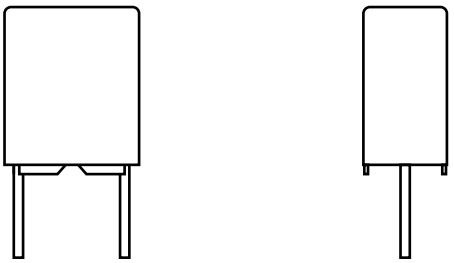
Interference Suppression Film Capacitors
MKT Radial Potted Type



FEATURES

- 15 mm to 37.5 mm lead pitch
- AEC-Q200 qualified for C ≤ 470 nF
- Supplied loose in box, taped on reel
- Material categorization:
  For definitions of compliance please see www.vishay.com/doc?99912

AUTOMOTIVE GRADE

Pb-free

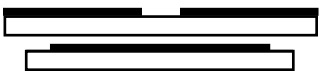
e3

RoHS COMPLIANT

APPLICATIONS

High stability grade for continuous across the line X2 applications.

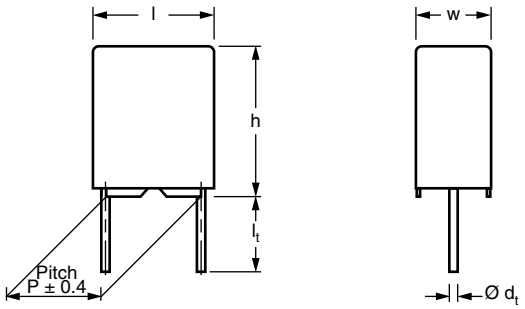
See also application note: www.vishay.com/doc?28153

QUICK REFERENCE DATA	
Capacitance range (E12 series)	E12 series 0.01 µF to 2.2 µF preferred values acc. to E6
Capacitance tolerance	± 10 %, ± 20 % (± 5 % on request)
Rated AC voltage	310 V_{AC}; 50 Hz to 60 Hz
Permissible DC voltage	800 V_{DC} at 85 °C 630 V_{DC} at 110 °C
Climatic testing class acc. to IEC 60068-1	40/110/56/C
Maximum application temperature	110 °C
Reference standards	IEC 60384-14 ed-3 and EN 60384-14 IEC 60065 pass. flamm. class C CSA-E384-14 UL 60384-14
Dielectric	Polyester film
Electrodes	Metallized
Construction	Series construction 
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; 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

DIMENSIONS in millimeters



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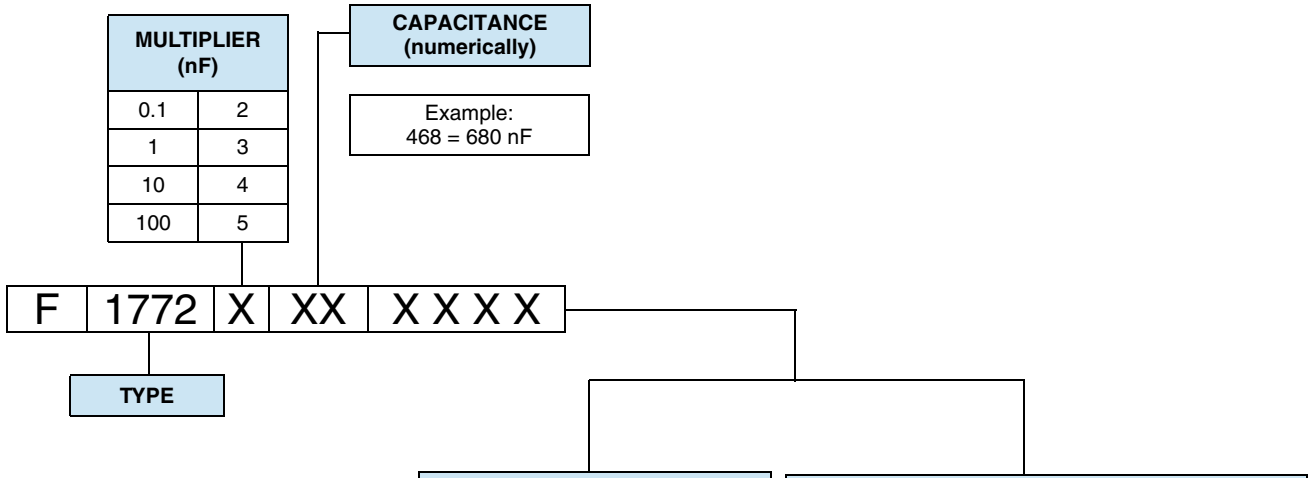
COMPOSITION OF CATALOG NUMBER



PACKAGING (Taped on reel) (1)		
Code	Code details	Tolerance
2290	H: 16.5 mm	± 20 %
2291	H: 18.5 mm	± 20 %
2960	H: 16.5 mm	± 20 %
2961	H: 18.5 mm	± 20 %
2900	H: 16.5 mm	± 10 %
2901	H: 18.5 mm	± 10 %
2970	H: 16.5 mm	± 10 %
2971	H: 18.5 mm	± 10 %

PACKAGING (Loose)		
Code	Code details	Tolerance
2004/2164	Lead length 4 - 1 mm	± 10 %
2000/2160	Lead length 6 - 1 mm	± 10 %
2015/2165	Lead length 15 - 1 mm	± 10 %
2030/2163	Lead length 30 + 5 mm	± 10 %
2204/2264	Lead length 4 - 1 mm	± 20 %
2200/2260	Lead length 6 - 1 mm	± 20 %
2215/2265	Lead length 15 - 1 mm	± 20 %
2230/2263	Lead length 30 + 5 mm	± 20 %

Notes

- For detailed tape specifications refer to packaging information www.vishay.com/doc?28139

(1) Taped on reel pitch ≥ 27.5 mm is not available

SPECIFIC REFERENCE DATA	
DESCRIPTION	**VALUE**
Rated AC voltage (U_{RAC})	310 V
Permissible DC voltage (U_{RDC})	630 V
Tangent of loss angle	≤ 100 x 10^{-4} at 1 kHz
Rated voltage pulse slope at $(dU/dt)_R$ 435 V_{DC}	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) (1); 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

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ELECTRICAL DATA AND ORDERING INFORMATION

U_{RAC} (V)	CAP. (µF)	PITCH (mm)	DIMENSIONS w x h x l MAX. (mm)	MASS [3] (g)	SPQ (pieces) SHORT LEAD	ORDERING CODE [1][2]
310	**d_t = 0.60 mm ± 0.06 mm; C-tol. = ± 10 %**					
	0.010	15	5.0 x 11.0 x 17.5	1.4	750	F177231020..
	0.012	15	5.0 x 11.0 x 17.5	1.4	750	F177231220..
	0.015	15	5.0 x 11.0 x 17.5	1.4	750	F177231520..
	0.018	15	5.0 x 11.0 x 17.5	1.4	750	F177231820..
	0.022	15	5.0 x 11.0 x 17.5	1.4	750	F177232220..
	0.027	15	5.0 x 11.0 x 17.5	1.4	750	F177232720..
	0.033	15	5.0 x 11.0 x 17.5	1.4	750	F177233320..
	0.039	15	6.0 x 12.0 x 17.5	2.0	500	F177233920..
	0.047	15	6.0 x 12.0 x 17.5	2.0	500	F177234720..
	0.056	15	6.0 x 12.0 x 17.5	2.0	500	F177235620..
	d_t = 0.80 mm ± 0.08 mm; C-tol. = ± 10 %					
	0.068	15	7.0 x 13.5 x 17.5	2.4	450	F177236820..
	0.082	15	8.5 x 15.0 x 17.5	2.7	300	F177238220..
	0.10	15	8.5 x 15.0 x 17.5	2.7	325	F177241020..
	0.12	15	8.5 x 15.0 x 17.5	2.7	300	F177241220..
	0.15	15	8.5 x 15.0 x 17.5	2.7	300	F1772415216.
	0.15	22.5	7.0 x 16.5 x 26.0	4.1	235	F177241520..
	0.18	22.5	7.0 x 16.5 x 26.0	4.1	235	F177241820..
	0.22	15	10.0 x 16.5 x 17.5	3.0	235	F1772422216.
	0.22	22.5	8.5 x 18.0 x 26.0	4.6	200	F177242220..
	0.27	22.5	10.0 x 19.5 x 26.0	6.7	170	F177242720..
	0.33	15	13.5 x 22.5 x 18.0	5.5	185	F1772433216.
	0.33	22.5	10.0 x 19.5 x 26.0	6.7	170	F177243320..
	0.39	27.5	11.0 x 21.0 x 31.0	9.1	125	F177243920..
	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	F177244720..
	0.56	27.5	11.0 x 21.0 x 31.0	9.1	125	F177245620..
	0.68	22.5	15.5 x 26.5 x 26.5	13.5	110	F1772468216.
	0.68	27.5	13.0 x 23.0 x 31.0	12.9	110	F177246820..
	0.82	27.5	13.0 x 23.0 x 31.0	12.9	110	F177248220..
	1.0	22.5	15.5 x 26.5 x 26.5	13.5	110	F1772510216.
	1.0	27.5	15.0 x 25.0 x 31.5	15.0	100	F177251020..
	1.2	37.5	14.5 x 24.5 x 41.5	18.9	80	F177251220..
	1.5	27.5	18.0 x 28.0 x 31.0	19.0	85	F1772515216.
	1.5	37.5	15.5 x 28.5 x 41.5	24.0	70	F177251520..
	1.8	37.5	15.5 x 28.5 x 41.5	24.0	70	F177251820..
	2.2	27.5	21.0 x 31.0 x 31.0	28.0	70	F1772522216.
	2.2	37.5	18.0 x 32.5 x 41.5	31.6	60	F177252220..
	d_t = 0.60 mm ± 0.06 mm; C-tol. = ± 20 %					
	0.010	15	5.0 x 11.0 x 17.5	1.4	750	F177231022..
	0.015	15	5.0 x 11.0 x 17.5	1.4	750	F177231522..
	0.022	15	5.0 x 11.0 x 17.5	1.4	750	F177232222..
	0.033	15	5.0 x 11.0 x 17.5	1.4	750	F177233322..
	0.047	15	5.0 x 11.0 x 17.5	1.4	750	F177234722..
	0.068	15	6.0 x 12.0 x 17.5	2.0	600	F177236822..
	0.10	15	6.0 x 12.0 x 17.5	2.0	600	F177241022..

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ELECTRICAL DATA AND ORDERING INFORMATION

U_{RAC} (V)	CAP. (µF)	PITCH (mm)	DIMENSIONS w x h x l MAX. (mm)	MASS [3] (g)	SPQ (pieces) SHORT LEAD	ORDERING CODE [1][2]
310	d_t = 0.80 mm ± 0.08 mm; C-tol. = ± 20 %					
	0.15	15	8.5 x 15.0 x 17.5	2.7	325	F1772415226..
	0.15	22.5	6.0 x 15.5 x 26.0	3.3	260	F177241522...
	0.22	15	10.0 x 16.5 x 17.5	4.5	300	F1772422226..
	0.22	22.5	7.0 x 16.5 x 26.0	4.1	235	F177242222...
	0.33	15	13.5 x 22.5 x 18.0	5.5	185	F1772433226.
	0.33	22.5	8.5 x 18.0 x 26.0	5.3	190	F177243322..
	0.47	22.5	10.0 x 19.5 x 26.0	6.7	170	F1772447226..
	0.47	27.5	9.0 x 19.0 x 31.5	6.8	160	F177244722..
	0.68	22.5	12.0 x 22.0 x 26.0	13.4	110	F1772468226..
	0.68	27.5	11.0 x 21.0 x 31.0	12.9	125	F177246822..
	1.0	22.5	15.5 x 26.5 x 26.5	13.5	110	F1772510226..
	1.0	27.5	15.0 x 25.0 x 31.5	15.0	100	F177251022..
	1.5	27.5	18.0 x 28.0 x 31.5	19.0	85	F1772515226.
	1.5	37.5	14.5 x 24.5 x 41.5	18.9	80	F177251522..
	2.2	27.5	21.0 x 31.0 x 31.0	28.0	70	F1772522226.
	2.2	37.5	15.5 x 28.5 x 41.5	24.0	70	F177252222..

Notes

(1) These capacitors can be delivered on continuous tape and reel.
The ordering code is:
F1772-...-2900 at H = 16.5 mm
F1772-...-2901 at H = 18.5 mm
F1772-...-2970 at H = 16.5 mm
F1772-...-2971 at H = 18.5 mm

(2) Further information about packaging quantities with different lead length and/or taped versions, see document “Packing Quantities” www.vishay.com/doc?27608

(3) Weight for short lead product only
- SPQ = Standard Packing Quantity
- For detailed tape specifications refer to packaging information: www.vishay.com/doc?28139

APPROVALS

SAFETY APPROVALS X2	VOLTAGE	VALUE	FILE NUMBERS
EN 60384-14 (ENEC) (= IEC 60384-14 ed 3)	310 V_{AC}	0.01 µF to 2.2 µF X2	40005079
UL 60384-14	310 V_{AC}	0.01 µF to 2.2 µF X2	E354331
CSA-E 384-14	310 V_{AC}	0.01 µF to 2.2 µF X2	E354331
CB test-certificate	310 V_{AC}	0.01 µF to 2.2 µF X2	DE 1-40110/A1

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.

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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.

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:

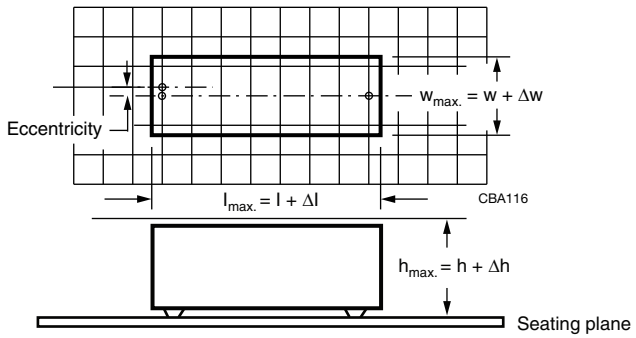
- For pitches ≤ 15 mm capacitors shall be mechanically fixed by the leads
- For larger pitches the capacitors shall be mounted in the same way and the body clamped

Space Requirements on Printed Circuit Board

The maximum space for length ($l_{max.}$), width ($w_{max.}$) and height ($h_{max.}$) of film capacitors to take in account on the printed circuit board is shown in the drawings.

- For products with pitch ≤ 15 mm, $\Delta w = \Delta l = 0.3$ mm; $\Delta h = 0.1$ mm
- For products with 15 mm < pitch ≤ 27.5 mm, $\Delta w = \Delta l = 0.5$ mm; $\Delta h = 0.1$ mm
- For products with pitch = 37.5 mm, $\Delta w = \Delta l = 0.7$ mm; $\Delta h = 0.5$ mm

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



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

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 ± 1 °C, an atmospheric pressure of 86 kPa to 106 kPa and a relative humidity of 50 % ± 2 %.

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

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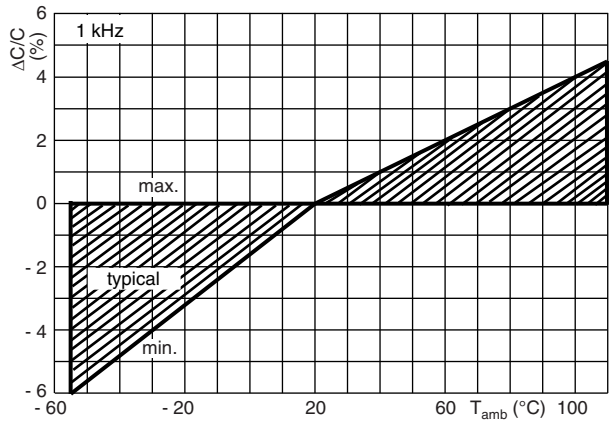
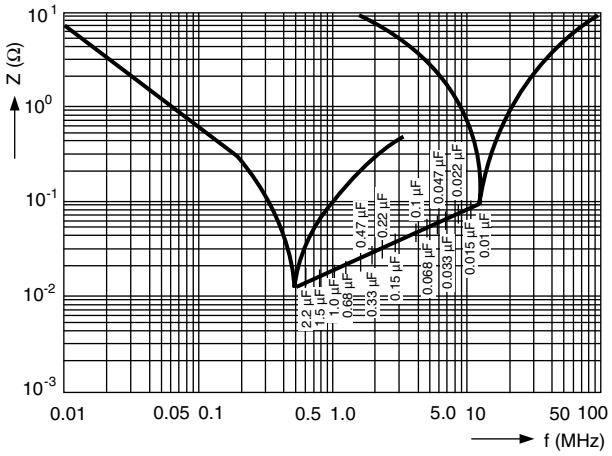
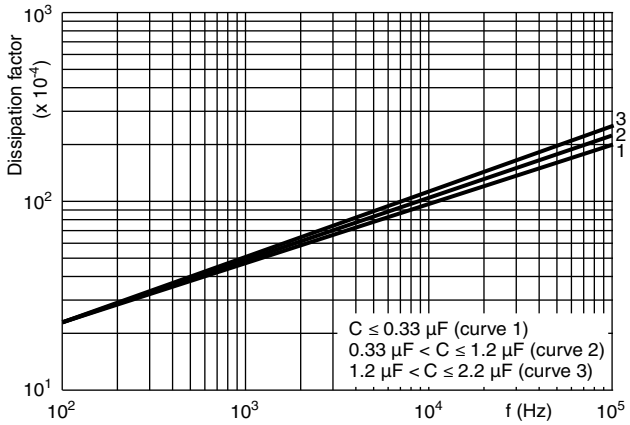
CHARACTERISTICS



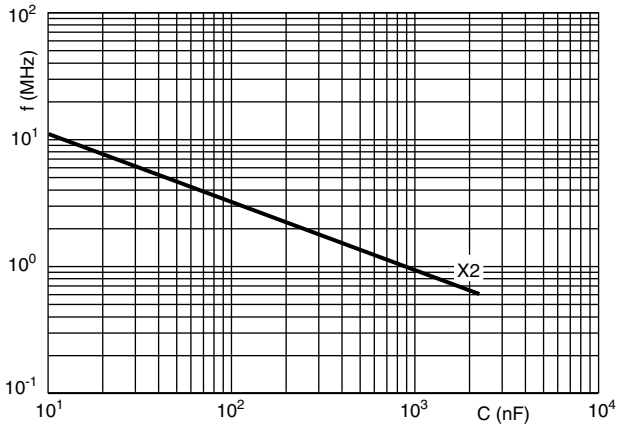
Capacitance as a function of ambient temperature
(typical curve)



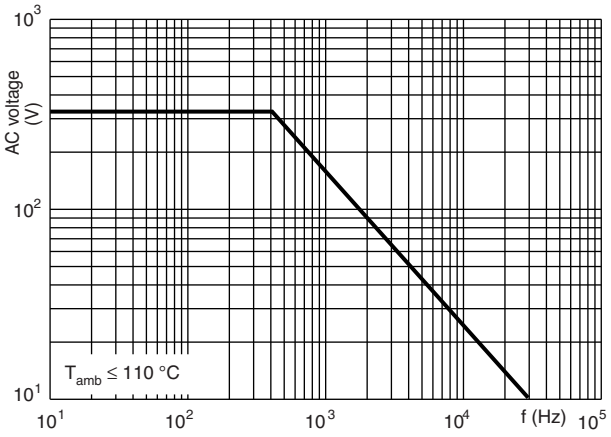
Impedance as a function of frequency
(typical curve)



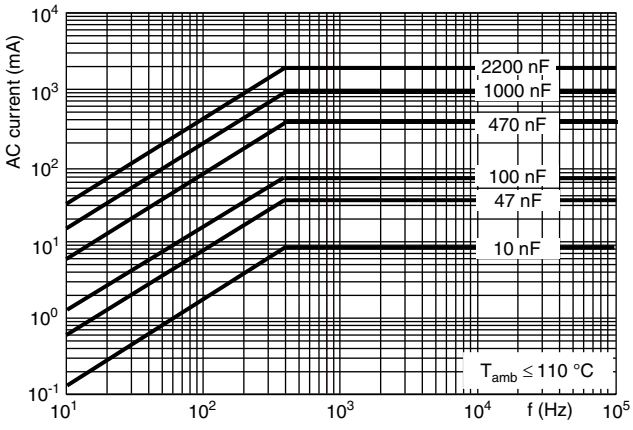
Tangent of loss angle as a function of frequency
(typical curve)



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

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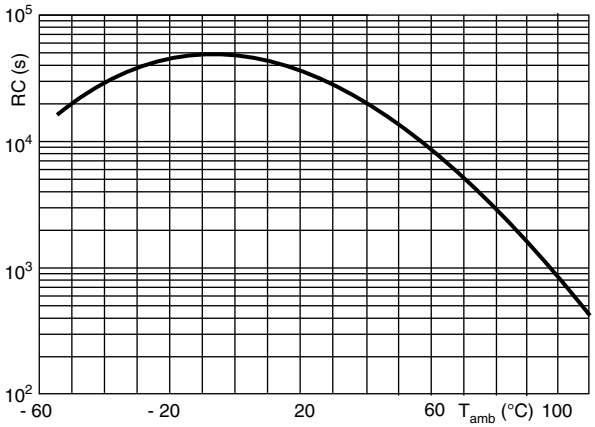

Insulation resistance as a function of ambient temperature (typical curve)

APPLICATION NOTES AND LIMITING CONDITIONS

- For X2 electromagnetic interference suppression where a higher stabililty grade is needed for **continuous across the line applications** (50 Hz/60 Hz) with a maximum mains voltage of 310 V_{AC}.
- 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
- 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_{DC} 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 Tangent of loss angle: For C ≤ 1 µF at 10 kHz For C > 1 µF at 1 kHz	
4.3 Robustness of terminations	Tensile: Load 10 N; 10 s Bending: Load 5 N; 4 x 90°	No visible damage
4.4 Resistance to soldering heat	No pre-drying Method: 1A Solder bath: 280 °C ± 5 °C Duration: 10 s	

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GROUP C INSPECTION REQUIREMENTS		
SUB-CLAUSE NUMBER AND TEST	**CONDITIONS**	**PERFORMANCE REQUIREMENTS**
SUB-GROUP C1A PART OF SAMPLE OF SUB-GROUP C1		
4.19 Component solvent resistance	Isopropylalcohol at room temperature Method: 2 Immersion time: 5 min ± 0.5 min Recovery time: Min. 1 h, max. 2 h	
4.4.2 Final measurements	Visual examination	No visible damage Legible marking
	Capacitance	$\lvert\Delta C/C\rvert \leq 5$ % of the value measured initially
	Tangent of loss angle	Increase of tan δ ≤ 0.008 for: $C \leq 1$ µF or ≤ 0.005 for: $C > 1$ µF Compared to values measured initially
	Insulation resistance	As specified in section “Insulation Resistance” of this specification
SUB-GROUP C1B PART OF SAMPLE OF SUB-GROUP C1		
Initial measurements	Capacitance Tangent of loss angle: For $C \leq 1$ µF at 10 kHz For $C > 1$ µF at 1 kHz	
4.20 Solvent resistance of the marking	Isopropylalcohol at room temperature Method: 1 Rubbing material: Cotton wool Immersion time: 5 min ± 0.5 min	No visible damage Legible marking
4.6 Rapid change of temperature	θA = - 40 °C θB = + 110 °C 5 cycles Duration t = 30 min	
4.6.1 Inspection	Visual examination	No visible damage
4.7 Vibration	Mounting: See section “Mounting” of this specification Procedure B4 Frequency range: 10 Hz to 55 Hz Amplitude: 0.75 mm or Acceleration 98 m/s² (whichever is less severe) Total duration 6 h	
4.7.2 Final inspection	Visual examination	No visible damage
4.9 Shock	Mounting: See section “Mounting” for more information Pulse shape: Half sine Acceleration: 490 m/s² Duration of pulse: 11 ms	
4.9.2 Final measurements	Visual examination	No visible damage
	Capacitance	$\lvert\Delta C/C\rvert \leq 5$ % of the value measured initally
	Tangent of loss angle	Increase of tan δ ≤ 0.008 for: $C \leq 1$ µF or ≤ 0.005 for: $C > 1$ µF Compared to values measured initially
	Insulation resistance	As specified in section “Specific Reference” of this specification

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

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GROUP C INSPECTION REQUIREMENTS		
SUB-CLAUSE NUMBER AND TEST	**CONDITIONS**	**PERFORMANCE REQUIREMENTS**
SUB-GROUP C3		
4.13.1 Initial measurements	Capacitance Tangent of loss angle: For C ≤ 1 µF at 10 kHz For C > 1 µF at 1 kHz	
4.13 Impulse voltage	3 successive impulses, full wave, peak voltage: X2: 2.5 kV for C ≤ 1 µF X2: 2.5 kV/√C for C > 1 µF Max. 24 pulses	No self healing breakdowns or flash-over
4.14 Endurance	Duration: 1000 h 1.25 x U_{RAC} at 110 °C Once in every hour the voltage is increased to 1000 V (RMS) for 0.1 s via resistor of 47 Ω ± 5 %	
4.14.7 Final measurements	Visual examination	No visible damage Legible marking
	Capacitance	|ΔC/C| ≤ 5 % compared to values measured in 4.13.1
	Tangent of loss angle	Increase of tan δ ≤ 0.008 for: C ≤ 1 µF or ≤ 0.005 for: C > 1 µF Compared to values measured in 4.13.1
	Voltage proof 1350 V_{DC}; 1 min between terminations 2120 V_{AC}; 1 min between terminations and case	No permanent breakdown or flash-over
	Insulation resistance	≥ 50 % of values specified in section "Insulation Resistance" of this specification
SUB-GROUP C4		
4.15 Charge and discharge	10 000 cycles Charged to 435 V_{DC} Discharge resistance: $R = \frac{435\ V_{DC}}{1.5 \times C(dU/dt)}$	
4.15.1 Initial measurements	Capacitance Tangent of loss angle: For C ≤ 1 µF at 10 kHz For C > 1 µF at 1 kHz	
4.13.3 Final measurements	Capacitance	|ΔC/C| ≤ 10 % compared to values measured in 4.15.1
	Tangent of loss angle	Increase of tan δ ≤ 0.008 for: C ≤ 1 µF or ≤ 0.005 for: C > 1 µF Compared to values measured in 4.15.1
	Insulation resistance	≥ 50 % of values specified in section "Insulation Resistance" of this specification

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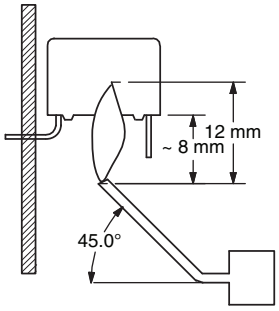
GROUP C INSPECTION REQUIREMENTS		
SUB-CLAUSE NUMBER AND TEST	**CONDITIONS**	**PERFORMANCE REQUIREMENTS**
SUB-GROUP C5		
4.16 Radio frequency characteristic	Resonance frequency	≥ 0.9 times the value as specified in section "Resonant Frequency" of this specification.
SUB-GROUP C6		
4.17 Passive flammability Class C	Bore of gas jet: Ø 0.5 mm Fuel: Butane Test duration for actual volume V in mm^3: V ≤ 250: 5 s 250 < V ≤ 500: 10 s 500 < V ≤ 1750: 20 s V > 1750: 30 s One flame application 	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.
SUB-GROUP C7		
4.18 Active flammability	20 cycles of 2.5 kV discharges on the test capacitor connected to U_{RAC}.	The cheese cloth around the capacitors shall not burn with a flame. No electrical measurements are required.

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