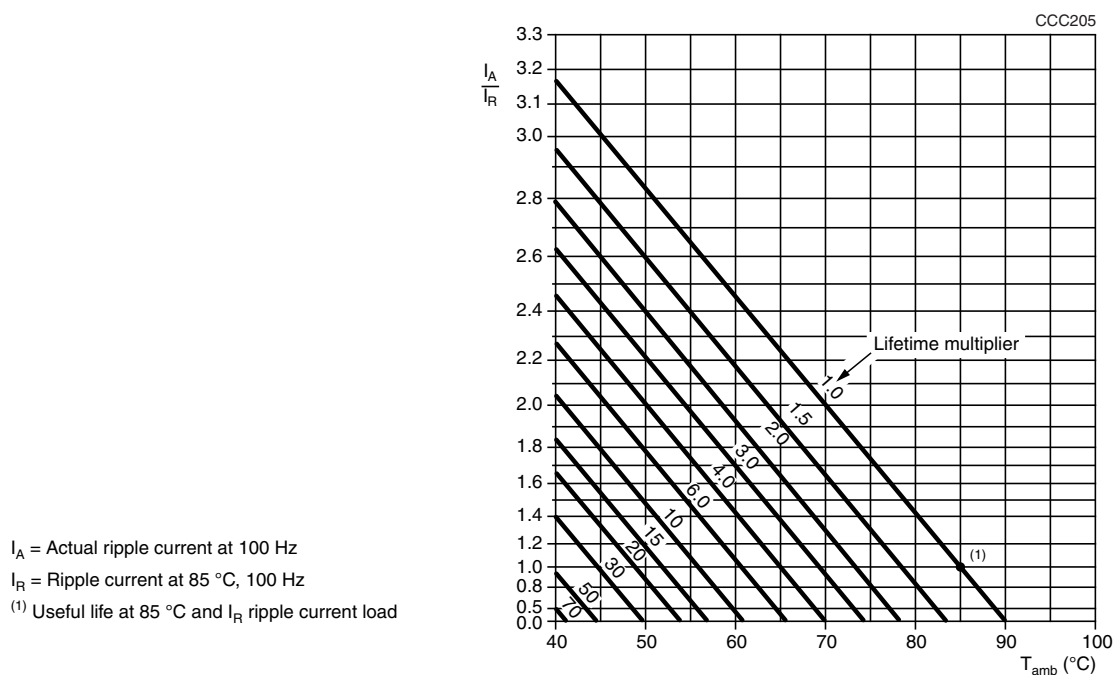


Fig. 11 - Multiplier of useful life as a function of ambient temperature and ripple current load

Table 2

| MULTIPLIER OF RIPPLE CURRENT ( $I_R$ ) AS A FUNCTION OF FREQUENCY |                       |                                                        |                                        |
|-------------------------------------------------------------------|-----------------------|--------------------------------------------------------|----------------------------------------|
| FREQUENCY<br>(Hz)                                                 | $I_R$ MULTIPLIER      |                                                        |                                        |
|                                                                   | $U_R = 6.3 \text{ V}$ | $U_R = 10 \text{ V, } 16 \text{ V, and } 35 \text{ V}$ | $U_R = 25 \text{ V and } 50 \text{ V}$ |
| 50                                                                | 0.90                  | 0.85                                                   | 0.80                                   |
| 100                                                               | 1.00                  | 1.00                                                   | 1.00                                   |
| 300                                                               | 1.12                  | 1.20                                                   | 1.25                                   |
| 1000                                                              | 1.20                  | 1.30                                                   | 1.40                                   |
| 3000                                                              | 1.25                  | 1.35                                                   | 1.50                                   |
| $\geq 10\,000$                                                    | 1.30                  | 1.40                                                   | 1.60                                   |

Table 3

| TEST PROCEDURES AND REQUIREMENTS            |                                              |                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TEST                                        |                                              | PROCEDURE                                                                                                                                            | REQUIREMENTS                                                                                                                                                                                                                                                                                                               |
| NAME OF TEST                                | REFERENCE                                    |                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                            |
| Endurance                                   | IEC 60384-4 /<br>EN130300, subclause 4.13    | $T_{amb} = 85\text{ }^{\circ}\text{C}$ ; $U_R$ applied; 2000 h                                                                                       | $U_R \leq 6.3\text{ V}$ ; $\Delta C/C$ : +15 % / -30 %<br>$U_R > 6.3\text{ V}$ ; $\Delta C/C$ : $\pm 15\text{ }%$<br>$\tan \delta \leq 1.3 \times \text{spec. limit}$<br>$Z \leq 2 \times \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$                                                                          |
| Useful life                                 | CECC 30301,<br>subclause 1.8.1               | $T_{amb} = 85\text{ }^{\circ}\text{C}$ ; $U_R$ and $I_R$ applied; 3000 h                                                                             | $U_R \leq 6.3\text{ V}$ ; $\Delta C/C$ : +45 % / -50 %<br>$U_R > 6.3\text{ V}$ ; $\Delta C/C$ : $\pm 45\text{ }%$<br>$\tan \delta \leq 3 \times \text{spec. limit}$<br>$Z \leq 3 \times \text{spec. limit}$<br>$I_{L2} \leq \text{spec. limit}$<br>no short or open circuit<br>total failure percentage: $\leq 1\text{ }%$ |
| Shelf life<br>(storage at high temperature) | IEC 60384-4 /<br>EN130300,<br>subclause 4.17 | $T_{amb} = 85\text{ }^{\circ}\text{C}$ ; no voltage applied; 500 h<br>After test: $U_R$ to be applied for 30 min,<br>24 h to 48 h before measurement | $\Delta C/C$ , $\tan \delta$ , $Z$ :<br>For requirements<br>see "Endurance test" above<br>$I_{L2} \leq 2 \times \text{spec. limit}$                                                                                                                                                                                        |

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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