



# THB Grade IIIB Class X1 Interference Suppression Film Capacitor Radial MKP 480 V<sub>AC</sub> - Three Phase Across the Line



### FEATURES

- IEC 60384-14: 2013 / AMD1: 2016 grade IIIB: 85 °C, 85 % RH, 1000 h at U<sub>RAC</sub> certified
- AEC-Q200 qualified
- Maximum permissible AC voltage up to 530 V
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



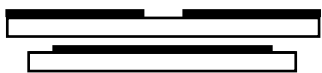
### LINKS TO ADDITIONAL RESOURCES



### APPLICATIONS

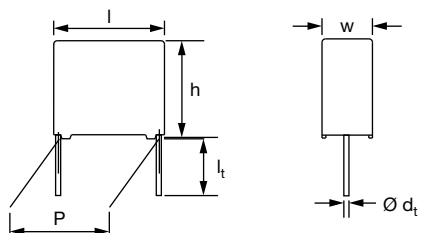
For standard across the line X1 and series impedance applications.

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

| QUICK REFERENCE DATA                  |   |
|---------------------------------------|---|
| Rated capacitance range               | 220 nF to 8.2 µF (preferred values according to E12)  |
| Capacitance tolerance                 | ± 20 %; ± 10 %  |
| Rated voltage range, U <sub>RAC</sub> | 480 V <sub>AC</sub>   |
| Permissible DC voltage                | 800 V <sub>DC</sub> at 105 °C<br>1000 V <sub>DC</sub> at 85 °C  |
| Climatic testing class                | 40 / 105 / 56 / B   |
| Maximum application temperature       | 105 °C  |
| Reference standards                   | IEC 60384-14:2013<br>IEC 60384-14:2013 / AMD1:2016<br>EN 60384-14<br>IEC 60065 requires passive flammability class B<br>UL 60384-14 (2 <sup>nd</sup> edition)<br>CSA-E60384-1:14 (3 <sup>rd</sup> edition)<br>CQC<br>AEC-Q200 qualified (rev. D) up to 105 °C |
| Dielectric                            | Polypropylene film  |
| Electrodes                            | Metallized  |
| Construction                          | Series construction<br>  |
| Encapsulation                         | Plastic case, epoxy resin sealed, flame retardant<br>UL-class 94 V-0  |
| Leads                                 | Tinned wire   |
| Marking                               | C-value; tolerance; rated voltage; sub-class; manufacturer's type; code for dielectric material; manufacturer location, manufacturer's logo; year and week; safety approvals  |

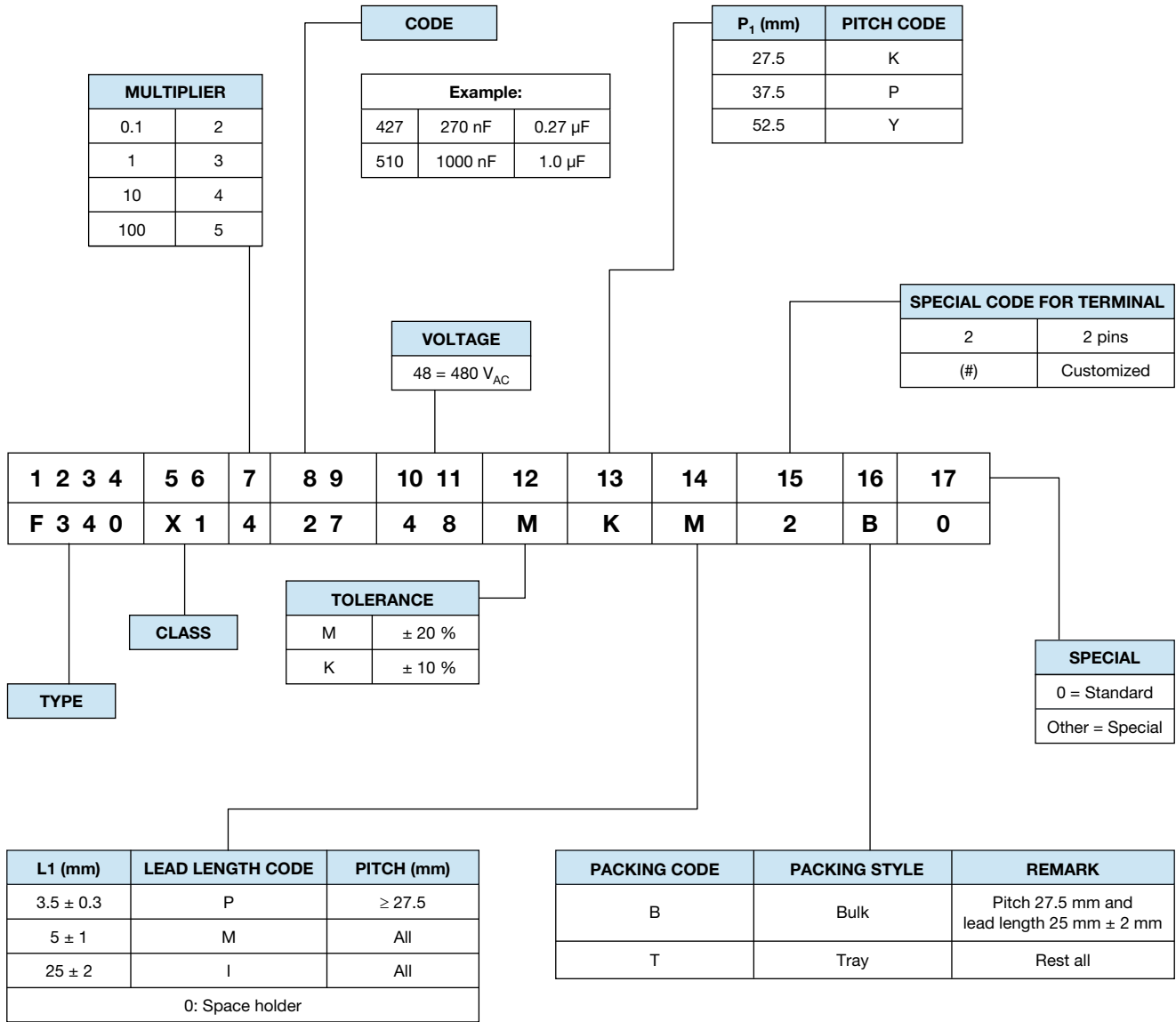
#### Note

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

| DIMENSIONS in millimeters  |
|--|
|  |



**COMPOSITION OF CATALOG NUMBER**



**Note**

- Taped on reel not available



| SPECIFIC REFERENCE DATA  |  |                          |
|--|--|--------------------------|
| DESCRIPTION  | VALUE  |                          |
| Rated voltage range, $U_{RAC}$   | 480 V <sub>AC</sub>  |                          |
| Maximum permissible AC voltage   | 530 V  |                          |
| Rated voltage range, $U_{RDC}$   | 800 V <sub>DC</sub> at 105 °C<br>1000 V <sub>DC</sub> at 85 °C |                          |
| Tangent of loss angle:   | At 1 kHz   | At 10 kHz                |
| $C \leq 1.5 \mu\text{F}$   | $\leq 20 \times 10^{-4}$                                       | $\leq 30 \times 10^{-4}$ |
| $1.5 \mu\text{F} < C \leq 3.9 \mu\text{F}$   | $\leq 30 \times 10^{-4}$                                       | $\leq 50 \times 10^{-4}$ |
| $C > 3.9 \mu\text{F}$  | $\leq 40 \times 10^{-4}$                                       | $\leq 80 \times 10^{-4}$ |
| Rated voltage pulse slope $(du/dt)_R$ at 670 V <sub>DC</sub>   |  |                          |
| Pitch = 27.5 mm  | 100 V/ $\mu\text{s}$   |                          |
| Pitch = 37.5 mm  | 80 V/ $\mu\text{s}$  |                          |
| Pitch = 52.5 mm  | 35 V/ $\mu\text{s}$  |                          |
| R between leads, for $C \leq 0.33 \mu\text{F}$ at 100 V; 1 min   | $> 15\,000 \text{ M}\Omega$                                    |                          |
| RC between leads, for $C > 0.33 \mu\text{F}$ at 100 V; 1 min   | $> 5000 \text{ s}$   |                          |
| R between leads and case; 100 V; 1 min   | $> 30\,000 \text{ M}\Omega$                                    |                          |
| Withstanding (DC) voltage (cut off current 10 mA) <sup>(1)</sup> ; rise time $\leq 1000 \text{ V/s}$ : |  |                          |
| $C \leq 1 \mu\text{F}$   | 3400 V; 1 min  |                          |
| $C > 1 \mu\text{F}$  | 2500 V; 1 min  |                          |
| Withstanding (AC) voltage between leads and case   | 2460 V; 1 min  |                          |

**Note**

<sup>(1)</sup> 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>( $\mu\text{F}$ )  | DIMENSIONS <sup>(2)</sup><br>w x h x l<br>(mm) | MASS<br>(g) <sup>(1)</sup> | CATALOG NUMBER F340X1... AND PACKAGING    |   |     |  |     |
|  |  |  |                            | LOOSE IN BOX                              |   |     |  |     |
|  |  |  |                            | SHORT LEADS                               |   |     | LONG LEADS                                 |     |
|  |  |  |                            | $l_t = 3.5 \text{ mm} \pm 0.3 \text{ mm}$ | $l_t = 5.0 \text{ mm} \pm 1.0 \text{ mm}$ | SPQ | $l_t = 25.0 \text{ mm} \pm 2.0 \text{ mm}$ | SPQ |
| 480                                      | PITCH = 27.5 mm $\pm$ 0.4 mm; $d_t = 0.80 \text{ mm} \pm 0.08 \text{ mm}$ ; C-TOL. = $\pm 20 \%$ |  |                            |   |   |     |  |     |
|  | 0.22   | 13.0 x 23.0 x 32.0                             | 9.2                        | 42248MKP2T0                               | 42248MKM2T0                               | 115 | 42248MKI2B0                                | 115 |
|  | 0.33   |  |                            | 43348MKP2T0                               | 43348MKM2T0                               |     | 43348MKI2B0                                |     |
|  | 0.47   | 15.0 x 25.0 x 32.0                             | 12.3                       | 44748MKP2T0                               | 44748MKM2T0                               | 95  | 44748MKI2B0                                | 95  |
|  | 0.68   | 18.0 x 28.0 x 32.0                             | 16.1                       | 46848MKP2T0                               | 46848MKM2T0                               | 80  | 46848MKI2B0                                | 80  |
|  | 1.0  | 21.0 x 31.0 x 32.0                             | 20.3                       | 51048MKP2T0                               | 51048MKM2T0                               | 65  | 51048MKI2B0                                | 65  |
|  | 1.5  | 22.0 x 38.0 x 32.0                             | 42.5                       | 51548MKP2T0                               | 51548MKM2T0                               | 60  | 51548MKI2B0                                | 65  |
|  | PITCH = 37.5 mm $\pm$ 0.4 mm; $d_t = 1.00 \text{ mm} \pm 0.1 \text{ mm}$ ; C-TOL. = $\pm 20 \%$  |  |                            |   |   |     |  |     |
|  | 2.2  | 21.5 x 38.5 x 42.0                             | 61                         | 52248MPP2T0                               | 52248MPM2T0                               | 84  | 52248MPI2T0                                | 84  |
|  | 3.3  | 30.0 x 45.0 x 42.0                             | 94.5                       | 53348MPP2T0                               | 53348MPM2T0                               | 63  | 53348MPI2T0                                | 63  |
|  | PITCH = 52.5 mm $\pm$ 0.4 mm; $d_t = 1.20 \text{ mm} \pm 0.12 \text{ mm}$ ; C-TOL. = $\pm 20 \%$ |  |                            |   |   |     |  |     |
|  | 4.7  | 30.0 x 45.0 x 57.5                             | 138.5                      | 54748MYP2T0                               | 54748MYM2T0                               | 45  | 54748MYI2T0                                | 45  |
|  | 6.8  |  | 135                        | 56848MYP2T0                               | 56848MYM2T0                               |     | 56848MYI2T0                                |     |




**Notes**

- SPQ = Standard Packing Quantity
- <sup>(1)</sup> Weight for short lead product only
- <sup>(2)</sup> For tolerances see chapter "Space Requirements for Printed-Circuit Board Applications and Dimension Tolerances"

| ELECTRICAL DATA AND ORDERING INFORMATION  |                    |  |                            |  |                                  |             |                                   |
|---|--------------------|--|----------------------------|--|----------------------------------|-------------|-----------------------------------|
| U <sub>RAC</sub><br>(V)   | CAP.<br>(µF)       | DIMENSIONS <sup>(2)</sup><br>w x h x l<br>(mm) | MASS<br>(g) <sup>(1)</sup> | CATALOG NUMBER F340X1... AND PACKAGING |                                  |             |                                   |
|   |                    |  |                            | LOOSE IN BOX                           |                                  |             |                                   |
|   |                    |  |                            | SHORT LEADS                            |                                  | LONG LEADS  |                                   |
|   |                    |  |                            | l <sub>t</sub> = 3.5 mm ± 0.3 mm       | l <sub>t</sub> = 5.0 mm ± 1.0 mm | SPQ         | l <sub>t</sub> = 25.0 mm ± 2.0 mm |
| <b>PITCH = 27.5 mm ± 0.4 mm; d<sub>t</sub> = 0.80 mm ± 0.08 mm; C-TOL. = ± 10 %</b> |                    |  |                            |  |                                  |             |                                   |
| 0.22  | 13.0 x 23.0 x 32.0 | 9.2  | 42248KKP2T0                | 42248KKM2T0                            | 115                              | 42248KKI2B0 | 115                               |
| 0.27  |                    |  | 42748KKP2T0                | 42748KKM2T0                            |                                  | 42748KKI2B0 |                                   |
| 0.33  |                    |  | 43348KKP2T0                | 43348KKM2T0                            |                                  | 43348KKI2B0 |                                   |
| 0.39  | 15.0 x 25.0 x 32.0 | 12.3   | 43948KKP2T0                | 43948KKM2T0                            | 95                               | 43948KKI2B0 | 95                                |
| 0.47  |                    |  | 44748KKP2T0                | 44748KKM2T0                            |                                  | 44748KKI2B0 |                                   |
| 0.56  | 18.0 x 28.0 x 32.0 | 16.1   | 45648KKP2T0                | 45648KKM2T0                            | 80                               | 45648KKI2B0 | 80                                |
| 0.68  |                    |  | 46848KKP2T0                | 46848KKM2T0                            |                                  | 46848KKI2B0 |                                   |
| 0.82  | 21.0 x 31.0 x 32.0 | 20.3   | 48248KKP2T0                | 48248KKM2T0                            | 65                               | 48248KKI2B0 | 65                                |
| 1.0   |                    |  | 51048KKP2T0                | 51048KKM2T0                            |                                  | 51048KKI2B0 |                                   |
| 1.2   | 22.0 x 38.0 x 32.0 | 22.5   | 51248KKP2T0                | 51248KKM2T0                            | 60                               | 51248KKI2B0 | 65                                |
| <b>PITCH = 37.5 mm ± 0.4 mm; d<sub>t</sub> = 1.00 mm ± 0.1 mm; C-TOL. = ± 10 %</b>  |                    |  |                            |  |                                  |             |                                   |
| 1.5   | 21.5 x 38.5 x 42.0 | 61.5   | 51548KPP2T0                | 51548KPM2T0                            | 84                               | 51548KPI2T0 | 84                                |
| 1.8   |                    | 61   | 51848KPP2T0                | 51848KPM2T0                            |                                  | 51848KPI2T0 |                                   |
| 2.2   |                    | 60   | 52248KPP2T0                | 52248KPM2T0                            |                                  | 52248KPI2T0 |                                   |
| 2.7   | 30.0 x 45.0 x 42.0 | 95.5   | 52748KPP2T0                | 52748KPM2T0                            | 63                               | 52748KPI2T0 | 63                                |
| 3.3   |                    | 92.5   | 53348KPP2T0                | 53348KPM2T0                            |                                  | 53348KPI2T0 |                                   |
| 3.9   |                    | 88.5   | 53948KPP2T0                | 53948KPM2T0                            |                                  | 53948KPI2T0 |                                   |
| <b>PITCH = 52.5 mm ± 0.4 mm; d<sub>t</sub> = 1.20 mm ± 0.12 mm; C-TOL. = ± 10 %</b> |                    |  |                            |  |                                  |             |                                   |
| 4.7   | 30.0 x 45.0 x 57.5 | 137.5  | 54748KYP2T0                | 54748KYM2T0                            | 45                               | 54748KYI2T0 | 45                                |
| 5.6   |                    | 136  | 55648KYP2T0                | 55648KYM2T0                            |                                  | 55648KYI2T0 |                                   |
| 6.8   | 35.0 x 50.0 x 57.5 | 171  | 56848KYP2T0                | 56848KYM2T0                            | 40                               | 56848KYI2T0 | 40                                |
| 8.2   |                    | 165.5  | 58248KYP2T0                | 58248KYM2T0                            |                                  | 58248KYI2T0 |                                   |

**Notes**

- SPQ = Standard Packing Quantity
- <sup>(1)</sup> Weight for short lead product only
- <sup>(2)</sup> For tolerances see chapter "Space Requirements for Printed-Circuit Board Applications and Dimension Tolerances"

| APPROVALS   |                     |                  |                       |  |
|---|---------------------|------------------|-----------------------|--|
| SAFETY APPROVALS X1   | VOLTAGE             | VALUE            | FILE NUMBERS          | LINK   |
| EN 60384-14 (ENEC)<br>(= IEC 60384-14 ed-4 (2013))  | 480 V <sub>AC</sub> | 220 nF to 8.2 µF | ENEC16/FI/19/10008/M1 | <a href="http://www.vishay.com/doc?28247">www.vishay.com/doc?28247</a> |
| UL 60384-14   | 480 V <sub>AC</sub> | 220 nF to 8.2 µF | E354331               | <a href="http://www.vishay.com/doc?28249">www.vishay.com/doc?28249</a> |
| CSA-E384-14   | 480 V <sub>AC</sub> | 220 nF to 8.2 µF | E354331               | <a href="http://www.vishay.com/doc?28249">www.vishay.com/doc?28249</a> |
| CQC   | 480 V <sub>AC</sub> | 220 nF to 8.2 µF | L-18001207457         | <a href="http://www.vishay.com/doc?28248">www.vishay.com/doc?28248</a> |
|   |                     |                  | F-18001205119         | <a href="http://www.vishay.com/doc?28250">www.vishay.com/doc?28250</a> |
| CB-test certificate   | 480 V <sub>AC</sub> | 220 nF to 8.2 µF | FI-39834/M1           | <a href="http://www.vishay.com/doc?28246">www.vishay.com/doc?28246</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.

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

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

- For pitches  $\geq 27.5$  mm the capacitors shall be mechanically fixed by the leads and the body clamped

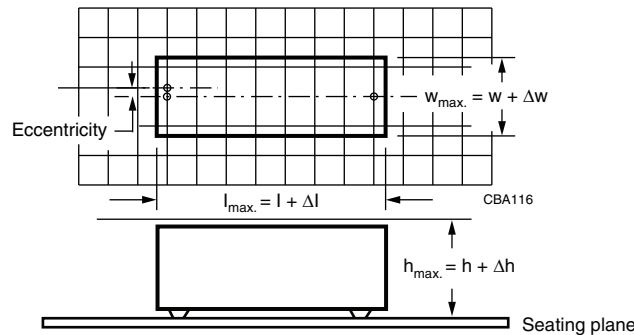
### Space Requirements for Printed-Circuit Board Applications and Dimension Tolerances

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.

$$l_{max.} = l + \Delta l, w_{max.} = w + \Delta w, \text{ and } h_{max.} = h + \Delta h$$

- For products with pitch = 27.5 mm,  $\Delta w = \Delta l = \Delta h = 0.7$  mm
- For products with pitch = 37.5 mm,  $\Delta w = \Delta l = \Delta h = 0.7$  mm
- For products with pitch = 52.5 mm,  $\Delta w = \Delta l = \Delta h = 1.0$  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:

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

- For products with pitch = 27.5 mm,  $\Delta w = \Delta l = \Delta h = 1.0$  mm
- For products with pitch = 37.5 mm,  $\Delta w = \Delta l = \Delta h = 1.0$  mm
- For products with pitch = 52.5 mm,  $\Delta w = \Delta l = \Delta h = 1.5$  mm

## SOLDERING CONDITIONS

For general soldering conditions and wave soldering profile we refer to the document "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.

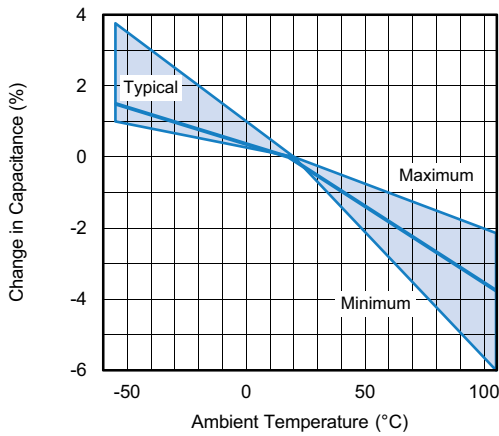
## RATINGS AND CHARACTERISTICS REFERENCE CONDITIONS

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 %  $\pm 2$  %.

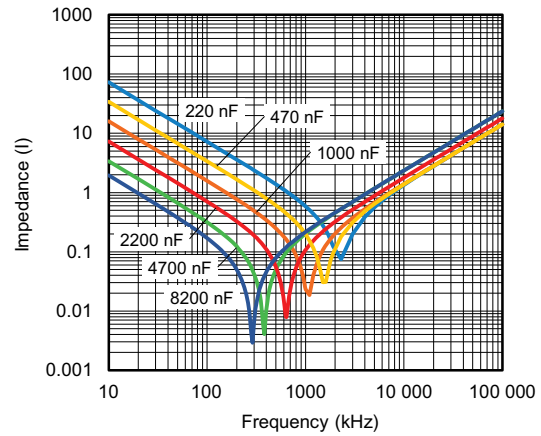
For reference testing. a conditioning period shall be applied over 96 hours  $\pm 4$  hours by heating the products in a circulating air oven at the rated temperature and a relative humidity not exceeding 20 %.



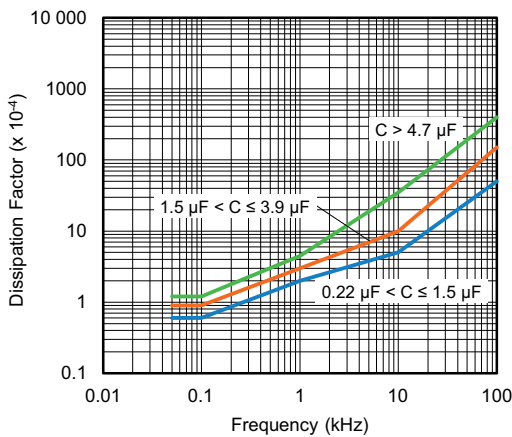
CHARACTERISTICS



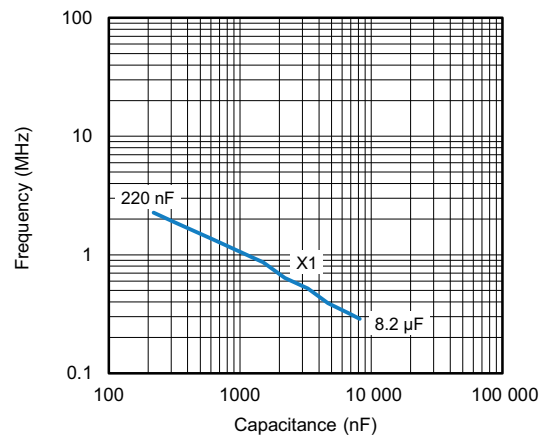
Capacitance as a function of ambient temperature (typical curve)



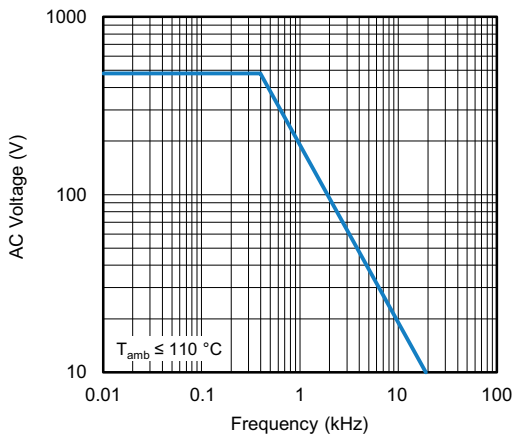
Impedance as a function of frequency (typical curve)



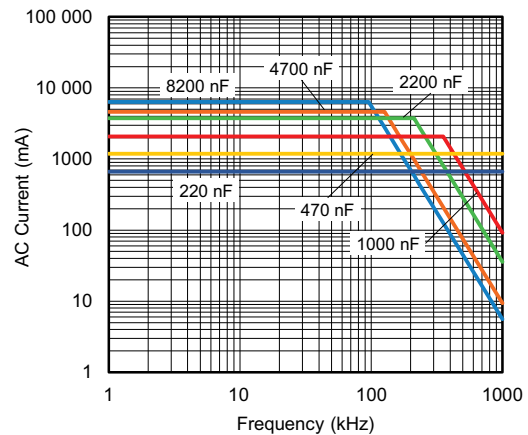
Tangent of loss angle as a function of frequency (typical curve)



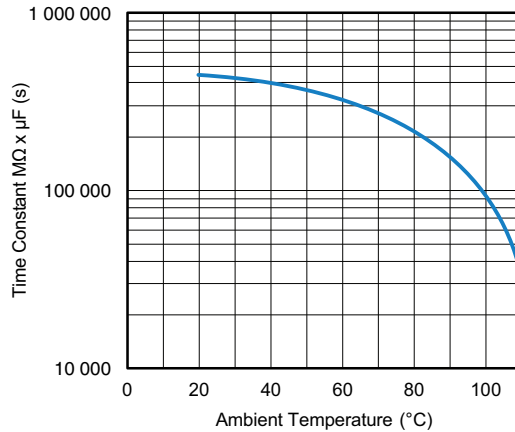
Resonant frequency as a function of capacitance (typical curve)



Max. RMS voltage as a function of frequency



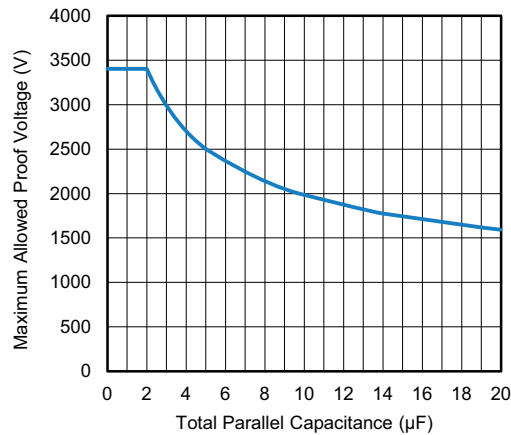
Max. RMS current as a function of frequency



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

**APPLICATION NOTES**

- For X1 electromagnetic interference suppression in standard across the line applications (50 Hz / 60 Hz) with a maximum of 480 V<sub>AC</sub> rated voltage including fluctuation of the mains. It is recommended to use these components in a mains with maximum nominal voltage of 400 V<sub>AC</sub>. Higher continuous applied voltages will shorten the life time
- For series impedance applications we refer to application note [www.vishay.com/doc?28153](http://www.vishay.com/doc?28153)
- To ensure withstanding high humidity requirements in the application the epoxy adhesion at the leads shall not be damaged. Therefore the leads may not be damaged or not be bent before soldering
- For capacitors connected in parallel, normally the proof voltage must be reduced in function of the total parallel capacitance value, see graph.



Proof voltage as function of total parallel capacitance

- These capacitors are not intended for continuous pulse applications. For these situations, capacitors of the AC and pulse programs must be used
- The maximum ambient temperature must not exceed 105 °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 670 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-4 (2013) and Specific Reference Data”.

| <b>GROUP C INSPECTION REQUIREMENTS</b>                    |   |   |
|---|---|---|
| <b>SUB-CLAUSE NUMBER AND TEST</b>                         | <b>CONDITIONS</b>   | <b>PERFORMANCE REQUIREMENTS</b>   |
| <b>SUB-GROUP C1A PART OF SAMPLE OF SUB-GROUP C1</b>       |   |   |
| 4.1 Dimensions (detail)                                   |   | As specified in chapters “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   |   |
| 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  | No visible damage<br>Legible marking  |
|   | Capacitance   | $ \Delta C/C  \leq 5\%$ of the value measured initially   |
|   | Tangent of loss angle   | Increase of tan δ:<br>≤ 0.008 for: C ≤ 1 μF<br>≤ 0.005 for: C > 1 μF<br>Compared to values measured initially |
|   | Insulation resistance   | As specified in section “Insulation Resistance” of this specification   |
| <b>SUB-GROUP C1B OTHER PART OF SAMPLE OF SUB-GROUP C1</b> |   |   |
| Initial measurements                                      | Capacitance<br>Tangent of loss angle:<br>for C ≤ 1 μF at 10 kHz<br>for C > 1 μF at 1 kHz  |   |
| 4.20 Solvent resistance of the marking                    | Isopropyl alcohol 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                           | θA = -40 °C<br>θB = +105 °C<br>5 cycles<br>Duration t = 30 min  |   |
| 4.6.1 Inspection  | Visual examination  | No visible damage   |
| 4.7 Vibration   | Mounting: 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 |   |





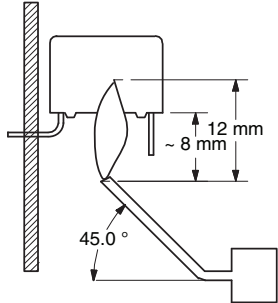
| <b>GROUP C INSPECTION REQUIREMENTS</b>                                     |   |  |
|--|---|--|
| <b>SUB-CLAUSE NUMBER AND TEST</b>  | <b>CONDITIONS</b>   | <b>PERFORMANCE REQUIREMENTS</b>  |
| <b>SUB-GROUP C1B OTHER PART OF SAMPLE OF SUB-GROUP C1</b>                  |   |  |
| 4.7.2 Final inspection   | Visual examination  | No visible damage  |
| 4.9 Shock  | Mounting: 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  | No visible damage  |
|  | Capacitance   | $ \Delta C/C  \leq 5\%$ of the value measured initially  |
|  | Tangent of loss angle   | Increase of $\tan \delta$ :<br>$\leq 0.008$ for: $C \leq 1 \mu\text{F}$<br>$\leq 0.005$ for: $C > 1 \mu\text{F}$<br>Compared to values measured initially  |
|  | Insulation resistance   | As specified in section "Insulation Resistance" of this specification  |
| <b>SUB-GROUP C1 COMBINED SAMPLE OF SPECIMENS OF SUB-GROUPS C1A AND C1B</b> |   |  |
| 4.11 Climatic sequence   |   |  |
| 4.11.1 Initial measurements  | Capacitance<br>Measured in 4.4.2 and 4.9.2  |  |
|  | Tangent of loss angle:<br>measured initially in C1A and C1B   |  |
| 4.11.2 Dry heat  | Temperature: 105 °C   |  |
| 4.11.3 Damp heat cyclic<br>Test Db<br>First cycle                          | Duration: 16 h  |  |
| 4.11.4 Cold  | Temperature: -40 °C   |  |
| 4.11.5 Damp heat cyclic<br>Test Db<br>remaining cycles                     | Duration: 2 h   |  |
| 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: $C \leq 1 \mu\text{F}$<br>$\leq 0.005$ for: $C > 1 \mu\text{F}$<br>Compared to values measured in 4.11.1. |
|  | Voltage proof<br>1900 V <sub>DC</sub> ; 1 min between terminations  | No permanent breakdown or flash-over   |
|  | Insulation resistance   | $\geq 50\%$ of values specified in section "Insulation Resistance" of this specification   |



| <b>GROUP C INSPECTION REQUIREMENTS</b> |   |  |
|--|---|--|
| <b>SUB-CLAUSE NUMBER AND TEST</b>      | <b>CONDITIONS</b>   | <b>PERFORMANCE REQUIREMENTS</b>  |
| <b>SUB-GROUP C2</b>                    |   |  |
| 4.12 Damp heat steady state            | 56 days, 40 °C, 90 % to 95 % RH, no load  |  |
| 4.12.1 Initial measurements            | Capacitance<br>Tangent of loss angle:<br>for C ≤ 1 µF at 10 kHz<br>for C > 1 µF at 1 kHz  |  |
| 4.12.3 Final measurements              | Visual examination<br><br>Capacitance<br><br>Tangent of loss angle<br><br>Voltage proof<br>1900 V <sub>DC</sub> ; 1 min between terminations<br><br>Insulation resistance | No visible damage<br>Legible marking<br><br> ΔC/C  ≤ 5 % of the value measured in 4.12.1.<br><br>Increase of tan δ:<br>≤ 0.008 for: C ≤ 1 µF<br>≤ 0.005 for: C > 1 µF<br>Compared to values measured in 4.12.1.<br><br>No permanent breakdown or flash-over<br><br>≥ 50 % of values specified in section “Insulation Resistance” of this specification                         |
| <b>SUB-GROUP C2A</b>                   |   |  |
| 4.12A Damp heat steady state with load | 85 °C, 85 % RH, load: 480 V <sub>AC</sub><br>Duration: 1000 h   |  |
| 4.12.1A Initial measurements           | Capacitance<br>Tangent of loss angle:<br>for C ≤ 1 µF at 10 kHz<br>for C > 1 µF at 1 kHz  |  |
| 4.12.3A Final measurements             | Visual examination<br><br>Capacitance<br><br>Tangent of loss angle<br><br>Voltage proof<br>1900 V <sub>DC</sub> ; 1 min between terminations<br><br>Insulation resistance | No visible damage<br>Legible marking<br><br> ΔC/C  ≤ 10 % of the value measured in 4.12.1A.<br><br>Increase of tan δ:<br>≤ 0.0240 for: C ≤ 1 µF at 10 kHz<br>≤ 0.0150 for: C > 1 µF at 1 kHz<br>Compared to values measured in 4.12.1A.<br><br>No permanent breakdown or flash-over<br><br>≥ 50 % of values specified in section “Insulation Resistance” of this specification |



| GROUP C INSPECTION REQUIREMENTS |   |   |
|---------------------------------|---|---|
| SUB-CLAUSE NUMBER AND TEST      | CONDITIONS  | PERFORMANCE REQUIREMENTS  |
| <b>SUB-GROUP C3</b>             |   |   |
| 4.13.1 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 Impulse voltage            | 3 successive impulses, full wave, peak voltage:<br>X1: 4 kV for C ≤ 1 μF<br>4 kV√C for C > 1 μF<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 105 °C<br>Once in every hour the voltage is increased to 1000 V <sub>RMS</sub> for 0.1 s via resistor of 47 Ω ± 5 %  |   |
| 4.14.7 Final measurements       | Visual examination<br><br>Capacitance<br><br>Tangent of loss angle<br><br>Voltage proof<br>1900 V <sub>DC</sub> ; 1 min between terminations<br>2380 V <sub>AC</sub> ; 1 min between terminations and case<br><br>Insulation resistance | No visible damage<br>Legible marking<br><br> ΔC/C  ≤ 10 % compared to values measured in 4.13.1.<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 4.13.1<br><br>No permanent breakdown or flash-over<br><br>≥ 50 % of values specified in section "Insulation Resistance" of this specification |
| <b>SUB-GROUP C4</b>             |   |   |
| 4.15 Charge and discharge       | 10 000 cycles<br>Charged to 670 V <sub>DC</sub><br>Discharge resistance:<br>$R = \frac{670 V_{DC}}{1.5 \times C (du/dt)}$   |   |
| 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  |   |
| 4.15.3 Final measurements       | Capacitance<br><br>Tangent of loss angle<br><br>Insulation resistance   | ΔC/C  ≤ 10 % compared to values measured in 4.15.1.<br><br>Increase of tan δ:<br>≤ 0.008 for: C ≤ 1 μF<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   |

| GROUP C INSPECTION REQUIREMENTS          |   |  |
|--|---|--|
| SUB-CLAUSE NUMBER AND TEST               | CONDITIONS  | PERFORMANCE REQUIREMENTS   |
| <b>SUB-GROUP C5</b>                      |   |  |
| 4.16 Radio frequency characteristic      | Resonance frequency   | $\geq 0.9$ times the value as specified in section "Resonant Frequency" of this specification  |
| <b>SUB-GROUP C6</b>                      |   |  |
| 4.17 Passive flammability<br><br>Class B | Bore of gas jet: $\varnothing 0.5$ mm<br>Fuel: butane / propane<br>Test duration for actual volume V in mm <sup>3</sup> :<br>Class B<br>V > 1750      60 s<br><br>One flame application:<br><br> | After removing test flame from capacitor, the capacitor must not continue to burn for more than 10 s. No burning particle must drop from the sample. |
| <b>SUB-GROUP C7</b>                      |   |  |
| 4.18 Active flammability                 | 20 cycles of 4 kV discharges on the test capacitor connected to $U_{RAC}$   | The cheese cloth around the capacitors shall not burn with a flame.<br>No electrical measurements are required.                                      |

| AUTOMOTIVE AEC-Q200, REVISION D QUALIFICATION |  |             |   |
|---|--|-------------|---|
| STRESS  | CONDITIONS   | SAMPLE SIZE | PERFORMANCE REQUIREMENTS  |
| 1. High temperature exposure (storage)        | Test as per MIL-STD 202, method 108<br>Temperature: 105 °C; unpowered<br>Duration: 1000 h  | 77          | $ \Delta C/C  \leq 10 \%$<br>Increase of tan $\delta$ :<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value |
| 2. Temperature cycling                        | Test as per JESD22, method JA-104<br>Total no. of cycles: 1000 cycles<br>Lower temperature: -40 °C<br>Upper temperature: +105 °C<br>30 min dwell time at each temperature as per rev. D<br>Transition time < 1 min | 77          | $ \Delta C/C  \leq 10 \%$<br>Increase of tan $\delta$ :<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value |
| 3. Moisture resistance                        | Test as per MIL-STD 202, method 106<br>No. of cycle: 10 cycles<br>t = 24 h/cycle   | 77          | $ \Delta C/C  \leq 10 \%$<br>Increase of tan $\delta$ :<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value |
| 4. Biased humidity AC                         | Test as per MIL-STD 202, method 103<br>Temperature: 40 °C; RH: 93 %; $U_{RAC}$<br>Duration: 1000 h   | 77          | $ \Delta C/C  \leq 10 \%$<br>Increase of tan $\delta$ :<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value |
| 5. Operational life AC                        | Test as per MIL-STD 202, method 108<br>Temperature: 105 °C; $U_{RAC}$<br>Duration: 1000 h  | 77          | $ \Delta C/C  \leq 10 \%$<br>Increase of tan $\delta$ :<br>$\leq 0.008$ for $C \leq 1 \mu F$ at 10 kHz<br>$\leq 0.005$ for $C > 1 \mu F$ at 1 kHz<br>IR > 50 % of initial specified value |



| <b>AUTOMOTIVE AEC-Q200, REVISION D QUALIFICATION</b> |   |                    |   |
|--|---|--------------------|---|
| <b>STRESS</b>  | <b>CONDITIONS</b>   | <b>SAMPLE SIZE</b> | <b>PERFORMANCE REQUIREMENTS</b>   |
| 6. Terminal strength (lead)                          | Test as per MIL-STD 202, method 211<br>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) | 30                 | No visual damage  |
| 7. Resistance to solvents                            | MIL-STD-202 method 215<br>- Also aqueous chemical<br>- OKEM clean or equivalent<br>Do not use banned solvents.  | 5                  | No visual damage<br>Legible marking   |
| 8. Mechanical shock                                  | MIL-STD-202 method 213<br>100 g's ; 6 ms<br>half-sine; 3.75 m/s   | 30                 | No visual damage  |
| 9. Vibration   | MIL-STD-202 method 204<br>5 g's for 20 min;<br>12 cycles x 3 directions<br>10 Hz to 2000 Hz   | 30                 | No visual damage  |
| 10. Resistance to soldering heat                     | MIL-STD-202 method 210<br>Temperature: 280 °C; Time: 10 s<br>Procedure 1 solder within 1.5 mm of device body  | 30                 | $ \Delta C/C  \leq 5\%$<br>Increase of tan $\delta$ :<br>$\leq 0.008$ for $C \leq 1 \mu\text{F}$ at 10 kHz<br>$\leq 0.005$ for $C > 1 \mu\text{F}$ at 1 kHz<br>$IR > 50\%$ of initial specified value |
| 11. Solderability                                    | J-STD-002<br>Leaded: method A at 235 °C, category 3   | 15                 | Good tinning as evidence by free flowing of the solder with wetting of terminations > 95 %  |
| 12. Electrical characterization                      | -   | 30                 | -   |
| 13. Flammability                                     | UL 94<br>One flame application<br>Class B   | 15                 | V-0 or V-1 are acceptable.<br>Class B or C acc. IEC is also acceptable  |



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