

# Interference Suppression Film Capacitor - Class X2

## Radial MKT 310 V<sub>AC</sub> - High Stability Grade



### FEATURES

- AEC-Q200 qualified (rev. D) up to 110 °C for  $\leq 470$  nF
- Compliant with IEC 60384-14: AMD1 grade IB  
- THB: 85 °C / 85 % RH, 168 h at U<sub>RAC</sub>
- THB: 40 °C / 90 % RH for 1000 h at rated voltage, in compliance with AEC-Q200
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)

AUTOMOTIVE  
GRADE  
Available



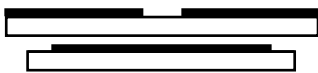
**RoHS**  
COMPLIANT

### APPLICATIONS

High stability grade for continuous across the line X2 applications.

See also application note: [www.vishay.com/doc?28153](http://www.vishay.com/doc?28153)

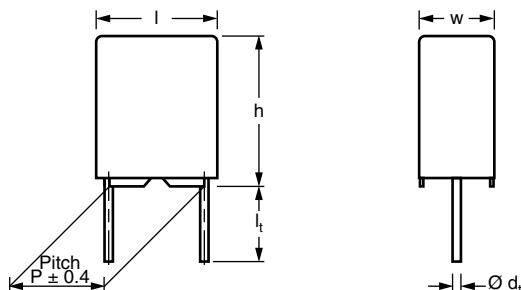
### QUICK REFERENCE DATA

|                                                 |                                                                                                                                                                                            |
|-------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Capacitance range (E12 series)                  | 0.01 $\mu$ F to 2.2 $\mu$ F<br>(preferred values acc. to E6)                                                                                                                               |
| Capacitance tolerance                           | $\pm 10$ %, $\pm 20$ % ( $\pm 5$ % on request)                                                                                                                                             |
| Rated AC voltage                                | 310 V <sub>AC</sub> ; 50 Hz to 60 Hz                                                                                                                                                       |
| Permissible DC voltage                          | 800 V <sub>DC</sub> at 85 °C<br>630 V <sub>DC</sub> at 110 °C                                                                                                                              |
| Climatic testing class according to IEC 60068-1 | 40/110/56/C for the product volume $\leq 1750$ mm <sup>3</sup><br>40/110/56/B for the product volume $\geq 1750$ mm <sup>3</sup>                                                           |
| Maximum application temperature                 | 110 °C                                                                                                                                                                                     |
| Reference standards                             | IEC 60384-14 ed-4 and EN 60384-14<br>IEC 60065 pass. flamm. class C<br>CSA-E384-14<br>UL 60384-14                                                                                          |
| Dielectric                                      | Polyester film                                                                                                                                                                             |
| Electrodes                                      | Metallized                                                                                                                                                                                 |
| Construction                                    | Series construction<br>                                                                                |
| Encapsulation                                   | Plastic case, epoxy resin sealed, flame retardant UL-class 94 V-0                                                                                                                          |
| Leads                                           | Tinned wire                                                                                                                                                                                |
| Marking                                         | C-value; tolerance; rated voltage; sub-class; manufacturer's type;<br>code for dielectric material; manufacturer location, year and week;<br>manufacturer's logo or name; safety approvals |

#### Note

- For more detailed data and test requirements, contact [rfi@vishay.com](mailto:rfi@vishay.com)

### DIMENSIONS in millimeters



**COMPOSITION OF CATALOG NUMBER**


Example: F1772415**2215** means 0.15 µF, ± 20 %; standard pitch 22.5 mm; lead length 15 mm - 1 mm;  
 F1772415**2265** means 0.15 µF, ± 20 %; reduced pitch 15.0 mm; lead length 15 mm - 1 mm

**Notes**

- For detailed tape specifications refer to packaging information [www.vishay.com/doc?28139](http://www.vishay.com/doc?28139)
- <sup>(1)</sup> Taped on reel pitch ≥ 27.5 mm is not available
- <sup>(2)</sup> Same capacitance values ≥ 0.15 µF are available in two different pitch sizes and dimensions

| SPECIFIC REFERENCE DATA                                                                 |                                   |
|-----------------------------------------------------------------------------------------|-----------------------------------|
| DESCRIPTION                                                                             | VALUE                             |
| Rated AC voltage (U <sub>RAC</sub> )                                                    | 310 V                             |
| Permissible DC voltage (U <sub>RDC</sub> )                                              | 630 V                             |
| Tangent of loss angle                                                                   | ≤ 100 x 10 <sup>-4</sup> at 1 kHz |
| Rated voltage pulse slope at (dU/dt) <sub>R</sub> 435 V <sub>DC</sub>                   | 100 V/µs                          |
| R between leads, for C ≤ 0.33 µF at 100 V; 1 min                                        | > 15 000 MΩ                       |
| RC between leads, C > 0.33 µF at 100 V; 1 min                                           | > 5000 s                          |
| R between leads and case; 100 V; 1 min                                                  | > 30 000 MΩ                       |
| Withstanding (DC) voltage (cut off current 10 mA) <sup>(1)</sup> ; rise time ≤ 1000 V/s |                                   |
| C ≤ 0.47 µF                                                                             | 2200 V; for 1 min                 |
| C > 0.47 µF                                                                             | 2150 V; for 1 min                 |
| Withstanding (AC) voltage between leads and case                                        | 2120 V; 1 min                     |
| Maximum application temperature                                                         | 110 °C                            |

**Note**

- See "Voltage Proof Test for Metalized Film Capacitors": [www.vishay.com/doc?28169](http://www.vishay.com/doc?28169)



## ELECTRICAL DATA AND ORDERING INFORMATION

| $U_{RAC}$<br>(V) | CAP.<br>( $\mu$ F)                                                     | PITCH<br>(mm) | DIMENSIONS <sup>(4)</sup><br>w x h x l<br>MAX. (mm) | MASS <sup>(3)</sup><br>(g) | SPQ<br>(pieces)<br>SHORT LEAD | ORDERING CODE<br>BULK<br>LEAD LENGTH<br>6 mm - 1 mm <sup>(1)(2)</sup> |
|------------------|------------------------------------------------------------------------|---------------|-----------------------------------------------------|----------------------------|-------------------------------|-----------------------------------------------------------------------|
| 310              | $d_t = 0.60 \text{ mm} \pm 0.06 \text{ mm}; \text{C-TOL.} = \pm 10 \%$ |               |                                                     |                            |                               |                                                                       |
|                  | 0.010                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723102000                                                          |
|                  | 0.012                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723122000                                                          |
|                  | 0.015                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723152000                                                          |
|                  | 0.018                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723182000                                                          |
|                  | 0.022                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723222000                                                          |
|                  | 0.027                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723272000                                                          |
|                  | 0.033                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723332000                                                          |
|                  | 0.039                                                                  | 15            | 6.0 x 12.0 x 17.5                                   | 2.0                        | 500                           | F17723392000                                                          |
|                  | 0.047                                                                  | 15            | 6.0 x 12.0 x 17.5                                   | 2.0                        | 500                           | F17723472000                                                          |
|                  | 0.056                                                                  | 15            | 6.0 x 12.0 x 17.5                                   | 2.0                        | 500                           | F17723562000                                                          |
|                  | $d_t = 0.80 \text{ mm} \pm 0.08 \text{ mm}; \text{C-TOL.} = \pm 10 \%$ |               |                                                     |                            |                               |                                                                       |
|                  | 0.068                                                                  | 15            | 7.0 x 13.5 x 17.5                                   | 2.4                        | 450                           | F17723682000                                                          |
|                  | 0.082                                                                  | 15            | 8.5 x 15.0 x 17.5                                   | 2.7                        | 300                           | F17723822000                                                          |
|                  | 0.10                                                                   | 15            | 8.5 x 15.0 x 17.5                                   | 2.7                        | 325                           | F17724102000                                                          |
|                  | 0.12                                                                   | 15            | 8.5 x 15.0 x 17.5                                   | 2.7                        | 300                           | F17724122000                                                          |
|                  | 0.15                                                                   | 15            | 8.5 x 15.0 x 17.5                                   | 2.7                        | 300                           | F17724152160                                                          |
|                  | 0.15                                                                   | 22.5          | 7.0 x 16.5 x 26.0                                   | 4.1                        | 235                           | F17724152000                                                          |
|                  | 0.18                                                                   | 22.5          | 7.0 x 16.5 x 26.0                                   | 4.1                        | 235                           | F17724182000                                                          |
|                  | 0.22                                                                   | 15            | 10.0 x 16.5 x 17.5                                  | 3.0                        | 235                           | F17724222160                                                          |
|                  | 0.22                                                                   | 22.5          | 8.5 x 16.5 x 26.5                                   | 4.6                        | 200                           | F17724222000                                                          |
|                  | 0.27                                                                   | 22.5          | 10.0 x 19.5 x 26.0                                  | 6.7                        | 170                           | F17724272000                                                          |
|                  | 0.33                                                                   | 15            | 13.5 x 22.5 x 18.0                                  | 5.5                        | 185                           | F17724332160                                                          |
|                  | 0.33                                                                   | 22.5          | 10.0 x 19.5 x 26.0                                  | 6.7                        | 170                           | F17724332000                                                          |
|                  | 0.39                                                                   | 27.5          | 11.0 x 21.0 x 31.0                                  | 9.1                        | 125                           | F17724392000                                                          |
|                  | 0.47                                                                   | 22.5          | 12.0 x 22.0 x 26.0                                  | 13.0                       | 110                           | F17724472160                                                          |
|                  | 0.47                                                                   | 27.5          | 11.0 x 21.0 x 31.0                                  | 9.1                        | 125                           | F17724472000                                                          |
|                  | 0.56                                                                   | 27.5          | 11.0 x 21.0 x 31.0                                  | 9.1                        | 125                           | F17724562000                                                          |
|                  | 0.68                                                                   | 22.5          | 15.5 x 26.5 x 26.5                                  | 13.5                       | 110                           | F17724682160                                                          |
|                  | 0.68                                                                   | 27.5          | 13.0 x 23.0 x 31.0                                  | 12.9                       | 110                           | F17724682000                                                          |
|                  | 0.82                                                                   | 27.5          | 13.0 x 23.0 x 31.0                                  | 12.9                       | 110                           | F17724822000                                                          |
|                  | 1.0                                                                    | 22.5          | 15.5 x 26.5 x 26.5                                  | 13.5                       | 110                           | F17725102160                                                          |
|                  | 1.0                                                                    | 27.5          | 15.0 x 25.0 x 31.5                                  | 15.0                       | 100                           | F17725102000                                                          |
|                  | 1.2                                                                    | 37.5          | 14.5 x 24.5 x 41.5                                  | 18.9                       | 80                            | F17725122000                                                          |
|                  | 1.5                                                                    | 27.5          | 18.0 x 28.0 x 31.0                                  | 19.0                       | 85                            | F17725152160                                                          |
|                  | 1.5                                                                    | 37.5          | 15.5 x 28.5 x 41.5                                  | 24.0                       | 70                            | F17725152000                                                          |
|                  | 1.8                                                                    | 37.5          | 15.5 x 28.5 x 41.5                                  | 24.0                       | 70                            | F17725182000                                                          |
|                  | 2.2                                                                    | 27.5          | 21.0 x 31.0 x 31.0                                  | 28.0                       | 70                            | F17725222160                                                          |
|                  | 2.2                                                                    | 37.5          | 18.0 x 32.5 x 41.5                                  | 31.6                       | 60                            | F17725222000                                                          |
|                  | $d_t = 0.60 \text{ mm} \pm 0.06 \text{ mm}; \text{C-TOL.} = \pm 20 \%$ |               |                                                     |                            |                               |                                                                       |
|                  | 0.010                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723102200                                                          |
|                  | 0.015                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723152200                                                          |
|                  | 0.022                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723222200                                                          |
|                  | 0.033                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723332200                                                          |
|                  | 0.047                                                                  | 15            | 5.0 x 11.0 x 17.5                                   | 1.4                        | 750                           | F17723472200                                                          |
|                  | 0.068                                                                  | 15            | 6.0 x 12.0 x 17.5                                   | 2.0                        | 600                           | F17723682200                                                          |
|                  | 0.10                                                                   | 15            | 6.0 x 12.0 x 17.5                                   | 2.0                        | 600                           | F17724102200                                                          |

**ELECTRICAL DATA AND ORDERING INFORMATION**

| $U_{RAC}$<br>(V) | CAP.<br>( $\mu$ F)                                                 | PITCH<br>(mm) | DIMENSIONS <sup>(4)</sup><br>w x h x l<br>MAX. (mm) | MASS <sup>(3)</sup><br>(g) | SPQ<br>(pieces)<br>SHORT LEAD | ORDERING CODE<br>BULK<br>LEAD LENGTH<br>6 mm - 1 mm <sup>(1)(2)</sup> |
|------------------|--------------------------------------------------------------------|---------------|-----------------------------------------------------|----------------------------|-------------------------------|-----------------------------------------------------------------------|
| 310              | $d_t = 0.80 \text{ mm} \pm 0.08 \text{ mm}$ ; C-TOL. = $\pm 20 \%$ |               |                                                     |                            |                               |                                                                       |
|                  | 0.15                                                               | 15            | 8.5 x 15.0 x 17.5                                   | 2.7                        | 325                           | F17724152260                                                          |
|                  | 0.15                                                               | 22.5          | 6.0 x 15.5 x 26.0                                   | 3.3                        | 260                           | F17724152200                                                          |
|                  | 0.22                                                               | 15            | 10.0 x 16.5 x 17.5                                  | 4.5                        | 300                           | F17724222260                                                          |
|                  | 0.22                                                               | 22.5          | 7.0 x 16.5 x 26.0                                   | 4.1                        | 235                           | F17724222200                                                          |
|                  | 0.33                                                               | 15            | 13.5 x 22.5 x 18.0                                  | 5.5                        | 185                           | F17724332260                                                          |
|                  | 0.33                                                               | 22.5          | 8.5 x 18.0 x 26.0                                   | 5.3                        | 190                           | F17724332200                                                          |
|                  | 0.47                                                               | 22.5          | 10.0 x 19.5 x 26.0                                  | 6.7                        | 170                           | F17724472260                                                          |
|                  | 0.47                                                               | 27.5          | 9.0 x 19.0 x 31.5                                   | 6.8                        | 160                           | F17724472200                                                          |
|                  | 0.68                                                               | 22.5          | 12.0 x 22.0 x 26.0                                  | 13.4                       | 110                           | F17724682260                                                          |
|                  | 0.68                                                               | 27.5          | 11.0 x 21.0 x 31.0                                  | 12.9                       | 125                           | F17724682200                                                          |
|                  | 1.0                                                                | 22.5          | 15.5 x 26.5 x 26.5                                  | 13.5                       | 110                           | F17725102260                                                          |
|                  | 1.0                                                                | 27.5          | 15.0 x 25.0 x 31.5                                  | 15.0                       | 100                           | F17725102200                                                          |
|                  | 1.5                                                                | 27.5          | 18.0 x 28.0 x 31.5                                  | 19.0                       | 85                            | F17725152260                                                          |
|                  | 1.5                                                                | 37.5          | 14.5 x 24.5 x 41.5                                  | 18.9                       | 80                            | F17725152200                                                          |
|                  | 2.2                                                                | 27.5          | 21.0 x 31.0 x 31.0                                  | 28.0                       | 70                            | F17725222260                                                          |
|                  | 2.2                                                                | 37.5          | 15.5 x 28.5 x 41.5                                  | 24.0                       | 70                            | F17725222200                                                          |

**Notes**

- SPQ = Standard Packing Quantity
- For detailed tape specifications refer to packaging information: [www.vishay.com/doc?28139](http://www.vishay.com/doc?28139)
- (1) For further packaging see table "Composition of Catalog Number"
- (2) Further information about packaging quantities with different lead length and / or taped versions, see document "Packing Quantities" [www.vishay.com/doc?27608](http://www.vishay.com/doc?27608)
- (3) Weight for short lead product only
- (4) For tolerances see chapter "Space Requirements for Printed-Circuit Board Applications and Dimension Tolerances"

**APPROVALS**

| SAFETY APPROVALS X2                                                                                                                                                                                                                                                                                                                                                 | VOLTAGE             | VALUE                          | FILE NUMBERS | LINK                                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|--------------------------------|--------------|------------------------------------------------------------------------|
| EN 60384-14 (ENEC)<br>(= IEC 60384-14 ed-4)                                                                                                                                                                                                                                                                                                                         | 310 V <sub>AC</sub> | 0.01 $\mu$ F to 2.2 $\mu$ F X2 | 40005079     | <a href="http://www.vishay.com/doc?28196">www.vishay.com/doc?28196</a> |
| UL 60384-14                                                                                                                                                                                                                                                                                                                                                         | 310 V <sub>AC</sub> | 0.01 $\mu$ F to 2.2 $\mu$ F X2 | E354331      | <a href="http://www.vishay.com/doc?28191">www.vishay.com/doc?28191</a> |
| CSA-E 384-14                                                                                                                                                                                                                                                                                                                                                        | 310 V <sub>AC</sub> | 0.01 $\mu$ F to 2.2 $\mu$ F X2 | E354331      |                                                                        |
| CB test-certificate                                                                                                                                                                                                                                                                                                                                                 | 310 V <sub>AC</sub> | 0.01 $\mu$ F to 2.2 $\mu$ F X2 | DE1-58410    | <a href="http://www.vishay.com/doc?28226">www.vishay.com/doc?28226</a> |
| The ENEC-approval together with the CB-certificate replace all national marks of the following countries (they have already signed the ENEC-agreement): Austria; Belgium; Czech. Republic; Denmark; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Luxembourg; Netherlands; Norway; Portugal; Slovenian; Spain; Sweden; Switzerland and United Kingdom. |                     |                                |              |                                                                        |
|                                                                                                                                                                                              |                     |                                |              |                                                                        |

## MOUNTING

### Normal Use

The capacitors are designed for mounting on printed-circuit boards. The capacitors packed in bandoliers are designed for mounting in printed-circuit boards by means of automatic insertion machines.

For detailed tape specifications refer to packaging information: [www.vishay.com/doc?28139](http://www.vishay.com/doc?28139).

### Specific Method of Mounting to Withstand Vibration and Shock

In order to withstand vibration and shock tests, it must be ensured that stand-off pips are in good contact with the printed-circuit board:

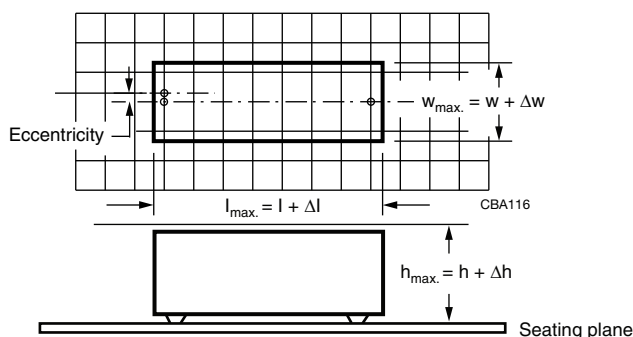
- For pitches  $\leq 15$  mm capacitors shall be mechanically fixed by the leads
- For larger pitches the capacitors shall be mounted in the same way and the body clamped

## SPACE REQUIREMENTS FOR PRINTED-CIRCUIT BOARD APPLICATIONS AND DIMENSION TOLERANCES

For the maximum product dimensions and maximum space requirements for length ( $l_{max.}$ ), width ( $w_{max.}$ ) and height ( $h_{max.}$ ) following tolerances must be taken in account in the envelopment of the components as shown in the drawings below.

- For products with pitch  $\leq 15$  mm,  $\Delta w = \Delta l = 0.3$  mm, and  $\Delta h = 0.1$  mm
- For products with  $15 \text{ mm} < \text{pitch} \leq 27.5$  mm,  $\Delta w = \Delta l = 0.5$  mm, and  $\Delta h = 0.1$  mm
- For products with pitch = 37.5 mm,  $\Delta w = \Delta l = 0.7$  mm, and  $\Delta h = 0.5$  mm

Eccentricity defined as in drawing. The maximum eccentricity is smaller than or equal to the lead diameter of the product concerned.



For the minimum product dimensions for length ( $l_{min.}$ ), width ( $w_{min.}$ ) and height ( $h_{min.}$ ) following tolerances of the components are valid:

$l_{min.} = l - \Delta l$ ,  $w_{min.} = w - \Delta w$ , and  $h_{min.} = h - \Delta h$  following

- For products with pitch  $\leq 10$  mm,  $\Delta l = 0.3$  mm, and  $\Delta w = \Delta h = 0.3$  mm
- For products with pitch = 15 mm,  $\Delta l = 0.5$  mm, and  $\Delta w = \Delta h = 0.5$  mm
- For products with  $15 \text{ mm} < \text{pitch} \leq 27.5$  mm,  $\Delta l = 1.0$  mm and  $\Delta w = \Delta h = 0.5$  mm
- For products with pitch = 37.5 mm,  $\Delta l = 1.0$  mm and  $\Delta w = \Delta h = 1.0$  mm

## SOLDERING CONDITIONS

For general soldering conditions and wave soldering profile, we refer to the application note: "Soldering Guidelines for Film Capacitors": [www.vishay.com/doc?28171](http://www.vishay.com/doc?28171)

### Storage Temperature

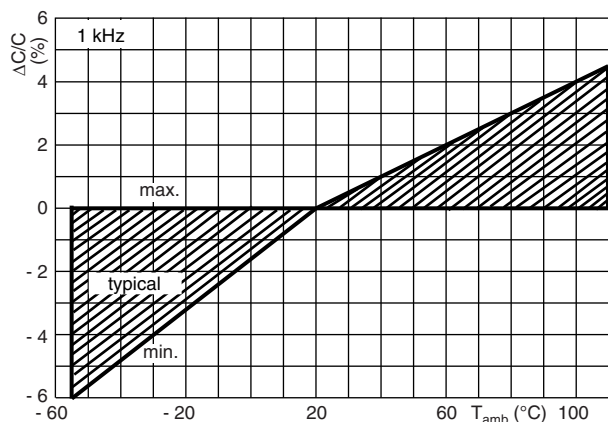
$T_{stg} = -25$  °C to  $+35$  °C with RH maximum 75 % without condensation

### Ratings and Characteristics Reference Conditions

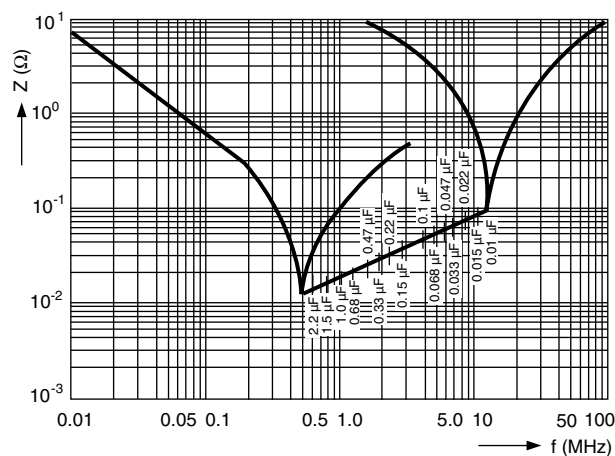
Unless otherwise specified, all electrical values apply to an ambient temperature of  $23$  °C  $\pm 1$  °C, an atmospheric pressure of 86 kPa to 106 kPa and a relative humidity of 50 %  $\pm 2$  %.

For reference testing, a conditioning period shall be applied over 96 h  $\pm 4$  h by heating the products in a circulating air oven at the rated temperature and a relative humidity not exceeding 20 %.

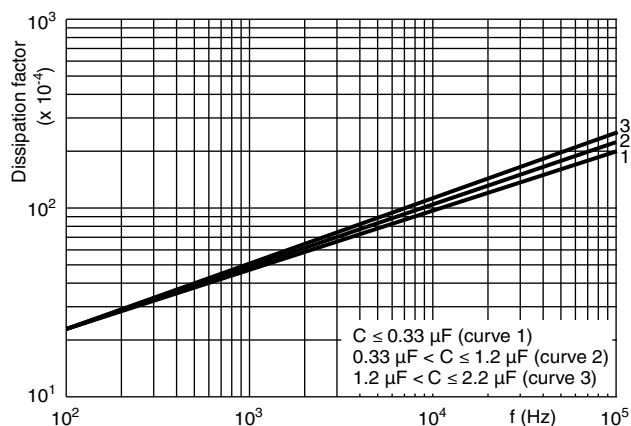
# CHARACTERISTICS



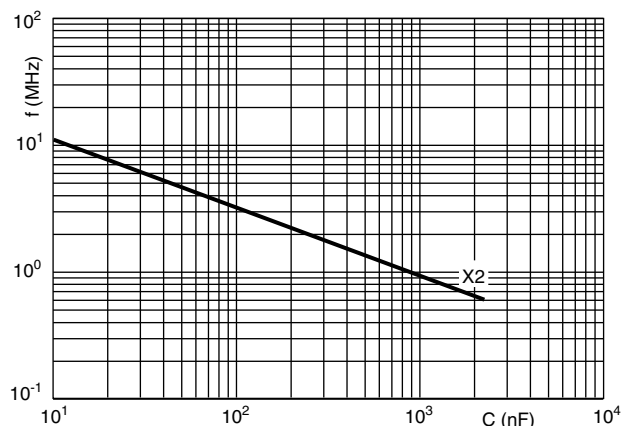
Capacitance as a function of ambient temperature  
(typical curve)



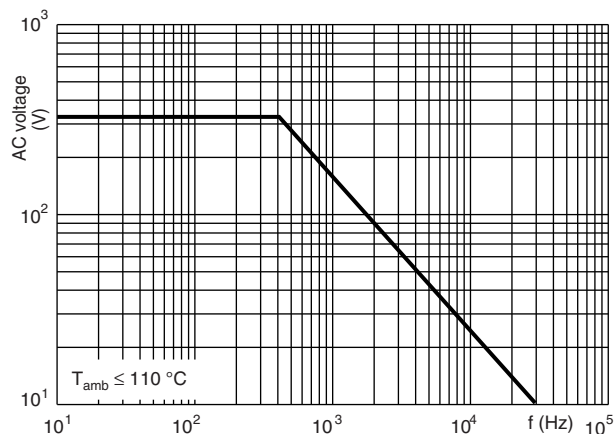
Impedance as a function of frequency  
(typical curve)



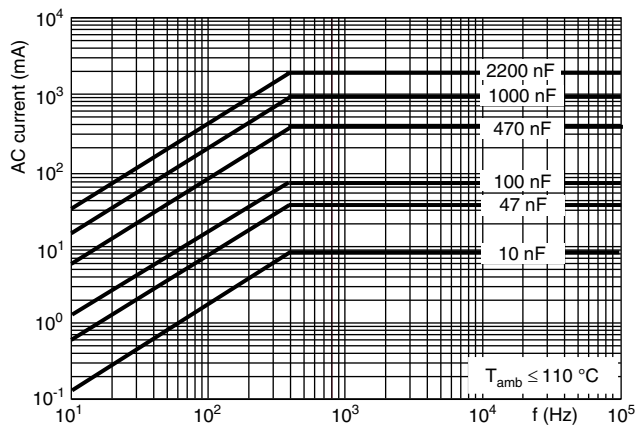
Tangent of loss angle as a function of frequency  
(typical curve)



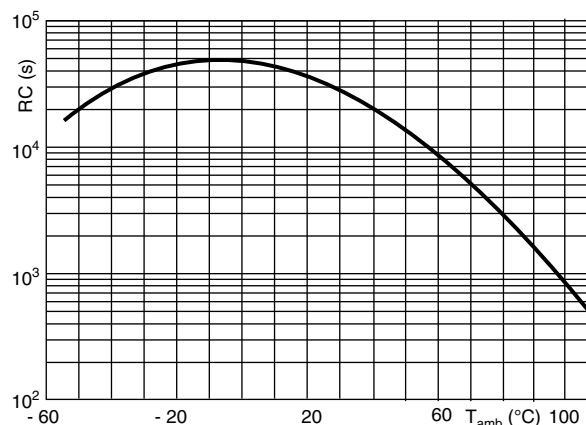
Resonant frequency as a function of capacitance  
(typical curve)



Max. RMS voltage as a function of frequency



Max. RMS current as a function of frequency



Insulation resistance as a function of ambient temperature (typical curve)

## APPLICATION NOTES AND LIMITING CONDITIONS

- For X2 electromagnetic interference suppression where a higher stability grade is needed for **continuous across the line applications** (50 Hz/60 Hz) with a maximum mains voltage of 310 V<sub>AC</sub>.
- These capacitors are not intended for continuous pulse application. For these situations capacitors of the AC and pulse programs must be used.
- For series impedance applications we refer to application note: [www.vishay.com/doc?28153](http://www.vishay.com/doc?28153)
- The maximum ambient temperature must not exceed 110 °C.
- Rated voltage pulse slope:  
if the pulse voltage is lower than the rated voltage, the values of the specific reference data can be multiplied by 435 V<sub>DC</sub> and divided by the applied voltage.

## INSPECTION REQUIREMENTS

### General Notes

Sub-clause numbers of tests and performance requirements refer to the “Sectional Specification, Publication IEC 60384-14 ed 3 and Specific Reference Data”.

| GROUP C INSPECTION REQUIREMENTS              |                                                                                          |                                                              |
|----------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| SUB-CLAUSE NUMBER AND TEST                   | CONDITIONS                                                                               | PERFORMANCE REQUIREMENTS                                     |
| SUB-GROUP C1A PART OF SAMPLE OF SUB-GROUP C1 |                                                                                          |                                                              |
| 4.1 Dimensions (detail)                      |                                                                                          | As specified in chapter “General Data” of this specification |
| Initial measurements                         | Capacitance<br>Tangent of loss angle:<br>for C ≤ 1 µF at 10 kHz<br>for C > 1 µF at 1 kHz |                                                              |
| 4.3 Robustness of terminations               | Tensile: load 10 N; 10 s<br>Bending: load 5 N; 4 x 90°                                   | No visible damage                                            |
| 4.4 Resistance to soldering heat             | No pre-drying<br>Method: 1A<br>Solder bath: 280 °C ± 5 °C<br>Duration: 10 s              |                                                              |



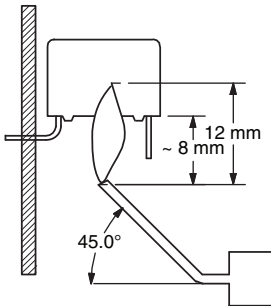
| GROUP C INSPECTION REQUIREMENTS                     |                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SUB-CLAUSE NUMBER AND TEST                          | CONDITIONS                                                                                                                                                                                                                    | PERFORMANCE REQUIREMENTS                                                                                                                                                                                                                                                                                                                             |
| <b>SUB-GROUP C1A PART OF SAMPLE OF SUB-GROUP C1</b> |                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                      |
| 4.19 Component solvent resistance                   | Isopropylalcohol at room temperature<br>Method: 2<br>Immersion time: 5 min ± 0.5 min<br>Recovery time: min. 1 h, max. 2 h                                                                                                     |                                                                                                                                                                                                                                                                                                                                                      |
| 4.4.2 Final measurements                            | Visual examination<br><br>Capacitance<br><br>Tangent of loss angle<br><br>Insulation resistance                                                                                                                               | No visible damage<br>Legible marking<br><br>$ \Delta C/C  \leq 5\%$ of the value measured initially<br><br>Increase of $\tan \delta$<br>$\leq 0.008$ for: $C \leq 1\ \mu\text{F}$ or<br>$\leq 0.005$ for: $C > 1\ \mu\text{F}$<br>Compared to values measured initially<br><br>As specified in section "Insulation Resistance" of this specification |
| <b>SUB-GROUP C1B PART OF SAMPLE OF SUB-GROUP C1</b> |                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                      |
| Initial measurements                                | Capacitance<br>Tangent of loss angle:<br>for $C \leq 1\ \mu\text{F}$ at 10 kHz<br>for $C > 1\ \mu\text{F}$ at 1 kHz                                                                                                           |                                                                                                                                                                                                                                                                                                                                                      |
| 4.20 Solvent resistance of the marking              | Isopropylalcohol at room temperature<br>Method: 1<br>Rubbing material: cotton wool<br>Immersion time: 5 min ± 0.5 min                                                                                                         | No visible damage<br>Legible marking                                                                                                                                                                                                                                                                                                                 |
| 4.6 Rapid change of temperature                     | $\theta A = -40\ ^\circ\text{C}$<br>$\theta B = +110\ ^\circ\text{C}$<br>5 cycles<br>Duration $t = 30\ \text{min}$                                                                                                            |                                                                                                                                                                                                                                                                                                                                                      |
| 4.6.1 Inspection                                    | Visual examination                                                                                                                                                                                                            | No visible damage                                                                                                                                                                                                                                                                                                                                    |
| 4.7 Vibration                                       | Mounting:<br>see section "Mounting" of this specification<br>Procedure B4<br>Frequency range: 10 Hz to 55 Hz<br>Amplitude: 0.75 mm or<br>Acceleration 98 m/s <sup>2</sup><br>(whichever is less severe)<br>Total duration 6 h |                                                                                                                                                                                                                                                                                                                                                      |
| 4.7.2 Final inspection                              | Visual examination                                                                                                                                                                                                            | No visible damage                                                                                                                                                                                                                                                                                                                                    |
| 4.9 Shock                                           | Mounting:<br>See section "Mounting" for more information<br>Pulse shape: half sine<br>Acceleration: 490 m/s <sup>2</sup><br>Duration of pulse: 11 ms                                                                          |                                                                                                                                                                                                                                                                                                                                                      |
| 4.9.2 Final measurements                            | Visual examination<br><br>Capacitance<br><br>Tangent of loss angle<br><br>Insulation resistance                                                                                                                               | No visible damage<br><br>$ \Delta C/C  \leq 5\%$ of the value measured initially<br><br>Increase of $\tan \delta$<br>$\leq 0.008$ for: $C \leq 1\ \mu\text{F}$ or<br>$\leq 0.005$ for: $C > 1\ \mu\text{F}$<br>Compared to values measured initially<br><br>As specified in section "Specific Reference" of this specification                       |



| GROUP C INSPECTION REQUIREMENTS                                            |                                                                                           |                                                                                                                                                              |
|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SUB-CLAUSE NUMBER AND TEST                                                 | CONDITIONS                                                                                | PERFORMANCE REQUIREMENTS                                                                                                                                     |
| <b>SUB-GROUP C1 COMBINED SAMPLE OF SPECIMENS OF SUB-GROUPS C1A AND C1B</b> |                                                                                           |                                                                                                                                                              |
| 4.11 Climatic sequence                                                     | Capacitance                                                                               |                                                                                                                                                              |
| 4.11.1 Initial measurements                                                | Measured in 4.4.2 and 4.9.2<br>Tangent of loss angle<br>Measured initially in C1A and C1B |                                                                                                                                                              |
| 4.11.2 Dry heat                                                            | Temperature: 110 °C<br>Duration: 16 h                                                     |                                                                                                                                                              |
| 4.11.3 Damp heat cyclic<br>Test Db, first cycle                            |                                                                                           |                                                                                                                                                              |
| 4.11.4 Cold                                                                | Temperature: -40 °C<br>Duration: 2 h                                                      |                                                                                                                                                              |
| 4.11.5 Damp heat cyclic<br>Test Db, remaining cycles                       |                                                                                           |                                                                                                                                                              |
| 4.11.6 Final measurements                                                  | Visual examination                                                                        | No visible damage<br>Legible marking                                                                                                                         |
|                                                                            | Capacitance                                                                               | $ \Delta C/C  \leq 5\%$ of the value measured in 4.11.1                                                                                                      |
|                                                                            | Tangent of loss angle                                                                     | Increase of $\tan \delta$<br>$\leq 0.008$ for: $C \leq 1\ \mu\text{F}$ or<br>$\leq 0.005$ for: $C > 1\ \mu\text{F}$<br>Compared to values measured in 4.11.1 |
|                                                                            | Voltage proof<br>1350 V <sub>DC</sub> 1 min between terminations                          | No permanent breakdown or flash-over                                                                                                                         |
|                                                                            | Insulation resistance                                                                     | $\geq 50\%$ of values specified in section<br>"Insulation Resistance" of this specification                                                                  |
| <b>SUB-GROUP C2</b>                                                        |                                                                                           |                                                                                                                                                              |
| 4.12 Damp heat steady state                                                | 56 days, 40 °C, 90 % to 95 % RH<br>No load                                                |                                                                                                                                                              |
| 4.12.1 Initial measurements                                                | Capacitance<br>Tangent of loss angle: 1 kHz                                               |                                                                                                                                                              |
| 4.12.3 Final measurements                                                  | Visual examination                                                                        | No visible damage<br>Legible marking                                                                                                                         |
|                                                                            | Capacitance                                                                               | $ \Delta C/C  \leq 5\%$ of the value measured in 4.12.1                                                                                                      |
|                                                                            | Tangent of loss angle                                                                     | Increase of $\tan \delta$<br>$\leq 0.008$ for: $C \leq 1\ \mu\text{F}$ or<br>$\leq 0.005$ for: $C > 1\ \mu\text{F}$<br>Compared to values measured in 4.12.1 |
|                                                                            | Voltage proof<br>1350 V <sub>DC</sub> ; 1 min between terminations                        | No permanent breakdown or flash-over                                                                                                                         |
|                                                                            | Insulation resistance                                                                     | $\geq 50\%$ of values specified in section<br>"Insulation Resistance" of this specification                                                                  |



| GROUP C INSPECTION REQUIREMENTS        |                                                                                                                                                                    |                                                                                                                                                              |
|----------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SUB-CLAUSE NUMBER AND TEST             | CONDITIONS                                                                                                                                                         | PERFORMANCE REQUIREMENTS                                                                                                                                     |
| <b>SUB-GROUP C2A</b>                   |                                                                                                                                                                    |                                                                                                                                                              |
| 4.12A Damp heat steady state with load | RH: 85 %; temp.: 85 °C, load: 310 V <sub>AC</sub><br>Duration: 168 h                                                                                               |                                                                                                                                                              |
| 4.12.1A Initial measurements           | Capacitance<br>Tangent of loss angle: 1 kHz                                                                                                                        |                                                                                                                                                              |
| 4.12.3A Final measurements             | Visual examination                                                                                                                                                 | No visible damage<br>Legible marking                                                                                                                         |
|                                        | Capacitance                                                                                                                                                        | $ \Delta C/C  \leq 10\%$ of the value measured in 4.12.1                                                                                                     |
|                                        | Tangent of loss angle                                                                                                                                              | Increase of $\tan \delta$<br>$\leq 0.024$ for: $C \leq 1\ \mu\text{F}$ or<br>$\leq 0.015$ for: $C > 1\ \mu\text{F}$<br>Compared to values measured in 4.12.1 |
|                                        | Insulation resistance                                                                                                                                              | $\geq 50\%$ of values specified in section<br>"Insulation Resistance" of this specification<br>or minimum 200 M $\Omega$ , whichever is higher               |
| <b>SUB-GROUP C3</b>                    |                                                                                                                                                                    |                                                                                                                                                              |
| 4.13.1 Initial measurements            | Capacitance<br>Tangent of loss angle:<br>for $C \leq 1\ \mu\text{F}$ at 10 kHz<br>for $C > 1\ \mu\text{F}$ at 1 kHz                                                |                                                                                                                                                              |
| 4.13 Impulse voltage                   | 3 successive impulses, full wave, peak voltage:<br>X2: 2.5 kV for $C \leq 1\ \mu\text{F}$<br>X2: 2.5 kV/ $\sqrt{C}$ for $C > 1\ \mu\text{F}$<br>Max. 24 pulses     | No self healing breakdowns or flash-over                                                                                                                     |
| 4.14 Endurance                         | Duration: 1000 h<br>1.25 x U <sub>RAC</sub> at 110 °C<br>Once in every hour the voltage is increased to 1000 V (RMS) for 0.1 s via resistor of 47 $\Omega \pm 5\%$ |                                                                                                                                                              |
| 4.14.7 Final measurements              | Visual examination                                                                                                                                                 | No visible damage<br>Legible marking                                                                                                                         |
|                                        | Capacitance                                                                                                                                                        | $ \Delta C/C  \leq 5\%$ compared to values measured in 4.13.1                                                                                                |
|                                        | Tangent of loss angle                                                                                                                                              | Increase of $\tan \delta$<br>$\leq 0.008$ for: $C \leq 1\ \mu\text{F}$ or<br>$\leq 0.005$ for: $C > 1\ \mu\text{F}$<br>Compared to values measured in 4.13.1 |
|                                        | Voltage proof<br>1350 V <sub>DC</sub> ; 1 min between terminations<br>2120 V <sub>AC</sub> ; 1 min between terminations and case                                   | No permanent breakdown or flash-over                                                                                                                         |
|                                        | Insulation resistance                                                                                                                                              | $\geq 50\%$ of values specified in section<br>"Insulation Resistance" of this specification                                                                  |

| GROUP C INSPECTION REQUIREMENTS      |                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                   |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SUB-CLAUSE NUMBER AND TEST           | CONDITIONS                                                                                                                                                                                                                                                                                           | PERFORMANCE REQUIREMENTS                                                                                                                                                                                                                                                          |
| <b>SUB-GROUP C4</b>                  |                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                   |
| 4.15 Charge and discharge            | 10 000 cycles<br>Charged to 435 V <sub>DC</sub><br>Discharge resistance:<br>$R = \frac{435 \text{ V}_{\text{DC}}}{1.5 \times C(dU/dt)}$                                                                                                                                                              |                                                                                                                                                                                                                                                                                   |
| 4.15.1 Initial measurements          | Capacitance<br>Tangent of loss angle:<br>for C ≤ 1 µF at 10 kHz<br>for C > 1 µF at 1 kHz                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                   |
| 4.13.3 Final measurements            | Capacitance<br><br>Tangent of loss angle<br><br>Insulation resistance                                                                                                                                                                                                                                | $ \Delta C/C  \leq 10 \%$ compared to values measured in 4.15.1<br><br>Increase of tan δ<br>≤ 0.008 for: C ≤ 1 µF or<br>≤ 0.005 for: C > 1 µF<br>Compared to values measured in 4.15.1<br><br>≥ 50 % of values specified in section "Insulation Resistance" of this specification |
| <b>SUB-GROUP C5</b>                  |                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                   |
| 4.16 Radio frequency characteristic  | Resonance frequency                                                                                                                                                                                                                                                                                  | ≥ 0.9 times the value as specified in section "Resonant Frequency" of this specification.                                                                                                                                                                                         |
| <b>SUB-GROUP C6</b>                  |                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                   |
| 4.17 Passive flammability<br>Class C | Bore of gas jet: Ø 0.5 mm<br>Fuel: butane<br>Test duration for actual volume V in mm <sup>3</sup> :<br>V ≤ 250: 5 s<br>250 < V ≤ 500: 10 s<br>500 < V ≤ 1750: 20 s<br>V > 1750: 30 s<br>One flame application<br> | After removing test flame from capacitor, the capacitor must not continue to burn for more than 30 s. No burning particle must drop from the sample.                                                                                                                              |
| <b>SUB-GROUP C7</b>                  |                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                   |
| 4.18 Active flammability             | 20 cycles of 2.5 kV discharges on the test capacitor connected to U <sub>RAC</sub> .                                                                                                                                                                                                                 | The cheese cloth around the capacitors shall not burn with a flame.<br>No electrical measurements are required.                                                                                                                                                                   |

| TEST CONDITIONS AND REQUIREMENTS ACCORDING AEC-Q200 REVISION D |                                      |                         |                                                                                                                          |                                                                                                                                                                                            |
|----------------------------------------------------------------|--------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NO.                                                            | TEST NAME                            | REFERENCE               | TEST CONDITIONS                                                                                                          | PERFORMANCE REQUIREMENTS                                                                                                                                                                   |
| 1                                                              | Pre- and post-stress electrical test | Spec.                   | -                                                                                                                        | -                                                                                                                                                                                          |
| 3                                                              | High temperature exposure (storage)  | MIL-STD 202 method 108  | 110 °C; unpowered<br>250 h / 500 h / 1000 h                                                                              | $ \Delta C/C  \leq 5\%$<br>Increase of $\tan \delta$<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz or<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value  |
| 4                                                              | Temperature cycling                  | JESD22 method JA-104    | 1000 cycles: -40 °C / +110 °C<br>30 min. dwell time at each temperature extreme<br>Transition time < 1 min.              | $ \Delta C/C  \leq 5\%$<br>Increase of $\tan \delta$<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz or<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value  |
| 6                                                              | Moisture resistance                  | MIL-STD 202 method 106  | 10 cycles at 24 h/cycle unpowered                                                                                        | $ \Delta C/C  \leq 5\%$<br>Increase of $\tan \delta$<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz or<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value  |
| 7                                                              | Biased humidity                      | MIL-STD 202 method 103  | 40 °C; 93 % RH; $U_{RAC}$ (310 V <sub>AC</sub> )<br>250 h / 500 h / 1000 h                                               | $ \Delta C/C  \leq 10\%$<br>Increase of $\tan \delta$<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz or<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value |
| 8                                                              | Operational life                     | MIL-STD 202 method 108  | $T_{amb} = 110\text{ °C}$ ; (310 V <sub>AC</sub> )<br>250 h / 500 h / 1000 h                                             | $ \Delta C/C  \leq 10\%$<br>Increase of $\tan \delta$<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz or<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value |
| 9                                                              | External visual                      | MIL-STD 883 method 2009 | Device construction, marking, and workmanship                                                                            | Device construction and workmanship; legible marking                                                                                                                                       |
| 10                                                             | Physical dimension                   | JESD22 method JB-100    | Spec.                                                                                                                    | Datasheet                                                                                                                                                                                  |
| 11                                                             | Terminal strength (lead)             | MIL-STD 202 method 211  | Test leaded device lead integrity only.<br>- A (pull-test): 2.27 kg (10 s)<br>- C (wire-lead bend test): 227 g (3 x 3 s) | No visual damage                                                                                                                                                                           |
| 12                                                             | Resistance to solvents               | MIL-STD 202 method 215  | - Also aqueous chemical<br>- OKEM clean or equivalent.<br>Do not use banned solvents.                                    | No visual damage<br>Legible marking                                                                                                                                                        |
| 13                                                             | Mechanical shock                     | MIL-STD 202 method 213  | 100 g's; 6 ms<br>half-sine; 3.75 m/s                                                                                     | No visual damage                                                                                                                                                                           |
| 14                                                             | Vibration                            | MIL-STD 202 method 204  | 5 g's for 20 min;<br>12 cycles x 3 directions<br>10 Hz to 2000 Hz                                                        | No visual damage                                                                                                                                                                           |
| 15                                                             | Resistance to soldering heat         | MIL-STD 202 method 210  | 280 °C; 10 s<br>solder within 1.5 mm of device body                                                                      | $ \Delta C/C  \leq 5\%$<br>Increase of $\tan \delta$<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz or<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value  |
| 17                                                             | ESD                                  | -                       | -                                                                                                                        | -                                                                                                                                                                                          |
| 18                                                             | Solderability                        | J-STD-002               | Leaded: method A,<br>category 3 (245 °C / 3 s)                                                                           | Good tinning as evidence by free flowing of the solder with wetting of terminations > 95 %                                                                                                 |
| 19                                                             | Electrical characterization          | -                       | -                                                                                                                        | -                                                                                                                                                                                          |
| 20                                                             | Flammability                         | UL 94 IEC 60384-1       | One flame application<br>Class B                                                                                         | V-0 or V-1 are acceptable.<br>Class B or C acc. IEC is also acceptable                                                                                                                     |



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